HOUSES OF BEIRUT 1860-1925

Restoration manual

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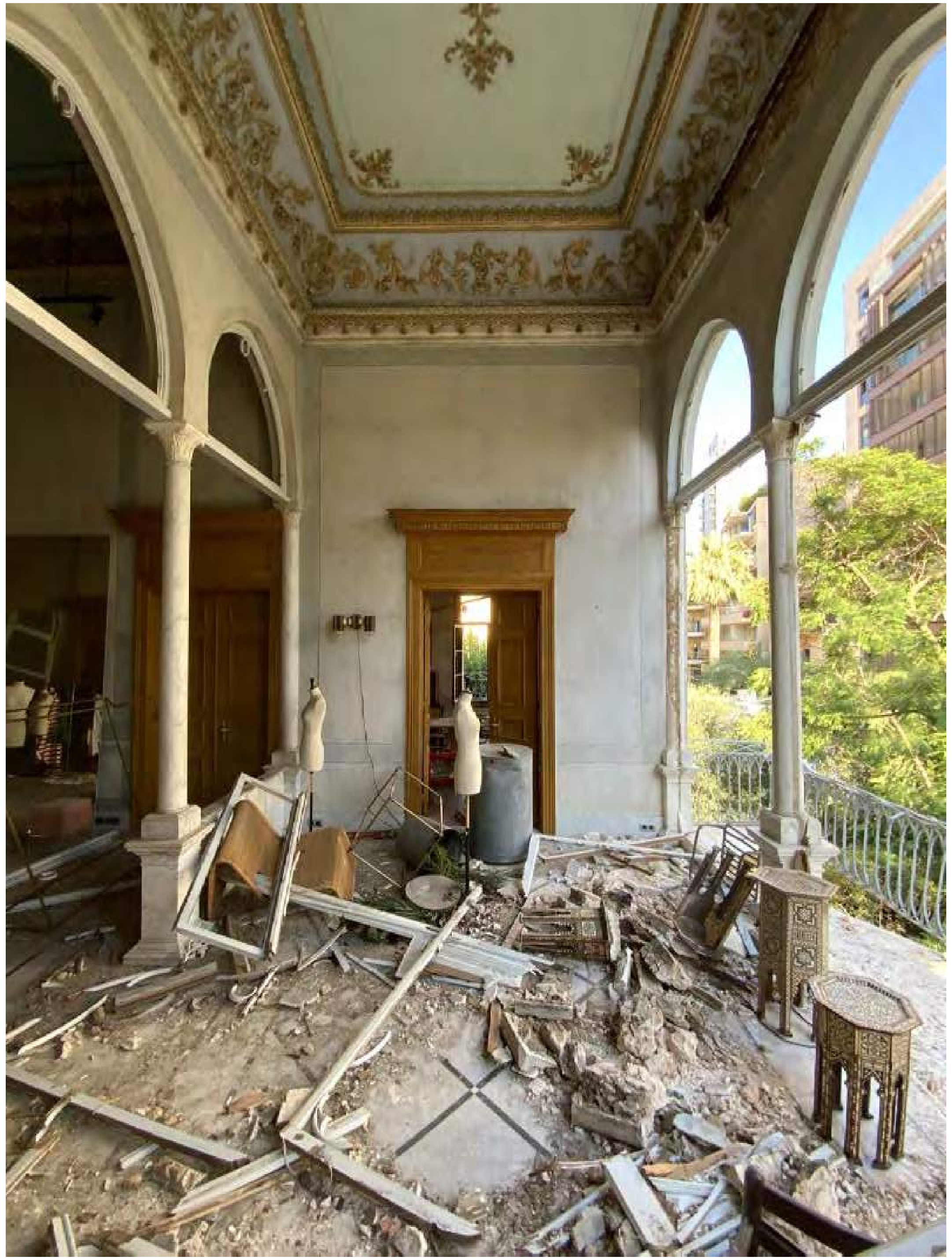
HOUSES OF BEIRUT 1860-1925

Restoration manual

under the direction of Nathalie Chahine and Fadlallah Dagher

For Beirut, a wounded city, its dwellers and its houses



Paula Abou Harb (BBHR2020) is an architect specialized in historic preservation. In recent years, she has worked on the restoration and conservation of 19th century *Beiruti* mansions, as well as medieval and Ottoman structures. She is involved in conservation and site presentation projects in the archeological field and World Heritage sites.

Ralph Bodenstein holds an MA in Islamic Studies, Islamic Art History, and Town Planning from University of Bonn; a degree in Building Archaeology and Conservation Studies and a doctoral degree from TU Berlin. Between 1997-2006, he lived and worked in Beirut, doing research on architectural and urban history. He worked as a DAAD Visiting Professor at Cairo University and as research fellow at the German Archaeological Institute, first in Cairo and then in Berlin. He was recently interim Professor for Islamic Art and Archaeology at the University of Bamberg.

Nathalie Chahine (BBHR2020) is an architect restorer who has been involved in research and conservation projects in the Ottoman cities of Tripoli, Saida, and Damascus. She has led and participated in the rehabilitation of 19th-century houses, public historic buildings, and archeological sites. She teaches Traditional Architecture and Rehabilitation and has trained Lebanese and Arab architects on the principles and techniques of restoration.

Michel Chalhoub (BBHR2020), is a structural engineer who specializes in the restoration and retrofitting of built heritage. A university professor and researcher, he is the author of several scientific publications including *'Rock Mass Homogenization and Numerical Classification'*. Chalhoub is also the founder and CEO of a design-build firm, DISTRUCT Solutions Sarl. Since 1999, he has conducted numerous consultancies and contracting projects on the consolidation of national and World Heritage monuments in Lebanon and abroad.

Fadlallah Dagher is a Beirut based architect. Along with his firm, Dagher Hanna and Partners, he has designed projects covering various building types, including historic building renovations. Dagher has taught at Académie Libanaise des Beaux-Arts and the American University of Beirut. He has been a member of APSAD since 1992, and was previously an advisor to the Minister of Culture for the protection and conservation of heritage buildings in Beirut. Following the August 4, 2020 explosion in Beirut, Dagher has joined efforts with colleagues and professionals to launch the Beirut Heritage Initiative. He has directed the publication of "L'homme, la terre et la pierre" (Fondation Nationale du Patrimoine, 2001), and has contributed to "Beit Saifi as time goes by" (Marc & Hala Cochrane, 2015).

Mazen Haïdar is a heritage architect and graduate researcher at the University of Rome-Sapienza. He has led and participated in several restoration projects in Lebanon and has also taught in various Lebanese and French institutions. His doctoral thesis in preparation at Université Paris I focuses on the reception and appropriation practices of the 20th century architecture in Beirut. His works include: "Città e memoria, Beirut, Berlino, Sarajevo" (Bruno Mondadori, Milan: 2006) and "La Ferronnerie architecturale à Beyrouth au XXe siècle" (Geuthner, Paris: 2021).

Jad Hammoud is an anthropologist and a conservation architect. He teaches Architecture, History of Architecture and Restoration at the Lebanese University. He focuses on the historical and material investigation of traditional and modern technology and the implications of this approach for the conservation of built heritage in Beirut (1840-1940). His works include: "Evaluation of Thermal Comfort in the Traditional Bourgeoisie Houses in Beirut" (2020) and "Evolution of Floor Construction System in Beirut (1840-1940)" (2020).

Jala Makhzoumi is adjunct professor of landscape architecture at the American University of Beirut, and co-founder and president of the Lebanese Landscape Association. In her practice, research and teaching, she explores place-responsive, community driven and ecologically embedded landscape design. Her expertise includes ecological landscape planning, landscape heritage conservation, sustainable urban greening and post-conflict recovery. Jala is recipient of the European Council of Landscape Architecture Schools Lifetime Achievement Award, 2019 for her outstanding contribution to landscape architecture education and practice.

Jean Semaha is an architect specialized in restoration and conservation of historical monuments and sites. He has led and participated in several restoration and contemporary projects in Lebanon and overseas. Samaha teaches at Académie Libanaise des Beaux-Arts and conducts research on the restoration and conservation of heritage sites in Lebanon.

Marc Yared (BBHR2020) is an architect specialized in Historic preservation. For the past few years, he has been working on the restoration of a 19th century mansion in Beirut and has contributed to the assessment studies of several heritage *Beiruti* houses. He is also involved in the study, conservation, and presentation of various Archaeological sites since 2016.

Coordinators

Houda Kassatly is an ethnologist and photographer in charge of the culture program at arcenciel association. She is also an associate researcher at Saint Joseph University and Balamand University. Having founded Al Ayn publishing house, she specializes in the cultural and architectural heritage of Lebanon and the Middle East. Author of numerous books, including several on Beirut and on earthen architecture in Lebanon and Syria, her photographs have been the subject of many exhibitions in Lebanon, France and Belgium. She is currently the general coordinator of Beirut Heritage Initiative.

Lara Maalouf (BBHR2020) is an architect specialized in restoration and conservation of cultural heritage. She has been involved in the research and rehabilitation of 19th century *Beiruti* houses and medieval edifices and has participated in the study and site presentation of archeological sites. She takes part in different cultural outreach programs and is currently preparing a degree in museology.

APSAD, Association pour la Protection des Sites et Anciennes Demeures

BBHR2020, Beirut Built Heritage Rescue, is an initiative established following the 4th of August explosion for the salvage of Beirut's damaged heritage houses.

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INTRODUCTION

Fadlallah Dagher

On August 4, 2020, the city of Beirut was devastated by huge blasts in the port perimeter that left hundreds dead and thousands injured and homeless. The catastrophe destroyed many neighborhoods of the city, including most of the heritage clusters and buildings from the late 19th and early 20th centuries. Thousands of volunteers and NGOs rushed to the rescue, organizing to manage the urgent works in a blatant absence of any consistent governmental response.

Despite the outpouring of solidarity amongst the Lebanese people, the operation lacked proper leadership and organization on several levels. With scarce means and aided by volunteer engineers and architects, numerous NGOs jumped in to restore buildings of heritage significance. However, most of the NGOs were not familiar with the late-Ottoman and early modern construction materials and techniques. Nonetheless, there are many specialized architects in Lebanon, most of whom studied at the Lebanese University. In the immediate aftermath of the disaster, and under the authority of the Directorate General of Antiquity, these professionals teamed up through the Beirut Built Heritage Rescue 2020 (BBHR2020). They volunteered to survey and assess the damages. Within weeks, the BBHR had established an emergency action plan, including the propping and sheltering of damaged structures.

With the support of *Fondation de France*, the Beirut Heritage Initiative is issuing two restoration manuals to introduce the *Beiruti* architectural heritage, its materials and techniques to NGOs and professionals on the ground:

- The first manual focuses on the buildings of the late-Ottoman period (1860-1925), nicknamed “the triple arched mansions” or the “Lebanese houses”.
- The second manual is dedicated to the buildings in reinforced concrete, which was introduced between the World Wars (1925-1945) and which spread widely during the modernist era (1945-1970).

Many experienced specialists have contributed to these publications. The two manuals target the novice and the non-specialist alike, as well as construction professionals in a hurry, through a simple literature strongly supported by drawings and photographs. One will get familiar with the elements of style, the materials, and techniques of each architectural type, as well as the pathologies and methods to treat them. However, one should be aware that reading these manuals does not replace years of academic learning or specialized publications. When confronted with specific problematic conditions, it is recommended to consult experienced and dedicated professionals.

Restoring the built heritage is one action plan amongst larger operations to be undertaken within the immense urban rehabilitation process. Yet, the specificity and character of the devastated neighborhoods—Saifi, Gemmayzeh, Mar Mikhael, Geitawi, Karantina, Ashrafieh, Zokak el Blat and Ain el Mreisseh—rely particularly on the remains of the built heritage which have, more-or-less survived the civil war and the urban frenzy post-1990. Along with the consolidation of the social fabric, observing a strict methodology based on the use of authentic material is key to preserving the soul of Beirut for future generations.

HISTORICAL AND SOCIAL BACKGROUND

Ralph Bodenstein

Beirut is known for being a city with over 5000 years of history. Nowadays, however, historical houses—including those we call *"Beirut houses"* or *"Beiruti houses"*—are almost exclusively found in the pericentral quarters, i.e., the neighborhoods that began to develop during the 19th century outside the historical core of the city. This is quite unlike other historical towns in Lebanon, such as Saida or Tripoli, where the 'old city' remains preserved in time and space. The peculiarity of Beirut begs some explanation. Simply stated, the main reason is the complete transformation the city underwent in the 19th and early-20th centuries.

Beirut's transformation was fueled by an array of factors. One factor is the city's political and economic rise—a process kick-started during the Egyptian occupation (1832-1840), when Beirut took over functions formerly held by the provincial capitals of Saida and Acre. It was made official capital of the Ottoman province of Saida in 1841, became capital of the newly created province of Beirut (*Wilāyat Bayrūt*) in 1888, and eventually the capital city of the new state of Lebanon, established in the 1920s under French Mandate rule.

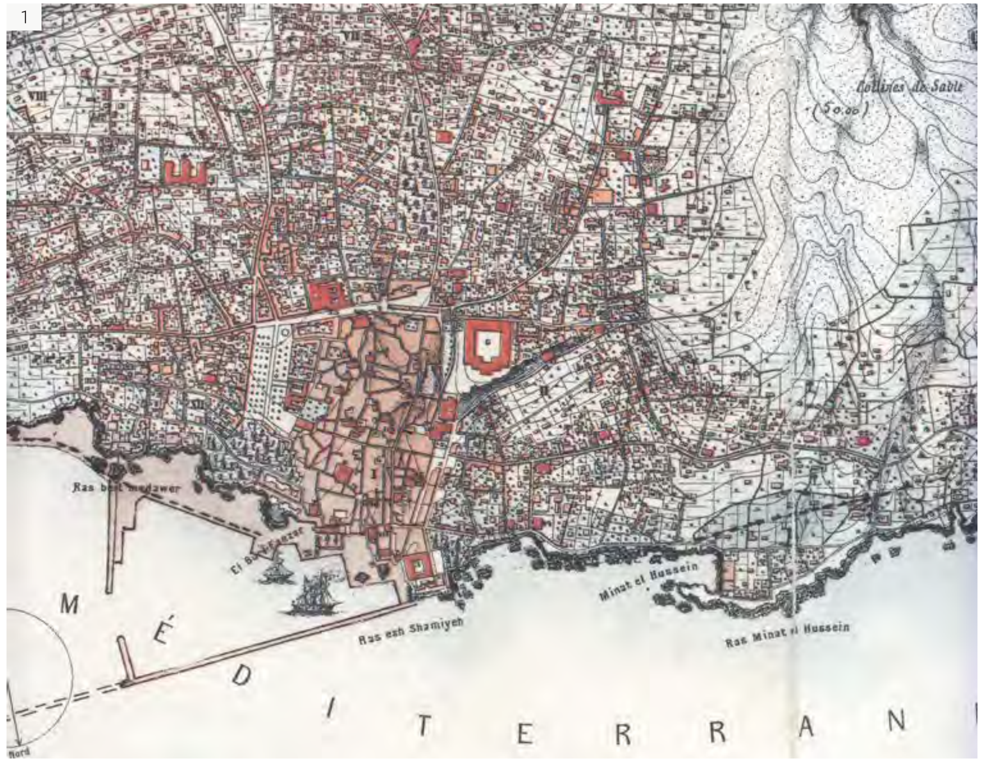
During the 1830s, the cultivation and export of silk as a cash-crop, massively expanded by the Egyptians, provided the basis of Beirut's new prosperity and its fast integration into the European-dominated world-economic system. Infrastructure development allowed Beirut to become the region's dominant port of transshipment for imports from industrializing countries in Europe and exports from the region. The harbor was repeatedly upgraded, with major extensions added in the 1830s and 1890s; a carriage road to Damascus was built between 1859 and 1863; a railroad connecting Damascus to Beirut was completed in 1894; modern overland roads to Saida and Tripoli were paved at the turn of the 20th century. The city received fresh-water supply from the Nahr el-Kalb in 1875, gas lighting in 1888, and an electric tramway and electrical supply in 1909.

Starting in the mid-19th century, Beirut also developed into a cultural hub. Important schools and colleges were established by missionaries and intellectuals. Newspapers and printing houses were founded, making the city one of the centers of the Nahda movement. The novel administrative role of Beirut led to a significant presence of bureaucrats (of Egyptian, Ottoman, and local descent) and increased the direct influence of modern Ottoman *tanzimat* politics and culture. Consulates, missions, and business opportunities triggered a slowly growing presence of Western foreigners and an influence of Western culture.

All this went along with rapid demographic growth. The population grew from between 5,000–6,000 inhabitants in the early 19th century to between 12,000–15,000 in the 1830s, averaging around 20,000–50,000 in the 1850s, before jumping to 60,000–80,000 in 1860. At the turn of the 20th century, Beirut boasted over 120,000 inhabitants, and in 1932, the French census registered a whopping 160,000. The rapid growth of the 19th century was only partly due to people moving to Beirut in search of economic and social opportunities. Especially during the 1840s to 1860s, the expansion can also be attributed to people fleeing socio-economic upheavals and repeated eruptions of violence and civil conflict in the Lebanese mountains and inner-Syrian cities (like Damascus and Aleppo).

Beirut managed to evade the violence. However, the economic and demographic development led to a profound upheaval of the social set-up, hierarchies, and confessional composition of the city. By the 1830s, old-established *Beirutis* had already been outnumbered by newcomers. By the 1860s, with the Maronite and Greek Catholic communities rapidly growing, the previous numerical balance between Muslims (mostly Sunni) and Christians (mostly Orthodox) had shifted to a Christian majority. The economic and educational opportunities offered by the city revolutionized the social stratification: the older type of notable-elite lost influence to a new type of money-elite. A bourgeoisie and educated middle-class developed, and the lower strata expanded and diversified.

Each of these aspects serves to highlight the extreme social, economic, and cultural dynamics that were at play in Beirut at the time. It was a city and urban society in the making. It was a time in which people were struggling to find their place in a fast-changing and modernizing city and world. The houses that were built during this period were also part of that effort.



Detail of the 1876 "Löytved-Map" of Beirut, showing the old city (pale red area) surrounded by developing extra-mural neighbourhoods.

In this context, several processes triggered the development of residential areas outside the old city. In the early 19th century, wealthy *Beirutis* had already begun to build summerhouses in the gardens, orchards, and mulberry plantations on the surrounding hill slopes of Kantari, Zokak el-Blat, Moussaitbeh and Ashrafieh. Of the growing number of immigrants that arrived, many first settled in the old city, contributing to a densification, and vertical extension of old houses in the neighborhood. Meanwhile, the old-established and the newcomers who could afford it moved to build new houses in the extra-mural areas. These areas offered fresh air, greenery, panoramic vistas, and privacy. By the 1840s, residences of this area, albeit still scattered, became more permanent. Every day, wealthy *Beiruti* merchants would walk down from their "trim villas" to their workplaces in the bazar and port areas of the old city. Simultaneously, landed property in the extra-mural areas became an important object of investment and business transactions, generating more land for purchase and construction.

In the second half of the 19th century, more and more houses were built. Some of the houses were big and prestigious, set in vast gardens, while others were small and simple, set on small plots, gradually forming the "first-ring" of suburbs. Soon after, higher density concentrations developed south and east of the old city, engulfing Sahat al-Burj (the latter-day Martyrs' Square), and coalescing along the main arterial roads to Saida, Damascus, and Tripoli. In the first half of the 20th century, new means of transport like the tramway and the motorcar prompted the development of residential areas even further afield. Under the French Mandate rule, road infrastructure was systematically expanded beyond the built-up areas and prepared the city for further urban expansion towards Ras Beirut, Horch Beirut and Nahr Beirut. This expansion process continued throughout the century until urbanization reached the foothills of Mount Lebanon and the Shouf Mountains. While Beirut expanded outwards, the old city, as the main area for business activities, was subjected to another development pressure. This led to its piecemeal demolition and redevelopment. In the later 19th century, policies of street alignment, accompanied by demolition, were implemented by Beirut's municipality. Due to these schemes, the city wall was demolished. In 1915, during the First World War, and in order to create wide modern thoroughfares, large tracts of the old city and its souks were razed by Ottoman military authorities. Brought to completion by the French in the 1920s, this project created the new urban design around Place de l'Étoile, Rue Foch and Rue Allenby. The changes continued throughout the 20th century, culminating in the destruction and clearance works of the Civil War as well as the post-war reconstruction under Solidere. The few historical buildings still standing in Beirut's Central District today are thoroughly renewed; it is the historical houses of the 19th century suburbs that have maintained their original substance and stand as historical witnesses to the rise of modern Beirut.

2

View of Zokak el-Blat in the 1890s, showing houses of diverse typologies, including numerous central-hall houses of various sizes and shapes.

Ralph Bodenstein

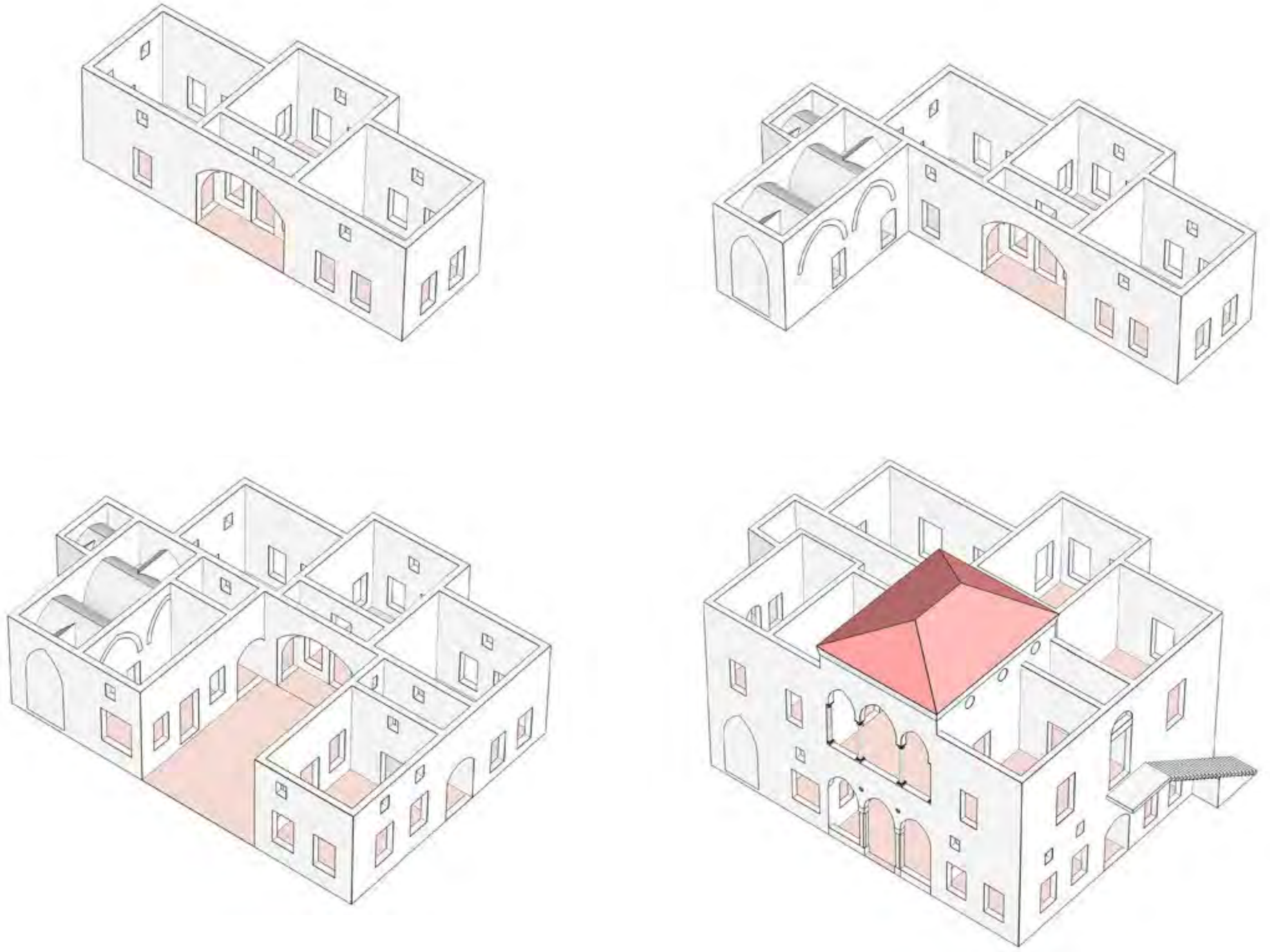
When we speak of *Beirut houses* today, we usually think of the most characteristic typology that developed in the 19th century, popularly called the "triple arch house" and referred to as "central hall house" by architecture historians. That said, it is important to keep in mind that until the later 19th century, the houses built extra muros (outside the walls of the city) showed a broad variety of typologies. In today's pericentral quarters, these diverse structures occasionally still survive. Often integrated into later construction, these structures have been made hard to discern for non-specialist observers. Nonetheless, such material remains, together with historical descriptions and drawings, allow us to trace some of the typological diversity and developments. It was at some point in the mid-19th century that these advances also produced the "central hall house."

Before Beirut began to expand into the extra-mural areas, there were already small stone buildings in place. These structures had either vaulted or flat timber roofs and were used as storage buildings, tool sheds, guard houses, and temporary accommodation for the cultivators of orchards and plantations. The early houses, built as summerhouses or more permanent residences, often re-used these pre-existing rural structures. Furthermore, these houses were built in an incremental manner, adding rooms as horizontal and vertical extensions. In the 1820s–1850s, tower houses and multi-level houses were often found either with vaulted ground floors or as single-floor houses, with rooms arranged in an L- or U-shape layout around a forecourt or courtyard. The extant ground floor vaults were often used for storage and stables, while the incremental additions would transform the original roof terrace into full-fledged dwellings. Courtyards and roof terraces were important spaces for household chores, food processing, and leisure time with the family and guests. Some houses would feature a rooftop room, called *'aliyya,* that served as a kind of *belvedere* and guest room.

A very typical element of the houses, as in houses of *Bilād al-Shām* more generally, was the *īwān or līwān.* This is a room opening onto the courtyard through a wide arch. In the rural surroundings of Beirut, there was a variation where the rear part of the *līwān* was closed off with a wall, creating a separate room communicating with the front part through a centered door flanked by two windows. The front part, with its open arch, served as a porch. These *līwāns* often appeared in combination with a lateral room *(murabba')* on either side—and with their doors symmetrically opening onto the arched porch. The resulting *līwān* group is considered one of the standard modules utilized for building houses in the extra-mural areas of Beirut. They either constituted a complete house in itself or were integrated into larger structures.

Around the mid-19th century, the first concrete evidence of central hall houses in Beirut is found. The first known descriptions—and earliest examples of these houses—can be dated to the early 1850s. This signifies that these examples may date back to the later 1840s. Their builders were *Beirutis* who belonged to different confessions—Muslims, Christians, and Jews; what they all had in common was that they belonged to the new wealthy upper class.

3



Axonometry of Bayt Aoun (Saifi 614): example of the gradual extension of a rural līwān house and its eventual transformation into a central-hall house. The process unfolded over the mid- and later 19th century.

In a broad sense, this typology is characterized by its fairly symmetrical floor plan. The plan features a large, covered hall *(called al-dār)* which is surrounded by rooms along three sides and has large arched openings on the fourth side. The fourth side is usually oriented north, offering sea views and mountain views. The central hall is the main distributional space, giving access to the surrounding rooms.

A more deeper look shows that some of the rooms that were arranged around the central hall had specific characteristics. One of the two rooms flanking the central hall on the northern main façade was usually designed to serve as a reception and guest room, called *manzūl*. It was distinguished by its larger size, rich decoration, numerous windows, and—a very important feature —by having multiple access doors: one from the outside or entrance corridor, one from the central hall, and occasionally one from a service corridor. This arrangement allowed for visitors to enter without passing through the central hall and, thus, protected the privacy of the house.

Another element that reappeared in the central hall house was the *līwān* group. The group was located at the rear of the central hall: either in a closed version with the *līwān* communicating with the hall through a centered door flanked by interior windows, or in a novel open form with arches replicating those of the central hall façade. This *līwān* often functioned as a sitting area.

A third constitutive element was the kitchen and service area that were usually slightly set off from the central hall. Located laterally or backwards at the southeast or southwest corner of the house, they often formed an annex with a separate exterior access for servants. Typically, the kitchen area was vaulted (when on the ground floor level) and equipped with a wooden mezzanine, called *titkhīteh,* for storage and servants' accommodation. The service area also contained a small bathroom and a toilet, which were initially the only sanitary installations in the house and were used by family and servants alike.

These constitutive elements remained relatively stable from the early known examples into the 20th century. However, other features changed. The early examples either had flat roofs, in timber construction, or were entirely vaulted in stone construction. Often, the central hall ceiling was higher than the surrounding rooms, rising above the roof as a kind of clerestory with round windows and providing additional light. It is only by the late 1850s that hipped and gable roofs, which were then covered with red tiles and initially only covered the central hall, are observed. The full, red-tiled roof, which is nowadays considered a hallmark of the *Beiruti* house, only became the norm in the late 19th century. In addition, the triple arch, the characteristic opening of the central hall, was also a later development. The early central hall houses either had one large arch, two arches, or even simple rectangular windows instead of arches.

Due to the lack of preserved early buildings and sources in Beirut, there is no accurate explanation as to how the central hall typology fully developed. However, a clear and major factor was the ongoing experimentation with locally developed elements and forms.

This experimentation was driven by the pressing need felt among the old and new elites in Beirut to build new and prestigious homes as a means of social distinction. In this context, a decisive formative influence was the model of Ottoman upper-class houses, namely the *sofa-house.*

4

Bayt Saadeh (Zokak el-Blat 122): groundfloor plan of an early, yet fully-articulated central-hall house that was erected en bloc during the 1850s. Built entirely in vault construction, it features a manzūl with triple access, a kitchen annex, and a līwān module as integral part of the new construction.

This type of central hall house became fashionable among the Ottoman and Egyptian elites in the early 19th century. It is only after the establishment of the central hall type in Beirut over the course of the later 19th century, that European influences are observed and become more visible—especially in the form of exterior and interior decoration. Subsequently, a strong influence of Ottoman Baroque style is found in the 1860s. Eventually, a gradual shift to more Italianate styles, followed by a brief wave of Neo-Islamic and Neo-Oriental styles are recorded in the 1920s. Art Deco and Modernist styles consequently take over in the 1930s-40s.

By 1900, the *Beiruti* central hall type, in its developed form with two or three floors, triple arcade and red-tiled hip roof, had not only become the standard model for upper-class and upper middle-class houses in Beirut, but also began to spread into other coastal cities and into the mountains. Contemporary Ottoman observers called this traditional urban courtyard house *"al-tirāz al-Bayrūtī* (the Beirut style), as opposed to *al-tirāz al-shāmī* (the Syrian style).

While the plan typology remained relatively stable once established, the spatial functioning continued to significantly develop. For instance, in the initial layout, all rooms surrounding the central hall only had access from the central hall, just as it used to be with rooms surrounding a courtyard. In addition, until the 1860s-1870s and even in upper-class houses, most rooms were still furnished in traditional ways. These furnishings included diwans, lightweight tables (*siniyyeh on a kursi khachab*) and mattresses that would be temporarily put up and stowed away again after use. Rooms tended to be multifunctional. With the gradual introduction of less versatile European furniture, like dining tables and bedsteads, the functionality of rooms began to be redefined more permanently, leading to functional specializations such as bedroom, dining room, etc.

Consequently, around the 1880s, some rooms began to be directly interconnected with doors in order to allow for internal communication without having to cross the central hall. Bedrooms were connected by doors, and dining rooms received more direct access from the kitchen area. Functional clusters began to develop in the floor plan of newly built large houses. By the 1920s, this process found fruition in the full-fledged articulation of "day areas" (for reception and living) and "night areas" (for bedrooms combined with modern bathrooms). In older, already extant houses, this process was replicated by inserting modern bathrooms into or between bedrooms. This is a clear indication of a general change in the conceptualization of domestic comfort and privacy within the household. In smaller houses, however, spatial limitations reduced the possibilities of functional specialization and clusters. Their floor plans remained more basic, and uses had to be more adaptable.

An important inherent quality of the central hall plan was that floors with almost identical surface and layout could be stacked on top of one another, each constituting potentially independent units. By the 1860s, independent floors of large central hall houses were used by separate households or were rented out. By the turn of the 20th century, multi-story apartment buildings had fully developed. These full-fledged buildings often consisted of the coupling of two central-hall houses, each with two or three floors of limited surface area and were connected by communal staircases. Such buildings were an urban typology, usually located along main thoroughfares and in more central locations. A further development was the "walk-up apartment buildings" of the 1920s and 30s, which began to feature *large verandahs,* making use of the novel technology of reinforced concrete. Such buildings were located in suburban areas and marked a process of urban densification. While these "walk-up apartment buildings" continued to have a central hall plan, the triple arch was substituted by large rectangular windows in Art Déco and Modernist styles.

For newly built upper-class villas in Beirut's expanding suburbs, the 1930s already mark the transition away from central hall plans to asymmetrical layouts. From then on, the central-hall *Beiruti* house went out of fashion.

Those that survived the development pressures and perils of the following decades stand as monuments for Beirut's phenomenal rise and multifaceted history in the 19th and early 20th century, persisting as steadfast vestibules of the city's heritage and memories.

Fadlallah Dagher

The construction process of *Beiruti houses* is poorly documented. Early builders did not leave any drawings, plans, or descriptive literature on their methods and techniques. Nor were there treaties on the commonly used rules of proportions. It is only through observation, comparison, and analysis of remaining specimens that one might encode the principles of construction, identify the defects and pathologies, and set the bases of a proper restoration.

Houses were often built hastily and in what seems to have been frenzied constructions. Many structures were extended over time without proper structural bonding but within a coded system of dimensions and prefabrication. The connections between phases were then hidden under plaster and lime-wash to give the illusion of one unified structure. Yet, poor maintenance, time, climatic conditions, natural disasters, and violent upheavals (including the August 4 blast) reveal the true nature of these structures – which all look alike in principle.

The assessment of the original structure is essential to any restoration process. Firstly, it is a key step in identifying the urgent measures that need to be taken in order to safeguard the structure and prevent it from sustaining further damage or collapse. Secondly, it helps identify specific architectural qualities of the house by listing its historical status, the materials used and their quality, its functional and decorative features, as well as their level of refinement and other specific or exclusive features of the structure. A thorough assessment will provide essential technical data that will serve as a base for planning and establishing a provisional budget for the restoration.

To assess the status of a structure, one must carefully observe, survey, and document it. A basic understanding of similar building features is crucial not only in aiding the detection of critical pathologies and defects, but also in unearthing unique decorative features hidden under multiple layers of plaster or paint applied over more than a century.

Precautions

Old, neglected structures are fragile and, as such, constitute hazardous areas that should only be accessed by specialized professionals.

To undertake any inspection, the architect/engineer must take all necessary safety measures, including but not limited to wearing a safety helmet, proper footwear, jacket, etc.

Inspections must be carried out by teams of two to three people. It is ill-advised for one person to venture alone into a damaged structure.

While walking around and inside the building, remain vigilant and on the lookout for rotten floors or ceilings.

Refrain from exploring hazardous areas like balconies, roof attics, etc.

Do not walk on *Baghdadi* ceilings while inspecting the attic under the roof—it is not a structural material.

Abandoned buildings and shady areas might be infested with fleas. Make sure to be properly protected (boots, long pants, and sleeves...)

Preparation

The building to be assessed will be identified on an area map—or better yet, on a cadastral map *(kharita `iqariyya)*. Official maps of Beirut are available at scales of 1/2000 and 1/500 and are pretty accurate.

During a preliminary inspection visit, the architect/engineer will observe and take as many photographs, notes, and sketches as possible. These will come in handy in the preparation of reliable preliminary documents for further detailed inspections.

On an enlarged copy of the area map, the architect/engineer will sketch the various levels of the building, including interior partitions and schematic position of openings; the grade level will show the land perimeter and its features (gates, fence, fountain, paved areas, vegetation, etc.)

The architect/engineer will sketch the elevations and a tentative section of the structure based on the dimensions observed on the cadastral map, his/her visual assessment, and the photographic inspection.

Once the preparatory documents are established, a detailed inspection can commence.

An assessment brief form will be prepared *(check assessment sheet page 30).*

Site inspection

Guided by their preliminary documents, the architect/engineer and her/his team will then inspect the site. The following tools are essential for the inspection:

- pads, pen/pencils, and paper
- a photographic camera of good quality
- measuring tools: a 500 cm tape; a meter scale (optional); a digital laser tape (optional)
- an electric torch

Elements to assess

- the structural condition of the building: construction systems and material (load bearing walls; type of slabs, vaults); type and size of cracks; level and location of damage; composite material
- condition of the timber truss and tiles of the pitched roof
- material and condition of balconies: marble slabs; corbels; concrete elements
- type, material, and condition of stairs
- conditions of windows and doors joinery
- condition of metal elements: gates, guardrails, protection grilles…
- type of tiling and condition
- type of decorative ceilings and walls: *Baghdadi*, paintings, murals, and their condition
- special features (well, washbasins, furniture, …)

Observations will be indicated on the assessment form and noted through a mapping of alterations and materials using the pre-prepared plans and elevations.

The elements listed above are sufficient for a preliminary assessment and to determine the propping and sheltering strategy should there be a need for urgent protective measures.

Additional investigations (once the building is secured)

It is recommended to undertake a complete and detailed survey of the building, with the assistance of a topographer or using 3D imagery tools. The architect/engineer shall indicate to the topographer the critical points to survey. The survey will make it possible to identify the architectural elements characterizing the different phasing of the building.

Material samples—such as stone, marble, plaster, gypsum, cement, etc. —will be selected and extracted, for reference and/or for testing.

On-site non-intrusive tests, such as sonic and ultrasonic tests, thermography tests, etc., can be carried out to better identify the problems at hand.

In case of vertical or diagonal cracks on the walls, foundations below grade will be investigated by digging 100 cm x 100 cm pits directly beneath said cracks. The compacted fill below the finish level will be thoroughly observed to detect traces of humidity and/or weaknesses. Foundations will be inspected to monitor the continuity of the cracks. Please note that deep pits at the corners of the structure will give precise information on the nature of the soil, as well as the depth and nature of the foundation itself.

The fill and its depth below the upper floors tiling will be inspected by removing one floor tile or more.

It is recommended to investigate the timber beams’ connection to the walls, as well as the top of the wood planks to assess their condition.

Depending on the scale and nature of the project, it is recommended to have a multidisciplinary team on board during the investigation.

Monitoring

It is essential to monitor all cracks and structural problems by putting glass tell-tale, gypsum bands, or more advanced crack monitoring tools in order to observe their expansion.

Urgent measures

Some measures are to be considered urgent and essential in order to protect the structural integrity of the building. Structural safety is a priority both for preserving the structures themselves and ensuring the security of the inhabitants and the working team.

Urgent measures may include propping actions, covering the structure, and eliminating sources of high moisture.

Once the above is completed, a comprehensive assessment report will be issued. It should include:

- the full survey of the existing condition (with drawings and photographs)
- legal documentation (deed of ownership, land certification, cadastral map…)
- a historical report
- a structural report highlighting the pathologies and defects
- proposed interventions on the short-, medium- and long-terms
- a provisional budget for restoration by division or trade
- projected plans in case of alterations, rehabilitations, or adaptive re-use of the building

Historical data sources are owners’ family archive or oral information; old photographs, publications and studies; Ottoman cadastral archives (if accessible), etc.

ASSESSMENT SHEET

Date	Function	Level	Mezzanine	Dimensions
23-11-20	*Actual service "Sas"*	*3rd floor*	*Y*	*3*5 m*

Description - Notes - Special features

Function

A buffer space located between the service area (kitchen and toilets) and the dining room.

A mezzanine is located above this area and a wooden stair is leading to it

Description

A rectangular space, with 5 doors and a mezzanine. It has a wooden ceiling, paintings on the walls and a marble fountain. The space is being propped following the explosion

Recommendations

The wooden ceilings to be restored.

The eastern wall to be dismantled and reconstrued.

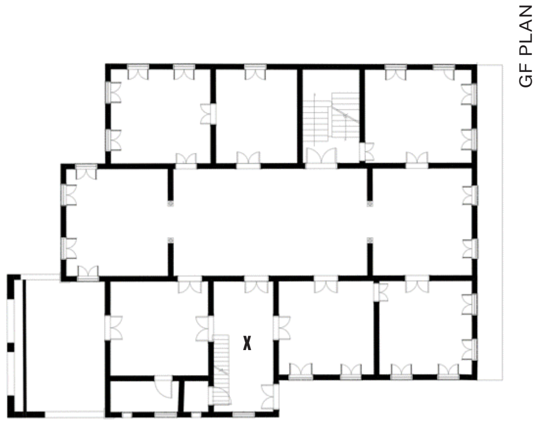
The wooden stair to be restored.

The doors and the windows to be restored.

The marble fountain and the tiles to be cleaned.

The plaster and the paintings to be restored.

Key plan



Floor

Authentic Y/N	*Y*	*State of conservation*	*Remarks / intervention*	*Decays*		*Location*
Type				1 Settlement	X	N - E - S - W
Terra cotta	X	*Bad*	*Cleaning and jointing Replace missing and eroded*	2 Water infiltration	X	E
Stone flooring				3 Micro - Organisms	X	
Marble				4 Vegetation		
Mosaics				5 Cracks	X	
Ceramics				6 Missing items		
Treshhold				7 Stains	X	
Marble	X	*Good*		8 Erosion	X	
				9 Late intervention		

Walls nature & finishing

Authentic Y/N	*Y*	*State of conservation*	*Remarks / intervention*	*Decays*		*Location*
Type				1 Settlement	X	N - E - S - W
Stone walls	X	*Bad*		2 Detached plaster	X	And Plinth detachment
Baghdadi				3 Micro - Organisms		
Hollow blocks				4 Buckling	X	
Finishing				5 Water infiltration		
Water based paint	X	*Detachment*	*Consolidate authentic lime paster and replace missing parts / Repaint*	6 Vegetation	X	
Lime plaster	X	*Detachment*		7 Cracks	X	monitor the cracks
Cement plaster				8 Major cracks	X	
Bare stones				9 Capillarity		
Traces of removed paitings				10 Crust - stains	X	
Mosaic				11 Late intervention		

Structure

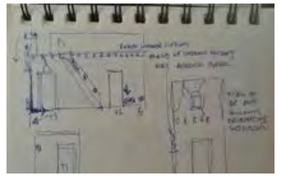
Authentic Y/N	*Y*	*State of conservation*	*Remarks / intervention*	*Decays*		*Location*
Type				1 Cracks	X	N - E - S - W
Bearing walls	X	*Bad*	*Dismantle and reconstruct*	2 Missing pieces	X	
Wooden ceiling	X	*Rot*	Treat and restore	3 Late intervention		
Vaults				4 Rust		
I-beam						
Concrete						

Metal

Authentic Y/N	*Y*	*State of conservation*	*Remarks / intervention*	*Decays*		*Location*
Type				1 Rust	X	N - E - S - W
Handrails				2 Missing pieces	X	
Windows protection	X	*Rust*	*Treat the rust*	3 Late intervention		

Room n°

36 *Boustany house. Rmeil I Room Log book*



STRUCTURAL SYSTEM

Nathalie Chahine, Michel Chalhoub, Fadlallah Dagher, Jad Hammoud, Jean Semaha, Marc Yared

MASONRY

Michel Chalhoub

Abbreviations

URM: Unreinforced masonry
GFRP: Glass fiber reinforced polymer
CFRP: Carbon fiber reinforced polymer
IP: In-Plane
OOP: Out-of-plane

Structural elements of *Beiruti* houses are divided into two main categories according to the materials used in the construction process. Foundations and vertical elements like walls, arches, vaults, and columns were generally executed with masonry, a material that is capable of supporting compression resulting from gravity load. However, slabs were created with a lighter material - such as wood or steel - capable of withstanding tension and bending.

The pathologies related to the structural elements of Beirut's historic buildings may be a consequence of the August 4 blast or any other structural decline origin. The identification of these structural decays and their sources determines the best-suited propping measures that need to be taken to stabilize the build on the short run, as well as the most appropriate methods for subsequent repair and consolidation.

Noteworthy, because of their structural weakness toward lateral loads, historical buildings require structural upgrades that reinforce them against earthquakes and blast loading.

Composition and Typology

Masonry is a heterogeneous construction material widely employed in most historical buildings, as well as in modern structures. The heterogeneous character of masonry is due to the diversity of its components, namely: masonry blocks, dry or mortar joints, infilling material, and reinforcement (5, 6).

Among the existing types of masonry, unreinforced masonry (URM) is the most common in the historical buildings that were built between 1860 and 1925 in Beirut. Mainly executed with local marlstone or sandstone blocks, the URM was used to construct foundations, walls, and vaults. Bricks were introduced after 1900 and spread widely after 1920 in the construction of slabs, partition walls, and in some particular cases of peripheral bearing walls.

URM is a durable material. In addition to its vertical load-bearing capacity,it is sufficiently sound-proofing, fire resistant, and energy efficient. Despite these advantages, URM can sustain several types of structural damages that will be elucidated in the following paragraphs along with the appropriate treatment of each. It is to be noted that certain damages observed after the August 4th blast may have been the result of other ruinous forces, such as earthquakes, settlements, aging, water infiltration, and vandalism. Consequently, the same proposed treatment can be adopted.

5

Deir Bella, Batroun - Liban

6

Propylaea, Baalbek temple - Liban

5, 6: Heterogeneity and components of a masonry structure

The blast has engendered two main categories of structural damages. The first category poses a severe risk of collapse and necessitates an immediate intervention comprised of temporary strengthening and propping support. The second category includes structural damages that should be repaired within a medium-term period - not exceeding a couple of years given that the build is protected from water infiltration.

The mechanical behavior of historic structures built with masonry depends principally on the quality of their structural elements' materials and these last connections conditions. The structural system of *Beiruti* heritage houses is composed of the following elements:

- Masonry foundations and walls are present in each building.
- Masonry arches and vaults are found in some buildings.
- Slender stone columns hold the central part of the typical triple arch.
- Slabs are made up of one or various types of materials.
- A combination of the previously stated elements poured with concrete was added to the main structure at a later stage of the initial construction phase.
- Attics are made up of wood.

Pathologies and repair

A characterization process based on understanding the different masonry components is crucial for detecting pathologies that may decrease structures' strength and accelerate their degradation.

Is it to be noted that the current chapter's main objective is to present the most common damages produced by the Beirut port blast. A rundown of a larger spectrum of decays and damages produced by aging, material degradation, environmental sources, water damage, biological colonization, and other potential disorders that arise in historical buildings can be found in classical bibliography such as the International Council on Monuments and Sites (ICOMOS) recommendations and Corpus Levant.

Although the Beirut blast did not cause significant structural damage at the foundational level, essential guidelines related to foundational inspection, diagnosis, and standard interventions will be presented in the following paragraphs.

Two main types of foundations can be identified in Beirut's heritage buildings (7, 8). The first type represents a continuous foundation constructed beneath the walls, while the second constitutes a system of isolated foundations linked together through stone arches. Both types are built with stone blocks and earth-lime mortar. Their cross-section usually has a bleacher shape supporting a foundation wall embedded in the soil.

The foundations' principal role is to disperse a structure's load onto the ground without exceeding its load-bearing capacity. Yet, structural anomalies deriving from foundational disorders may arise at any point in time. These may originate from one or more of the following factors:

- the aging of masonry and degradation of its mechanical properties
- an initial wrong design of the footings' dimensions
- poor mechanical properties of the soil
- added pressure on the foundations due to accidental loads, the construction of additional floors, and/or the execution of excavations in the building's periphery
- desertification and cyclic variation in the water table

As a result, differential settlements and soil movement occur. Their symptoms manifest in the following:

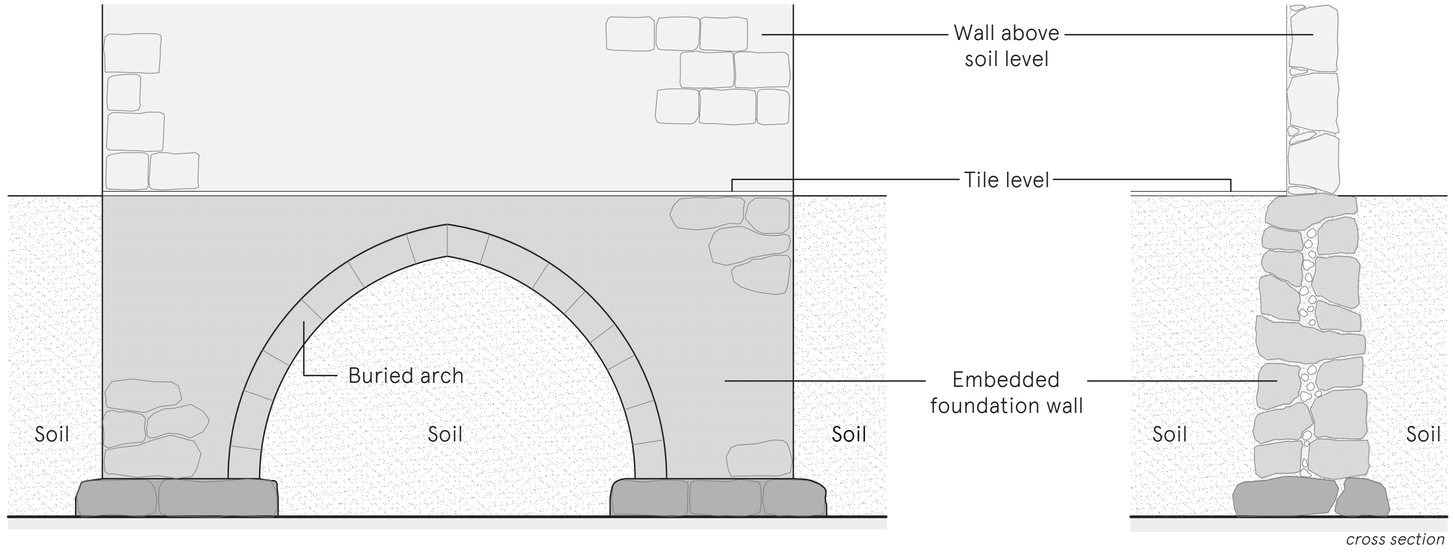
- The horizontality of bed joints is disturbed. Different levels are identified for a certain bed joint.
- Inclined active cracks appear in a stair shape on a wall. They usually cross the windows and doors corners.
- Active joints openings arise in vaults and arches.
- A detachment and a rotation of a corner angle of the building occur, indicating a local settlement beneath this area. This may result also from an abundance of water due to the presence of rainwater pipes at the building's corners.

It is to be noted that a geotechnical engineer should intervene when soil settlements or foundational disorders are suspected. A proper soil investigation should be conducted in order to determine the soil's hydro-mechanical properties. However, a basic inspection consisting of excavating a 1 m x 1 m pit with a depth reaching the foundation's lower level can be conducted by a non-specialist to help identify the problem's source.

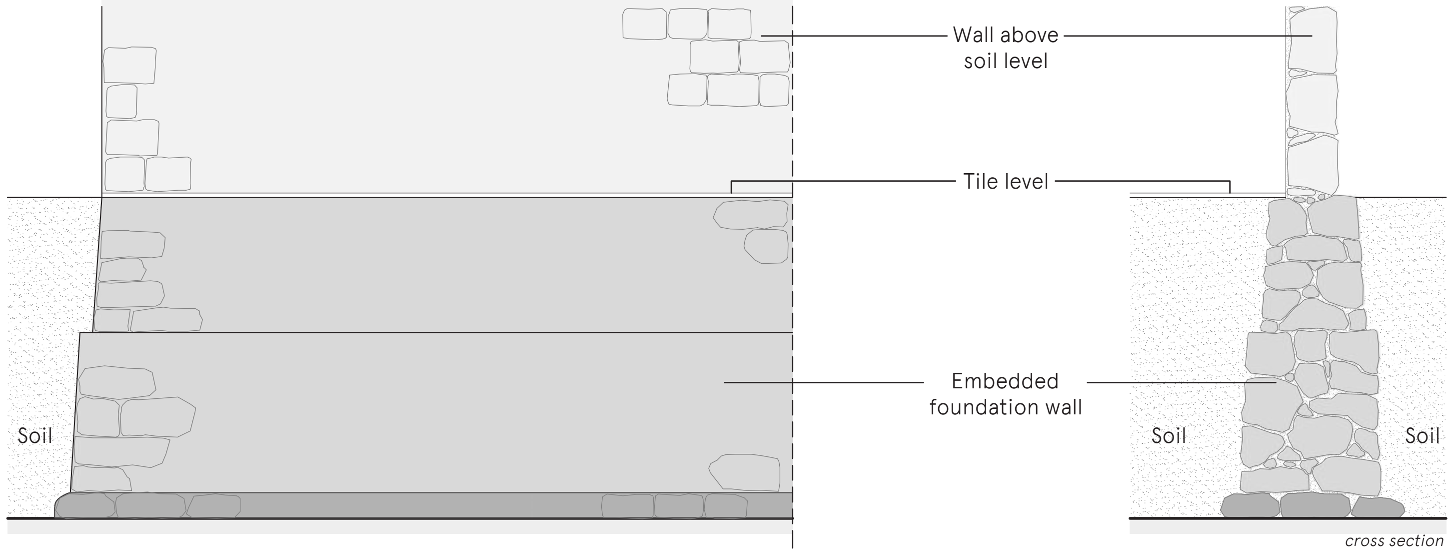
7

8

Footing beneath arches



Continuous footing

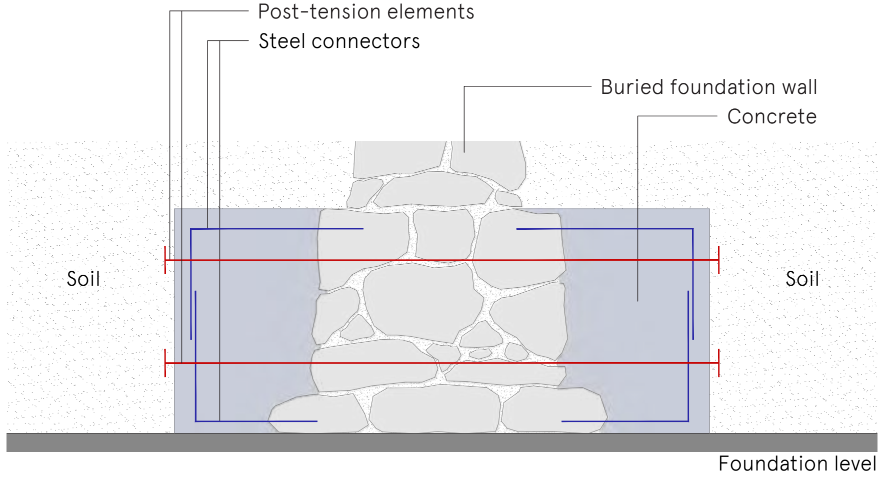


Main types of masonry footings in Beirut's historical buildings

Pits' location is usually chosen at the vertical continuity of a structural crack. A consolidation process should be foreseen if the structural crack crosses the foundation. Different solutions may be implemented for this purpose. It is up to a geotechnical engineer to decide which of the following techniques is best suited for the restoration:

- Improve the soil's mechanical properties by soil injection or jet grouting - i.e., mixing the soil with a cement grout introduced at high pressure.
- The addition of micro-piles either isolated or in a group of rows is suitable to calibrate differential settlements and carry out extra load due to the building's geometric modification.
- Enlarge the footing dimensions by a jacketing process (9). Footing enlargement can be done with concrete. The connection between stone blocks and concrete is ensured through L-shaped connectors chemically glued with an appropriate epoxy product. A lateral post-tensioning process may also be used in historic monuments' foundations that have been subjected to heavy loads.

9



Enlargement of footings by jacketing and post-tensionning process

WALLS

Michel Chalhoub

The geometry of masonry walls can follow a periodic or non-periodic arrangement composed of one or multi-layers in the thickness direction (10, 11, 12, 13). Periodic walls are usually made of blocks of equal size with periodic geometry like brick walls (10). Quasi-periodic walls are constructed with rectangular blocks of the same height per course and variable lengths parallel to bed joints (11). Irregular walls represent a combination of different shapes and sizes like rubble walls (12). Their surface texture is not meant to be visible but plastered. The thickness of masonry can be composed of one or multiple layers (13).

Bearing walls constitute the main, vertical structural elements of the built heritage in Beirut. Most of them were built with a single leaf layer. They are classified as slender and structurally fragile due to multiple factors related to their geometry and their materials' mechanical behavior. These include: a. the significant ratio between their height H and their thickness t (H > 4 m, t < 35 cm), b. their non-monolithic mechanical behavior due to joints presence, c. the increase of their buckling length resulting from their weak connection to horizontal floors and attics, d. the weak compressive strength of the masonry blocks due to high porosity and aging factors, e. their weak resistance toward tension, shear, and bending caused by out-of-plane loads.

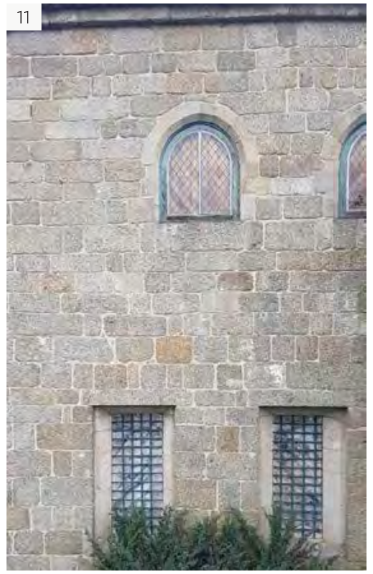
Bearing walls of heritage buildings were initially conceived to handle in-plane vertical loads such as self-weight and live loads. Consequently, their resistance against lateral loads produced by earthquakes or blasts is poor. During their lifetime, *Beiruti* built heritage was subjected to several earthquakes—some of which, like those of 1956 and 1998, were considered major. Despite this, these buildings survived due to the in-plane great inertia of their walls. However, during the Beirut blast, the walls' out-of-plane ultimate capacity was exceeded because of the high intensity of lateral loads acting perpendicularly to their surfaces. This perfectly explains the appearance of in-plane cracks and out-of-plane failure mechanisms in walls, in addition to the detachment mechanism of connections.

The overall damages and failure patterns induced by the blast are described next. First, the in-plane (IP) damage mechanisms are presented, followed by the out-of-plane (OOP) mechanisms, and the Hybrid mechanism.

10

Periodic, Burj Abi Haidar Beirut - Lebanon

11



Quasi-periodic, Guimarães - Portugal

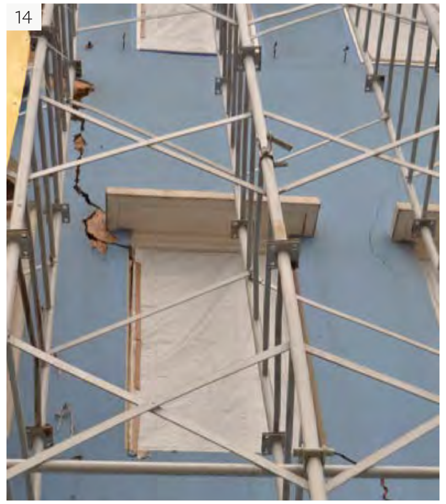
12

Rubble, Eddeh - Jbeil - Lebanon

13

Double-leaf, Behdaydet - Jbeil - Lebanon

10, 11, 12, 13: Typical geometry of masonry walls

14


Single inclined IP crack

15


X shape IP crack

16


Hazardous IP cracking pattern

In-plane damage (IP)

URM are characterized by weak resistance to shear stress because of their heterogeneity and their components' low tensile strength. The consequence of excessive IP stress caused by the blast is the appearance of hazardous IP cracks, remarkably in multi-inclined directions and patterns. Despite its damage aspect, an IP mechanism is the most desirable outcome of a blast or earthquake. Unlike an OOP mechanism, it causes wall damages without leading to a partial or a global collapse. Photos 14, 15 and 16 illustrate different types of typical IP mechanisms produced by the August 4th blast.

The most critical pattern of IP cracks is the inclined one. It may occur in a single, diagonal direction on a rectangular wall (14), in double, intersected diagonal directions (15), or following a hazardous distribution threatening a high degree of wall damage (16). Based on cumulative site observations, IP mechanisms are assumed to be repairable if the cracks' width is insignificant. Mathematically speaking, there is no precise value for crack width defining the limit between a repairing process and a demounting process. It is a case per case decision based on the building's entire structural state and the civil engineer/restorer's judgment. However, a crack width exceeding 10 mm (e > 10 mm) indicates a high probability of wall dismantling and reconstruction.

The injection technique is the basic remedy for IP damage. Cracks should be sealed to their depth with a fluid grout to guarantee a homogeneous and monolithic behavior of the wall. The type of mortar/grout must be carefully chosen to avoid any chemical or physical incompatibility with the wall. Lime is the fundamental component of a grout used for this purpose. NHL 5 is to be used, either by the assistance of gravity or under a low-pressure injection. The more fluid organic mortars (such as polyester or epoxy) should only be used when there is a need for higher resistance, without compromising the compatibility between the materials. The injection process must be executed from the lower level to the upper level of a wall and from its vertical edges to its central area. When the crack is deep, or its width is relatively significant, the injection process must be accompanied by additional interventions.

The most common methodology to repair an inclined IP mechanism is the stitching-injection process. It consists of creating a mechanical link to reconnect the two separated parts of a cracked wall. A briefing of the execution sequence is presented below.

Plaster surrounding the cracked area should be stripped from each side of the crack. The minimum width to be considered is the maximum of 30 cm and a course height from each side (17, 18, 19). If the crack crosses the masonry block's thickness, the plaster stripping and stitching process should be applied to the wall's double faces.

14, 15, 16: IP damage mechanism of peripheral and internal bearing walls

Stitching may be applied using two different techniques. The first one is related to masonry with parallel bed joints (periodic and quasi-periodic, 17, 18, 19). It consists of the following steps:

- Cut slots into the horizontal bed mortar joints with an electric saw to a depth of at least 50 mm.
- Clean the whole treated area with pressurized air or a vacuum.
- Spray the treated area with normal water.
- Bead a first layer of a high fluid lime mortar grout (volume: 1/2 NHL5 to 1/2 sand) into the back of the slot using a grout gun or an appropriate pump.
- Insert a U shape flat stainless-steel 316 L strip inside the joints (minimum dimensions: 30 mm x 3 mm). The metal strip edges are hooked with a minimum length of 50 mm and embedded vertically inside the head joints. GFRP or CFRP may also be used instead of metal.
- Bead a second layer of grout over the iron strip. The mortar depth covering the metal strip must be at least 30 mm. In the case of a brick wall, the mortar grout may contain crashed red tile product (volume: 1/2 NHL5, 1/4 sand, 1/4 crashed red tile).

17

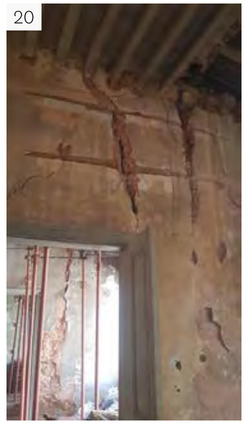

18


19


17, 18, 19: IP cracks stitching technique 1, Rmeil 474 - Beirut: plaster around cracks stripped, U shape stainless steel 316 L flat strips introduced inside the joints followed by a structural mesh installation

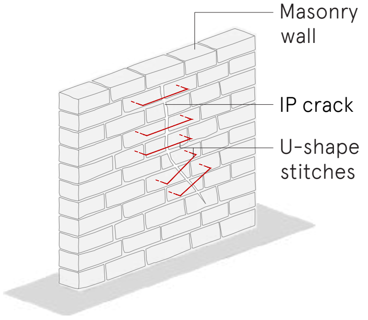
The second technique can be applied on walls whose texture has been designed to be plastered - not visible (rubble walls) and on periodic or quasi-periodic walls with clean parallel bed joints. The direction of a stitch may be horizontal or perpendicular to the crack's direction (20,21,22). U-shaped stitches made up of threaded stainless-steel 316 L rods are to be created in a minimum diameter of 12 mm. The aforementioned procedure is to be applied. However, threaded rods should be anchored in masonry blocks, not in the mortar area (20,21,22). The hook has to be placed perpendicularly to the wall surface to a depth of 2/3 the wall thickness. As per the spacing between two consecutive hooks, it should not exceed 40 cm.

20



21

22



20, 21, 22: IP cracks stitching technique 2: U shape stainless 316 L threaded rods introduced perpendicularly to the wall surface inside the stone blocks

When the cracking pattern is hazardous and copious (16), the stitching technique is not practical. The wall should be either demounted and rebuilt, or it should be injected and jacketed with lime mortar and mesh reinforcement (refer to the paragraph *"Earthquake and blast resistance upgrade"*).

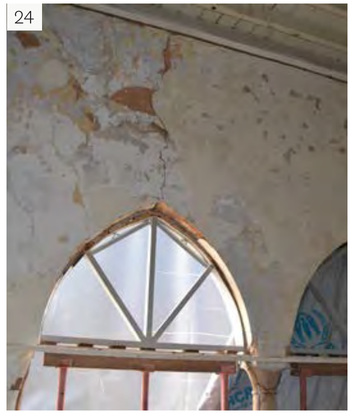
IP cracks are commonly found around openings, such as doors, windows, arches, and lintels (23, 24). They may be treated with the same stitching-jointing techniques detailed in the previous paragraphs.

Lintels are made up of three stones in *Beiruti* historic buildings. When highly damaged, or in the possibility of the blocks' detachment, the lintels should be replaced. Every replacement maneuver must be preceded by a propping operation of the ceiling and loose elements. In some cases, the entire damaged area above a lintel should be demounted and reconstructed (23,24). Lintels showing a unique crack can be repaired similarly to the second stitching technique used for walls (25). In this case, two parallel U-shaped threaded rods each 40 cm minimum in length and 12 mm in diameter are installed at the lower face of the lintel. Then, the crack is filled by a lime mortar grout. Moreover, it is possible to fix two parallel stainless-steel 316 L strips (minimum 30 mm x 3 mm) to the lintel's lower face by the means of a mechanical anchor on its edges (25).

When the IP damage mechanism arises in an arched opening, one must check if the crack is taking place in a joint. If so, it is sufficient to fill the joint with an injected grout. Otherwise, i.e., when a crack is crossing a masonry block, it is necessary to apply at least two diagonal stitches perpendicular to the arch's intrados, linking the separated parts of the broken stone (25).

23

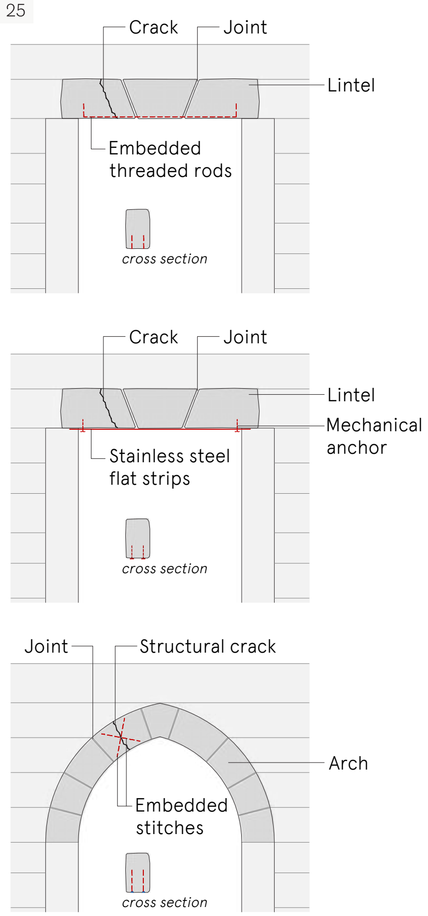
24



23, 24: IP damage mechanisms around doors, windows, arches and lintels

25: Repair of a broken lintel or an arched opening

25



Out-of-plane failure mechanisms (OOP)

An essential factor in enhancing lateral load resistance of buildings is the “Box-like behavior”. It consists of connecting the vertical structural elements in a unified response with rigid horizontal diaphragms. When a “Box-like behavior” is absent, which is the case in most of Beirut's historical buildings, lateral loads perpendicular to the walls’ surfaces, i.e., inertial seismic forces or blast pressure, lead to the appearance of acute bending and OOP damage mechanisms.

Before any further intervention, the installation of a propping system is required. The observations of damages caused by the August 4th explosion reveal that OOP damage mechanisms include but are not limited to the following:

- partial collapse of peripheral walls (26, 27).
- partial collapse of peripheral walls, interior walls, and triple or double arch façade (28, 29).
- end-walls overturning (30).

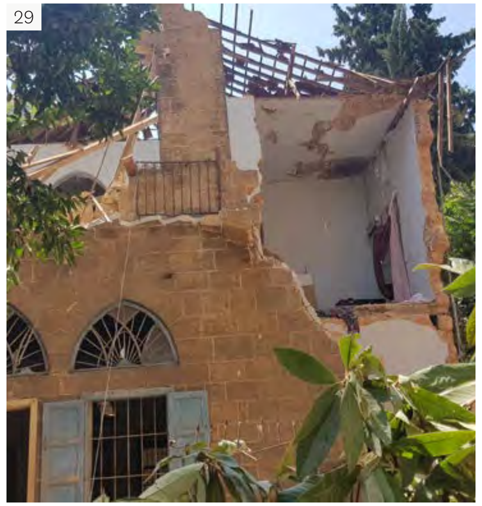
26

27

26, 27: OOP partial collapse of peripheral walls, Medawar 201 – Beirut

28

29



30

28, 29: OOP partial collapse of peripheral walls, interior walls, and triple arch façade

30: End-walls overturning

Suitable treatment of these three failure mechanisms consists of reconstructing the collapsed areas via traditional techniques:

- Stone blocks should be washed and cleaned from dust before any use. It is recommended to use NHL5 during the construction phase (volume: 1/3 NHL5, 2/3 sand). Lime mortar should surround the blocks on their head-joint and bed-joint level.
- Corner blocks should be interlocked, and their horizontal length should be at least double their height.
- In the case of end-walls overturning and absence of the attic, temporary buttresses should be installed to ensure the remaining free-standing walls' stability.
- The construction process should be followed by the injection of cracks - (if present) with fluid lime mortar (volume: 1/2 NHL5 to 1/2 sand) and structural plastering, including fibers and appropriate mesh (31,32).
- Particular attention should be paid to wall-to-wall and wall-to-slab intersections in order to strengthen the connection between these different elements (33,34). For this purpose, horizontal stitching technique may be adopted. Sainless-steel, CFRP, or GFRP rods with a minimum diameter of 10 mm and a length of 1 m should be installed horizontally to connect the intersection between two intermediate or corner walls. An appropriate epoxy binder compatible with the stone material will ensure the adherence of the tie rod to the blocks. A vertical strip of structural mesh with maximum grid dimensions of 40 mm x 40 mm and a minimum width of 1 m is to be installed on the intersection's outer face. The mesh strip should be connected to tie rods by a system of nut and circular washer.
- The reconstruction of a triple arch façade depends on the damage level of its columns and arches. In most of the observed cases, triple arch columns were utterly detached from their place. If the damage is minor, it is possible to reposition the columns to their initial state *(refer to the paragraph "Columns and arches")*. However, when the arches and the area above are highly damaged or absent altogether, a complete operation should be done to recreate the missing area and ensure the attic's support.

31

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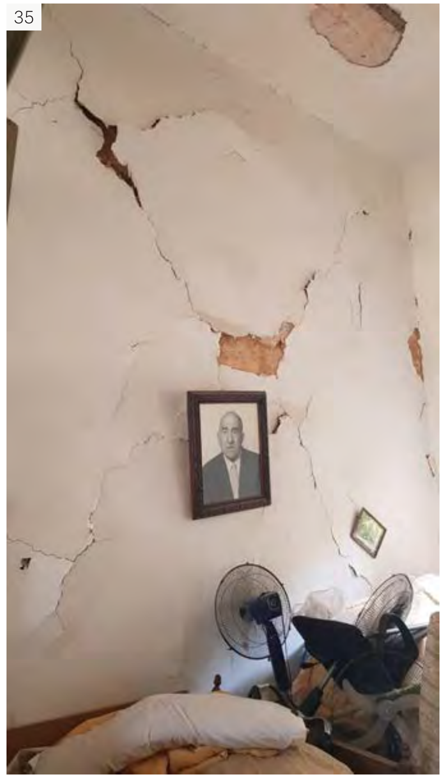
33

34

31: Reconstruction of a totally collapsed end-wall beneath attic, Rmeil 474 - Beirut

32: Reconstruction of a partially collapsed double arch façade, Rmeil 474 - Beirut

33, 34: Wall-to-wall reinforcement, from left to right: structural mesh, stitching of two corner walls, stitching of two perpendicular intermediate walls, Rmeil 320 - Beirut



Hybrid In-plane damage (IP) and Out-of-plane deformation (OOP)

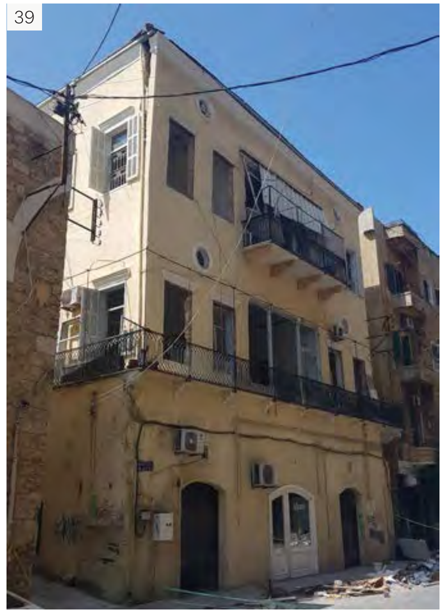
Earthquakes and blasts generate bending moments in walls in addition to IP stresses. If the lateral pressure or the inertia forces induced by a blast or an earthquake is high, failure lines appear on the walls' surfaces accompanied by OOP deformations.

A failure line indicates that the material's mechanical capacity was exceeded, which explains the appearance of cracks in particular geometric patterns. Failure line patterns depend principally on connection conditions with other walls and slabs, also called boundary conditions. Different patterns of failure lines were identified in the walls of heritage buildings hit by the August 4th blast. These include:

- IP X cracks and an OOP bulging were identified on intermediate walls connected at their base and head to slabs, as well as on their vertical edges to perpendicular walls (35). If the bulging deflection does not exceed an allowable value - generally considered as the wall height / 250 and the IP cracks remain clogged, a stitching process followed by structural plastering can be adopted to repair the wall. Otherwise, the slab area around the wall should be propped, and the wall should be dismantled and rebuilt.
- IP trapezoidal cracks above two adjacent openings and OOP overturning failure appeared on end-walls where the mechanical connection between the wall and the attic is generally poor (36, 37). The majority of cases observed reveal critical damage, a high probability of falling blocks, and a need to manually remove and rebuild the part above the lintels.
- IP cracks and excessive inward wall bulging were observed between two adjacent openings of an intermediate wall (38). The entire wall should be dismantled and reconstructed.
- Corner detachment and wall-to-wall connection were also frequently identified at the last floor level. In some severe cases, the detachment continues its way down to the lower floors (39). Consequently, damaged elevations should be laterally stabilized by a temporary bracing system such as tie rods, confining belts system, etc. (40, 41, *refer to paragraph "propping and urgent interventions"*). Then, corners should be dismantled manually and rebuilt. If the gap between the walls is insignificant, i.e., less than the wall height / 250, lime mortar injection technique should be applied (volume: 1/2 NHL5 to 1/2 sand), and the wall-to-wall connection should be stitched with the same procedure mentioned in the previous paragraph. It is worth mentioning that historic tie-rods were identified in some buildings. They consist of a plain circular steel section tightened at its two extremities by a plate-nut system (40).

35 : IP X crack pattern and OOP bulging of a wall, Rmeil 695 - Beirut

36, 37 : IP trapezoidal crack pattern above two adjacent openings and OOP excessive deformation of end walls, Rmeil 358 - Sursok palace - Beirut



38: IP cracks between two adjacent openings and inward excessive wall bulging, Rmeil 300 - Beirut

39: OOP corner detachment Rmeil 407 - Beirut

40: Historic tie-rods at walls' corners, Beirut - Lebanon

41: Tie-rod system, Rmeil 733 - Beirut

Several typologies of vaults are present in *Beiruti houses*. Mainly, it is possible to identify barrel vaults and cross vaults. Most of the vaults, however, appear at the ground floors or only partially present on higher floors. Since their geometrical form allows them to support high vertical stress if correctly conceived, they can be considered impervious elements, resistant even to lateral loads induced by earthquakes and blasts. This fact was proven true following the Beirut blast when no significant damage endangered the structure of the existing vaults. Usually, cracks occurring in vaults may result from pointed loads due to construction additions, soil settlements, and excessive displacement of the vault birth support due to weak lateral stiffness of the wall underneath. In these cases, the intervention of a structural engineer is mandatory. Once the source of damage is eliminated, it is possible to treat the remaining cracks by lime mortar injection (volume: 1/3 lime NHL 5, 2/3 sand, and crashed sandstone powder). If some stones are damaged, they must be replaced. Additionally, it is possible to enhance the vertical and lateral resistance of vaults and their waterproofing conditions by applying the following steps:

- The vaults should be first propped with a homogenous distribution of props, perpendicularly to their circumference.
- Filling material over the extrados surface of the vault should be removed.
- Joints should be cleaned, and a deep repointing process should be conducted with lime mortar (volume: 1/3 lime NHL 5, 2/3 sand, and crashed sandstone powder).
- Attach fiberglass, resin, or polypropylene meshing over the whole area of the extrados surface with non-corrosive connectors that must be anchored up to 1/3 of the vault thickness.
- Two layers of structural lime plaster mixed with fibers should be applied over the meshing grid (volume: 1/3 lime NHL 5, 2/3 sand, and crashed sandstone powder).
- Fill the volume over the vaults with fine gravel material.

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42, 43: Structural treatment of a cross vault extrados, Baz palace Deir Al Qamar-Lebanon

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Unlike structures designed in reinforced concrete, masonry columns and arches are rarely found in Beirut's historical buildings. The presence of bearing walls compensates for their absence. Very few buildings include single arches. However, marble or local stone circular columns and pointed arches are frequently present in triple arched houses. They are structurally categorized as slender columns because of their significant height and small section. Triple arch columns hold three arches and the area above, in addition to a part of the attic. They are capable of handling vertical loads. In addition to that, their IP stiffness and load capacity are enhanced by the wooden frames of windows and doors. However, triple-arch columns' lateral resistance is weak because of their slenderness, the rigid masonry frame surrounding them, and the poor connection with arches and lower supports. Two categories of damages were identified after the Beirut port blast.

- A total collapse: the blast pressure removed the columns from their initial position and the triple-pointed arches. In most of the observed cases, columns were split into several pieces. In some special cases, they were found intact in their original shape.

  A new column should replace the old one if the latter is split into more than three pieces (44, 45, 46). If not, it may be reassembled by connecting the fragments via a stainless-steel 316 L bar with a minimum diameter of 14 mm and a total length of 400 mm (44). The stainless-steel bar is anchored at the center of two broken parts using an appropriate epoxy binder compatible with the column's material. The binder should also cover the cross-section of the broken area. Then, the column is carefully repositioned into its initial place (45). Formwork should be used in the pointed arches construction phase. It should be placed symmetrically with respect to the triple arch center (46). The operation must start from the columns' heads and continue toward the top of the arches using a lime mortar grout (volume: 1/2 NHL5 to 1/2 sand).

- An excessive deformation: columns were subjected to a visible tilting and a lateral displacement at their top (47, 48). In this case, it is recommended to surround the column's surface with wood planks parallel to the column's height. Wood planks should be laterally tightened in order to increase the lateral stiffness of the column. If the column-arch connection is loose, the column can be easily repositioned, and the connection should be filled with a non-shrinkable binder. If the column-arch connection is stiff, arches should be propped before distressing the column. The connection between the column's base plate and its support should be cut horizontally using an electric saw. Once the column is released, it would be possible to remount it as per its initial position.

44, 45, 46: Reconstruction of a triple arch broken columns and collapsed arches, Burj Abi Haidar kindergarten school, Beirut - Lebanon

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47, 48: Tilting and excessive deformation of a triple arch column head, Beirut – Lebanon

TECHNIQUES

"The ubiquity of earth as a construction material was due to its wide availability at low cost and the ease with which it can be worked into a range of materials to construct durable buildings." T. Morton

The building materials are made from natural components widely available locally. These building techniques, the earth-lime mortar among others, are very much dependent on handcrafts, which might go back as far as the Bronze Age.

Application

Earth mortars were typically used as the bulk mortar to construct the walls—with their face pointed or rendered in lime to create a more durable external finish. Typically, the masonry is laid on a bed of a reddish-brown earth mortar made from local natural soil and stabilized with a quicklime inclusion to enhance performance. The poorly-graded natural subsoils were enhanced by the addition of sand and aggregates.

The aggregates are gravel, coarse sand, fine plant fibers, and straw up to 30mm in length. Occasionally broken terracotta pieces and coal were added (49, 50, 56). The aggregate-grading varies from 0 to 9 mm and the reported dose ratio is 1 volume of binding material to 3 volumes of aggregates. The terracotta is used to increase the hydraulicity of the lime and the coal pieces and to extract excess humidity. The sand is used to preserve the plasticity and reduce the effects of shrinkage, while the fibers increase tensile strength.

The compressive strength for this kind of mortar is 2.2 N/mm2 and a bulk density of 1.8 g/cm3.

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PATHOLOGICAL PROBLEMS

Reduction of the strength of the mortar: The key characteristic of earth mortars is their vulnerability to moisture; humidity can reduce the strength of the mortar by 15%. Another reduction in its strength can be caused by the biochemical leaching processes due to the penetration of trees and plant roots (52).

Powdering: Loss of cohesion with spontaneous detachment of dust-shaped material found in areas with high moisture.

Detachment: Separation of the mortar from the masonry. The pressure from the August 4th blast in Beirut caused significant detachment.

Micro-biological patina: Water infiltration causes severe moisture, leading to micro-biological growth.

Humidity by capillarity: It is a consequence of humidity on the lower part of the walls (up to 100 cm above the ground) (51).

Crystallization of salt: The salts involved in the process are probably those dissolved in seawater (mainly chlorides and sulphates) which arrive to the houses as aerosols transported by wind. When water evaporates, salts crystallize, and internal stresses are produced. This causes efflorescence and disintegration, while creating long-term damage to materials with pathologies such as alveolization, powdering, exfoliation, and flaking.

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RESTORATION AND CONSERVATION METHODS

Non-stabilized earth mortars can be re-plastified by pressing and kneading a sponge saturated with water against the mortar. However, the mortar used in the Beiruti houses is often a stabilized one and, therefore, cannot be re-plastified. If the mortar lost its plasticity, it needs to be replaced with a new one.

Ideally, repair mortars will be similar in character, appearance, and performance to the original material of construction (57). However, it is desirable to enhance the performance of earth mortar because the sandstone used in the *Beiruti* houses is very permeable and leaves the mortar significantly exposed to moisture. On the other hand, it is important to repoint and render with lime-based products because earth mortars demand high breathability in any surface treatments (53, 54, 55).

- Local soil will make the most appropriate material to use in repairs.
- First, mix the new earth mortar with water to a consistency slightly above the liquid limit of the earth. This will enable the clay to engage with the lime most effectively.
- Then, add 5% quicklime powder and aggregates* (56) to bring the mortar back below the liquid limit and enhance its workability. The quicklime is mixed with aggregates before being slaked, because it is believed that the steam generated in the process leads to a better pore structure.

** sand (both sharp and fine) and other additives (fine plant fibers and straw, coal, etc.)*

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Nathalie Chahine & Jad Hammoud

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Slabs are defined as horizontal structural surfaces. In addition to their resistance to vertical loads, slabs should ensure an acceptable resistance to fire and allow comfortable conditions in terms of vibration and sound insulation. A variety of slab typologies is recognized in Beirut's historical buildings.

TECHNIQUES

Timber ceilings have been used in building structures for centuries in Beirut. The form of the timber elements and how they are shaped helps date the buildings because the type of beams and the framework design changed over the decades. The ceiling of a *Beiruti house* is usually made of cedar from Anatolia *(cedrus libani)*—characterized by its density, smell, texture, and durability. The wood exposed to the inclemency of the weather and moisture was locally coated with wood tar, “kotran” (from the French word goudron). The wood tar, a substance derived from the wood and roots of pine trees, acts as a natural water repellent. Main beams are often made of hackberry wood *(mays, celtis australis).*

Timber ceiling (72, 73)

- The wooden joists with a cross-section of about 17 cm x 9 cm are put in a single layer row with an average distance of 15 cm between them (58).
- For large spans, the joists are carried on large machine-cut beams having a cross-section of around 20 x 20 cm. In cases where the span is relatively small (3 m maximum), no main beam is needed (59).
- The bearing depth of both the joists and the girders varies from 12 to 18 cm.
- The system is covered by timber flooring planks of 2 cm in thickness and with a width ranging between 20 and 25 cm. The joints between the planks are then covered with long wooden strips (60).
- In some houses, the planks follow a geometric pattern for a decorative purpose.
- A thick layer of sand and aggregates is placed above the wooden planks; it serves as a leveling layer beneath the tiles and satisfies thermal insulation requirements. The layer consists of big aggregates such as pieces of locally available stones.
- A thin layer of the lime mix is poured over. The mix consists of quick lime with fine aggregates like broken seashells, corals, and fine sand.

Timber and I-beams ceiling (74, 75)

- One can take advantage of the inherent benefits of each material and overcome their limitations. In the case of the timber and I-beam ceiling, for example, steel excels in tension while wood reacts much better to compression.
- The I-beams are the main load-bearing beams on the stone wall. The average distance between them ranges from 120 to 250 cm (61).
- The secondary beams are the timber joists with a cross-section of about (12 x 7 cm) and an average distance of 17 cm between them.
- The beams are covered with planks receiving the same system as in the timber ceilings. (refer to previous paragraph).

PATHOLOGICAL PROBLEMS

Timber’s structural problems are usually brought about by decay, over-loading, and moisture, or as a result of poor design and alterations carried out in the past. The unprecedented force of the August 4th blast caused the structural breaking, cracking, or crushing of timber beams, as well as their detachment from the masonry walls.

Deformation

- When the wood is exposed to high temperatures, changes can occur in its structural performance. The wood can lose its internal water content, which leads to changes in its dimensions, deformation of its shape, flexures, dislocations, torsional flexural buckling, and fractures.
- The strength and performance of the structure as a whole is also affected by the size and location of knots, the quality and strength of the timber, and the integrity of connections—whether primary or secondary (from beam-to-wall and from joist-to-beam, for example).
- Overloaded structural members fail by cracking, bending, or crushing. The overloading may arise either as a result of weakening following a decay, a poor design, or if the structure was meant to endure different loads than it is currently bearing.

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Moisture (63, 64, 65)

- Moisture is often owing to a leak, poor maintenance, or condensation. High moisture leads to the colonization of micro-organisms such as bacteria and fungi (dry rot for example) or wood-boring insects (such as woodworm and deathwatch beetle). The action of these micro-organisms reduces the overall strength of the wood.
- Moisture will cause deformations due to the expansion and shrinkage of the wood.
- Increased moisture levels are mainly found at the end of the beams and on the edge of the beams on their wall-facing side where it is mainly caused by moisture entering through the exterior walls.

Xylophage (wood-eating beetle) (62)

- Colonies of insects can find shelter in an appropriately moist climate, causing the powdering of the beams, soft rot, and, ultimately, leading to structural deficiencies if left untreated.

Defect of the I-beam

- Iron has an affinity for oxygen leading to its oxidization and rust. Left unprotected and exposed to air and dust, I-beams can have rust accumulate on their flange and web, forming a corrosion pit at the surface.

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RESTORATION AND CONSERVATION METHODS

General notes

Before any intervention, it is essential to fully understand the nature of the ceiling's structure, its condition, and the cause of the problem, as well as ensuring that the structural members are capable of taking the loads they may have to bear.

Old, traditional repairs consisted of using carpentry methods or iron ties, splints, and brackets. In modern times, new materials such as steel, epoxy resins, carbon fiber rods, and wire rope have been introduced.
The main factors to take into consideration when intervening on timber ceilings are:

- Minimal intervention: retaining the maximum amount of historical timber and minimizing the introduction of a new element. The best solution is usually to repair rather than replace components.
- Reversibility: Repairs may be needed to improve the bearing while allowing for a degree of reversibility.
- Like-for-like: Where possible, use the same materials and techniques previously used in the building.
- Repairs should be discernable and true to the original. They must disturb the surrounding fabric as little as possible, especially if painted plaster is attached to the timber beams.
- Documentation: record the fabric before intervention and document the intervention itself so that future conservation work is well informed.

Other major considerations preceding every intervention:

- Decisions and design solutions are the realms of professionals.
- After removing the planks, beams need to be inspected from above as well.
- Prop the structure weighing on the elements to be consolidated using transferring loads on sound elements.
- Make sure that all sources of high moisture are eliminated.

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Reparation of the end of the timber beams

Rotting timber is the main cause for repair interventions on historical timber structures. Repair is typically needed for the end of the timber beam and on unprotected areas (timber-to-stone masonry connection). As a general rule, damaged areas need to be cut off 30 cm behind the last visible damage (66).

After completing the reparation:

- Remove the existent paint and repaint the beams with a breathable, thin-film, anti-moisture, and antifungal paint.
- Clear and level the cavity where the end is installed.
- Close the gaps around beam heads with lime mortar in addition to stone chips when needed (67).

Like-for-like technique (68,70,71)

It is a common technique consisting of using a new piece of timber connected to the existing one by a bolted or pegged joint. The new wood will be of the same or similar quality, free from large, loose dead knots, sap, and pest infestations like borer or beetle. All wood will be dry before using it, i.e., with a moisture level of less than 17%.

Steel splints

This technique consists of supplementing the timber with steel splints fixed to the sides of the wood joists to improve shear and bending strength and stiffness.

Extending the bearing

Where beams or joists are not deep enough for their loading, the result is excessive bending, bouncing floors, and possibly even cracks.

An increase in the effective depth could be accomplished by installing additional timber to the top of the beam. If the depth of a beam only needs to be increased marginally, one very neat solution is to firmly attach the floorboard material to the top of the beam.

The bearing can also be extended by introducing steel or timber bolted under the beam. This can be accomplished by:

- forming a whole box section steel shoe attached into the beam or,
- creating a timber or steel corbel on the wall beneath the end of the timber (69).

Reparation of a timber beam rupture and structural deterioration

This defect is the typical result of the blast's high, impulsive loading. Structural girders failed when their connection with the wall lost their efficacy.

Several solutions can be adopted:

- One solution consists of using a stainless-steel plate screwed in the timber girders. Pairs of pre-drilled “L” section stainless-steel plates are screwed on both the bottom edges.
- Where beams need a little more assistance, flitch plates can be inserted along the length of the beam. This method involves cutting a slot into the timber and making the beam a composite of steel and timber.
- Timber-Resin Splice technique (TRS): This technique consists of connecting timber prostheses to the damaged beam using smooth or ribbed stainless-steel rods, connectors, bars, or carbon fiber rods. These are usually fixed with an epoxy resin. The letting-in phase can involve cutting slots or drilling holes lengthwise from the end of the timber or diagonally across cracks.

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Treatment of wood disinfestation

Areas of severe insect attack usually indicate the presence of moisture in the wall in which the timber is embedded. Before making the intervention, the restorer must:

- make sure that the insects are still alive and active
- make sure to stop the source of humidity

The intervention will be done with insecticides to exterminate micro-organisms, fungi, and insects. All areas with exposed surfaces will be treated with insecticides and fluid biocides with high penetration levels to create an area of poison impregnation through which the timber-boring insects will have to pass to get to the surface.

Treatment of Fungi

- Anti-fungal treatment requires the use of products based on fluorides, chromium, and arsenic compounds.
- The infested wood will be eliminated or burned. Cracks in the masonry in which fungi have penetrated will be treated.
- It could be necessary to carry out a radical intervention using a biocide injection (tar derivatives, chloride naphthalene, zinc ammonium compounds...).
- Two years after the first treatment, the operation should be followed by an intervention using a spray with the same salts. This should be repeated at the 5 and 10 year marks.

Reparation of the corroded steel I-beam

Corrosion can cause serious structural failures. Preventive measures and immediate curative actions should be undertaken. These include:

- sandblasting to remove corrosion
- applying protective coatings such as rust-resistant paint
- priming with a zinc-rich primer.
- painting with at least two coats of acrylic paint.

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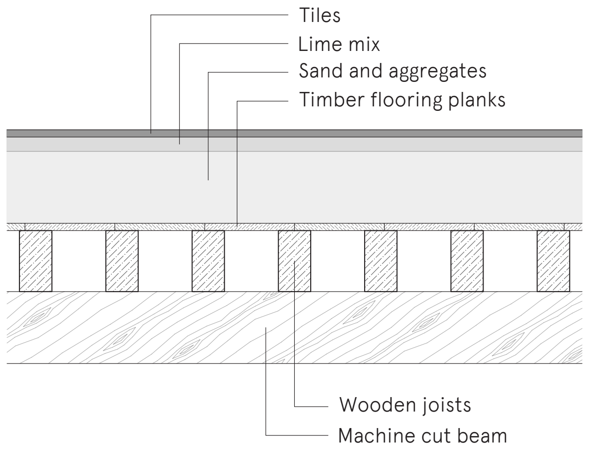

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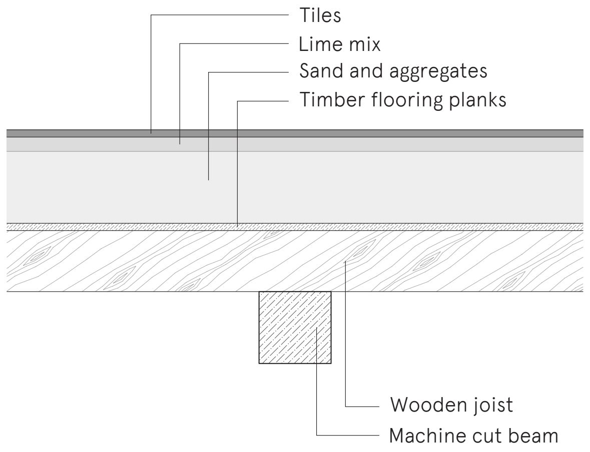

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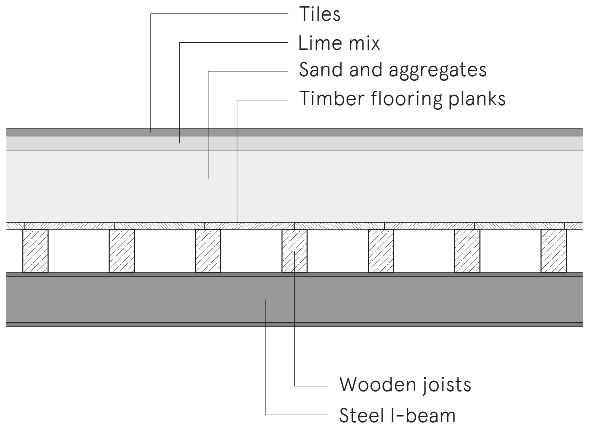

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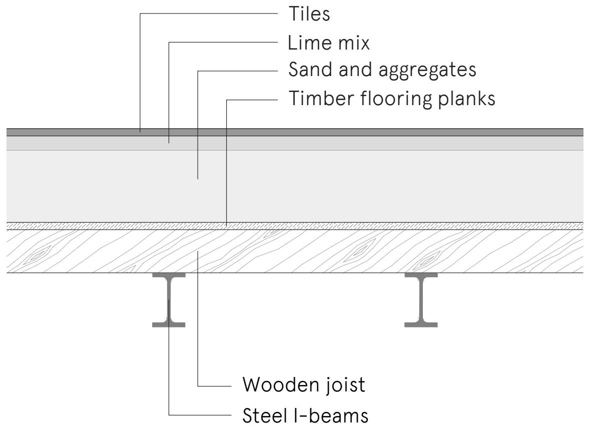

72, 73: Typical sections of a timber ceiling

74, 75: Typical sections of a timber and I-beams ceiling

TECHNIQUES

The jack arch is a flat arch where the vertical gravity load is balanced by the strong lateral buttressing.

With the rise of the industrial era in the early 19th century in Britain, and with the need for larger spans in industrial buildings, engineers introduced the jack arch slab. This slab is a composite roofing structure made of a series of steel I-beams supporting light brick masonry arches. In the second half of the 19th century, the structure soon spread through the British Empire and the Middle East, where it became very popular for its numerous advantages: it covers larger spans and is more resistant than traditional timber flat roofs; it is easier to build than the standard vaulted ceilings; it is a light, fireproof and easy-to-build structure with minimal lateral load and, therefore, needing less material for the bearing walls; it provides good seismic resistance.

As of 1870, the jack slab arch was introduced to Beirut in the large palaces of the upper class (Moussa Sursock palace; the Tueni and Bustros palaces) and in community buildings (Greek-Orthodox Hospital). With floor spans ranging from 8 to 10 meters, the gravity load slabs sat on lateral, sandstone bearing walls.

The *Beiruti* jack arch slabs feature steel beams aligned at 60-70 cm distance from each other. The intervals are filled with sandstone masonry or bricks with lime or limecrete. They follow a shallow arch or, more commonly, a flat soffit generally hidden by decorated lime and gypsum plasterwork. The beams are connected from the top by steel tie-rods spread evenly. These maintain the stability of masonry parts under compression and prevent movement between I-beams (76, 79). The slab is covered with a thick layer of fill (15 to 25 cm in thickness) and tiles. For acoustic and insulation purposes, and in order to reduce the dead load, hollow clay pots were sometimes displayed upside down on a regular pattern within the fill (77, 78).

Compared to timber roof slabs and *Baghdadi* ceilings, a jack arch slab system provides much stronger resistance to rainwater infiltration. This explains the absence of pitched roofs on some or parts of the heritage buildings. Its resistance to fire also makes it very suitable for kitchens, where it replaced cross-vaults and their massive corner pillars. However, it was mainly restricted to some large, prestigious, and monumental buildings, and it did not really compete with the commonplace timber slab system used in mid- and small-scale dwellings before the turn of the 20th century.

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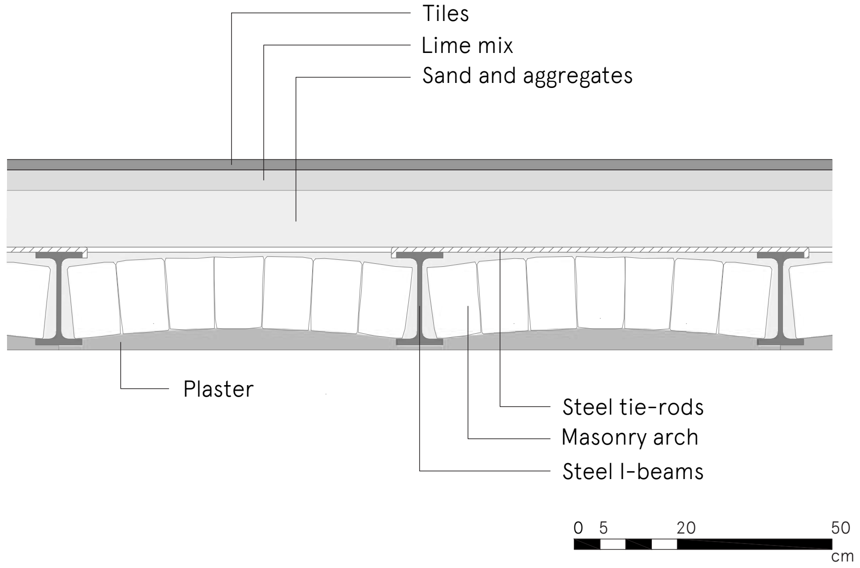

79: Typical section of a Beiruti jack arch slab

PATHOLOGICAL PROBLEMS

Having showed little decay over 150 years, the jack arch slab is markedly stable and resistant. However, the rusting on the surface of the ageing steel beams impacts the lime plaster's adherence, creating cracks in the plaster all along both edges of the beams and resulting in the partial loss of the decorative plaster. Severe cases of highly corroded flanges are also identified where the beams' lower flange is detached from the web.

Moreover, minor vibrations sometimes cause mild discomfort to inhabitants–yet, there is no structural risk resulting from such vibrations.

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RESTORATION AND CONSERVATION METHODS

The repairs and treatment on jack arch slabs must be supervised by a specialized structural engineer.

Steel rust and cracked plaster: such repairs are a very delicate operation as they might damage the original decorative plaster applied on the soffit of the slab. All loose plaster is to be dismantled and removed after thorough documentation. The surface of I-beams is to be carefully cleaned from plaster dust and rust. The edges of the plaster along the beams will be cut in a herring bone pattern to create a key for the adherence of the new plaster. The surface of the steel beams will be protected with an appropriate anti-rusting, cementitious product with a rough surface for adherence and compatible with the plaster. The plaster pattern or decorative painting will then be reproduced to match the remains of the initial design.

Detachment of the beam's lower flange from the web: It is a delicate operation that must start by propping the steel beams. Then, the corroded flange and the lower part of the damaged web should be removed manually or using an electric saw, paying particular attention to not harm the plaster and the light brick masonry arches. A cementitious fluid grout should be then injected between the brick blocks. A T section with the same initial thickness of the web and the flange must replace the beam's missing part. To this end, an I-beam may be cut horizontally into two parts at the web mid-height level (82).

Slab vibrations: In order to reduce the vibrations in the slab, the beam's inertia should be increased. Tiles and fill will be removed carefully and properly stocked for further re-use. The top of the I-beams should be cleaned of all dust and potential rusting. A layer of steel (to be specified by the structural engineer) will be welded on the top of the I-beams and protected with an appropriate anti-rusting, zinc-rich epoxy paint coating. The fill and the tiling will then be put back in place. Worth noting, this operation is an opportunity to install electrical or mechanical infrastructure within the fill's thickness.

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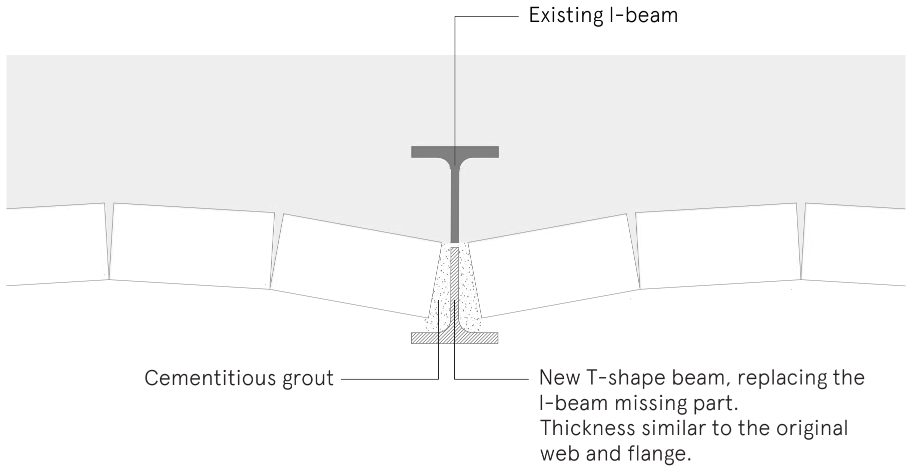
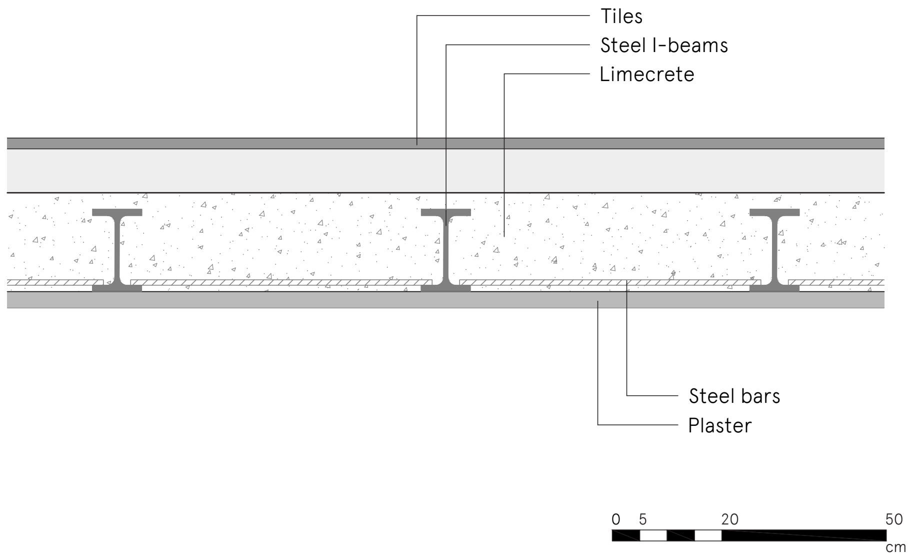


"Reinforced limecrete slabs appeared in Beirut in a transitional phase with the increase in imports of steel and steel beams and before the introduction of cement." R. Saliba

83



83: Typical section of a reinforced limecrete slab

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TECHNIQUES

Limecrete, which has been used for centuries, is strong in compression but relatively weak in tension. Steel reinforcement was designed to overcome this limitation. Bonding and mechanical attachment of the reinforcements to the limecrete are essential for the two materials to combine and to form a high strength material.

The limecrete comprised a mix of lime, wood ash, aggregates which included various sizes of sandstone chips and crushed brick leftover from the main building work. The ash and bricks had a pozzolanic effect, enabling the lime mix to achieve a hydraulic set before the mortar fully dries out and simultaneously helping to dry it.

The limecrete slab is supported by I-beams that would span the floor and be placed every 60 cm. The 6 mm mild steel bars with their compressive strength of around 240 MPA are laid diagonally between the web of the I-beams, and the slab is then hidden from view with painted lime plaster (83, 86).

The reinforcement is principally used to increase the strength of concrete, but it also serves to limit crack propagation when the limecrete is placed in tension. This type of ceiling is also known as beam-and-fill-slab.

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PATHOLOGICAL PROBLEMS (84,85,87)

Detachment of the protective plaster and the corrosion of the I-beam

Exposed to water infiltration and high humidity levels, the reinforced limecrete slabs show deterioration due to the corrosion of the embedded metal reinforcements. High humidity, combined with the naturally poor tensile strength of limecrete, means that a small steel section loss of the original embedded steel bars can initiate cracking in the surrounding limecrete.

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RESTORATION AND CONSERVATION METHODS

The extent of the damage and the new functions required of the building can be a major constraint in the conservation of the reinforced limecrete slabs. Nonetheless, completely replacing the ceilings would mean the loss of the early century slabs.

Repairing of the existing slab and matching the original limecrete

Initial investigations

Prior to undertaking repairs, samples must be taken and a full assessment of damages to the reinforced limecrete slab should be carried out in order to determine:

- The number and nature of required limecrete repairs: This can be carried out by Hammer testing to identify, by the hollowness of their sound, the areas subject to corrosion and delamination.
- The extent of steel corrosion: This can be determined by an electrical potential and possibly corrosion rate survey of the steel.
- The risk of corrosion: This can be examined by a cover meter survey to identify and record the minimum and average depths of limecrete cover to the embedded steel.

Samples should be taken for laboratory examination to assist in the selection of the most appropriate repairs:

- petrographic analysis (core sampling) to examine the alkali silica reaction, cracking, and other microscopic defects, as well as to identify the type and size of aggregates
- chemical analysis to determine the composition of the mix and type and content of the lime
- mechanical analysis of samples to determine the compressive strength

Interventions

The removal or the decay of any of the elements of the slab can have a detrimental effect on its structural performance. Any action should be conducted by a structural engineer restorer.

Repair of limecrete normally encompasses traditional patch repairs and replacement, but it can also include more modern approaches like the use of cathodic protection, re-alkalisation, chloride removal, corrosion inhibitors, and anti-carbonation coatings.

All corroded bars and I-beams should be mechanically cleaned to remove the loose corrosion product. Consequently, all reinforcements must be grit blasted before applying protective coatings to the cleaned steel. The following steps must be followed to ensure a successful repair:

- The reparation areas must be marked out on site.
- The depth of the cut-outs should be specified.
- Steel reinforcements with previously low cover are either replaced at a deeper position or hammered back into the limecrete.
- The apparent surface of the existing steel reinforcement is treated for corrosion.
- The corroded bars are wire brushed to remove the loose corrosion product. They shall not be coated; the new lime patch will effectively re-passivate the corroded steel. After pouring the lime in the specified areas, the repairs must be vibrated to achieve complete filling of the voids.

Reinforced concrete slabs are intruders in Beirut's heritage buildings.

They were added in at a later stage of the initial construction phase with the advent of the cement industry. Executed with plain concrete, reinforced concrete slabs are structurally known for their high inertia and vibration damping in comparison to timber slabs. Mild steel bars were combined with concrete as reinforcing elements against tension and bending. Solid slabs are usually supported by bearing walls or drop beams or directly laying on columns. The main problems encountered in the concrete slab found in *Beiruti* heritage buildings are due to the following factors:

- aging of concrete
- poor quality of concrete affecting the long-term behavior of the concrete element
- concrete surface deterioration by carbonation decreases the concrete's protective alkalinity. Carbonation is caused by the absorption of moisture and carbon dioxide
- steel rebars embedded in carbonated concrete corrodes in the presence of water and oxygen. The corroded metal can expand up to 10 times its original volume. As a result, cracks and delamination appear due to intense bursting forces (88)
- continuous water infiltration accelerates the corrosion process
- chloride attacks since the buildings are facing the seacoast

Simple in-situ tests may be conducted to check the concrete's quality. These include the Schmid hammer test (to test the compressive strength of concrete) and the carbonation test. Consequently, the structural engineer will be able to define the degree of intervention to be done. Sophisticated techniques may be used; the reader may find further details in the scientific literature. However, for *Beiruti* historical buildings, a classical technique will be presented.

- If the corrosion level is in an early stage, the cross-section of the reinforcing steel is slightly reduced (less than 10% of the initial cross-section). Cracked concrete should be removed manually using a hammer. Corroded steel should be manually cleaned with a steel brush and painted with an epoxy-base product. The damaged surface should be plastered with high-strength cementitious grout.
- If the corrosion level is advanced and the reinforced steel is dislocated from the concrete's surface, it is necessary to replace the steel rebars and proceed with a jacketing process. A new grid of steel rebars will be attached to the existing slab using L shaped connectors. Then, a formwork is installed beneath the new grid. Multiple vertical holes should be driven through the existing slab to allow the pouring of new concrete with the aid of gravity or pressurized injection.
- If the concrete damage is very high, the slab will lose an important portion of its thickness. In this case, it is recommended to demolish and reconstruct a new slab

Similar steps may be used to repair reinforced concrete beams or columns. Jacketing process consists of enlarging the initial cross-section. First, it is necessary to roughen the surface of the concrete elements and install L shaped steel connectors attached to the concrete elements using epoxy glue product. Then, longitudinal and transversal reinforcement should be added to the existing section. The newly added thickness around the existing section should not be less than 8 cm, and the concrete compressive strength of the poured concrete should exceed 25 MPa.

88

88: Concrete and steel rebars damage of a solid slab

TIMBER TRUSS ROOFS

Jean Semaha

89

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91

At the top of the hierarchy and the axial composition of *Beiruti* houses, the terracotta pitched roof stands for more than a colorful orange contrast with the blue sea and sky background. It is the lighter element above the heavy walls and vaults, a geometrical accident, the most noble amongst the common shapes, and a material procured from far away topping those supplied locally. Yet, it is the first one to decay.

Unlike millennial cut stones, timber does not stand the test of time. Methods and doctrines for standard building materials are not all applicable to wood, and its replacement is inevitable.

However, it is necessary to assess it thoroughly and with a careful inspection in order to take the proper decisions.

THE CONTEXT

Environmental context

- Dry and wet cycles, specifically sudden ones, remain the most common triggers of wood losses; while water can temporarily affect the physical and the structural performance of a beam, constant moisture will bring fatigue and fungal or biological infections.
- Beirut's Mediterranean climate is relatively mild, and it is not common to witness roofs on fire as solid wood is fire-retardant.
- Timber, made of resinous Larix and Picea, gained its high density in the slow-growing cold weather at the northwest of the Ottoman Empire. The treated wood was knackered and formatted in order to be shipped using manual tools for the heavy sections. Later on, the industrial cut was introduced for both heavy and standard sections.

Pathological problems

Due to the unprecedented upheaval caused by the August 4th blast, the majority of the roofs located in the affected areas lost their clay tiles cover and were suddenly exposed to the humid heat of the warm summer, followed by heavy rain showers in autumn (90, 91).

Restoration and conservation methods

- Disposal of unused or infected wood pieces: after thorough inspection and documentation, infected pieces should be burned for sanitary reasons. Valid, unused pieces should be stored properly away from humidity for re-use.
- Avoid water infiltration and keep appropriate ventilation.
- Never use grinders and welding machines.
- Regularly monitor the PVC tarps and the TOT covers installed as temporary shelters after the blast.
- Note that electricity poles and residential towers provide efficient protection against lightning.

Access

An unguarded place like a distressed heritage house can attract all kinds of unwanted visitors: from unskilled people and hazardous interventions to insects, and pigeons (100).

Restoration and conservation methods

- Make sure that the space is protected from unwanted intrusion and electromechanical equipment.
- Vent tiles should be properly installed while avoiding wind exposures.
- Perform periodic inspections using temporary lighting devices. Clear tiles should be identified and inspected because old ones may become a fire trigger.

Structural context

Beiruti carpentry is a modular, rational structure–which makes detecting disruptions a relatively easy task when compared to similar typologies (89, 95).

Restoration and conservation methods

- Consult specialists and follow a methodic approach.
- Detect displacements and structural failures; find the causes and consequences of these disturbances.
- Consider the previous and temporary situation of the roof; a clear diagnosis should be undertaken with respect to all constraints and values—from live loads to contextual ones.
- Keep the roof clean from dust; avoid blowers.

92

93

THE SKELETON (97)

The truss (95)

- Trusses are the main bearing elements that counteract lateral thrusts.
- They are usually tagged by the carpenters and enclose their particular know-how.
- For king post frames, the largest wooden sections are pre-drafted and executed off-site, and then erected in-situ.
- Fine leveling and alignment of the truss testify to the good condition of the building.
- The layout can cross considerable spans, up to 8 meters in central hall houses, and 15 meters in larger edifices, such as religious buildings or silk factories.
- Soft slopes of approximately 30 degrees are enough for Beirut's precipitation and are in harmony with the hills and mountaineer background.
- Thanks to the lightness of the frames on the summits, houses and monuments retain unexpected resistance to earthquakes.
- Qualitative observation of a truss should always precede any quantitative calculation of its loads and stresses. It is important to understand the anatomy and the structural behavior of each element, as well as its specific role.
- The following factors need to be verified and checked: the load's diagram, the joint's behavior, and the nature of the stresses (for example, the traction for tie beams, the flexion for rafters and purlins, the compression in struts, etc.)

Pathological problems

These include failures, displacement, twist, cracks, missing parts, and defective joints.

Restoration and conservation methods

- If the roof is unloaded, carefully reinstall it to its original status. Otherwise, proceed with temporary substitution parts (double sections, props...).
- Transplant: this entails the partial replacement of a beam using the proper connection and similar wood, while tagging the new part.
- Cables: in case of conceptual failures, a contemporary element may be used to preserve the integrity of the original shape. A cable can compensate for traction weaknesses (tie beams).
- Reinforced resin: used to preserve certain pieces with local damage. However, its use is limited due to its high cost and the technicality of its application. If adopted, special care must be given to vapor transpiration between wood and resin.
- Braces: a temporary solution to connect wood, keeping an acceptable density (>0.5) and using metal elements and rods.
- Joints:
    - Bolted scarf joint with nibs for a steep-sloped principal rafter.
    - Key locked hooked scarf joints with nibs for tie beams and soft sloped principal rafters
    - Bridle joints for king post.
- Stainless-steel nails in industrial and traditional shapes are frequently used.
- Tags are a valuable historical evidence to be kept at any cost.

The purlins

- Purlins are hyperstatic horizontal beams that are connected with scarf joints and hold the principal rafts (96).
- They are occasionally propped where the walls below coincide.
- Angular stiffeners reduce the span of the purlins and brace the skeleton.
- The wall plates are linked with dovetail or halved joints.
- The average sections are 14-17 cm x 7 cm with an average distance of 3 m, resulting in a potential span of a 7.5 cm x 5 cm rafter.

Pathological problems

These include failures, displacement, twist, excessive flexion, missing parts, ceilings modification, and defective joints.

Restoration and conservation methods

- Replacement with identical pieces preserving the traditional know-how.
- Improvement of sections with additional wooden planks.
- Metallic braces: riveted or bolted, to bind tear fibers.
- Joints: Wedges for nibbed key locked hooked scarf joints shall be well inserted (96).
- Metallic accessories: in case they are added, they should be perforated to avoid water confinement inside wooden sections.

94

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96

The rafters

- Rafters are distribution elements that sharpen the roof's shape and allow the installation of the lattice
- They are linear elements of an average section of 7.5 x 5 cm, spaced less than 50 cm (to support the 2.5 cm slats)
- They are not assembled, rather simply overlapped.

Pathological problems

- disruption: this frequent pathology with the purlin flexion is mostly due to aging (94). The August 4th blast, however, was another major cause of this decay. If the tolerances are acceptable for the purlins, common rafters shall be aligned
- failures and ruptures
- moistures next to wall plates
- distortion: a distorted lattice cannot receive the interlocked terracotta tiles

Restoration and conservation methods

- leveling: using wooden blocks
- cutting and displacement: to save extra length, an overlapping piece can be placed

Otherwise, the piece should be replaced. Seldom available readily, the 7.5 cm cuts can be obtained by splitting 15 cm planks in half.

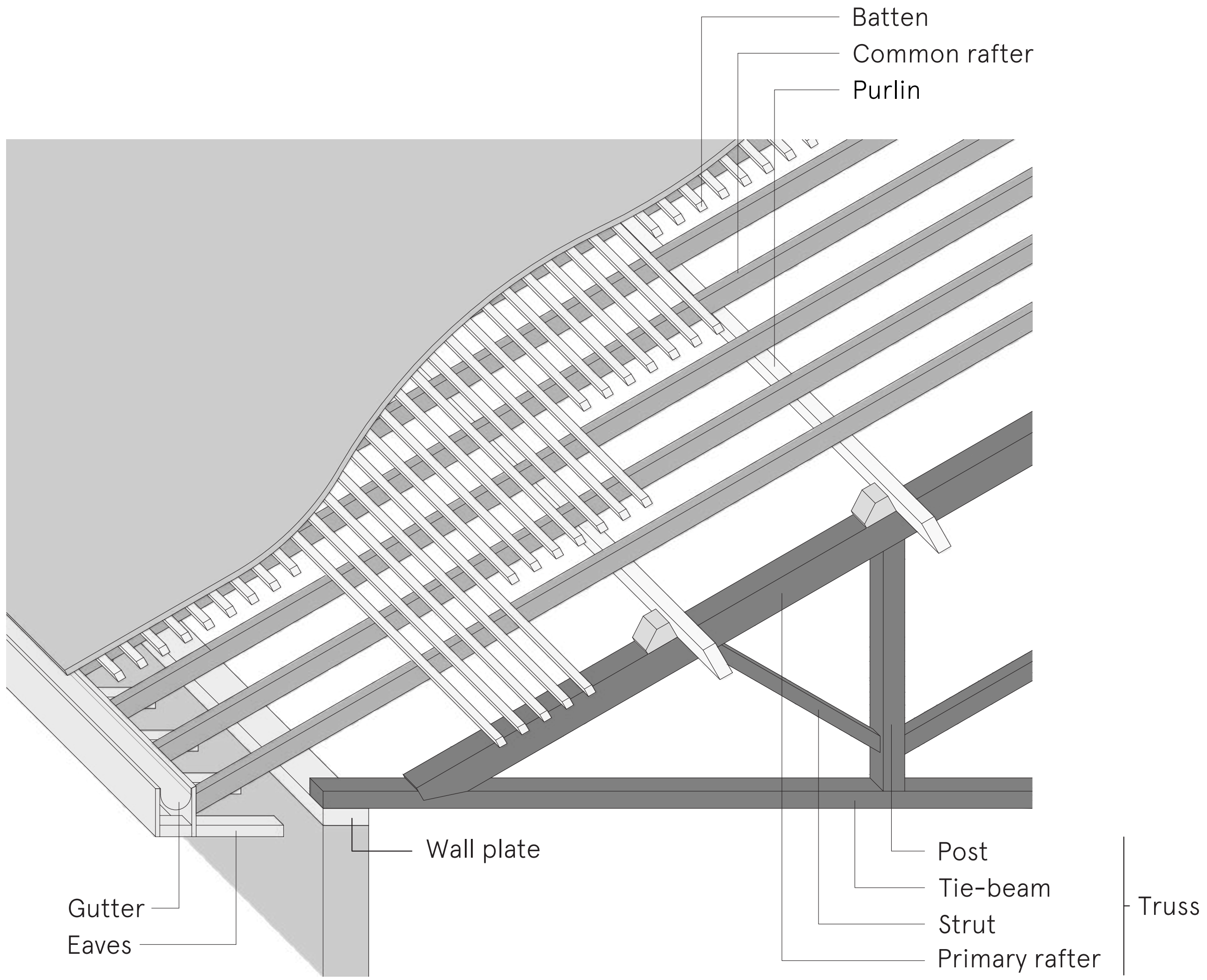
The battens

- The battens brace the roof and hold the pyramid shape in place.
- They are the consumable part of the roof and need to be replaced each time the tiles are replaced. They have an average section of 5 cm x2.5 cm.

Restoration and conservation methods

- Careful replacement by section, or totally once the tiles are off.
- Treated fir wood that should be nailed and not screwed.

97



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The eaves

- The eaves are the lowest part of a pitched roof, where it meets, or overhangs, the wall top (98). They have the main function of ensuring that rainwater is thrown clear of the top of the masonry walls.
- They crown the walls at the most stressful point, inflecting styles, lines, loads, materials, colors, trades, waterway...
- Made of wooden and lead plates at early stages, this detail is executed by the later comers on site: the carpenters, and the plumbers.
- In the wealthiest mansions, the eaves are replaced by a sculpted, plastered cornice or a marble one with a concealed gutter and subtle arithmetic figures.
- Overhanging eaves are usually supported with wooden or stone corbels.
- The usage of heavy traditional gypsum in the façade's decorative elements is common in the medieval period and till the end of the 19th century. Contemporary industrial and fine gypsum is very solvable and unsuited for such outdoor features (99).

Pathological problems

- displacement: due to wall plate or carpentry failures
- biological infections: due to the water infiltration
- missing and falling elements: due to a lack of stability
- detached plaster: the original composition, material, and technique are lost
- deteriorated gutters
- modern waterproofing membrane above stone eaves blocks capillary rise inside stone gutters

Restoration and conservation methods

- Despite their noble shape, the eaves provide a corrective gap/buffer joint between approximately linear walls and perfectly shaped roofs. Small gaps could be shaped and carved or treated at render level, whereas serious ones need the partial dismantling of the wall.
- Walls or roof failures should be corrected; all horizontal loads should be neutralized.
- Deep mortar tests should be performed from both sides of the masonry. Dynamic displacement monitoring must be read, and surface render can be tested using hammer impact test.
- Eaves are not structural elements. Cracks could be just cleaned and filled, while damaged parts could be replaced using a similar stone with drawer technique, lime mortar, and specific tools.
- Hazardous lead elements should be replaced with zinc. Dismantling must be done with strict protection, and the byproducts must be recycled or disposed of properly.
- Bituminous membrane must be removed and replaced with metallic gutters, then levelled using wooden wedges or mortar.

THE COVER

Terracotta interlocked tiles

- Dimensions: average 43 x 26 mm, Weight: 42.5 to 47.5 kg/m².
- The structure is covered with red brick tiles made in Marseille, France. These are mostly manufactured and stamped by "Les fils de Jules Bonnet, La Viste-Marseille", "Guichard Carvin & Co – Marseille Ste Andre" or "Pierre Sacoman St Henry".
- The tiles are connected with steel or copper wires to the wooden laths to protect them from being blown up by strong winds and from damaging weather conditions. Some roofs have vent-hole tiles to provide natural aeration.

Pathological problems

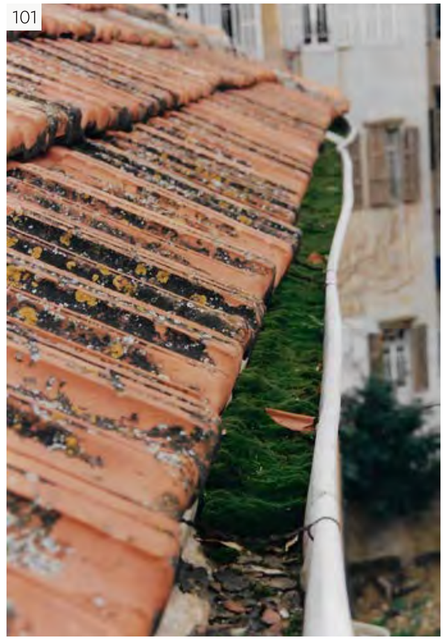
- Broken and loose tiles: due to projectiles, age, walk through, etc.
- Inappropriate interventions: fixing the tiles with cement or foam, mainly the ones covering the ridge and the hip rafters.
- Replacement of the broken tiles with new brick tiles of different dimensions causes water infiltration to the roof structure.
- Lichens, microbiological deposits, and efflorescence (101)
- Fretting: the clay tiles begin to break down into flakes and powder.

Restoration and conservation methods

- Format: Make sure to use the same format of tiles. Calculate the sloped area, adding a 5% waste ratio.
- Limited replacement: Some tiles can be replaced separately. Free the adjacent ones from fixation prior to this operation.
- Replacement: In case of damage exceeding 20%, the tiles must be replaced. Note that the lower tiles and the ones next to the ridge are difficult to remove without sustaining damage.

100

101



- Existing original tiles have a historical value: Clean and brush them, then place them randomly on the pitched roof to maintain the homogeneity of the external appearance.
- Fixation: Fasten 30% of the tiles and all the ones adjacent to the edges using fine copper rods. Avoid nailing on the existing roof.

Waterproofing

Metal sheets are added under the water line at critical locations to insure a final barrier against water infiltration. This entails flashing next to vertical walls, chimneys or skylights, gutters under valleys, and corner plates above gutters. The installation should not allow additional condensation.

Pathological problems

The installation of a hermetic system: Although valid for contemporary frames, it seems to have more disadvantages than benefits:

- It increases the heavy static charges in height, but also in the air resistance applied to this roof.
- It increases the condensation and the modification of the current microclimate, negatively affecting the hundred-year-old beams.
- It creates a visual inconsistency: the clear and modern planks add a brutal aspect to the historical frame.
- The change in the water level under the tiles, even in small quantities, may not be well controlled in the gutters and adjacent valleys: Any accidental infiltration will be undetectable until a high concentration invades the wall plates.
- Those are non-reversible systems that can affect the historical roofs.

EPDM [ethylene propylene diene monomer] rubber mats over ceilings: this method eliminates ceiling suspension, along with some transitional beams, and may be catastrophic without proper drainage.

Restoration and conservation methods

Traditional tiling systems have protected the houses for centuries ;

- It could be upgraded and reinforced.
- A periodic inspection of the waterproofing system is needed each autumn to keep water out. It consists of checking and cleaning the metallic reinforcement of the waterproofing at critical locations (chimney/vents and protrusions flashing, valley flashing, concealed gutters, etc...)

- Replacing broken tiles, identical tiles shall be spared and stored.
- Use appropriate panels like corrugated aluminum sheets, isolation sheets, or separators to avoid condensation.

Channels: gutters and downspouts

Gutters are metallic, horizontal, and semicircular open channels with a diameter of 15 cm. They collect stormwater from the pitched roof to downspouts (102). Downspouts are multiple vertical spouts of 3 inches—some of which feed a buried cistern for constructions prior to 1930.

Pathological problems

- broken pieces and small perforations
- missing parts, severe thickness losses due to polluted air or anti-congestion solvents
- missing brackets

Restoration and conservation methods

- Replaced pieces shall respect the existing style in its visual complexity and detail. The finishing should be handmade.
- Eaves are the continuous crown: a partial replacement shall be coherent, and new pieces shall be tagged using patina to correct the visual ruptures.
- Make sure channels are below water drip, and that any overflow will be drawn away from the walls.
- Welded metallic gutters are leveled; the slope is unnecessary.
- Use the traditional tin welding to install a connector and patches or to fabricate new accessories.
- Inspect and clean periodically to avoid any obstruction.
- Collect stormwater to have an appropriate network.
- Make sure to use non-corrosive brackets, nailed inside the wooden frame for spouts. When inserted inside the stone walls, avoid using epoxy mortar for anchorage, as epoxy resins expand excessively due to thermal variation.

102

Fadlallah Dagher

Stairs are a major feature of the late-Ottoman period houses in Beirut. Besides functionality, stairs serve as an expression of prestige and greater esthetical impact.

Stairs are also a technical tour de force that show off the craftmanship of the stonemason who erected them. On older buildings, elegant flying stairs outside the structure indicate that the villa was erected in stages—the upper level added long after the ground level. In more recent structures executed after 1880, and as the central hall floorplan was finally established, the stairwell was fully integrated into the building block, rising to two or even three upper levels.

TECHNIQUES

Material: Some high-end large villas and palaces had Carrara marble stairs (103). However, standard stairs were mostly made of Mansourieh limestone treads, prefabricated in workshops and delivered to the building site (104). Accordingly, most treads have a triangular profile and standard, identical dimensions: (D) 300 mm; (H) 175 mm; (L) 1200 mm to 140 mm.

From 1925 on, the Mansourieh limestone was abandoned, and precast cement terrazzo treads were introduced in various colors (yellow ochre, dark grey, red, green, etc.).

Cantilevered stairs: cantilevered stone treads are a traditional feature of local architecture in Lebanon. In the *Beiruti* houses of the late 19th century, triangle-shaped treads are embedded 15 to 25 cm inside the wall and project 120 cm outwards. The steps are rebated, which means they are interlocked between each other to better resist torsion (103, 104, 106).

Types: We can identify three main types of stairs, which are relevant to the standard of the building and to the stages/period of its construction:

103

104

The main entrance stairs

- In large villas, the building entrance floor was always elevated from the ground (between 1 and 3 meters). It was accessed through monumental stairs of Carrara marble or Mansourieh limestone, usually centered on the façade and its central bay.
- These stairs had various shapes in plan, sometimes elaborate: straight, curved, “L” or “U” shaped, etc.
- The cast or wrought iron railings are fixed into grooves using molten lead that makes an excellent medium for securing iron as it provides a strong friction-fit, and it forms an almost watertight joint.

The external staircase

- Most of the primitive central hall houses were built in stages: the grade level was extended, and, at one point, an upper floor was added as the family grew. Accordingly, most houses have two levels with separate access.
- The stairs leading to the upper floor were of different shapes in plan (straight, “L”, or “U”).
- The flights of stairs were raised on sandstone arches (similar to flying buttresses). In some cases, the last flight was cantilevered.
- The external stair can either be exposed, or it can be part of a detached, covered volume.

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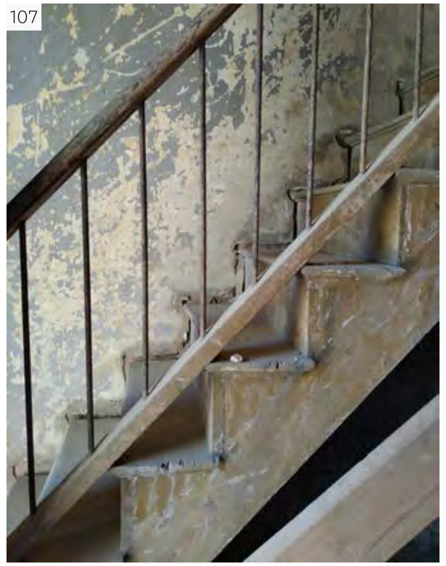

108

The integrated staircase

- In prestigious villas, monumental internal marble stairs connected the two main levels. Cast-iron railings were generally topped by a walnut wood handrail.
- As Beirut's population grew and construction techniques improved, the multi-storied central hall buildings of the turn of the century became preplanned and built in one go. The houses featured three to four levels distributed by a staircase integrated within the original plan. That staircase was also the main entrance space to the building. Around 1920, apartment blocks were introduced with one staircase leading to two opposite central hall units per level.
- The integrated staircases are generally confined within a square space on the eastern, western, or street-facing side of the building. Four flights of eight steps, each with three intermediate landings, were necessary to climb the height of one floor.
- The triangular treads are made of Mansourieh limestone cantilevered from the side walls.
- The landings are made of Carrara marble slabs supported by steel I-beams.
- The railing is generally made of wrought iron, and it is fixed to the tread by melted lead.
- Light and ventilation are introduced through twin arched windows positioned at intermediate landings.

Note: the mezzanines in the service areas, and the roof attics are accessed through fixed light structure wood steep ladders (inclined at 45 degrees) (107). The balustrades are in wood or steel, simple bars topped by a wooden handrail.

PATHOLOGICAL PROBLEMS

Stone stairs are extremely resilient. They have resisted the test of time, as well as gunfire and shelling during the civil war.

The force of the August 4th explosion caused deformations to the buildings. Cracks, broken or detached treads, and deformed iron railings are the consequence of debris falling from above (108).

The stone treads can sometimes have their edges broken where the railings are fixed. This can be attributed to:

- The lead putting a strain on the edge which can cause surface spalling, detachment, or deep cracks.
- The movement of the iron within the tread, which tends to compress the lead and creates loose joints that increase the possibility of water infiltration. Rust jacking, in turn, risks splitting the stonework.

RESTORATION AND CONSERVATION METHODS

The staircase should be propped and documented.

Displaced and broken elements will be dismantled, numbered, and reconstructed with the same or similar material.

Broken cantilevered treads will be dismantled. The cavity in the wall should be cleaned of sand, lime, debris, or any loose material. Do not reassemble the broken tread with iron bars and glue, as it will hardly resist the effort on the long term. New solid stone treads will be cut and integrated inside the cavity. Rebated edges must be perfectly cut to allow their assembly with lower and upper treads without mortar. Lime mortar and grout will be injected inside the cavity until it is completely filled in. It should be left to cure for 21 days. The treads will remain propped until the mortar is completely dry.

Railings and balustrades will be dismantled to be readjusted, then fixed back with melted lead after completion of the stone works.

When railings are fixed into new treads:

- Fixing holes should be made using a non-percussive system such as a diamond drill to reduce the risk of damage from vibration.
- Drilled holes will have smooth sides that create weaker adhesion to the lead. Drilling angled holes will create a more effective key for the joint.
- Clean and dry the holes before pouring the molten lead.
- The iron that is to be leaded-in should have an anti-rust finish applied.
- Once the iron is in place, protection should be made around the bar.
- Molten lead is poured into the hole with a small ladle. It is important to ensure that enough lead is poured in because it shrinks upon cooling. Remove any excess with a chisel.
- The lead should extend above the surface of the stonework and slope down and away from the bars of the railings in order to carry away any moisture.

Note: that the use of resins instead of lead is an acceptable alternative for historical ironwork. However, it is always recommended to retain the authentic design, materials, skills, and processes involved in the original work.

"In contrast to the other types hidden and giving to the inside, the central hall house was exposed to the exterior. The balcony which was often placed in front of the triple arched window symbolized this change: inhabitants wanted to see their surrounding and wanted to be seen by the public" Anne Moellenhauer (2005)

Balconies, generally of rectangular shape, are located on the main façade in front of the triple arches. Their position on the other façades depends on the location of the house and the surrounding streets or gardens. Sometimes, they run across the full width of the elevation. After 1920, other shapes of balconies, such as round or curved balconies, appeared.

TIMBER BALCONIES

Timber balconies are not a common feature of *Beiruti houses*. Few examples of wood balconies still remain, whereas others can be found on postal cards and old photos of demolished buildings like "Khan Antoun Bey" and the "Grand Hotel Bassoul."

DESCRIPTION AND CONSTRUCTION TECHNIQUES

The few remaining examples show a lightweight structure consisting of either thin iron brackets, stone corbels, or I-beams supporting timber joists and wooden planks [1.5 cm thick and 20 cm wide]. The finishing varies between marble slabs, tiles, or an 8 cm concrete slab with cement finishing.

109

Timber on iron brackets

Iron brackets are the main supporting elements on which the wooden structure rests. Each bracket is composed of two iron bars:

- A **horizontal bar** with a rectangular section (about 2 x 4 cm), inserted and connected to the wall's masonry. This bar is positioned on its smaller edge, and in some cases, it is nailed to the timber joists through riveted iron braces.
- An **inclined bar** inserted in the wall's masonry from one side and fixed on the cantilevered horizontal bar from the other side. It works as a support for the horizontal components, translating the loads down to the sandstone wall (114).

The wooden joists are spaced at an average distance of 30 cm. They can either have a square or a rectangular section—sometimes curved at the edges.

The wooden planks are nailed to the joists. In some cases, they can protrude up to 30 cm. They are covered by tiles or cement finishing.

The wrought iron railings are fixed to the walls and to the iron brackets through holes in the tiles. In the case of concrete slabs, the railings' posts are often installed during the pouring of the mixture.

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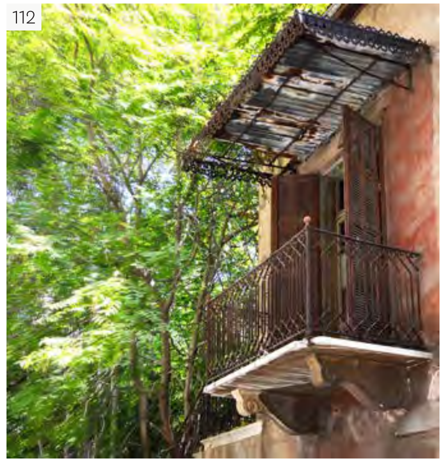

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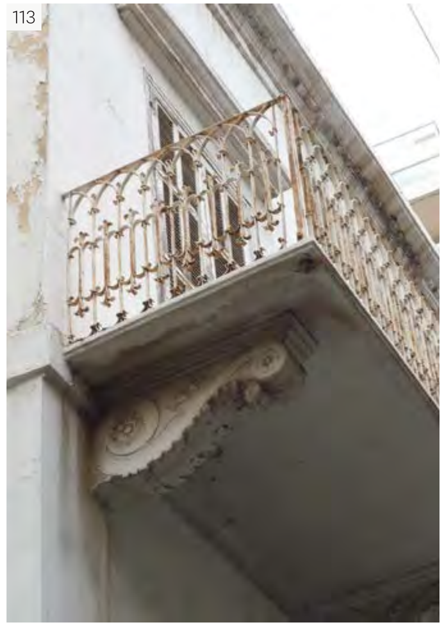


TIMBER ON STONE CORBEL

- **The stone corbels** consist of a single, carved limestone block with various geometric and floral motifs. The corbels are integrated within the masonry wall, and their protrusion varies up to 100 cm depending on the corbel's span limitations.
- **Square shaped wooden joists** (around 10 x 10 cm) rest on the corbels, with about 30 cm space between them. They are covered by wooden planks.
- **Marble or limestone "Furni" tiles** are placed on the timber joists/planks.
- **The wrought iron railings** are fixed through lead-filled holes in the tiles by riveting and bolting.
- In some cases, it is possible to have a *Baghdadi* system on the balcony's soffit where wood laths are nailed to the joists and are covered with gypsum or lime. The side profile is then closed with either gypsum or lime molding or a wooden frame fixed with small, curved iron straps.

TIMBER ON I-BEAMS

- **The steel I-beams** support the timber joists. In some cases, the I-beam can be supported by the walls from both sides (111).
- **The wooden joists** are inserted in the masonry walls from one side and rest on the I-beam from the other. The 10 x 10 cm square shaped timber joists are spaced from one another at an interval of around 30 cm. They protrude from the I-beam almost the same distance and are covered by wooden planks on top of which rest the "Furni" tiles.
- **The wrought iron railings** can have a special fixation detail to the I-beams. The posts can be extended to the I-beams level and connected to them via iron bolts.

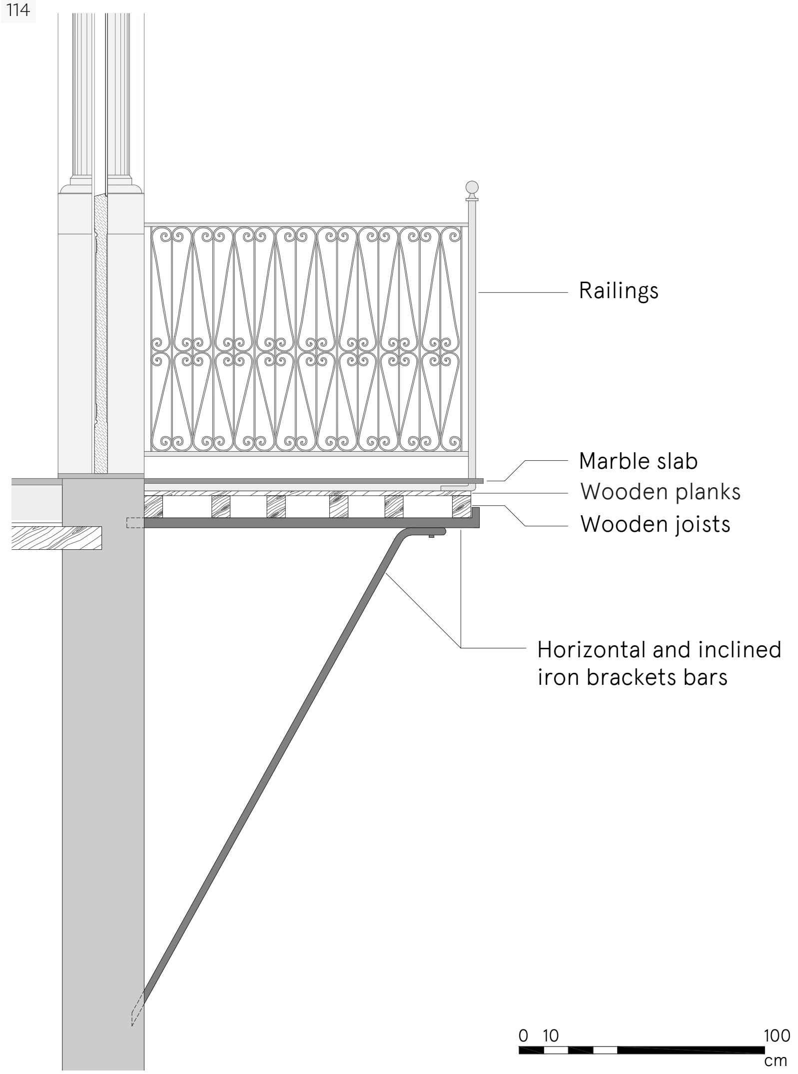
MARBLE BALCONIES ON CORBELS

Dating back to the late 19th and early 20th centuries, marble slabs on corbels are one of the most commonly found construction techniques for balconies.

DESCRIPTION AND CONSTRUCTION TECHNIQUES

The balcony *(shurfat)*, consisting of a 4 to 5 cm thick Carrara marble slab resting upon corbels, is an extension of the central hall and, in some cases, of its adjoining rooms. It gives shade to the façade and protects it from the rain.

114



114: Typical section of a timber balcony on iron brackets

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THE CORBELS

The stone corbels *(zifr)*

They are made of monolithic pieces of limestone inserted perpendicular to the façade and projecting out of it. The classical Renaissance-inspired corbel was introduced after 1860 along with the large marble slabs. It features a double spiral scroll-shaped ornament (volutes). The standard corbel is carved in Mansourieh ochre limestone (128). However, rare examples of Carrara marble can be observed in high-end villas and palaces (113).

The scroll-shaped ornament evolved in the early 20th century into simpler, more squarish designs and plain corbels.

The corbels are placed at intervals of about 150 cm to 200 cm; projecting up to 90 to 100 cm, with an approximate thickness of 18 to 20cm. It is inserted 25 to 30 cm deep into the masonry wall and placed under the column of the triple arches or in a solid wall for structural stability. Occasionally, the corbel is covered with lime wash to homogenize the colors of the façade.

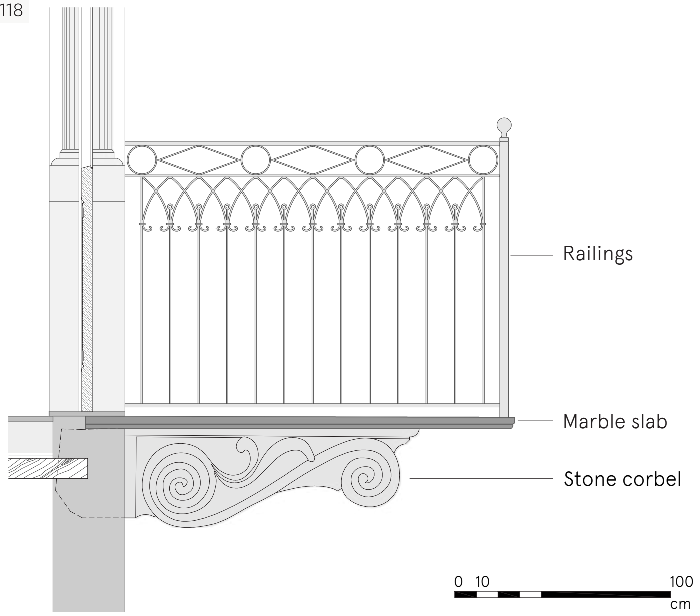
The corbelled stones

In the traditional Syro-Lebanese architecture, corbels were made of two, three, or more layers of cantilevered stones with a convex edge and in successive projections of about 25 cm. The corbelled stones support stone slabs or timber balconies and kiosks.

THE MARBLE SLAB

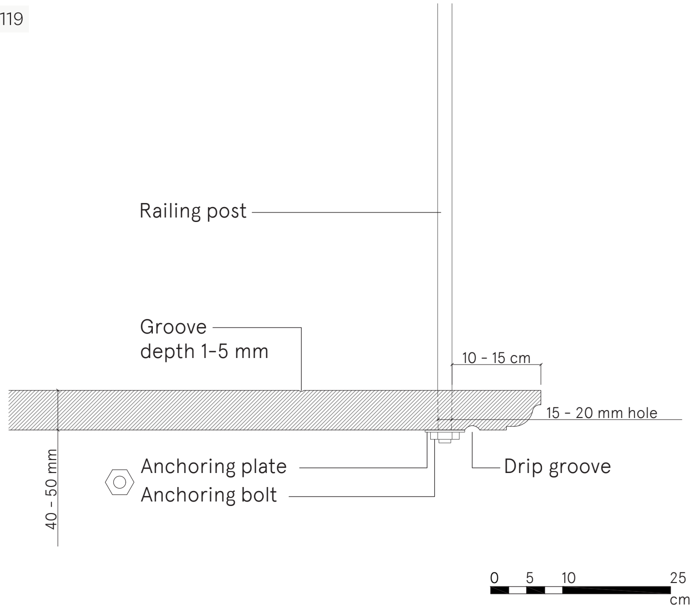
- The slab is made of Carrara marble imported from Italy.
- It is about 4 to 5 cm thick and is inserted into the hosting wall during the construction. The slab is of varying depths, ranging from only a few millimeters to the full thickness of the wall.
- The slab's protrusion is relative to the corbel's size, with an average overhang of around 30 cm from the corbel's edge and approximately 135 cm deep.
- Standard balconies are made of 3 marble slabs on 4 corbels.
- The marble is slightly sloped towards the exterior for drainage purposes.
- The slab is often designed with straight edges or with a molded edge and a lower drip groove, 8 cm away from the edge.

118

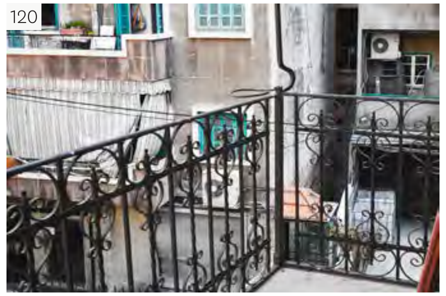


118: Typical section of a marble balcony on corbels

119



120



121

122

THE RAILINGS

- The railings are usually 90 cm high and are connected to the façade's masonry wall, as well as to the marble slab.
- The posts and the handrail are made of iron with a filling of either wrought iron or cast-iron panels.
- The wrought iron railings are crafted through a technique of riveting, bolting, and tie bands.
- The posts are located 10 to 15 cm from the edge. They are fixed by a threaded rod of 15 to 20 mm diameter, passing through the marble slab and held from below by an iron plate and a bolt.

THE CANOPY

- The canopy is composed of an iron structure connected to the façade and sometimes to the handrail posts (120).
    - type a: composed of vertical iron supports holding iron plates covered by a sloped corrugated iron sheet or by a textile cover
    - type b: composed of iron brackets holding a grid with round, simple, translucent, or colored glass panels
- The upper contour or lambrequins can be ornamented with various decorative arrangements (121). Similarly, the iron brackets were often enriched with scrolls and designed in geometric patterns.

PATHOLOGICAL PROBLEMS

Different types of damages arose in balconies as a result of the August 4th blast, as well as a manifestation of chronic decays.

Complete or partial collapse of the balconies

Following the explosion and the resulting collapse of various façade elements, balconies were subject to major damages ranging from partial collapse and detachment of elements to complete collapse and loss of corbels, beams, marble slabs, and railings.

Wood elements decay

Rotten timber joists

Exposed to rainwater and variations of temperature and humidity, timber joists can rot. The wood cellulose is destroyed, and the wood loses its strength. Joists edges inserted into masonry walls where the moisture level is high are particularly more susceptible to deterioration.

Insects and fungus

Wood is vulnerable to insect attacks such as termites and to the growth of fungus in favorable environments. They weaken the wood's structure and lead to its entire deterioration if left untreated.

Oxidation of iron elements

Iron rust, which causes an increase in its volume, can have a significant impact on the balcony's components. It:

- harms the marble slab as well as the masonry wall by causing cracks and breaking due to the rust jacking
- causes stains as a result of weathering and rainwater dripping

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Stone surface alteration

The surface of the stone may sustain several changes that include:

- discoloration caused by rust and staining
- deposits from dust and pollution
- biological colonization (algae, mildew, lichens, moss, or fungi) as a result of limited sun exposure and high humidity levels in specific areas

Fractures and cracks in the marble slabs

Cracks can either be the direct result of the port blast, or a consequence of aging, excessive use, and other structural complications. Cracks can manifest in different types: star-shaped cracks can be the result of a mechanical impact or of iron rust at the corners and the edges, while fractures crossing the slab's thickness can be caused by structural instability.

Marble surface alteration

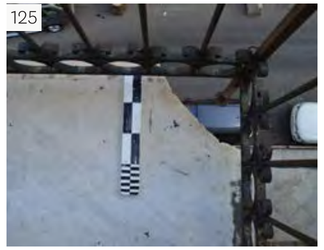
The surface of the marble may sustain several alterations that include:

- oil-based stains, identified by the darkening of the marble surface
- organic stains, such as food, leaves, bird droppings that can cause a pinkish-brown coloration
- inorganic metal stains (126), orange to brown in color, imprinted by the staining object, such as nails, bolts, etc
- ink and paint stains
- water spots and rings as a result of the surface accumulation of hard water

Loose elements

Balcony elements can become loose, inclined, or prone to movement as a result of structural instability or the material's aging and degradation. This applies to corbels' wall insertion points, unstable marble pieces, and insecure railings.

124


125


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RESTORATION AND CONSERVATION METHODS

Iron brackets restoration

Broken iron brackets

In case the iron brackets are recoverable, they should be repaired and reinstalled in their original location.

If they were broken or lost, new brackets, similar to the original ones, should be manufactured using traditional iron forging techniques, connecting the iron elements by riveting and bolting.

Corroded iron brackets

After brushing the iron brackets and removing all rust particles from its surface, the brackets should be treated against corrosion by galvanization if possible or by the application of a protective primer coating.

Timber joists restoration and treatment

Broken timber joists restoration

In case of broken or missing wooden joists, the survey of an original joist must be made (dimensions, profile, and grooves)—based on which a new wooden joist will be cut to match the original one. The newly used wood should be well-dried cedar or similar Pinaceae wood. It should be coated with a double or triple layer of protective anti-moisture and anti-fungi substance since it will be exposed to the exterior weathering agents.

Rotten timber joists restoration

The severity and depth of the affected sections must be evaluated.

- If only the first few millimeters are rotten, the loose wood can be removed, and the remaining section can be kept and treated with a protective wood coating.
- In case of partial or complete rot of wooden joists, the joists should be replaced by new ones.

Insects and fungus treatment

It is essential to eliminate the threat caused by insects and fungi by treating the infected areas. In case the infected area was deep and has spread into a large portion of the wooden element, it is crucial to replace it entirely.

127


128


LIMESTONE OR MARBLE CORBELS RESTORATION AND CONSERVATION

Complete or partial collapse of the balcony, and the corbel is irrecoverable

A new block shall be carved similarly to the broken one. The carved block shall be tagged with the date and it shall be inserted in the masonry wall and laid on lime mortar according to its original construction technique (insertion, location, levels...).

Complete or partial collapse of the balcony, and the corbel is recoverable

The corbel should be reused in the restoration and reinstalled in its original location.

The corbel has one of its pieces broken

When the fractured part is smaller than the one remaining in place, it could be reconnected using stainless-steel bars according to the design of a structural engineer.

The stone corbel is loose or out of its original position (leaning)

it should be repositioned by propping it to its original location and level

Dry cleaning

using a soft brushing tool

Wet cleaning

using a low-pressure water jet

MARBLE SLABS RESTORATION AND CONSERVATION

Marble slabs are heavily damaged

Heavily damaged slabs should be replaced entirely with a new marble slab upholding the original slab's colors and veins and having similar details (thickness, profile, and drip groove).

The slab should be inserted more than 3 cm into the masonry wall beneath the marble columns and parapets.

The railings' fixation: Prior to the post's installation, the sides of the hole should be protected with a durable and flexible material to prevent the metal from putting a strain on the edge of the slab and causing cracks. It is recommended to secure the railings' posts with stainless-steel threaded rods to prevent further rust damage.

The marble slabs show broken edges smaller than 15 cm (129)

The edges can be restored by gluing the fallen pieces or new similar ones. This can be accomplished by either cutting the new pieces to meet the broken edge's contour or by adjusting the broken edge of the slab to match a complementary piece. The operation should be carried out using a marble-adapted glue mixed with marble powder. Dowels can be added if needed. Ideally, the cut shall create a key (like a trapezoidal puzzle).

Marble pieces are broken or cracked around the railings' posts

Once the previously mentioned repairs are executed, the slab can be drilled to fix the railings' posts.

Marble surface cleaning

- Oil based stains must be chemically dissolved so the stain source can be rinsed away. Cleaning should be done gently and using distilled water or white spirit.
- In the case of organic stains, removing the sources might be enough; sun and rain action would generally bleach out the stains. If they persist, cleaning can be done with 10% hydrogen peroxide and few drops of ammonia.
- Inorganic metal stains must be removed with a poultice. Deep seated rusty stains are extremely difficult to remove, and the marble may be permanently stained. Poultice treatment can be applied as follows:

  Prepare the poultice by mixing the cleaning agent to the paste; wet the stained area with distilled water; apply the poultice; cover the poultice with plastic; tape the edges to seal it. The poultice must be applied thoroughly up to 48 hours. Afterwards, it can be removed, and the process is to be repeated until the desired result is obtained.

- Ink stains can be cleaned using bleach or hydrogen peroxide. In case the stain persists, acetone can be used.
- Paint stains can be removed with a lacquer thinner or scraped off carefully with a razor blade.
- Water spots and rings can be removed by buffing with dry steel wool.

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When subjected to destructive earthquakes and explosions like Beirut's August 4th blast, the lateral resistance of unreinforced masonry structures reveals its weakness. Walls and slabs are the main components that should be strengthened to reduce the building's global lateral deformability and increase its resistance. In this regard, basic qualitative recommendations will be addressed in the following paragraph. However, their use should be limited to the conceptual phase; a structural engineer restorer should develop an advanced quantitative solution based on accurate data acquisition, structural analysis, and drawings details. Particular attention should be paid to the execution phase by ensuring regular and controlled supervision.

RETROFITTING OF WALLS

In order to increase the walls OOP and flexure resistance, different approaches may be adopted. Several techniques exist in the literature. An easy and inexpensive intervention consists of the following steps:

- Carefully remove existing loose plaster without inducing any significant vibration to the structure.
- The injection technique is to be used if the wall includes deep void volumes. The injection sequence should start from the lower to the upper level of the wall and from the wall's vertical edges to its central area.
- Repoint joints where needed with lime grout material (volume: ½ sandstone of crashed materials and sand to ½ NHL5).
- Roughen the remaining surface of the plaster with basic manual tools for a better adherence of the new plaster.
- Attach fiberglass, resin, or polypropylene meshing over the whole area of a wall with non-corrosive connectors that must be anchored up to a depth of 1/3 of the wall's thickness and with a maximum grid of 70 cm x 70 cm. If possible, the meshing tissue should be installed to the wall's inner and outer side and linked together with connectors crossing the wall's entire thickness.
- Apply two layers of lime plaster reinforced with fibers (volume: 1/3 lime NHL 3.5 to 2/3 sand). A curing time not less than ten days should be respected between the first and second plaster layers. Plaster should be continuously watered to avoid shrinkage and to reach the maximum mechanical resistance.

An IP structural upgrade may also accompany the upgrade of an out-of-plane wall's behavior by adding in-plane braces. It is possible to add IP X braces using traditional material like stainless-steel 316 L flat plain strips, FRP or GRP attached to the wall using non-corrosive connectors. It is also possible to use FRP strips if the wall's surface condition is homogenous enough to allow the use of a chemical binder - usually epoxy product - to attach the strips to the wall.

IMPROVING STRUCTURAL CONNECTIONS

A partial or an entire failure of a wall-to-wall connection and/or wall-to-floor connection was frequently observed after the Beirut blast. Therefore, it is necessary to enhance the connections between the different structural elements of the building. The aim is to ensure a monolithic, three-dimensional behavior of the structure, called "box like behavior", against horizontal, seismic or blast loads. Typical interventions include but are not limited to the following:

Metallic tie-rods: They should be located at the floor level and anchored at their end using bearing plates, X's, or straight metallic strips. The latter may be visible (132) or embedded in the mass of the wall (33, 34). Tie-rods may be executed with plain circular section or wire ropes; they should ensure a connection between two parallel peripheral walls. They also provide a valuable connection between orthogonal walls and consequently a restraint against OOP failure mechanisms. It is necessary to install the tie-rod system in such a way as to connect the different opposite walls of the building, mainly in two orthogonal directions 132). The IP behavior of a wall with openings is also improved by the addition of a tie-rods system. In fact, it develops a strut and tie mechanism in the spandrels below and above the opening.

132

132: Système de tirants et appuis en forme de X en acier inoxydale installés sur les murs orthogonaux, Chamat Jbeil - Liban

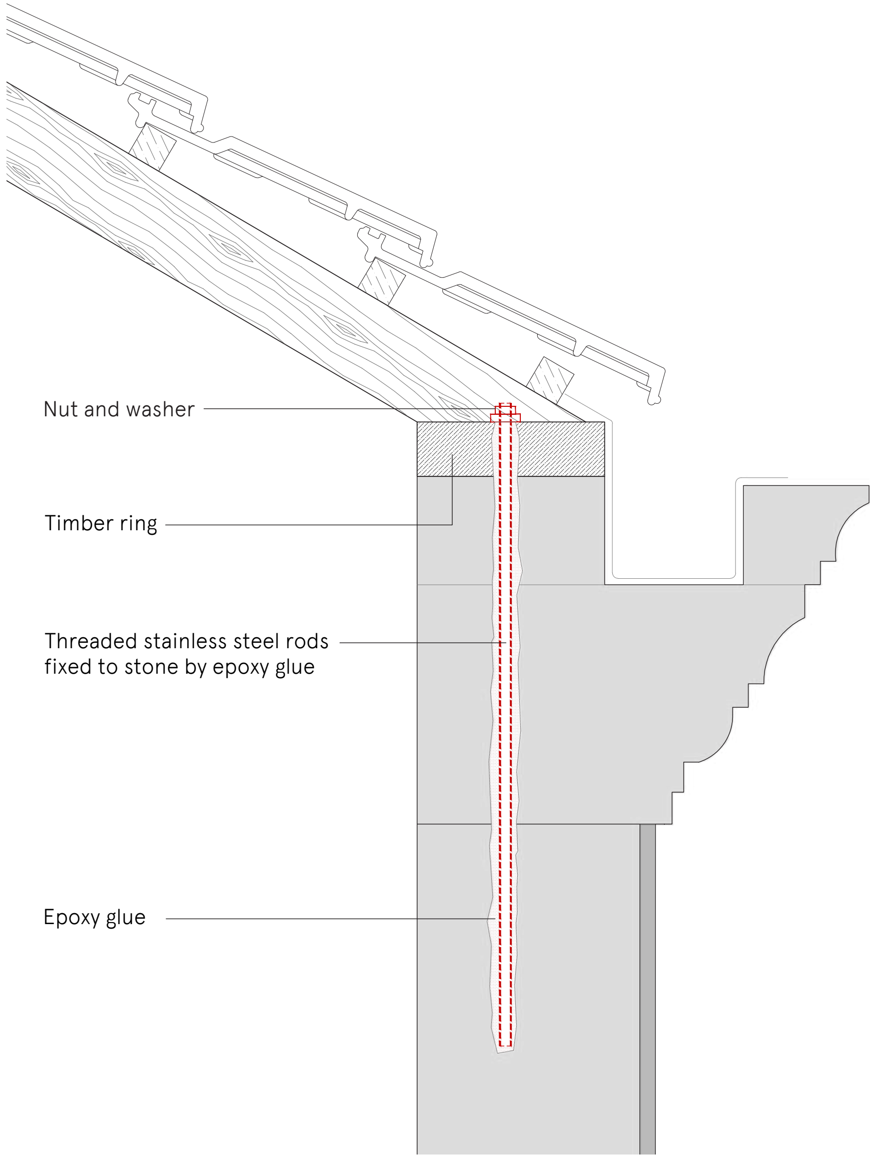
Wall-to-wall stitching: When the horizontal stress exceeds the stone's tensile strength, detachment occurs at the wall-to-wall connections. By adding horizontal stitches over the wall's height, it is possible to improve the connections' horizontal tensile strength and avoid wall-to-wall connection failure. This intervention is to be applied to L-shaped intersections (corner walls) and T-shape intersections. *For more details about the stitching process, refer to paragraph "Out-of-plane failure mechanisms".*

Peripheral belts: Normal iron, stainless-steel 316 L, FRP, or composite materials may be used to execute peripheral belts that should be installed at the floor level. Peripheral belts should be constantly subjected to tensile forces, which induce a confining pressure at the floor level. Similar to the tie-rods system, peripheral belts ensure a valuable connection between orthogonal walls and consequently a restraint against OOP failure mechanisms. It is worth mentioning that tie-rods and peripheral confining belts may be combined for better OOP resistance of the building.

Wall-to-attic connection: The transition between the wooden attic and walls is ensured via a wooden ring simply supported over the peripheral and internal walls. End-walls behave like vertical cantilever beams. Consequently, their deflection at the attic level is very important when subjected to lateral, seismic or blast loads. This was recurrently observed after the Beirut blast. Linking the wood ring to the end-walls top level will reduce the wall's deflection and prevent any relative movement between the wall and the attic. For this purpose, it is possible to apply vertical stitching using stainless-steel 316 L, GRP, or FRP threaded rods. Vertical perforation crossing the wooden ring and stone blocks should precede the installation of threaded rods, which should be attached to stone material using a compatible epoxy binder (133). The spacing between threaded rods should not exceed 70 cm with a minimum diameter of 14 mm. These values are tentative and should be tuned case per case according to the judgment and final design of a structural engineer. When possible, the installation of a tie-rod system combined with horizontal bracing above the *Baghdadi* ceiling will highly decrease the end-walls' torsional deformability and the OOP failure mechanisms.

Wall-to-floor connections: Because of the weak connection between slabs and masonry walls, wall-to-floor connection detachments, especially for timber and hybrid floor, were frequently observed following the port blast. In order to rigidify this type of connection, it is possible to link the wood or steel beams to the outer face of the peripheral walls or to the peripheral confining belt. Multiple connection details may be adopted. For instance, steel plates may be attached mechanically to the vertical sides of the wood beams. On these plates, horizontal, threaded rods are welded. They should cross the whole thickness of the wall to reach its outer face, where they are fixed to the peripheral belt or to the wall's surface using a nut and washer system (134).

133



Upgrade of wall-to-attic ring beam connection

REDUCING HORIZONTAL SLABS DEFORMABILITY

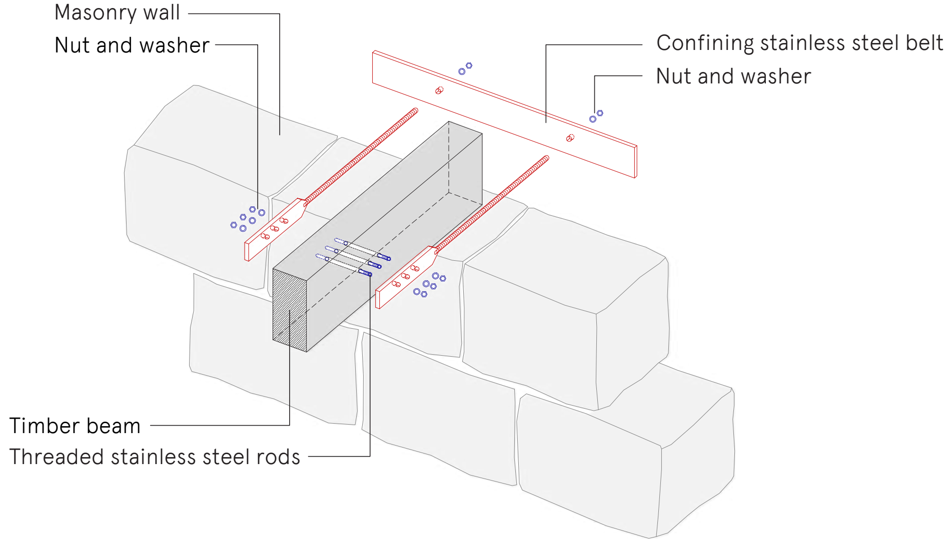
Horizontal slab should act as a rigid diaphragm that transfer seismic or blast loads to masonry walls and prevent walls' OOP failure. Existing timber and hybrid slabs in Beirut's heritage buildings cannot be considered rigid diaphragms since they are covered by one layer of wood planks above timber beams.

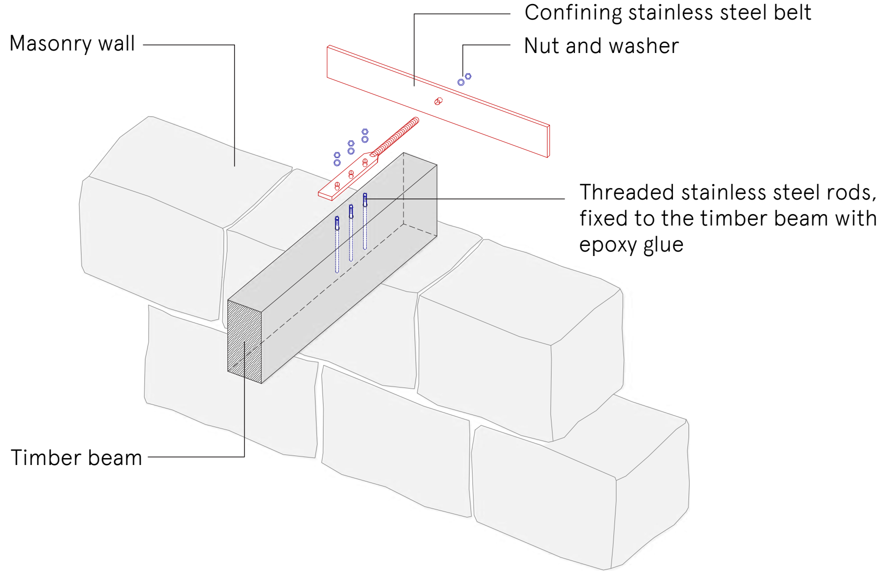
- A simple way to increase slabs' lateral stiffness is to add one or multiple layers of plywood planks attached together over the existing ones. This must be done with a polyurethane glue after removing the tiles and the filling material beneath. Single or multi-layered planks should be nailed or screwed to the existing joists.
- An efficient solution to increase horizontal slab stiffness and internal wall-to-floor connection entails adding a ring beam on the contour of the existing slab over the wooden planks. The ring beam should be connected to the walls through a series of horizontal, threaded rods and braced horizontally with an X tie-rods system.
- If the extrados surface of the wood planks does not suffer any damage or biological attacks, it is possible to implement a modern intervention by adding an FRP grid over the existing planks. The grid is to be installed at 45 degrees with respect to the slab edges.

INCREASING VAULTS RESISTANCE

Refer to paragraph "Vaults".

134





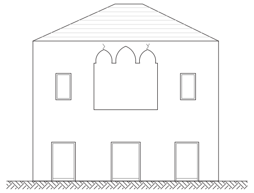
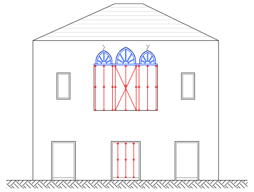
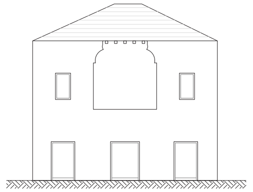
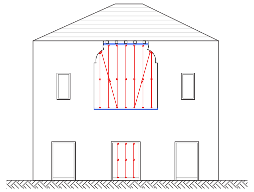
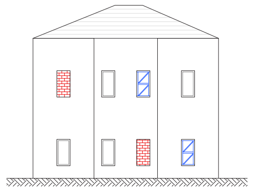
Upgrade of wall-to-floor connection

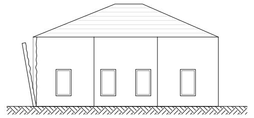
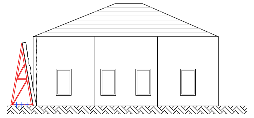
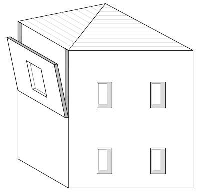
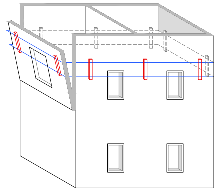
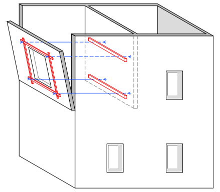
PROPPING AND URGENT INTERVENTIONS

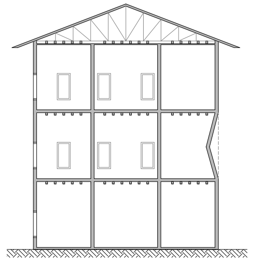
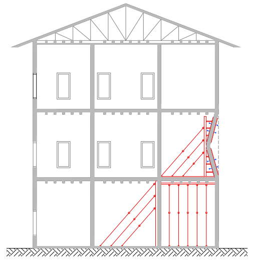
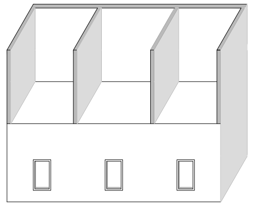
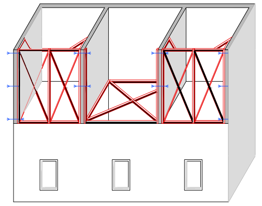
Michel Chalhoub

Multiple patterns of structural damage have been documented after the August 4th blast. It was possible to group them into 9 major categories. Because of the vulnerable structural state in cases of significant risk of collapse, some damages required immediate, short-term interventions. Other less severe damages necessitated an intervention before wintertime. In either case, propping must precede any other action in a damaged building. The type of interventions mentioned in the table below served to support the building and avoid water infiltration into the structural elements' mass. Thus, several buildings were structurally stabilized, while others still require special structural care to be saved. It is worth noting that similar interventions may be applied to stabilize historical buildings damaged by earthquakes.

Typology of damage *Highly damaged and partially collapsed building*			
Description	Sketch	Proposal of immediate intervention	Illustration
 		Stabilize the remaining part of the building and dismantle the risky parts in order to reconstruct it.	 

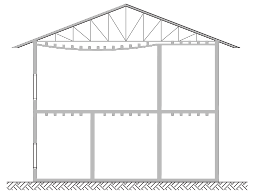
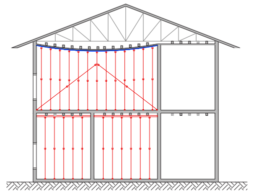
Typology of damage *Triple arch elevation, or openings damage*			
Description	Sketch	Proposal of immediate intervention	Illustration
 Columns are missing from the triple-arch elevation.		 Add a propping system beneath the triple arcades.	
 The whole triple arch's elevation is missing.		 Add a steel or a timber beam that will support the slab system. The beam should be supported by a vertical propping system.	
 Windows and doors are missing.		 Add a strangling system with timber frames or temporary filling with hollow blocks.	

Typology of damage *Wall-to-wall and corner detachment*			
Description	Sketch	Proposal of immediate intervention	Illustration
Walls on the ground floor.		 Add a vertical lateral bracing system.	
 Peripheral walls beneath attic or in a floor different from the ground floor.		  Add tie rods or confining belts connecting the peripheral walls to the internal walls. If possible, add a system of confining belts around the peripheral walls.	 

Typology of damage *Bowing of walls*			
Description	Sketch	Proposal of immediate intervention	Illustration
		 Add a lateral, vertical bracing system connected to the damaged wall. Add a propping system in the lower floors.	
Collapse of some peripheral end walls beneath the attic			
		 Add lateral, vertical bracing in the area of missing peripheral walls. Add a horizontal diaphragm if the slab of the last floor is missing. Add a propping system in the lower floors.	

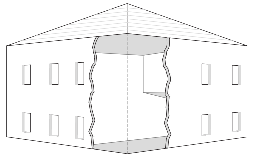
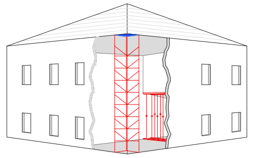
Typology of damage

In plane cracks with limited crack width < 2 cm

Description	Sketch	Proposal of immediate intervention	Illustration
		Lime injection Add a propping system where needed.	
Broken beams or excessive deflection of the ceilings			
		 Add a vertical propping system. If the slab is Baghdadi, a soft interface between the propping system and the slab should be included (e.g., foam).	

Typology of damage

Damage in attics

Description	Sketch	Proposal of immediate intervention	Illustration
 Partially or quasi-totally damaged.		Repair the structure of the damaged truss. Add a temporary sheltering or tarpaulin system.	 
Out-of-plane failure - Local collapse with an unstable attic condition			
		 Hold the attic temporarily with a telescopic crane. Create a provisional structure (of steel or timber) where needed in order to retrieve the initial structural conditions of the building. Cover the attic and the collapsed elevation with tarpaulin or a sheltering system.	

SURFACES

Nathalie Chahine, Fadlallah Dagher

PATHOLOGICAL PROBLEMS

The main risk posed to heritage houses is the progressive disintegration of their masonry due to the deterioration of its materials, texture and surface. This process largely occurs from exposure to weathering agents. The different degrees and morphology of the masonry's deterioration are connected to its intrinsic properties, petrographic characteristics, and porous structure. They also depend on the environment and the building's exposure to it.

The north-facing façade of *Beiruti* houses— sometimes left unplastered—is exposed to humid sea air. Similarly, the back façade is subjected to rainy South-Western winds. Furthermore, *Beiruti houses* endure the worst effects of a polluted urban environment.

These houses are built with sandstone *(ramli),* which is a fine, medium grain rock ranging in color from brown to pink ochre. It is a porous stone with a low compressive strength of 4 to 10 N/mm2 and a density of 2.0 to 2.7 g/cm³.

Some of the most common pathological problems found in the buildings are presented in the following table:

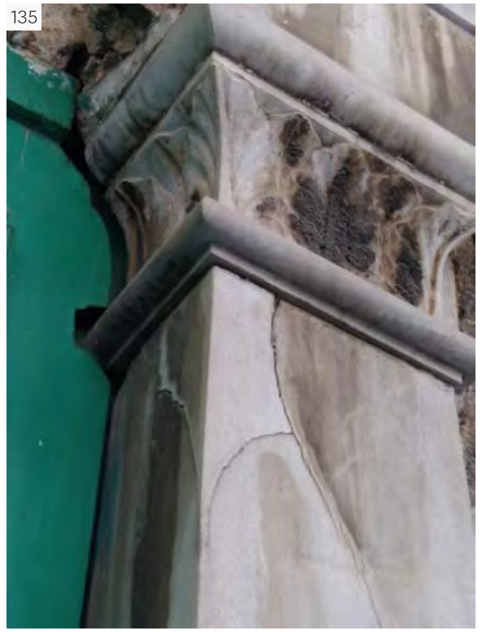
Particle soiling and Black crust

This can be caused by the airborne deposition of vehicle exhaust fumes, sea salts, and other contaminants.

Acid rain causes carbonate dissolution, which leads to the degradation of the inside of the stone and triggers the formation of a black crust at the surface. In parallel, the residual concentration of calcite inside the stone could be heavily affected, causing stone alteration.

Areas that are not exposed to the rain have a deposit of dust and show a darker color.

Poor maintenance may promote the accumulation of soiling.


135

Poor water management

Water is the most destructive agent specially for lime or gypsum-based decorations.

Humidity can be caused by several factors:

- condensation caused by infiltration and penetrating and rising damps
- capillary water transport (i.e. humidity by capillarity on the base of the walls)
- backfilling behind the retaining walls in the ground floor areas
- rainwater that generates changes in the porous sandstone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Staining

This is a natural process that can be dramatically accelerated by cleaning.

It is caused by dark colored minerals such as iron or manganese that naturally occur in sandstones and gradually seep out over many years.


137

Alveolisation

This manifests in cavities of variable shapes and dimension—comparable to honeycombs.

It is caused by high moisture levels.


138

Higher plants

Presence of colonization of plants with sizable roots.


139

Bird fouling

The corrosive effects of the acids in birds' excrement have a prolonged impact that persists even if the fouling is removed.

Fungi that live on pigeon excrement enter the stone, transporting naturally produced acids that are strong enough to dissolve stone and form soluble salts. This process increases the porosity of the stone's structure, allowing water to penetrate more readily.


140

Graffiti

It is caused by highly penetrating aerosol paints that can permeate deeply into the stone's structure.

141

War damages

Missiles and shelling produce extreme temperatures that damage the stones and affect their resistance.

Bullet impacts.


142

Powdering

This is visible in the spontaneous detachment of dust-shaped material.

It is caused by high moisture levels.


143

Efflorescence

The salts involved in the process are those dissolved in seawater (mainly chlorides and sulfates) which arrive at the house as aerosols transported by wind.

Sandstone provides a porous surface for water to penetrate and stagnate. The soluble salts in the seawater dissolve and get absorbed by the masonry before re-crystallizing at the point of evaporation. This causes an efflorescent appearance at the surface of the stone.


144

Biological surface soiling - colonization by micro flora (fungi, algae, lichen, moss) and bacteria

It is caused by atmospheric and micro-climatic conditions, fluid movement and concentrations, surface roughness, and physical changes.

The umbra of trees located close to walls could also encourage the algal staining.

In addition, water-holding and run-off surfaces are prone to biological surface soiling.


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RESTORATION AND CONSERVATION METHODS

Cleaning

The cleaning of stone surfaces is the most visible aspect of building conservation work.

Before launching the cleaning process, however, it is crucial to determine its necessity and whether a cleaning would benefit the building.

Risks

- Improper cleaning techniques can cause damage either immediately or on the long term since they destroy the protective surface formed on the masonry.
- Soiling and decay agents can easily attach to a freshly cleaned surface.
- Using inadequate materials and methods can harm the stone and cause minerals to migrate, change color, or disintegrate.

General notes

As a first step, it is important to understand not only the nature of the building material and the "dirt" in question, but also its remedy and how removing this pathology will affect the underlying material.

For example, determining whether the dirt is material leached out of the stone by chemical reaction (like calcin C5H6Ca) or an accumulation on the surface produced by airborne deposition will influence the approach.

It is important to outline the desired result and stipulate what is to be expected of the process.

Trials should be mandatory for work of this type, and cleaning action needs to be undertaken by skilled and experienced teams.

Cleaning trials should always start with the least aggressive method, usually water, and stop once a successful method has been found. Off-site analysis can help predict the reaction of the substrate to the cleaning process.

Operatives should follow product guidelines in terms of application and removal. They must wear the appropriate protective gear and equipment. Measures must be taken to ensure that run-off substances, aerial mists, drips, and splashes do not threaten passers-by.

Should removals leave unexpected and/or unforeseen holes and damaged surfaces in the finished work, patch and repair are needed to match adjacent finished surfaces.

It is fundamental to use distilled water with no impurities and salts in solution as they can deposit on the treated surface.

Good maintenance will keep a building free from the accumulation of dirt while allowing natural weathering to occur.

Physical methods

Dry cleaning

(dirt, black crust, stains, calcareous deposits, cement puttying, incompatible materials, etc.)

Mainly adapted for vulnerable stones.

Applied via utensils: aspirators (exhausters), rags, brooms, wire brush (smooth non-metallic) of vegetable fiber, scalpels, metal spatulas (148), micro scalpels (149), micro drills, micro chisel, electrical or compressed-air Vibro- incisors (146, 147).

- To remove strongly bonded and solidified deposits, incisive cycles of cleaning can be applied.
- Particular attention must be given to avoid damaging the underlying masonry.

146

147

Humid basic cleaning

Water is the most common and effective cleaning agent. However, if used unwisely, the building may appear clean on the outside but be rotting inside.

- Brush, spray, and hand wash with water surfaces where serious staining has developed. Saturate masonry and surfaces with clean water before brushing and flushing loose mortar and dirt.
- Divert excess water from the cleaning process to appropriate drains.

Low pressure cold waterjet cleaning

The pressurized water from the waterjet can infiltrate through the joints and the porous sandstone reaching the structure. It is recommended to schedule water-based cleaning work during dry season. This allows the infiltrated water to dry faster (150).

The level of pressure employed should be determined by a series of tests conducted on the stones prior to the actual cleaning work.

While the depth of soiling only extends to a few microns in thickness on the surface, unmoderated use of pressure can bite deeply into the surface below, destroying the quality of the original banker mason's workmanship.

148


149


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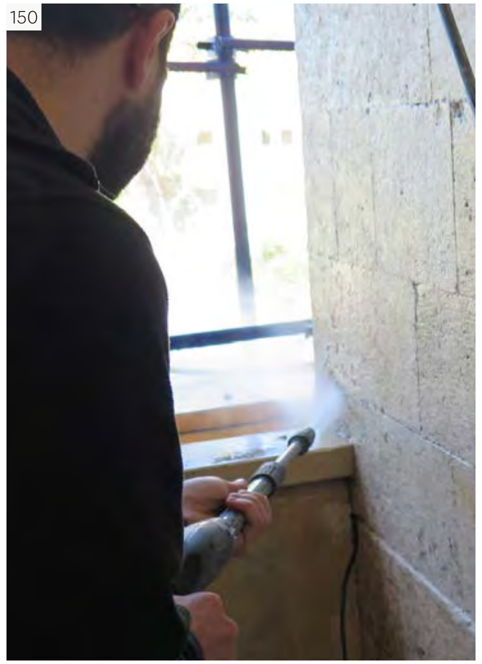

Water sprays (nebulization and atomization)

They are one of the less abrasive methods.

The best results are obtained through nebulization or better yet, the atomization of water using special nozzles that suit the soiled surface.

Drops of water remove soluble composites. Due to the long time required by this method to be effective (1-2 days), it is advised to store big quantities of water.

The operation should be undertaken gradually, at regular intervals, and at a minimum external temperature of 14°Ce. Furthermore, the time of intervention should never exceed 4 consecutive hours of water spraying to avoid the excessive impregnation of the masonry.

Chemical methods

If all the aforementioned methods fail, chemical cleaning methods can be used. These include applying liquids or poultices, using alkaline treatments, acidic treatments, or organic solvents, either individually or in combination.

These methods require a higher degree of caution and expertise, as there is an increased risk for undesirable effects, such as the corrosion of the stone or the formation of soluble salts.

Products for chemical cleaning are based on the application of reagents that attack the binding substances of the deposits. Reagents are usually salts (carbonates) of ammonium and sodium applied with supports of Japanese paper, compressed cellulose, or attagel.

The application's duration varies anywhere from 2 seconds to over 10 minutes depending on the material to be treated and the thickness of the crusts (151, 152).

A thorough cleansing should be applied to the stone's surfaces to wash off all chemical residue at the end of the operation. Otherwise, traces of efflorescence from the cleaning residue will appear on the surface in the form of white lines.

Bird fouling

Anti-perching wire (sprung wire): the wire consists of nylon-coated stainless-steel attached by tension springs to either horizontal or vertical posts. The springs cause the wire to 'bounce' when birds try to land on them—therefore disorienting the bird and causing it fly away.

Anti-perching spikes: they are designed to prevent birds from landing in certain areas.

151


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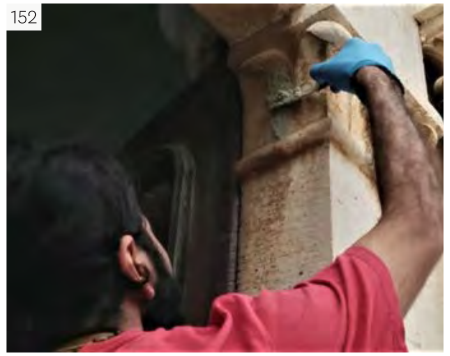

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Graffiti removal

It is considered a priority to remove graffiti as quickly as possible after it appears; paints, glues, and inks dry out over time and become difficult to remove.

Identify the type of media used, the area affected, the type and condition of the surface, as well as the time and manner of its execution.

Treatment of the area should begin once cleaning trials establish the most effective method.

- A solvent/poultice-based treatment: the solvents can range from water to chemical mix. Many companies produce proprietary graffiti-removal products—most of which will be based on similar solvents. The chemical is usually applied first to dissolve the pigment, followed by the poultice to draw the pigment in solution out of the substrate. Repeated applications of the poultice and solvent may be necessary to reduce the concentration of pigment in the substrate to an acceptable level (153).
- Mechanical systems: such as wire-brushing and grit-blasting attempt to abrade or chip the media from the surface. These include a variety of wet or dry air-abrasion systems using a broad range of abrasive media. However, even at low pressure, these systems will remove a layer of the substrate material (the stone).
- Anti-graffiti coating: The coating should ideally be permeable to water vapor, allowing the stone to behave as it would in its natural state. It should also be to remove from the surface; the process must be reversible.

Vegetation removal

- Vegetation must be removed manually and with care before the application of an approved herbicide (Glyphosate or similar). Such herbicides must be used with great care and caution for safety reasons and to avoid harming the gardens or plantation around the building (154).

Biological patina removal

The removal of moss cannot commence unless the drainage of the summit of the walls is achieved, and only after ensuring that the rainfall problem causing the biological micro-organisms is solved.

- Use an approved quaternary ammonium on 2 applications and brush. Follow the manufacturer instructions. Rinse thoroughly to remove all residues of salt.

Harmonization

To avoid a patchy appearance at the end of the cleaning process, the cleaned area can be graded into the surrounding masonry to give a more subtle tonal transition.

- Rub in or dust cleaned stones to match adjacent non-cleaned surfaces as close as possible.
- Use carbon black in small amounts; rub it in well with burlap rags or medium bristle brush (155).
- After each application, dust off surplus and wash down with a low-pressure hose. Allow surface to dry before proceeding with following applications.
- Continue process until a desirable look is achieved.

Protective coating

It is advisable to forgo the coatings. If unavoidable, a layer of limewash, mixed with pigments when needed, and renewed every two years is sufficient.

Risks

- Protective finishes that are designed to change the way the surface absorbs moisture and dirt will also change the way it breathes and releases moisture.
- Most of the coatings cause a darkening of the surface or sheen. A good coating should perform consistently in wet and dry conditions.

Stone patching

When the degraded parts are small compared to the whole stone surface, patching is applicable.

- Remove the disaggregated and powdered part. The area to be treated should be at least 6mm thick to avoid feathered edges for the patch.
- Remove loose particles, soil, debris, oil, and other contaminants from existing stone by cleaning with a stiff-fiber brush.
- Fix a mesh and/or stainless-steel screws if needed. Meshes should be cut at each joint in the stones (vertical or horizontal) in order to ensure the resistance of the patching mortar to expansion or withdrawal (156, 157).

155

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158

- Immerse with water.
- Brush-coat stone surfaces with the following mortar:
  - 2 powdered volumes of crushed stone (old stone or stone of the same origin)
  - 1 volume of sand (to simulate the color)
  - 1/8 of NHL3.5 with mineral color matched to the color of the stone to be obtained
  - water added gradually to reach a consistency of paste that holds well on the trowel
- Apply the patching mortar in layers no thicker than 50 mm. Roughen the surface of each layer to provide a key for the next layer.
- Keep each layer damp for 72 hours or until mortar has set.
- Protect from the sun and the rain.

Unacceptable patches are those with hairline cracks or that show separation from stone at edges, in addition to those that do not match the adjoining stone in color or texture (158).

Surface consolidation

Risks

- The first aim of consolidation is the recovery of the cohesion and resistance of the material (159). However, few products can reach deeper than 20mm from the surface of the stone. This leads to a formation of a purely superficial layer with high resistance.
- It is hard—if not impossible—to saturate the material's pores at the highest degree.
- Most of the products do not maintain acceptable degrees of breathability and permeability to steam.
- It is an irreversible action: it is almost impossible to remove substances that have penetrated and have solidified inside a porous material.

General notes

Consolidation aims at improving the mechanical characteristics of a material, and in particular its resistance to stresses and cohesion, without pathologically altering its hydrothermal performances.

Consolidation is a particularly complex and delicate operation in the conservation project. It necessitates an attentive analysis of the general pathological framework, as well as in-depth knowledge of the specific nature of degradation and the state of physical-material consistency of the artefacts.

Each consolidation intervention should be of a localized character and never generalized.

After the operation, it is advisable to verify its efficacy through tests, successive analyses, and with periodical controls over time.

The consolidating substances can be binding agents of either the same type as those naturally contained in the material (such as limewash or silicates), or natural or synthetic substances foreign to the original composition of the material but that can improve its physical characteristics.

As a general rule, the used materials have to follow the below criteria:

- mono-component non-toxic product
- allow optimal penetration
- complete drying without formation of sticky substances
- forms reaction sub products that do not damage the material
- forms a binder that is stable to UV rays and not -vulnerable to corrosive atmospheric agents
- complete impregnation without film effects, allowing good permeability to steam
- does not cause chromatic variations in the material

Application methods

- Utensils: brushes, rollers, airless spray tools, nebulizers, compresses of cotton, cellulose, or Japanese paper
- Optimize impregnation by covering the parts to be treated with polyethylene sheets and sealing the edges with gum latex and adhesive tape. This creates a vacuum between the stone surface and the protective sheets where the resin will be injected.
- Application periods change and can vary from a few hours to days depending on the product, the method chosen, and the porosity of the material.
- Remove areas of blind exfoliation and delamination, as well as biological patina before applying.
- Apply an approved consolidant in cycles to small sections of stonework, not more than 9 sq. m in area. Each cycle should consist of 3 successive saturating applications, applied at 5 to 15 minutes intervals depending on drying conditions.
- Protect treated surfaces from rain for 48 hours after treatment.
- Allow treated surfaces to dry for at least 21 days before repointing and patching.

159

LIME-BASE PLASTER

Nathalie Chahine


160


161


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TECHNIQUES

In the cities, plaster finish was introduced at the turn of the century, mainly in order to allow the use of the porous local sandstone (Raguette, 1985).

With the exception of the north/main elevations where fine stone masonry was meant to be exposed, most of the interior and exterior façades were covered with lime-based plaster.

Earth lime-based plaster

Depending on the roughness of the wall, the plaster can have 2 to 3 layers, in addition to a layer of limewash (162).

Layer 1
20-30 mm earth mortar stabilized with lime inclusions and aggregates: sand, fine plant fibers and straw up to 30 mm in length. Terracotta can also be used to increase the hydraulicity of the lime.

Layer 2
10-20 mm earth mortar with lime inclusions and aggregates.

Layer 3
5 mm finishing coat of lime plaster (lime mixed with sand, stone powder, or marble powder) (160).

Layer 4
The last layer is a mix of lime, natural pigments, and alum salt *(chabbé)*. It is called a lime wash and can offer various colors.

Lime plaster

Layer 1
15 mm of a setting coat. The mix is one-part lime putty to two-and-a-half-parts coarse, sharp, well-graded sand (163).

Layer 2
15 mm of a levelling coat (164). The mix is typically one-part of lime putty to three-parts of coarse, sharp, well-graded sand.

Layer 3
2-5 mm of a finishing coat.
This mix of lime and finer, sharp sand or stone powder can vary depending on the hardness and the type of finish required (165).

Aggregate's characteristics

Coarse sand preserves the plasticity and reduces the effects of shrinkage.

Cattle hair, straw, and fine plants fibers increases its tensile strength.

Set-enhancing pozzolan, crushed brick/terracotta and coal added to non-hydraulic lime plasters all reduce setting time at the expense of malleability. Naturally, hydraulic lime has a similar effect.

Patterns

Stone pattern: in the last coat before the lime wash, a groove is done in order to be filled later on with a protruding, 1 cm band imitating the joints between the stones.

Decorative motifs pattern: hexagonal or dado patterns on the lower part of the walls are applied with the Tyrolean gun.


163


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PATHOLOGICAL PROBLEMS

Detachment: Separation of the plaster layer from the masonry leads to collapse.
The impact of the August 4th explosion caused the detachment of the plaster from the walls (166).

Cracks:

Structural reflection of the masonry cracks caused by structural problems.

Surface related to the fatigue of the plaster and to water infiltration (167).

Powdering and sanding: As the stone loses its cohesion, particles begin to detach forming dust-shaped material (168).

Alveolisation: Alveolar weathering producing cavities of variable shape and dimension.

Moisture and micro-biological patina: caused by humidity and water infiltration.

Incoherent materials: addition of cement plaster during earlier maintenance actions.

Salt efflorescence: poorly adhesive deposits of salt aggregates.

Stains: chromatic alteration caused by intrusion of rust or copper solutions.

Chromatic decays: fading of original colors (167).

Surface deposits: dust deposits.

166

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RESTORATION AND CONSERVATION METHODS

Conservation of original plaster

Urgent and reversible provisional protections should be carried out in areas where plasters have partially lost their connection to the hosting surface, threaten to fall off, or have already caused lacunas.

Consolidation of the existing plaster holding historical paintings (to be done by specialists)

For plaster showing forms of pulverization, flaking, exfoliation, cracking, micro cracking, detachment, or missing parts:

- Prop the existing plaster.
- Moisten with a wetting agent [ethyl alcohol and water mixture for example].
- Apply a consolidation product by paintbrush, syringe, pipette, or by means of pack for deep impregnation, to restore the cohesion of the pulverized areas.
- Fill joints and lacunas using syringes, cannulas, or thin tubes for micro filling (169, 170). Use hydraulic lime mortars of suitable granulometry and color to restore the adherence of the detached plaster to the support, as well as in between the different layers of the plaster. The water input into the existing plaster is to be kept as low as possible.
- Treat the minor defects of the plaster by:
    - Removing and replacing detached parts that risk falling
    - Applying a smoothening filler layer with a spatula
    - Scratching and moistening the area with thinner glue solution
    - Applying mortar putty that simulates surrounding texture
    - Edging the limits

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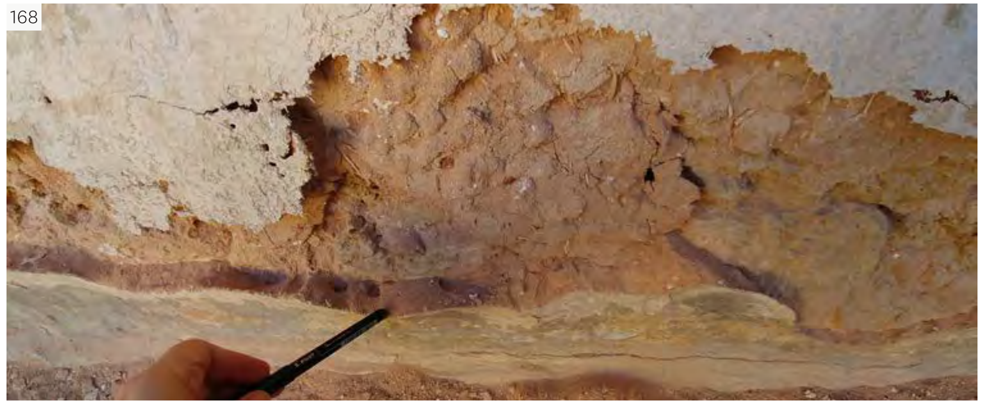

Consolidation of the Tyrolean plaster render

- Identify the areas that are detached from the masonry wall. This needs to be documented and surveyed in detail before removal.
- Carefully survey the façade pattern (dado, stone courses, hexagons, etc.).
- Manually remove the deteriorated areas. Cut the edges in herring bone pattern for a strong connection between the original and new plaster.
- Apply lime plaster layers to match the required thickness of the initial plaster. Final layer should be smooth.
- On that final layer, with a pencil and a wooden rule, draw the pattern to match the original and the remaining surrounding areas. Over the lines drawn, one of two methods will be applied:
    - A wooden mold matching the pattern and made of flat sticks will be applied on the final layer of smooth plaster; Tyrolean plaster will be projected. The mold will be removed and applied to the adjoining area, and so on until the pattern is complete.
    - Masking tape strips following the pattern lines will be applied to the final layer of smooth plaster. The tape will be removed once the Tyrolean plaster layer has dried.

Cleaning

This is done to remove deposits, crusts, biological patina, vegetation, salts, and oxidized metalwork, such as joints, stirrups, nails.

Tools and techniques: brushes, biocides, poultices of inorganic salts, paper pulp with distilled water

Application of a new lime plaster

Preparation of the walls - Before the application of any type of plaster

- Remove the old, decayed plaster without altering the masonry.
- Clean the joints and surfaces to insure better adherence with the plaster.
- Cure substrates and remove dust, loose particles, oil, efflorescence, or other deleterious materials.
- Temporarily apply, plumb, and level wooden blocks known as dots (widaa).
- Moisten the surfaces to be plastered uniformly to ensure that the plaster does not dry out as this will cause it to shrink and potentially fail.

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Application of the plaster

Quicklime plaster

	Coat 1 **Setting coat** *rashit mesmar*	Coat 2 **Levelling coat** *waraát assas*	Coat 3 **Finishing coat**
	Its surface is scratched with lines to give a key for the next coat.	*It is used to bring the surface to a level plane.*	*Its mix varies depending on the desired type and hardness of the finish.*
Mix	1 part of lime putty 2.5 parts of coarse, sharp, well-graded sand	1 part of lime putty 3 parts of coarse, sharp, well-graded sand	1 part of lime putty 1 part of sand or finer sharp stone powder
Thickness	No thicker than 15 mm	No thicker than 15 mm	Varies between 2 and 5 mm
Technique	Apply the mixture. While still wet, scratch the surface in straight lines diagonally to the line of the wall, and in both directions to create a diamond pattern.	Apply lines of plaster (known as screeds) to join the dots already installed. Level them using a floating ruler *(eddé).* Fill the spaces between the screeds using trowels. To achieve a levelled surface, use a floating ruler with its ends bearing on the screeds. Once the mix begins to stiffen, consolidate the floating coat by 'rubbing up' *(fark)* the surface using a wooden float in order to counteract shrinkage. When the surface is compacted, rub over it to form a key for the finish coat using a devil float*.	Use a cross grain float for scouring. Work over the surface using either a trowel to achieve a fine, dense finish, or a combination of wooden and sponge floats to create an open, textured finish. Some water is likely to be required in this process. Splash it on with a brush.
Setting time	Two weeks**	About a week or so	

**A devil float is a wooden float with nails or screws driven through the corners to project about 2 mm.*

**Shrinkage cracks are likely to appear as it dries, but this is not a problem. Once the thumb can no longer depress the coat, it is ready to take the next coat.

Natural hydraulic lime plaster NHL2 or NHL3.5

	Coat 1 **Setting coat** *rashit mesmar*	Coat 2 **Levelling coat** *a smoother insulation layer*	Coat 3 **Finishing coat***
Mix	400 to 450 kg of hydraulic lime 1 m^3 of sand	300 to 350 kg of hydraulic lime 1 m^3 of sand	250 to 300 kg of hydraulic lime 1 m^3 of sand or stone powder
Thickness	Around 5 mm	15 to 30 mm	Less than 7 mm

*To avoid cracking and for better adherence of old and new plaster, this layer should cover the whole wall.

Humidifying and drying each layer of plaster takes around three days.

The interior of Beiruti historical houses was often adorned with plaster-painted ceilings. This decoration ranges from flat painted ceilings to complex cornices, detailed figurative modelling, and elaborated ornaments.

TECHNIQUES

Painted baghdadi ceilings

Origin

This technique, used for ceilings and partitions, is brought from Baghdad, where painters used to cover the reeds with gypsum and paint over it. In Beirut, the reeds was replaced with wooden laths, and the finishing varied between lime and gypsum.

Application

The internal flatwork on ceilings traditionally comprised 3 layers (171, 172):

- A setting coat, applied to the lathed backgrounds
- A levelling coat, considered a render or pricking coat
- A finishing coat, that ensures smoothness

The lime or gypsum is applied to a frame of wooden laths, and a physical key for each successive coat is formed by scratching the partially set surface of the preceding one.

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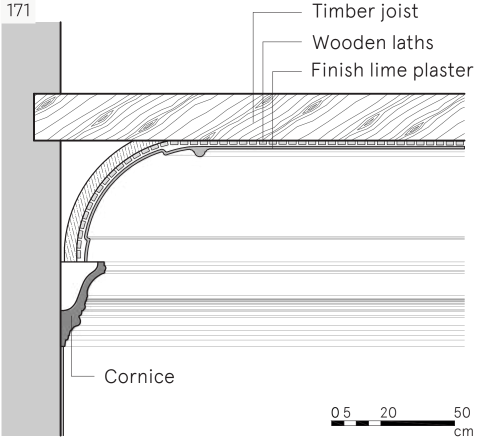

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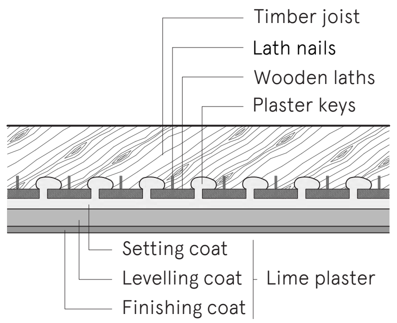

Composition

Lime - usually non-hydraulic: Lime plasticity and setting time restrict coat thickness of the first 2 coats to a maximum of 18mm and necessitate several days between applications to allow for shrinkage and the development of adequate strength. Lime is mixed with aggregates in the first two coats. The final coat is given a finer finish applied around 5mm thick. It is usually carried out without hair or straw, and stone powder might replace the sand.

Aggregates:

Coarse sand preserves the plasticity and reduces the effects of shrinkage.

Cattle hair or straw increases tensile strength.

Set-enhancing pozzolan such as crushed brick added to non-hydraulic lime plasters reduces setting time at the expense of malleability, as does the use of naturally hydraulic lime.

The resulting mixture may be used to render ceilings, run moldings, press ornament, and model in situ.

Gypsum

Combined with water, it sets rapidly and rigidly within 15 minutes of mixing with water. Unlike lime, gypsum is not weather resistant and is for internal use only.

173

Plaster modelling and cornices - Stucco ceilings

Methods and materials related to this type of ceilings were integrated in Beirut at the end of the 19th century, when European styles started to influence Ottoman mansions.

Most of the molded motifs found in *Beiruti houses* were made of gypsum or a mix of quick lime and marble powder—or less commonly, a mix of quick lime and gypsum.

Mixed with water to a creamy consistency, gypsum was poured into low relief molds. Exploitation of these attributes in the late 19th century *Beiruti houses,* together with the rise in popularity of the neoclassical style, enabled large quantities of repetitive low relief ornaments to be produced in situ. Flexible gelatins molding materials allowed a large number of ornaments, such as limbs, foliage, grapes, busts, etc., to be achieved in a single cast (174 – 177).

Molded elements required the use of an armature, usually metal bars, that attach them to the slab or the wood joists till adequately carbonated.


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Baghdadi partitions

Lath and plaster partitions grace many traditional homes. It is an interior partition construction technique that generally predates the 1920s.

The *Baghdadi* partition is a system of a wood-frame structure consisting of studs, plates, and cripples, in addition to narrow wooden laths nailed horizontally across the studs and coated with lime plaster. The plasterer applies slight pressure to push the wet plaster through the spaces. The plaster slumps down on the inside of the wall, forming plaster keys that hold the plaster in place. The sleepers of the wooden frames are inserted into notches in the stone walls (178, 179).

The composition of the plaster is the same one applied to the *Baghdadi* ceilings.

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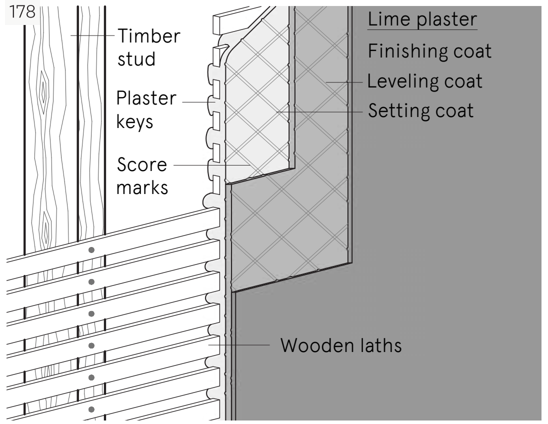

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PATHOLOGICAL PROBLEMS

While lime plaster itself is generally not directly affected by water, many of the materials it is applied over are more vulnerable. To make things more challenging, these materials are often buried within or beneath the plaster, like the *Baghdadi* laths for instance.

Poor water management

Water is the most destructive agent of lime, wood, and gypsum.

Leaks from open areas in the roof or upper floors can lead to pronounced deterioration of the wooden laths, resulting in cracking, detachment, as well as loss of the plaster renderings and ornamental moldings.

Condensation caused by infiltration and penetrating and rising damps can lead to superficial pulverization and flaking of the painted surfaces.

Gypsum (alone or combined in a lime plaster matrix) if persistently and permanently exposed to water, can gradually decay and soften until physical failure occurs. Thus, using gypsum in outdoor areas caused several problems in the *Beiruti houses.*

Whenever ceilings are affected by the humidity, the ferrous armatures attaching the molded decorations to the joists get rusted and become the major cause of the deterioration and, eventually, the loss of the modelling (174, 177).

Differential settlement and structural problems

Inadequate structural timber, poor loadings and hard inflexible plasters can cause serious cracking ranging from a light detachment of the plaster to the total collapse of the ceilings and walls.

Leaching of the lime-based binder

This can disfigure the paintings over time.

Recent interventions with inadequate materials

An example is the use of cement.

The blast of the August 4th explosion caused the detachment and dislocation of the *Baghdadis* walls and ceilings (181, 182).

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RESTORATION AND CONSERVATION METHODS

Painted Baghdadi ceilings

"To achieve an appropriate methodology and specification of materials, it is vital that all variables are given due consideration: Plaster may itself be fragile, be dependent upon a fragile substrate, or even provide the ground for delicate decorative coatings and wall paintings, all of which may be archaeologically and historically important" –Ireland Richard.

Pre-Consolidation

A pre-consolidation of the original paint with a temporary binder might be needed during the restoration of the plaster.

The aim of this phase is securing the detached plaster:

- Ensure that all water leaks and infiltration points are closed and proper lead-away of the water is done.
- To treat a deformed area, cover it generously with two overlapping layers of Japan paper and adhesive (183). If not sufficient, propping is needed. Make sure to use soft materials in contact with the plaster and paint and not to alter the deformation at this point.

Conservation

The conservation of Baghdadi ceilings can begin as soon as the work on the pitched roofs are concluded. The following guidelines must be observed during the conservation process:

- Strengthen the attachments of the laths on the joists.
- Reconstruct the wooden supporting structure where needed.
- Inspect wooden laths for material flaws and degradation, apply strengthening and conservation measures as necessary, include substitution and biocide/fungicide treatments for the wood (184, 185).
- Reattach the plaster to the laths in sections by re-inserting the detached plaster keys
- The detached plaster keys will be reinserted in between the lath where possible. Otherwise, it will be reformed and consolidated with both the plaster and the wooden slats.
- Substitute areas of loss with similar material (186).
- Clean (dry, humid, chemical)
- Restore the paintings.

Plaster modelling and cornices - Stucco Ceilings

- Lightly push loose cornice plaster.
- Treat and close cracks by grouting and pointing.
- Reconstruct missing ornamental plaster moldings elements by casting existing molded plasterwork with silicone or similar (187, 188).
- Re-attach the ornamental plaster motifs with stainless-steel bars / screws.
- Perform final grouting and pointing of the plaster (189).
- Clean (dry, humid, chemical).
- Restore the paintings.

Baghdadi partitions

- Check that all timbers are free from rot, insect activity, and are generally sound. Remove all rotten laths. Utilize a brush to dispose of any leftover materials and loose plaster. Vacuum to eliminate dust.
- Ensure that all current laths are safely fixed and re-nail where necessary. Replace rotten laths with cedarwood or similar wood laths with a textured surface that helps with giving a better key. Spray the laths with an anti-moisture product to help eliminate the problem of distorted laths when the wet lime is applied.
- Fix the new laths at every joist using stainless-steel fixings while ensuring there is a 6mm–10mm gap between every lath so the plaster can squeeze through and hook onto the back of the laths. Avoid having continuous edges when fixing laths; this will help prevent long cracks from developing. Once the entire partition is lathed, it should be dampened about 10 minutes prior to the application of the first coat of plaster to give time for any excess water to run off.
- Cut the edges of the original remaining plaster to halfway of the nearest joist; angle the cut on the old plaster at 45 degrees so the new material is applied over the bevel and holding the edge of the original plaster in place.
- For plastering, use the same techniques and mixes of Baghdadi ceilings' plaster. When plastering onto laths, apply the plaster diagonally to the line of the laths, joining up each time with the previous area laid to achieve a consistent key between the laths. The scratching should be in straight lines, diagonally to the laths or the line of the wall. It should be applied in both directions to create a diamond or lattice pattern.
- When the material is well compacted, apply the finishing coat tightly over the surface to fill any voids. Finish with a steel trowel and water to a smooth, even surface. Leave ready for painting.


187


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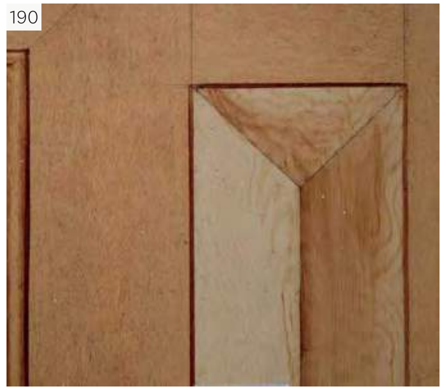
189

PAINTINGS

Nathalie Chahine



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191

“Wall paintings are reflections of the world their patrons were living in, they bear not only information about the person who commissioned the painting, but to a certain degree about its viewer as well” Weber Stefan

The painted ceilings and walls flourished in Lebanon between 1840 and 1930. With their lavish interior decoration, late-Ottoman Beiruti mansions reflected influences from such European artistic traditions as the baroque and rococo as well as an early stage of Orientalizing decoration.

TECHNIQUES

Mix and ingredients

For each artist, his recipe. It was a knowhow transmitted through the generations using three main components:

The pigment: coloring and protecting the surface to be painted, the substrate.
Many different materials have been used as pigments. For example, the ultramarine, found naturally in the mineral of Lapis Lazuli, was used to get the blue color commonly found in Beiruti houses. A synthetic ultramarine was invented in 1826, and it is commonly known under the name of *Neel*.

The binding holding the pigments together and binding them to the substrate. For example:

- Raw linseed oil: improves hardness by absorbing oxygen from the atmosphere to form a hard flexible film. It keeps the permeability of the substrate, allowing the new plaster to dry out.
- Egg yolk: is used to make an egg tempera painting which is a permanent, fast-drying painting consisting of colored pigments mixed with glutinous material such as egg yolk.
- Casein: is a natural organic and traditional binder made from the precipitate which occurs upon acidifying skim milk. To make it usable and soluble in water, casein is mixed with slaked lime.
- Diluted lime: is an excellent disinfectant that takes away the humidity from the walls and keeps the flies and mosquitos away. It was sometimes mixed with curd cheese.
- Glue: is extracted from animal tissue like bull’s tails, rabbit’s bones, or skin. The gelatin allows a good bonding of the pigments as well as the treatment of the permeable support.

The diluent or solvent thins the mixture of pigment and binder sufficiently for it to be applied to the substrate.

Geometry (192)

In most cases, the walls were painted with simple rectangular ornaments that divided the wall horizontally into a lower pedestal and an upper area. Otherwise, paneling divided the wall into sections organized according to the architecture (doors and windows)

Faux-marble (193)

The imitation of marble is obtained with diluted ash. The essence of the burnt wood must have been extracted from a local tree which essence has so far remained unidentified.

Faux-wood (190)

Applied in the dining rooms and occasionally on the doors.

Gold Painting (194)

Paintings gilded with real gold leaves (22 to 24 carats). The gypsum or lime plaster is mixed with *blanc de Meudon* and rabbit skin glue. A mix of skin glue and Armenian red bolus is then spread on the surface to be gilded. Gold leaves are then added with alcohol diluted in water and burnished with agate for sheen.

Stencil (195)

Identical motifs obtained with the use of a paper or a perforated metal plate. This technique spread in the beginning of the century, and one can find it in nearly all the central hall houses in Beirut or the provinces.

Paintings (196)

Figurative drawings sometimes adorn the friezes, medallions, or ceilings. They represent landscapes, elements of nature (flowers, birds, etc.) or, in the dining rooms, victuals: meat, fish, fruit (pomegranates, watermelon, grapes, ...), etc.

Painted medallions often replace stucco reliefs. In these cases, a relief effect is obtained by drawing shadows (191).

192

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PATHOLOGICAL PROBLEMS

Structural decays

Paintings are the exterior facets of complex wall and ceiling structures. Any movement, weakness or disintegration affecting the plaster, mortar, wall's stone or ceiling's slabs and beams will affect the painting layers. Sometimes several layers of decorative paint are superimposed and detach due to a lack of adhesion.

Surface disintegrations (197 - 199)

Paintings require constant maintenance and protection from weathering factors. Condensation caused by infiltration and penetrating and rising damps can lead to superficial pulverization and flaking of the painted surfaces. On the other hand, Lignin staining and leaching of the lime-based binder can disfigure the paintings over time. Moreover, aging signs—along with patinas, stains and discolorations—begin to appear on the painted surfaces over time and neglect. These effects are catalyzed in humid environments where poor water management causes the deterioration of the binder. Without proper treatment, such decays threaten the historic pigments and painted layers.

197

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RESTORATION AND CONSERVATION METHODS (to be executed by specialists)

The initial paintings are often covered with one or more layers of paintings that had been applied over the years and that vary in taste. The original layer will be revealed by a meticulous scraping of the added layers of paintings (200).

Pre-Consolidation

The aim of this phase is securing the detached painting throughout the works and re-generating the binding materials.

- Ensure that all water leaks and infiltration points are closed, and proper lead-away of the water is done.
- To treat a deformed area, cover it generously with two overlapping layers of Japan paper and adhesive. If insufficient, propping is needed. Make sure to use soft materials in contact with the plaster and paint. Be careful not to alter the deformation at this point.
- Pre-consolidation of the original paint with a temporary binder might be needed during the restoration of the paintings.
- Pre-consolidation of the flaked paint with cellulose: The fragility of the paint surface will determine the application method of the consolidation agent. It is important to ensure the physical and chemical compatibility of the introduced consolidation agent and selected solvent with the original paintings and their binder.

Some Natural Aqueous adhesives

Rice or wheat starch paste: These pastes can set down flaking paints due to their two basic components, amylose and amylopectin. They can be applied under the flakes with a brush. The paint layers consolidated with these pastes remain visually and physically stable after 5 years of natural aging.

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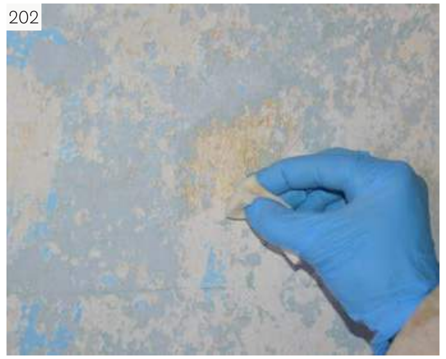

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Conservation of the painted surface

Note that using mock-ups can help identify possible color changes in a particular piece.

Start by stabilizing and consolidating the support, i.e., the plaster.

Strip the overpaint layers from previous interventions by using a scalpel. Lightly clean with a sponge.

Delicately clean the surfaces from loose materials and salts.

- **Dry cleaning:** Gently remove loose dust and dirt mechanically with brushes, dry sponges, scalpels, or glass fiber pens. Fairly stable paint may tolerate direct contact such as brush application. Very friable or otherwise delicate paintings may require the use of an eyedropper, a gentle spray, or the sparing use of a small brush (201).
- **Wet cleaning:** Use distilled water. Alcohol components (ethanol) can be added to the water when needed. The water input should be kept to a minimum (202, 203).
- **Chemical:** Dissolve and remove the persistent dirt layer using soap or poulticing methods.

Note that the scale of cleaning will adhere to the preservation of the patina and aged appearance of the painted plaster decorations.

Stabilize the paint layer: To secure the paint layer and reconnect it to the support, inject a cellulose-based setting agent dissolved in water or ethanol.

Fill paint lacunas: Moisten the surface, and apply a smoothing putty layer with a spatula.

Peel off carefully, and smoothen the surface with increasing firmness. Make sure not to cover any paint layer.

Color reintegration: This entails reconstructing the original paint scheme and artificial patination to match aged appearance of surrounding surfaces. Lightfast pigments and an aqueous bonding system should be used (204).

Retouch: With lime, lightfast pigments, and a water-soluble binder, retouch the tones of the paint layers. The retouching should be as true to the patina and the original paint as possible (i.e., matching in color and texture).

205

DADO PANELS AND PEDESTALS

Fadlallah Dagher

206

207

In classical architecture, the lower part of a wall (dado) or a column (pedestal) is emphasized for both technical and esthetical means. It is the expression of support and protection against capillary rise and shocks. It is also a major decorative feature that adds nobility and grandeur. Dado panels along the walls—also called orthostates, column pedestals, and the parapets in between columns are composed of a low skirting, a central panel (or dice), and a cornice at the top. Dados, pedestals, and parapets are generally aligned to create a strong, horizontal unifying pattern with a total height of 75 to 90 cm.

TECHNIQUES

In the upper-class villas and palaces of Beirut, such elaborate features are standards of interior decoration;

- The dado is clad in marble or painted in an elaborate or delicate trompe-l'oeil imitating wood or marble (206). Both marble and painted dados are organized within the global composition of the walls (208).
- Internal columns in the central hall can be free-standing on a pedestal in full solid Carrara marble (209) or rise from the top of a masonry parapet with a marble veneer.
- Sometimes within the triple arches feature (both inside and on the façade), instead of the masonry parapet, thin marble dado membranes panels (4 to 5 cm thick) are inserted vertically in between the pedestals and the side walls. These are typically fixed with tongue and groove and copper clips without any glue or mortar.

Less elaborately painted dado panels above a plain skirting in the central hall and along stairs are featured in middle class buildings, in continuation with masonry parapets supporting the columns of the triple arches.

It is a paradox though that such decorative elements do not appear on most of the façades, which are generally left plain and simple. However, on Tyrolean plastered façades of the early 20th century, the lower part features a dado pattern under a decorative stone course or hexagonal patterns.

PATHOLOGICAL PROBLEMS

Such decorative elements have been greatly affected by the August 4 blast:

- Dado panels and/or skirting have been detached from the walls by the force of the blow and have sometimes broken while falling (207).
- Light marble membrane parapets have been broken or displaced.
- "Trompe-l'oeil" painted dados have been either affected by the cracks in the unsealed supporting plaster or scratched by shrapnel from broken glass and wood. Note: such decoration is often covered with layers of limewash and paint due to evolving tastes through the century.
- Parapets and pedestals in the triple arches' composition on north façades and inside the central hall were displaced, dismantled, or destroyed.

RESTORATION AND CONSERVATION METHODS

Marble elements

Detached and broken pieces will be carefully documented, cleaned, labelled, and moved away. Broken pieces will be re-used if possible. If not, new pieces will be supplied, identical in shade, veins, and dimensions to the original ones. These pieces will feature the date of installation on the back.

Dado panels/skirting

The old lime mortar fixing the dado will be carefully removed from the walls. Great attention must be given to the lime plaster and decorative paintings above the dado, which should be protected and preserved. The masonry behind the dado will be inspected with the support of a specialized structural expert who will advise on the best plan of action: deep repointing or any other type of reinforcement. According to the available depth between plaster and masonry, a base layer of rough plaster will be applied. The marble dado will then be reinstalled in place on a lime mortar filling and buttressed with wood supports until the mortar cures.

Marble parapets

The restorer will advise if the slabs are broken in too many pieces, as it will be impossible to make it stand. Re-assembled slab or new slab will be installed with similar initial dry techniques, i.e., by tongue and groove and copper clips.

Painted elements

The painted dado restoration process will be identical to that of the decorative painted walls *(refer to chapter"paintings")*

208

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MOLDINGS: PILASTERS, SLAB EDGES AND CORNICES

Fadlallah Dagher

The composition of the elevations of the *Beiruti House* is generally structured within a grid of vertical and horizontal lines (pilasters, moldings, and cornices). These lines correspond to the edges of the building and to the intersecting walls and floor slabs. However, they may sometimes be added for aesthetic reasons. The façade is crowned by a strong horizontal cornice—more or less elaborate depending on the standard of the building. The cornice holds the peripheral rain water channel at the base of the pyramidal pitched roof.

DESCRIPTION AND CONSTRUCTION TECHNIQUES

Pilasters and Slabs moldings

The vertical pilasters and horizontal slabs moldings protrude 4 to 6 cm out of the elevation wall. They are generally executed within the plaster (217). In high-end constructions, the relief is executed in the stone with a plaster finish, and it may include windows and arch frames. Sometimes, it is put forth by limestone inserts within the sandstone background (219).

Most of the moldings are executed via additional layers of lime plaster. These thick layers are reinforced with iron nails (214).

Cornices

The cornices are horizontal elements protruding from the façade, located over the windows (and sometimes over the doors), and on the periphery of the building at its top.

210

Window cornices

The window cornices are meant to protect the window wood frame and architrave from rainfall above. There are two types of window cornices:

- The plain, simple cornice is executed with a triangular profile of 25-30 cm height and protruding 8-10 cm at the bottom, immediately above the window architrave (211). This basic type is generally found at the ground level and executed in thick layers of lime plaster. Sometimes, the relief is already carved into the stone lintel to reduce the thickness of the plaster.
- The standard molded cornice is a horizontal feature with a profile that reproduces classical moldings derived from the Renaissance (212, 213). Ranging from the simple to the very elaborate, this type reflects the Western influence on the architectonic elements. It can be executed in gypsum plaster on a roughly carved sandstone or in exposed limestone, and it is generally higher than the wooden architrave by 20-25 cm (to create a virtual frame around the window). The top is slightly slanted out for drainage, and, in some cases, it is covered with marble or terra-cotta tiles, or with a zinc sheet to sustain rainfall.

At the turn of the century, more elaborate designs included pediments on top of the cornice made out of molded gypsum or sculpted limestone (218).

Roof Cornices

Roof cornices feature a strong, horizontal belt crowning the façade. The protrusion carries the peripheral rainwater channel out of the building footprint and protects the façades from water dripping. There are two types of roof cornices:

- The standard roof cornice is executed in sandstone, slightly cantilevered and molded over a height of 50-60 cm. It is plastered and painted with the façade.
- The composite deep roof cornice: somehow an exception, it is found on rare examples of larger villas (221). It offers optimal protection from rainfall. The cornice overhangs on limestone corbels, placed 60-70 cm apart from one another. The corbels are similar to those supporting the balconies but shorter in length (50-60 cm). The edge of the cornice is made of limestone monoliths spanning between corbels (20 x 20 cm) and carved in a doucine profile (a molding that is convex and concave in a continuous curve). The soffit is made of Carrara marble slabs, 20 mm thick, standing in between the corbels, the top of the wall, and the limestone edge.

On some buildings, the elements of the deep roof cornice were reproduced with low-cost material: wood, Baghdadi, and gypsum. In a sort of “trompe-l’oeil” fashion, these materials were colored to emulate the expensive ones (limestone, marble...) (215, 216).

Deep cornices are generally adorned with decorative motifs—rosettes or garlands molded in gypsum.

211

212

PATHOLOGICAL PROBLEMS

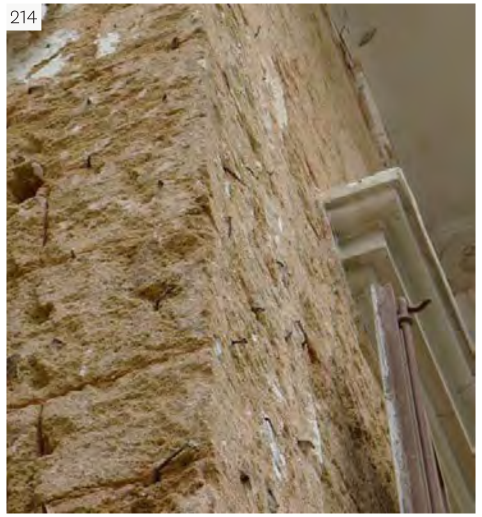
Despite being relatively fragile, the moldings made out of layers of lime and gypsum plaster have sustained the test of time.

Plastered and stone moldings surface alteration

Moldings are particularly exposed and can be affected by:

- erosion, shocks, or movements in the structure, leading to cracks and loss of plaster
- deposits from dust and pollution
- deposits caused by birds standing (defecating) on top of moldings
- biological colonization (algae, mildew, lichens, moss, or fungi) as a result of exposure to humidity and shade in specific areas
- cracks caused by the rusting of iron anchors (protection grilles or shutters holders)
- discoloration of stone caused by rust and human/animal staining


213


214

Composite deep roof cornices disorders

Of all molding's elements, the deep roof cornices have been the most severely affected by the August 4 blast (215, 220), revealing latent disorders due to:

- movement in the structure, specifically at the base of the pitched roofs: These can be observed as systematic horizontal cracks at the intersection between the façade and the pitched roof timber frame. Subsequently, the top of walls and roof cornices were disturbed and left out of plumb.
- movement, breaking, and falling of corbels, marble slabs, and limestone edges. These are more visible at the corner.
- destruction of wood, *Baghdadi*, and plaster features
- partial or total loss of decorative molded motifs

RESTORATION AND CONSERVATION METHODS

Plaster moldings

- Pilasters, slab edges, cornices, and motifs must be inspected and surveyed in detail.
- Broken and detached pieces of plaster need to be removed either partially or totally, depending on the plaster's condition and adherence.
- The sandstone surface is to be cleaned with a soft brush and a very low pressure water-jet. Deep repointing will be applied to joints.
- Plain motifs will be reproduced by applying successive layers of lime plaster until reaching the required thickness. Stainless-steel nails or wire mesh may be used to reinforce the thick moldings.
- Molded motifs and profiles on cornices will be carefully reproduced by applying wooden stamps on the lime or gypsum plaster. Great care will be given to reproducing the exact proportions of each element.
- Concerning rosette and garland motifs, a plaster or silicone mold will be created based on the remaining elements.
- Iron anchors are to be inspected and either protected or replaced according to their degree of rust. Make sure to carefully remove the loose particles of rusted iron.
- To make the lime plaster stronger on the moldings, lime may exceptionally be mixed with white cement.


215

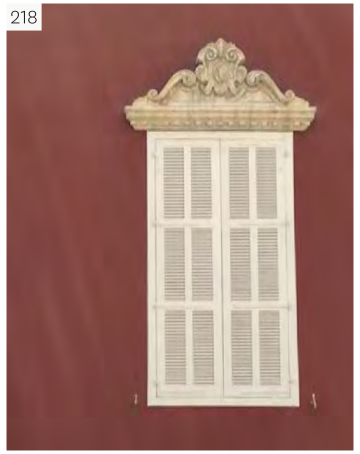

216


217

Stone moldings

- Moldings are to be inspected and surveyed; inserts of potential iron elements must be carefully observed.
- Reconstitution and surface cleaning is a conservation choice; if the surface alterations are not particularly harmful on the short and long term, they could be kept in their existing condition.
- In the case of cracks with no loss of material, the cracks will be carefully grouted with a mix of lime and stone powder to match the finish of the stone
- In the case of minor decays, the stone can be reconstituted with a mixture of lime, stone powder, and resin.
- In case of minor to moderate damage, including broken pieces: broken pieces will be assessed and reassembled if deemed possible. Stainless-steel rods and anchors may be inserted for additional stability on the long term.
- In the case of displacement, the causes of movement need to be assessed and fixed with the assistance of a structural engineer. Accordingly, displaced elements will be put back in place by propping and repointing.
- In the case of heavier damage, stone pieces will be replaced by similar material (marlstone, *Mansourieh* limestone, or sandstone).
- Stone surfaces restoration and conservation: Employ either dry cleaning using a soft brushing tool or wet cleaning using a low-pressure water jet. A poultice may also be applied.
- Iron inserts are to be inspected and either protected or replaced according to their degree of rust. Make sure to carefully remove the loose particles of rusted iron.

218



219

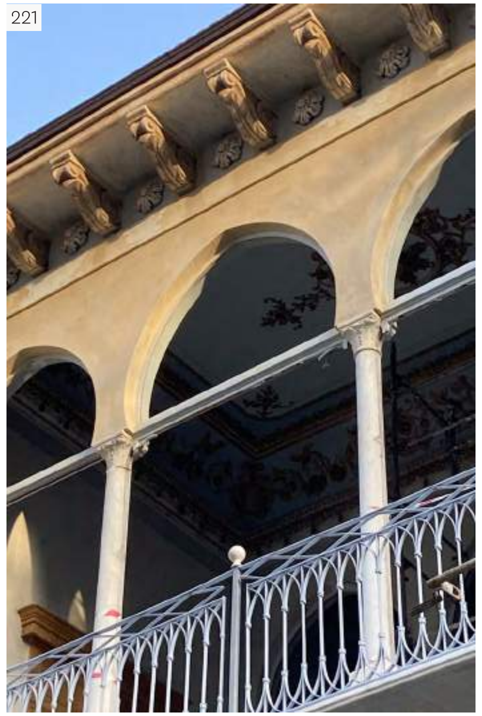
Composite cornices

In the case of various levels of damage, the assistance of a structural engineer is mandatory to assess the causes of distress and the structural remedies.

- Minor damage, displacement of pieces or cracks: pieces will be propped and put back in place.
- Minor to moderate damage, including broken pieces: broken pieces will be assessed and reassembled if deemed possible. Stainless-steel rods and anchors may be inserted for additional stability on the long term.
- Heavier damage:
    - General condition to be assessed with the assistance of a structural engineer, and a precise method statement for reconstruction should be established.
    - Displaced elements will be propped, reinforced, and put back in place.
    - Stainless-steel rods and anchors may be inserted for additional stability on the long term.
    - Lost pieces will be reproduced in similar material and reinstalled in place.

220

221



OPENINGS AND CARPENTRY

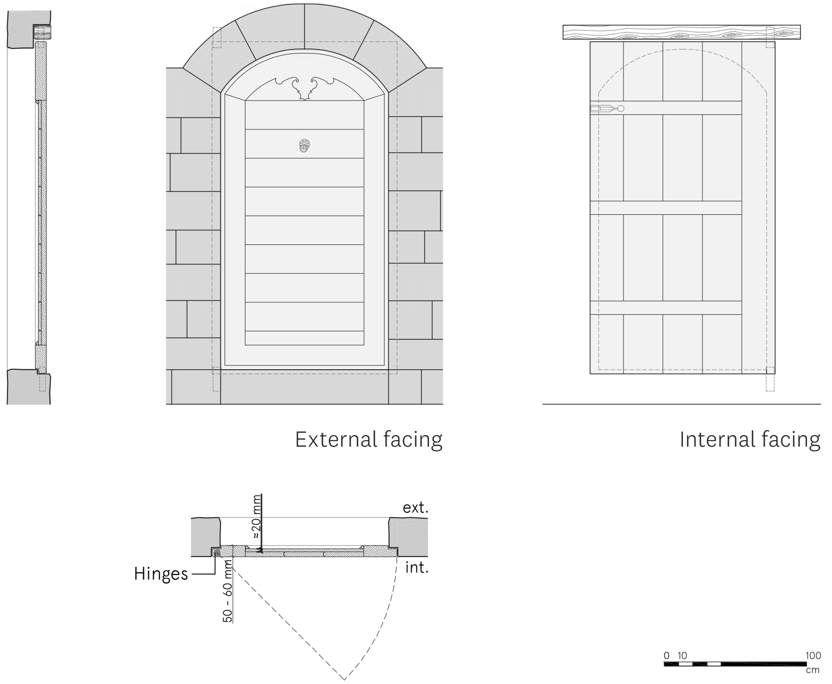
Paula Abou Harb

Doors and windows are the main elements of a building's elevation. They define the functionality and relationship between inside and outside. They create movement, direct flow and organize the hierarchy of façades and spaces. Many openings are notable for their craftsmanship, placement, rhythm, and finishes. Their typology and style provide an important sense of scale, proportion, and character to the building and offer invaluable clues to its history.

Oriental type doors (Pre-1860)

Prior to 1860, doors were extremely solid and perfectly integrated into the construction. They are found on the lower levels of many houses, which helps identify the dates and stages of construction.

222



The doors consist of openings in the stone, closed by an interior wooden leaf that extends in width. Fixed with no wooden frame by a latch (wood or metal), the leaf pivots on crapaudine, *souss wa no'ta,* embedded in the floor and a wooden lintel fixed to the interior soffit.

The opening is framed by carefully cut stones. It usually has a segmental arch, *hilâli,* with an average height and width of 190 cm and 95 cm respectively and a raised threshold on its lower part.

The leaf's structure, visible from the inside, consists of a main stile (the axis of the hinges, 50 to 60 mm thick) in which 3 rails are fitted (top, bottom and intermediate). The facing consists of 3 to 5 adjoining panels, 20 mm thick and of variable widths, fixed to the rails by metal nails. The door is decorated with a brass ring and rosette with 8 lobes.

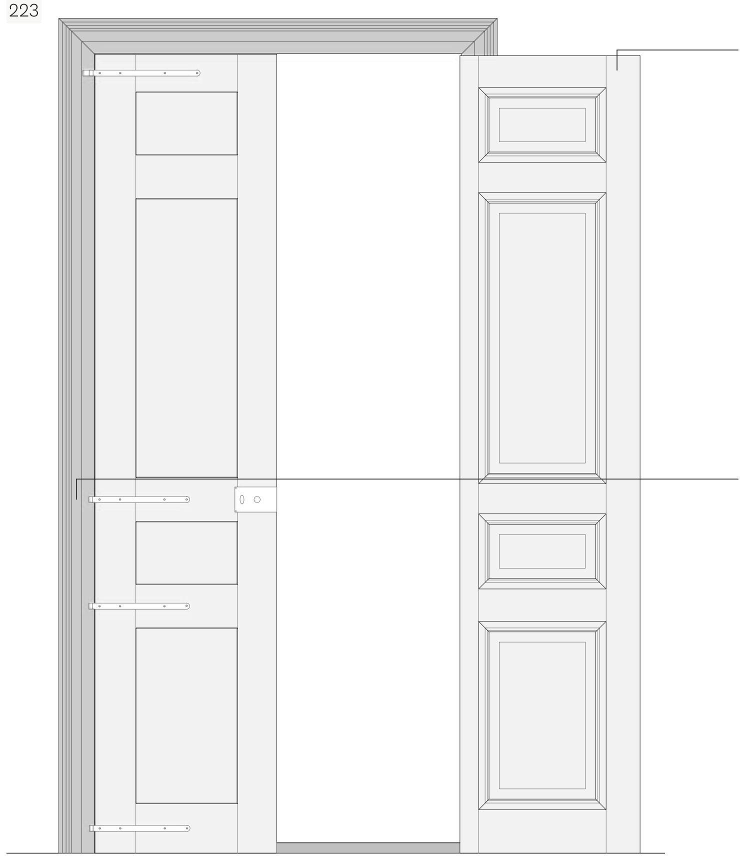
Western type doors (Post-1860)

As of 1860, a Western frame model was introduced. It was rectangular, fixed frame, with jambs and a double leaf door. Associated with the construction process, it allowed standardization and mass production.

The typical rectangular door, made of cedar wood, *kotrani,* was often surmounted by a 3-piece masonry lintel (with a central key). Its average dimensions vary from 100 to 110 cm in width and 200 to 220 cm in height.

This new type is adapted not only for interior doors, but also for wider and ornamented main entrance doors. Vestibules and secondary spaces had doors that followed the same model, with a single leaf of 70 to 85 cm width, individual panels, and plane architraves.

223



Leaves

Two wooden leaves, 35 to 50 mm thick, have two stiles each with 4 to 5 rails and panels infill (plane or with decorative patterns).

The wooden pieces are assembled by interlocking wooden tongues and tenons without metal nails. The leaves swing inwards on handcrafted hinges with steel arms. The left leaf is fixed to the ground and upper lintel of the frame by steel latches; the one on the right is the main opening leaf and is equipped with an industrial lock and a porcelain handle and crutch.

Fixed frame (Casing)

The frame surrounds and supports the whole system.

It is composed of the upper lintel and posts assembled without nails according to a system of mortise and tenon.

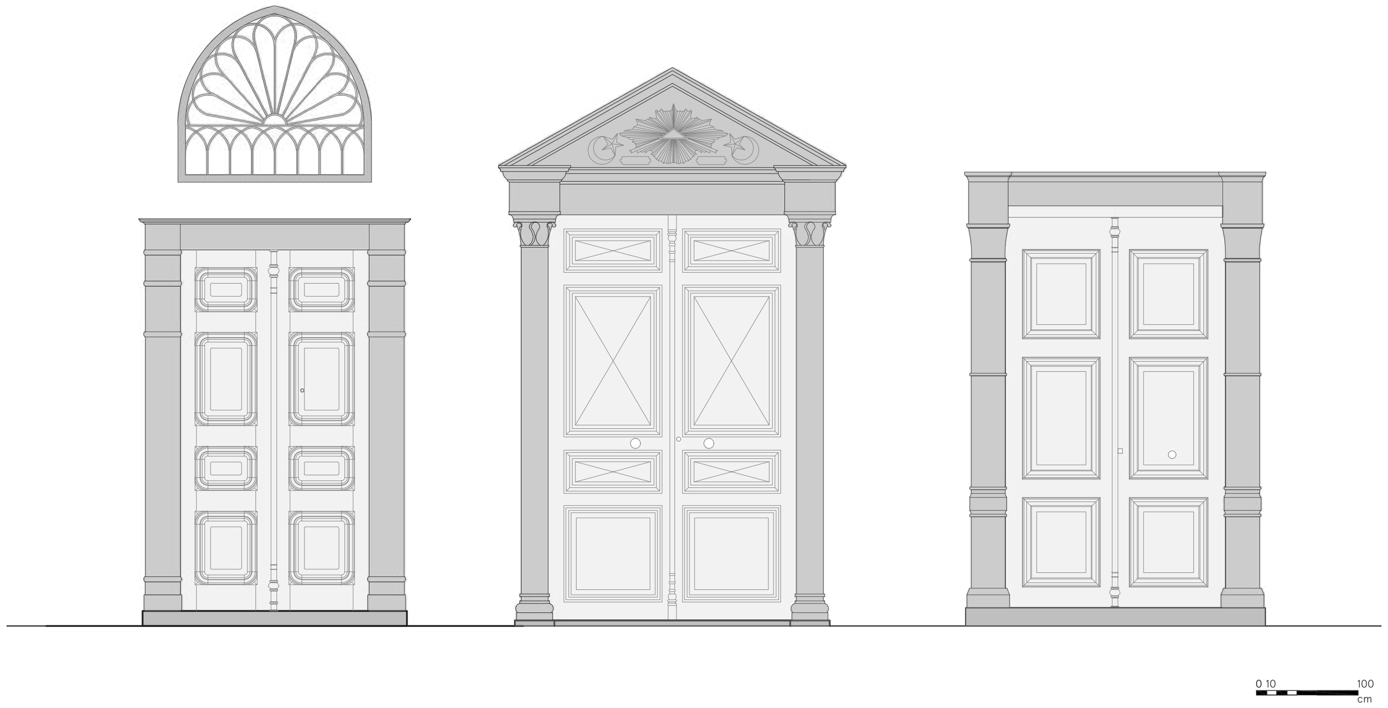
With an average width of 25 to 40 mm, the frame is secured by wooden wedges inserted into the walls approximately every 50 cm.

The depth of the frame is equal to the thickness of the wall (between 25 and 30 cm).

The residual space between the frame and the stone is left empty or stuffed with stone chips and lime. This peripheral interval is masked by molded or plane architraves on the interior and exterior faces.

Entrance doors

224



Generally located on the sides of buildings (east or west), entrance doors are distinguished by their framing. This consists of two pilasters and a lintel often in ochre Mansourieh limestone, but sometimes in sandstone *(ramli)*, marly limestone, or Carrara Marble.

The ornamentation of entrance doors varies depending on the status of the owners.They are often surmounted by either a blind or openwork relief arch, with a tympanum that is adorned by wrought iron grating, a carved pediment, or decorative moldings.

In some cases, entrance doors can be recessed and preceded by a wrought iron gate.

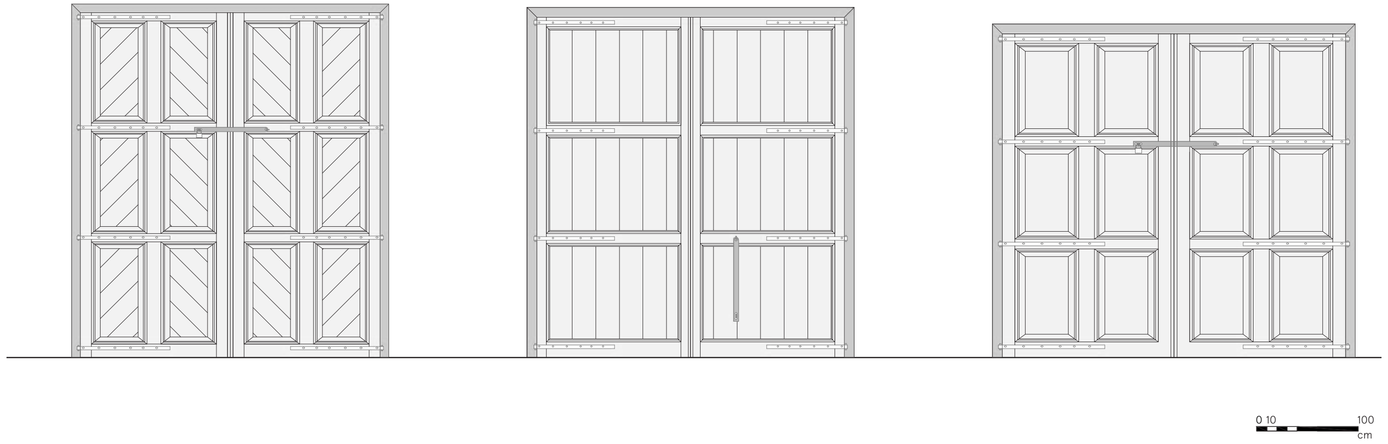
The doorframes

Two leaves in cedar wood, *kotrani,* pivot on hinges. They are 50 to 70 mm thick and can be either blind or open.

The doors leading to the garden or the balcony have glazed panels surmounting a solid panel at sill height. These panels are either swinging or fixed.

Store fronts

225



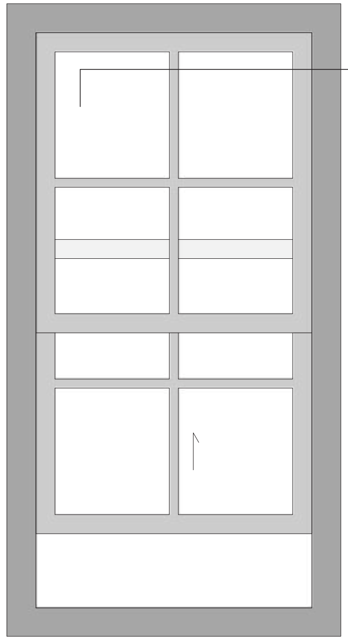
Located at the ground floor level and facing the street, the storefronts are generally closed by two, three, or four doors that open outwards and pivot on steel strap-hinges.

They are normally 40–50 mm thick and can be made of different types of wood depending on style and availability.

These doors are surmounted by a discharging arch, (which follows the shape of the ground floor vault), whether blind or open.

Most store doors have been replaced over the years with metal roller blinds, or more transparent storefronts.

226



Internal facing

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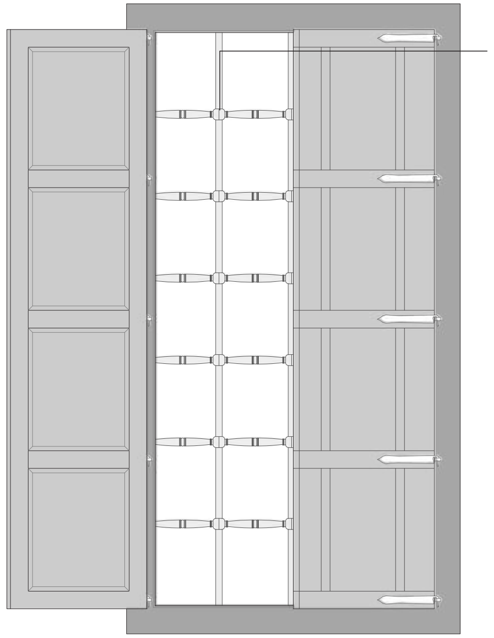

External facing

The Older Type

Sash Glazed Openings

The sash is made of wood and composed of two parts: a top and a bottom.

The upper part is fixed, guided by a wooden rail over the side posts.

The lower part slides upwards to allow air to pass.

Each part has a frame 30 to 40 mm thick.

Each part is divided into four squares by a central cross.

The glass panels are 3 mm thick and are sealed to the wood with putty.

Wooden Grating (Protection Grid)

The wooden grating is integrated into the fixed window frame between the leaves and the shutters.

It is handcrafted from twisted, wood pieces 30 to 40 mm in diameter and that interlock to form crosspieces of approximately 20 cm.

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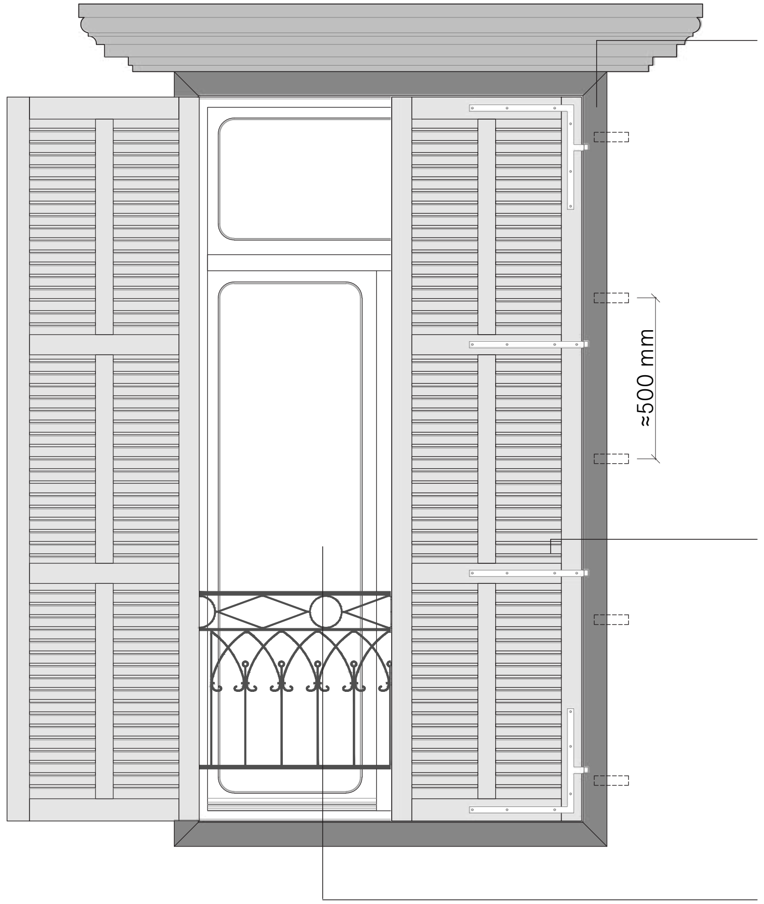

The Modern Type

Fixed Frame (Casing)

Placed on top of an approximately 75 cm high parapet, it surrounds and supports the entire system.

It is composed of the head, the jamb, and the sill—generally assembled without nails using a traditional system of interlocking wooden members.

With an average thickness of 30 to 50 mm, the frame is secured by wooden wedges inserted into the walls, approximately every 50 cm.

The depth of the frame is equal to the thickness of the wall (between 25 and 30 cm).

The residual space between the frame and the stone is left empty or stuffed with stone chips and lime. This peripheral interval is masked by architraves on the interior and exterior faces.

Shutters

Attached to both sides of the external frame with handcrafted hinges, shutters serve to control external light and preserve the residents' privacy.

They consist of a 40 to 50 mm thick frame, composed of 3 stiles (2 lateral and 1 central) and 4 to 5 rails (top, center, and bottom) between which are installed 15 mm solid panels or louvers (either fixed or adjustable).

They open outwards with the help of an iron espagnolette and can be painted in various colors.

Glazed leaves

They consist of two wooden leaves divided into squares, in which are inserted 3 mm thick glass panels, sealed with putty.

These 35 to 40 mm thick elements are fitted with a cast iron and steel lock bolt, and they pivot inwards on side hinges.

The leaves generally occupy three quarters of the frame's height and are topped by a fixed glazed transom.

Over time, the thin muntins dividing the glass panes were diminished and eventually discarded altogether at the beginning of the 20th century.

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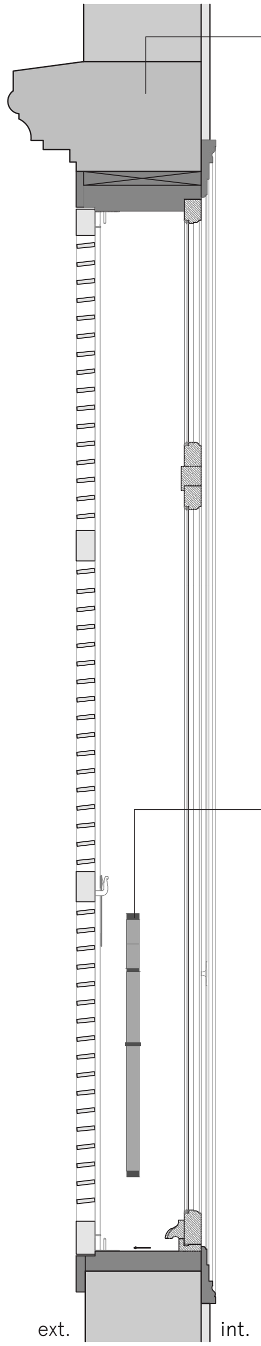

Exterior cornice

The cornice is a projected horizontal element which crowns the opening and protects it against the rain.

It can be carved in stone or made of wood and covered with a protective zinc sheet that is slightly inserted into the masonry.

The shape of the cornice can either be plain or have a uniquely decorated profile.

Steel grill

The steel bars penetrate around 50 mm in the wooden frame or in the stone wall between the shutters and the interior leaves.

When introduced in masonry walls, the steel is sealed with lead to prevent its corrosion and the cracking of the stone.

On the lower floors, the wrought iron protective grilles are formed of cross bars with a 12 to 20 mm diameter or vertical bars and flat traverses. In some cases, decorative cast iron pieces are used to ornament these grates.

As for the upper floors, the wrought iron protection is commonly designed as guardrails that have either a simple or elaborate design. The pieces were not welded together but riveted and held by means of bolts or interlocking arrangements.

High Windows

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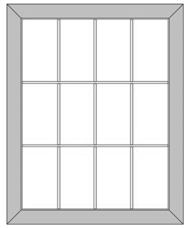

Rectangular or pointed high windows generally decorate houses of the first generation since they preceded the introduction of the oculus.

Small in size (40 cm wide), they have shutters, glazed leaves and/or steel protection.

They are found in kitchens or attics and can be opened or closed depending on the required ventilation.

Arched Windows

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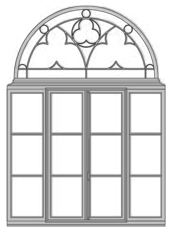

Arched windows generally decorate a corridor or a stairwell.

The lower part of the window is rectangular while the upper part is pointed or semicircular.

The desire to enlarge openings led to the use of arches which remove tensile stresses and provide structural stability. The use of this form, therefore, was not merely an aesthetic choice.

Coupled Windows

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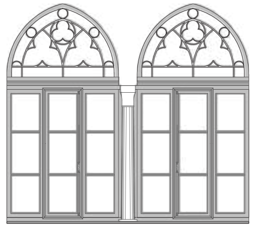

This type of bay consists of two twin arched openings and an intermediate column.

It is generally used to decorate stairwells whereby each arch corresponds to a flight.

Often, these bays do not have a frame.

The Oculus, Rosettes, or Bull's-Eye, *Qamariyeh*

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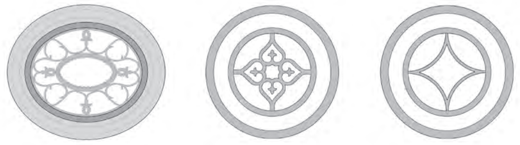

These fixed circular glazed openings are positioned in an organized pattern on the upper part of the walls. Often, the oculus situated on the middle axis of the *liwan* has an oval shape.

In addition to bringing in daylight, the oculus was adopted for aesthetic reasons. It is often decorated with floral or geometric wooden patterns.

"[The central bay] symbolizes and conveys the changing tastes and lifestyles of Beirut's middle class under the increasing influence of Western trade and fashion. Its archetypal pointed arch evolved through a multiplicity of shapes before taking its modern form as a simple rectangular bay." -R. Saliba

Combined with a greater use of glass and the possibility of enlarging the openings, the triple arches became an emblem of craftsmanship and social standing of the house's owners. They can be designed as a balcony bay (235), as an entrance bay, through which one can enter the house from the ground floor (sometimes like an entrance *liwân*), or in some cases, as a window bay.

The pointed arches are built in sandstone or marly limestone on the north façade—protected from the sun and rain. The arches' stones are sometimes decorated with elaborate motifs *(fleur-de-lys)* or contour moldings. Supported on the lateral walls, the arches rest on two intermediate Carrara marble columns in the Tuscan or Gothic style (in initial constructions, the columns were made of Mansourieh limestone). Sometimes, to decrease the load on the columns, a large blind discharging arch is built over the triple arched bay.

The upper parts of the bay openings (transoms and arches) are decorated with an interlocking system of glass and painted cedar wood, *kotrani* (234). In the lower part, the frame consists of a central door and side windows, with accessories like iron hinges, steel plates, decorated iron, and porcelain handles, casement stays, and fasteners.

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The upper section or arched head:

The bay occupies the width of the central hall. The proportions of the arches vary according to this width and the arch's type.

The most common arches in Beirut are the pointed arches. Semicircular, horseshoe, or three-lobed arches are exceptions.

The designs of the wooden tracery adorning the arches and transoms are of Gothic, floral, or geometric inspiration. They are carved in two complementary layers, outer and inner, that are beveled in glass divisions and sealed with putty.

The Intermediate Bay (Transom)

Fixed, rectangular, and horizontal

Decorated with patterns that are coordinated with the interior design of the arcades

Glazed leaves of Doors and Windows:

The central door is composed of two to four glazed wooden leaves.

The doors are operable by means of a single or double mobile leaves and fixed side leaves.

Glazed windows usually surmount a 75 to 90 cm high masonry parapet with a marble still. Sometimes the parapet itself is made of a 4 to 5 cm thick marble panel with no masonry. Windows are also composed of two to four mobile leaves opening to the inside and possible fixed lateral elements.

The Marble Columns

The two intermediate columns are placed on a pedestal in continuation with the parapet and are composed of 6 Carrara marble pieces laid dry.

The square base: 20 to 24 cm wide and 12 to 15 cm high

The lower torus: 2 cm thick and 18 to 22 cm in diameter

The monolithic flute: 16 to 20 cm in diameter and about 2 meters high

The upper torus: 2 cm thick and 18 cm in diameter

The capital (various styles): 16 to 24 cm high

A square upper piece: 18 to 20 cm wide and 2 to 3 cm thick

The two lateral half-columns can be flanked in marble or built with sandstone or limestone as a continuation of the façade's masonry. They are often plastered to ensure consistency with the interior and exterior wall plastering and painted in faux marble.

Note: The intermediate columns were carved in Italy and imported as a finished product, like all Carrara marble pieces.

PATHOLOGICAL PROBLEMS

Damages caused by August 4th explosion

- Damage to the lintels and keystones: This was caused by the shock wave of the explosion and the dislocation of the opening's frames.
- Loss of opening's components: Apart from the dominant loss of glass panels, many wooden openings were completely torn off and/or dislocated, which led to the loss of many wooden panels, shutters, accessories, and sometimes frames. Note that the damage was amplified due to the aging of the wood and its decomposition.

The triple-arched bay was one of the most damaged elements by the August 4 explosion. Located at the center of the façade, it forms a light diaphragm nestled amongst rigid elements. As a result, it could not withstand the deformations the structure was subjected to by the blast.

- Several columns, and subsequently their arches, collapsed—shattering not only the shafts and keystones, but also the slabs and corbels of the balconies.
- Out of Plumb Structures: This refers to the masonry walls or columns that are found in a leaning, bowing, or buckling position. It is either a direct effect of the explosion or a result of accumulated load, movement, or structural problems.
- Cracks in masonry: Cracks can be found in the masonry walls surrounding and forming the arches especially in the middle of the arch or keystone and in the stone columns of the triple bay.
- Cracks in marble: These are found in the marble columns, capitals, doors, and windows' sills.
- Systematic loss of the wood, glass frames and transoms.

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Wood deterioration

Following its exposure to the elements, its lack of maintenance, and the deterioration of its protective paint layer, the wood is susceptible to degradation, material loss, rotting and insect attacks.

Steel rust

After the loss of its protective paint layers, the steel starts to rust. It can cause spalling and staining of the wood frames. The ironmongery's rust can also cause functional problems, as well as wood decay.

Non-Functional Opening Mechanism

Many of the previously mentioned problems can lead to the failure of the door's opening mechanisms, be it pivot boxes, hinges, handles, locks, or latches.

Incoherent Interventions

A lot of damage can also be caused by human intervention. Making inconsistent additions (like hinges, locks, handles, etc.), for example, and/or repainting, obstructing openings, or replacing them with modern accessories are all detrimental interventions that can damage the overall structure.

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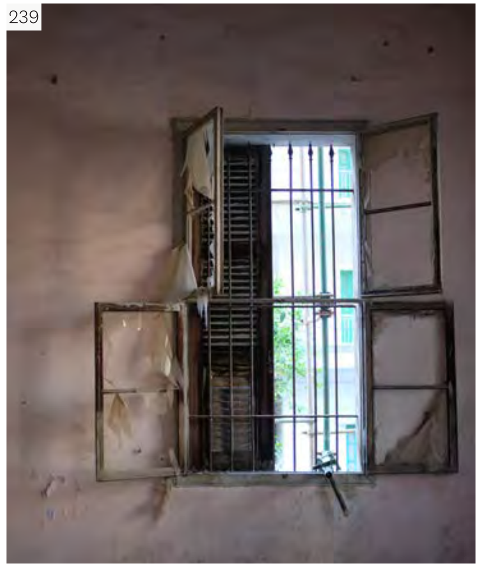

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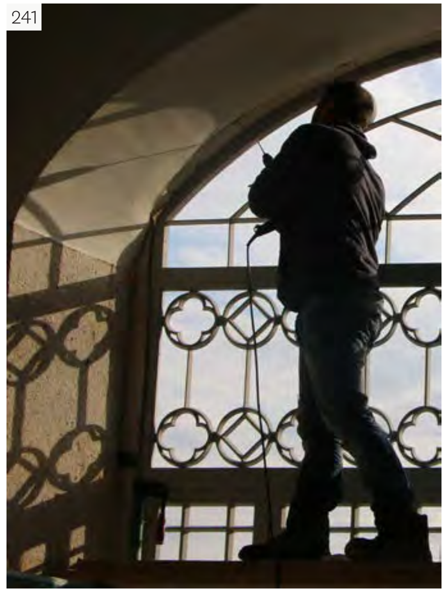

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RESTORATION AND CONSERVATION METHODS

For interventions targeting the structure of the openings and the hosting walls

- Keystones and lintels should be consolidated. In case of loss or damage, they must be replaced with a new, similar stone that bonds to the wall's structure by means of a lime mortar mixture.
- If elements of the bay are broken and irrecoverable, their debris should be gathered and documented, and the missing elements (spandrels, columns, and arches) must be reproduced and reassembled in an identical manner. This must be made with the compatible material and by specialized masons
- In masonry displacement and out of plumb cases, it is necessary to observe the assembly in detail to identify and, if possible, return the parts to their places by means of shoring and clamping. The process must be done without negatively impacting the future stability of the system. In general, it is recommended to dismantle the structures and rebuild them to ensure plumb and structural stability.

For interventions on the wooden and glazed doors and windows

If the opening element is very damaged, irrecoverable, or completely lost:

A new opening shall be made similar to the older one, with properly dried and treated Cedar wood and similar iron accessories. If doors' accessories can be recuperated from the old openings, it is recommended to reuse them.

Triple arches openings have various wood and glass compositions, as well as carefully conceived patterns with high historical significance. The intervention should always aim to uphold and accurately reproduce these motifs and all their authentic detailing and assembling techniques from glass divisions according to the patterns to wood layering and installation features (242).

If the openings' damage ranges from light to medium:

Its elements and built can be restored. After inspection, an appropriate surface treatment, such as cleaning, rust removal, limited paint removal, or re-application of protective coating systems and paint must be made. Damaged parts, infected wood, and damaged ironmongery can be repaired by replacing, patching, splicing, and consolidating (244, 245). A curative and preventive insect treatment can be adopted. All substitute or added elements should be similar to the existing parts and compatible with the opening's original material.

Temporary removal and storing of the wood elements

If such actions are required, a careful dismantling of the elements should take place, preceded by a complete documentation and numbering. The elements should be carefully stored at the right temperature and away from humidity, for later reuse.

Improvement of thermal insulation

Considering the vulnerability of the empty space between the opening's wooden frame and the masonry wall, it is possible to improve, seal, and protect the opening and its corresponding room. This can be done by inserting a proper gasket between the inner side of the frame and the wall and closing it with an adequate sealant.

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FLOORS

Nathalie Chahine

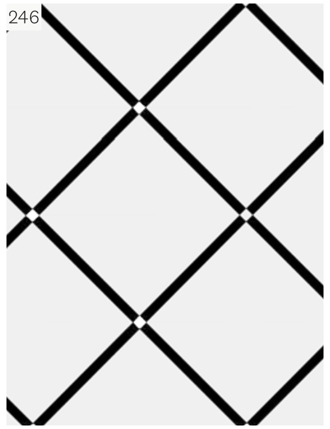
“In the second half of the nineteenth century, frequently-used entrance areas, central halls and reception rooms were provided with Italian marble flooring, while small square terracotta tiles were used in the multipurpose family sitting rooms. Domestic parts of the house, wet areas and kitchens were furbished with irregular slabs of polished, pale yellow limestone” Anne Moellenhauer, 2005.

MARBLE FLOORS

Nathalie Chahine

TECHNIQUES

As of 1860, marble tiles were widely imported to the area from Italy. The white/grey Carrara marble was mainly used to tile the floors of the main rooms—the central hall, entryway, and the reception—due to its strength and durability. Some of the marble slabs delivered to Beirut from Italy had the letter B or the word Beirut written on their back (247, 248). The marble slabs—around 2 cm thick and varying in size between 49*49 cm and 53cm*53 cm) are typically laid on a bed of lime mortar and placed diagonally (249), forming a pattern that is often enhanced with 3 cm black marble divider stripes alternating with small Carrara squares. Furthermore, a high level of craftsmanship is observed in the absence of grout joints between the slabs (250). In some houses, the black marble stripes were substituted with black slates. The result is identical in appearance, but the slates are vulnerable to moisture as they can get delaminated. Another layout without the black stripes can be found as well. In luxurious houses, marble also lined toilet floors.



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PATHOLOGICAL PROBLEMS

Even within the walls of the house, marble tiles are subject to a range of processes that can cause deterioration. Moisture is usually the key agent of decay, with condensation or penetrating and rising damp leading to direct surface erosion. Clear effects of the August 4th explosion were seen in cracking, spalling, and settlements (256).

Mechanical breakdown

Erosion (251, 253): This problem is mainly caused by the aging of the marble and its weathering. For example, marble exposed to direct rain (as in the balcony) will generate a surface layer that is hard to remove without a thorough cleaning. Marble can also be damaged if it is exposed to acids and strong alkalis. Lemon juice, vinegar, and wine can etch the surface and remove the polish. Repeated exposure may erode the surface even further.

Abrasion and Degradation (254): Most marble has a low abrasion-resistance rating: i.e., it is likely to scratch.

Cracks (252): Water leakage can weaken the mortar beneath the tiles, which, in turn, causes crack formation. Cracks can also be an indicator of a structural settlement. Additionally, while veining gives a decorative effect, note that it can also be a source of weakness in the stone.

Alteration – deposition

Surface soiling and staining (255): it can be attributed primarily to airborne dust and pollutants, degraded coatings, staining through condensation or water ingress, corrosion of metallic elements and fixings, such as radiators elements, and human activity (such as previous maintenance and restoration, handling, and graffiti).

Efflorescence: this phenomenon refers to salts migrating on the surfaces of the marble. The primary source of these salts is the cement used beneath the marble.

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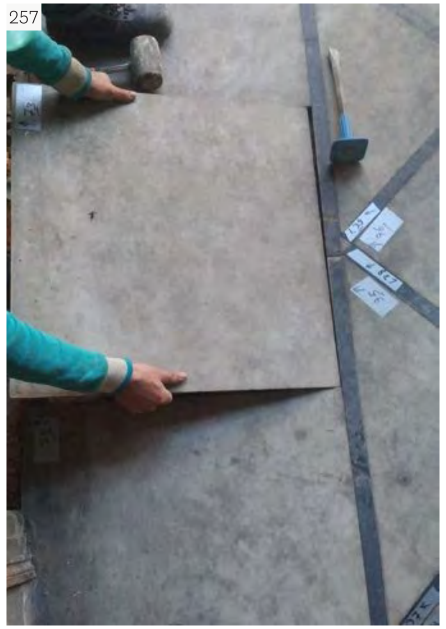

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RESTORATION AND CONSERVATION METHODS

Cleaning

Marble is prone to varying degrees of soiling and deterioration which, in turn, can be detrimental to the appearance and appreciation of a floor. Therefore, cleaning aimed at refreshing or restoring a marble surface is often considered the most appropriate approach. Marble has a dense crystalline structure that makes a polished surface possible. The cleaning should involve the simple removal of damaging or disfiguring deposits from the surface. It is an irreversible process, and so the choice and application of the right materials and techniques are vital.

Liquid cleaning use distilled water or White spirit to remove spots of wax and/or greasy dirt. Wipe over the surface thoroughly several times using swabs or sponges slightly dampened with water. Note that detergents might leave a residue on the surface which can increase the rate of re-soiling.

In addition, liquid cleaning using big amounts of water is inadvisable because marble is permeable, and water could infiltrate through the wooden slabs causing significant decay on the wood.

Dry cleaning for small spots, use a cleaning, natural rubber product, free from moisture, solvents, or chemical additives. Wrap it around the end of a bamboo stick, and roll it lightly over the surface.

Polishing and waxing If the marble has been damaged by treatment or by aging, it can get repolished with a succession of ever finer abrasives. Use small quantities of water as a lubricant to remove remaining residues and to hone the stone to a patina finish. Each stage reduces the roughness of the surface by abrading it away until the surface is smooth and glossy.

Dismantling and reinstalling in the same space (settlement problems)

- Clean the marble with a soft tissue and removing all residue.
- Give a code for each tile on the survey papers [e.g.: rows are marked with numbers, columns with letters] (260).
- Mark each tile with duct tape according to the above coding system. Make sure that the tape's label specifies that it is safe to use on marble (257).
- Find a cracked stone to be the first tile to be gently removed. Carefully remove the grout around the tile without damaging the neighboring tiles using a chisel or a flathead screwdriver and a hammer (258).
- Clean the back of the marble by using a hammer and a trowel and soaking the tiles in water for about 30 minutes to soften the mortar if needed. Scrape off the mortar with a trowel and brush off remaining particles of mortar with a medium brush.
- Store the marble in plastic boxes. Insert geotextile 150 g/m2 between every 2 tiles and give a code to every box (259).
- Consolidate the new soil to receive the tiling. Lay down a new layer of sand and lime mortar, and reinstall the tiles in their original location.
- For jointing, humidify the floor, then spread a grout with a well-dosed binder [1 volume of lime to 1 volume of water] on the surface.
- Scrape the surplus and clean.

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Replacing

- Find replacement tiles that match as closely to the original ones as possible.
- Carefully remove the grout around the tile so not to damage neighboring tiles.
- Use a chisel or a flathead screwdriver and a hammer.
- For optimal adhesion, put the mortar in the empty cavity and on the back of the tile. Then, make sure it completely dries before re-grouting.

Attaching fragments, sealing, etc.

- Pieces of marble that exhibit cracks could be salvageable using glues, dowels, or special mortar and a reinforced net from behind (261).

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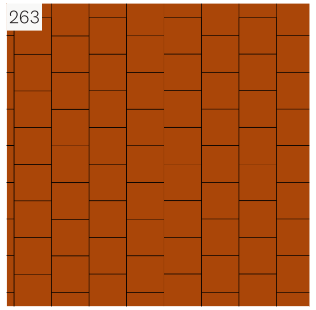
TECHNIQUES

Clay floor tiles

Clay floor tiles of 20*20 cm were generally imported from Marseille to Beirut. Their colors can range from dark reds to browns. In rich houses, the surface of the clay floor tiles is glazed for extended longevity. The tiles are 20 mm thick and are bedded in lime mortar—often in a staggered pattern. Clay floor tiles usually cover multipurpose family rooms like the sleeping rooms, the sitting rooms, and the dining rooms.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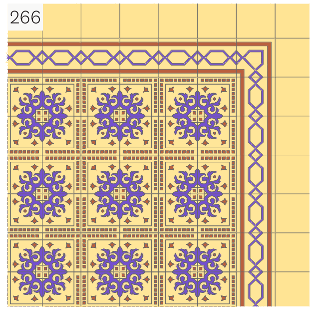
Decorated cement tiles - the cemento

In *Beiruti houses* dating from the 1920s and 1930s, the fabric of patterned colored tiles is integrated with the architecture of the living spaces and, later on, of all the rooms. Generally speaking, each room displays a different pattern consisting of a colored "carpet", the centra, and a border of neutral cement. Tile patterns include oriental, floral, and geometric, among other motifs.

Manufacturing

The 20 x 20 cm tile has an overall thickness of 20 mm and was locally produced starting 1920s.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The cast-iron mold

It consists of base, frame, model or forma imported from Europe and a cover. The pattern is carved into the forma and set in the metal frame.

The mixture

- The colored cement: consisting of a thin layer of white cement, stone powder or sand, and pigments, without any gravel or stone fragments.
- The foundation of the tile: consisting of stone powder, fine gravel, and black cement.
- The semi-liquid colored mixture is poured into the indented compartments of the forma.
- The stone powder is sprinkled on the surface of the tile as a bonding agent, and the forma is lifted by its handle.
- The foundation of the tile is then poured.
- The tile is placed in a press before it is left to dry.

The color

The artisanal process was developed into an industrial production with a minimum of two and a maximum of seven colors (like the motif found in the Daʿūq Palace). The vivid cobalt blue was used more sparingly, as it was expensive.

Application

Tiles were always laid in a wet lime-based screed, and the skill of the tilers can be appreciated in the alignment and the setting out of the tiles. Grout lines are usually so fine that many people think these tiles were butted together.


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PATHOLOGICAL PROBLEMS

Clear repercussions of the August 4th explosion were seen in cracking, spalling, and settlements (271).

Mechanical breakdown

Abrasion and Degradation: it is the loss of the tile surface and pattern. Heavy wear can lead to an undulated floor profile that reveals the core material of the tiles.

Erosion: This problem is mainly caused by the aging of the tile, weathering, and exposure to acids.

Cracked and individual loose tiles (271): Individual loose and broken tiles are normally the results of wear and tear or sudden impact damage (i.e., where something heavy had been dropped on the floor). Corroded ironwork may also cause fracturing due to the expansion of the ironwork.

Larger areas of loose tiling: This problem is due to a movement in the floor structure: Water leakage can weaken the mortar beneath the tiles, inducing cracks. Loose tiling can also be an indicator of a structural settlement. In this case, the cause of the settlement must be identified and corrected before any re-tiling takes place.

Unbonded tile: It is the detachment of the background due to the weakness of the mortar beneath. This can be detected by a hollow or rattling sound. Tapping across the floor with a metal object similarly reveals the voids beneath the tile.

Cement jointing between tiles: The difference in the structural properties between the cement and the lime mortar might cause a settlement and cracks.

Scaling: It is caused by the high level of moisture in the soil.

Alteration - deposition

Surface soiling and staining (270, 274): It can be attributed primarily to airborne dust and pollutants, degraded coatings, staining through condensation or water ingress, and corrosion of metallic elements and fixings such as radiator elements.

Efflorescence *(temlîh):* This phenomenon refers to salts carried by rising damp to the surfaces of the tile. The major source of these salts is the cement used beneath the tile.

Human activities: Some repairs are carried out using colored ceramic replicas of the clay floor tile. These introduce a visual disharmony and a potential for failure.
Lack of maintenance and the use of harsh cleaning agent will affect the appearance of the tile.

Biological colonization (273): (algae, mildew, lichens, moss, or fungi) This is a result of exposure to humidity and shade.

RESTORATION AND CONSERVATION METHODS

Cleaning

General notes

In the case of the clay floor tiles, the surface seal was important for internal tiling, as these tiles are a little absorbent. Traditionally, the floors were often waxed or oiled (generally using linseed oil). In cases where the floor is left for many years without being waxed or oiled, the dirt might get absorbed into the tiles and intensive cleaning is then needed to remove it.

Tiled floors should not be saturated with large volumes of liquids as this could eventually loosen the tiles, damage the substrates, and even cause structural damage. All cleaning should be done with as little liquid as possible and any surpluses mopped away.

Application

- Use a low concentrated alkali-based cleaner by scrubbing in a circular motion. If necessary, a low-speed scrubbing machine with a plastic scrubbing pad can be used. However, this action should be tested as some tiles might not handle the weight of the machine and crack.
- Clean small areas at a time, and when each area has been scrubbed well, rinse several times with clean water and mop as dry as possible. Throughout this process, it is most important to monitor the cleaning solutions and rinsing water and change them frequently as they get dirty.
- Use distilled water or White spirit to remove spots of waxes and/or greasy dirt. Wipe over the surface thoroughly several times using swabs or sponges slightly dampened with water.
- Paint splashes from decorating work should be cleaned off with a chemical paint remover. Clean treated areas with plain water to remove paint remover residue.
- Organic growth, such as mold or mildew, can be eliminated with a dilute solution of tri-sodium phosphate. Afterwards, it is necessary to scrub the floor with a nylon brush, and then rinse with clear water.
- If a traditional finish is required, a colorless oil rub-in is an option as long as this action is repeated once or twice a week.

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Dismantling and reinstalling in the same space (settlement problems)

The same method of dismantling and reinstalling the marble floors applies but without numbering the tiles (275 – 279).

Replacing and laying tiles

General notes

In order to retain the historical integrity of the building, replace tiles locally and based on the assessment of the condition of the existing tiles and the associated support.

The new tiles should wear in a similar manner to the historic ones;

- Damaged tiles should be replaced with new ones that match the originals as closely as possible in terms of surface color, texture and finish, and physical qualities. Alternatively, similar reused or salvaged tiles can be used.
- The differences in artwork quality in some of the new low-quality reproduction of original cemento tile tends to disrupt the continuity of pattern across the floor.
- The new replacement tiles are thinner than the original ones and are designed to be laid on a hard mortar bedding like cement. The original construction of 20-25 mm tiles, however, was laid in soft mortar and had a monolithic quality able to accommodate movement without cracking.

Repair is always more preferable, but both cemento and clay floor tiles can be difficult to repair adequately.

Tiles that are in good condition, including tiles slightly chipped around the edges or with minor cracks not detracting from their overall appearance, should be retained in situ wherever possible.

Unless the tiles are laid on a soft lime bed, taking up and relaying the original tiles is not a practical action.

Application

- Work on the tiling can begin once the floor structure has been secured.
- Loose tiles should be lifted carefully as it may be possible to reuse them.
- Cracked and damaged tiles that are still firmly fixed will have to be cut out with a hammer and chisel. This must be done very carefully as collateral damage to adjacent tiles is likely.
- Mortar should be carefully cut back. Lime mortar infill is relatively soft and easy to remove.
- In case the tiles were laid in cement mortar, the mortar can be taken off from the back of the tiles with a water-fed diamond face grinder.
- Areas should always be dry when the tile-laying commences.
- Before fixing the tiles, some of the tile dimensions may need adjusting to fit the space available.
- A thin bed of lime mortar should be used to fix the tiles. The levels and alignment of points should be checked frequently with a straight edge.
- Take into consideration that the set times are long even if a hydraulic lime is used, and the floor may have to be out of use for up to three weeks.

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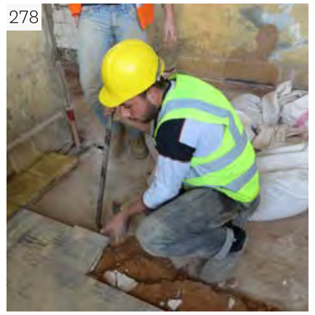

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LIMESTONE “FURNI” FLOORS

Nathalie Chahine

TECHNIQUES

The “Furni” is a limestone, ranging from light yellow to white and mostly composed of calcite. It is used on floors, stairs, corbels or even columns because of its hardness and durability. The kitchen and outdoor floors of most Beiruti houses comprised solid floors of Mansourieh quarry tiles laid directly on a well rammed earth or sand. The tiles, with their irregular lower face and variable dimensions, were butt-jointed. Their thickness varies between 10 and 20 cm.

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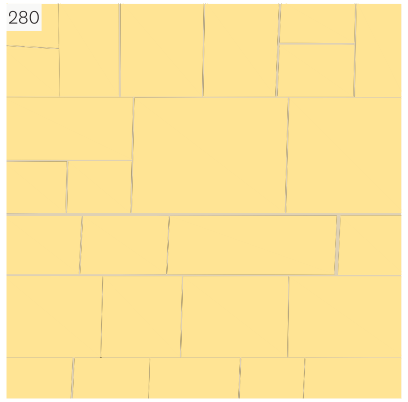

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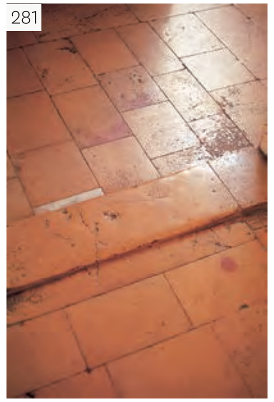

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PATHOLOGICAL PROBLEMS

The degree and morphology of deterioration of the “Furni” tiles are connected to their intrinsic properties and characteristics, and they depend on the environment and their exposure to it. “Furni” are hard stones which makes them impervious to cracking, peeling, flaking, and chipping. Furthermore, these floors have the joints between the slabs open and not pointed, which allows the moisture to evaporate freely through the open joints.

Clear actions of the August 4th explosion were seen in cracking, spalling, and settlements.

Mechanical breakdown

Abrasion and Degradation (283, 284): It is the loss of the stone surface as heavy wear can lead to an undulating and polished floor profile. However, this wear usually results from years of footfall and is, therefore, a reminder of the building’s history.

Delamination: It is the result of the separation along the bedding planes that causes the tile to crack, and an uneven bed appears. It is usually preferable to accept these defects rather than disturb the historical floor.

Erosion: Being mainly installed in wet areas and kitchens, “Furni” tiles are subject to two factors that can cause deterioration;

- Moisture: condensation or penetrating and rising damp leading to direct surface erosion
- Exposure to acids and strong alkalis: such as vinegar, lemon, etc.

Large areas of loose tiling: This is an indicator of a structural settlement. The cause of the settlement must be identified and corrected before any re-tiling takes place.

Voids beneath the tiles: These can arise because of the shrinkage of the clayey earth under the tiles. The stone tile can then act as a beam until one fails, and a hole appears.

Alteration – deposition

Surface soiling and staining (283): This is primarily attributed to airborne dust and pollutants, degraded coatings, staining through condensation or water ingress, and corrosion of metallic elements and fixings such as railings or radiator elements.

Efflorescence *(temlîh)*: This phenomenon refers to salts carried by rising damp to the surfaces of the tile. Changes in the environment can drive the salt to crystallize below the surface of the tile or between the bedding mortar and the tile, causing significant damages.

Biological colonization (284) (algae, mildew, lichens, moss, or fungi) This is a result of exposure to humidity and shade.

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RESTORATION AND CONSERVATION METHODS

Cleaning

Liquid cleaning

"Furni" tiled floors should not be saturated with large volumes of liquids; as this could eventually loosen tiles, damage substrates, and even cause structural damage. Cleaning should be done using minimal quantities of clean water and restricted to infrequent intervals, because "Furni" is naturally absorbent. In addition, it is difficult to prevent dirty water from seeping into the open joints.

The addition of a little neutral pH soap may be necessary on very dirty areas. However, household cleaners, bleach, and abrasives should be avoided.

Deep stains may need poulticing, and expert advice should be sought.

For hard stains, use a diamond grinding system to remove remaining residues and to hone the stone to a patina finish.

Waxes and oily stains marks can usually be removed with a solution of water and white spirit in equal proportions.

Dry cleaning

For small spots, use a cleaning, natural rubber product, free from moisture, solvents, or chemical additives, by wrapping it around the end of a bamboo stick and rolling it lightly over the surface.

Polishing and waxing

"Furni" floors were rarely waxed in the past and most have developed a fine natural sheen. "Furni" might not take well to a polish, and a response test on a small trial area should be made prior to application on an untreated floor. It is recommended to conserve the natural patina of this material.

285

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Dismantling and reinstalling in the same space (settlement problems)

The same method of dismantling and reinstalling of marble floors applies (285-289).

Note that the thickness of the stones can be reduced to 3cm and one tile can be divided into 2 to 4 smaller tiles. The lower face will be regular and consume less thickness of the bedding mortar.

Replacing

Due to urban expansion, stone blocks are no longer extracted from Mansourieh. However, excavations for new construction are a potential source of limited new material.

- Find replacement limestone tiles that match as closely to the original ones as possible.
- Using a chisel or a flathead screw driver and a hammer, carefully remove the grout around the tile so not to damage neighboring tiles.
- Once the tile pieces are out, make sure to get the remaining soil and debris out of the space left behind.
- For optimal adhesion, put the mortar in the empty cavity and on the back of the tile. Then, make sure it completely dries before re-grouting.
- Cracked tiles can be repaired with lime mortar if necessary, without being replaced.
- Voids beneath the tiles can be injected with weak lime-based grout without removing them, or they can be filled with dry sands/aggregates. This ensures that ground bearing is reinstated without damaging the floor.
- Jointing: Dense mortar pointing may trap dampness into a previously dry floor. Dry-jointing with a coarse, well graded sand swept into the joints without lime could be used.

Attaching fragments

Pieces of "Furni" tiles displaying cracks could be re-attached using glues, dowels, or a special mortar.

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In *Beiruti houses,* a variety of flooring materials have been used to give a more robust and hard-wearing surface. Lime screed—supplanted later by cement screed—was the most basic type of finishing. In the ground floors, the screed was either bedded directly on well rammed earth or a layer of sand/clay, all on a bed of well compacted rubble hardcore. It was laid directly on the ground and not tied into the building structure. The use of this screed on ground floors was systematic in early constructions (prior to 1860), and it was later on usually limited to secondary side rooms. As wealth increased, screed floorings were slowly replaced with terracotta or cement tiles. Remaining evidence of such flooring is key to assess the construction period and the social status of the inhabitants.

LIME SCREED

Lime screed comprised a form of cement based on slaked lime mixed with wood ash from lime-burning kilns and aggregates that include stone chips and crushed brick leftover from the main construction. The inclusion of ash and brick imparted durability, color, and finish. They had a pozzolanic effect, enabling the lime mix to achieve a hydraulic set before the mortar had fully dried out, and the brick particles helped it to dry.

Although much softer than Portland cement, lime cement is durable. It is a breathable floor that allows moisture to evaporate, establishing an equilibrium between the ground and the air above, thus reducing the chances of concentrated damp areas that might damage the building's fabric.

Natural oils and waxes were often used to protect floors and to help keep them dust-free while retaining most of their permeability.

PATHOLOGICAL PROBLEMS

Mechanical breakdown

Erosion (290): Lime screed is readily eroded; this problem is mainly caused by aging and weathering.

Cracks: Caused by wear and tear, sudden impact damage (where something heavy had been dropped on the floor), or by a movement and a settlement in the floor's structure.

Scaling: It is caused by a high level of moisture in the soil.

Alteration – deposition

Surface soiling and staining: It can be attributed primarily to airborne dust and pollutants, staining through condensation or water ingress.

Biological colonization (algae, mildew, lichens, moss, or fungi) This is a result of exposure to humidity and shade.

REPAIRING AND MATCHING THE ORIGINAL LIME SCREED

The repair of lime screed normally encompasses fine traditional patch repairs or full replacement. Reparation is not a practical option, and most likely cracks around reparation areas will show.

- Major constraints oppose the repair of the original lime screed: the extent of the damage, the new functions and loads to be implemented in the building, and the lack of availability of the original constituents. Note that the original aggregates were sourced from local and close-by sources and quarries.
- When removing the existing lime screed, it is recommended to gently smash it into small pieces, soak it in water, and sieve it to retain the aggregates in order to reuse them in the new screed for the same finishing colors and texture.
- After pouring the new mix in the specified areas, the repairs will be vibrated to achieve complete filling of the voids.

MAKING OF A NEW LIME SCREED

Where a new screed is to be created, one option is to use a lime screed that is breathable rather than one based on cement, which is less permeable. A lime screed floor can be designed to meet modern insulation requirements and can even incorporate under-floor heating.

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Preparation method

Once the ground is excavated, compacted, and levelled, proceed to:

- Lay a breathable geotextile membrane.
- Mix 1 volume of well-graded, sharp sand (3 mm) with 1 volume of fine gravel (up to 10 mm) in a 50/50 mix. The dosage of hydraulic lime will be 400/450 kg per m3 of aggregate (1:2 by volume). Glass fibers can be mixed in to give a more durable screed.
- Pour the first layer at around 8 cm.
- Thirty minutes later, pour the final layer of 2 cm. The selection of the color and size of the aggregates in this layer depends on the desired final finishing.
- The surface can then be worked over, using either a trowel to achieve a fine closed finish or a combination of wooden and sponge floats to create an open-textured finish. Some water is likely to be required in this process. Splash it on with a brush.
- Leave it for around three weeks to dry while spraying with a light water mist 3 times a day.
- Apply several coats of a drying oil such as linseed to consolidate the surface.

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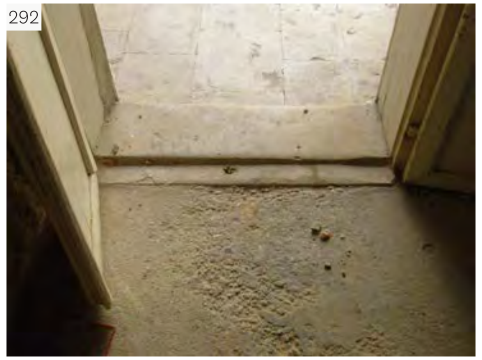

CEMENT SCREED

PATHOLOGICAL PROBLEMS

In the 1920s, the advent of ordinary Portland cement that became widely available and is relatively impermeable replaced lime screed with cement screed. Cement acts as the binding agent that holds the aggregates together, playing a key role in the setting and hardening properties of the screed.

Mechanical breakdown

Erosion: This problem is mainly caused by aging and weathering.

Cracks: These are the results of wear and tear, sudden impact damage, or a settlement movement.

Scaling: It is caused by the high level of moisture in the soil.

Alteration – deposition

Surface soiling and staining: It is primarily attributed to airborne dust and pollutants, staining through condensation or water ingress.

Biological colonization (algae, mildew, lichens, moss, or fungi) This is a result of exposure to humidity and shadow.

Efflorescence: This phenomenon refers to the migration of the salts present in the cement.

REPAIRING AND MATCHING THE ORIGINAL CEMENT SCREED

The repair of the cement screed normally encompasses patching repairs or full replacement. Reparation is not a practical option, and most likely cracks around reparation areas will show. After pouring the new mix in the specified areas, the repairs will be vibrated to completely fill the voids

MAKING OF A NEW CEMENT SCREED

Once the ground is excavated, compacted, and levelled, proceed to:

- Prepare a mix of 1 part of Portland cement and 4.5 parts of aggregates and water. Glass fibers can be mixed in to give a more durable screed.
- Pour the first layer of around 8 cm.
- After 10 minutes, pour a final layer of 2 cm. The selection of the color and size of the aggregates in this layer depends on the desired final finishing.
- The surface can then be worked over using either a trowel to achieve a fine closed finish or a combination of wooden and sponge floats to create an open-textured finish. Some water is likely to be required in this process. Splash it on with a brush
- Before the screed is set, sprinkle cement powder on the ground. The powder is integrated into the screed using a trowel, making the surface smooth and shiny.
- Leave it for around three weeks to dry while spraying with a light water mist 3 times a day.
- Apply several coats of a drying oil such as linseed to consolidate the surface. Modern materials such as transparent resin can be used as well.

Nathalie Chahine

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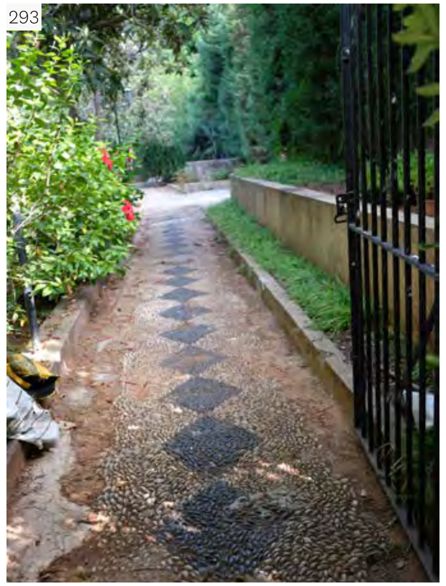

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TECHNIQUES

Pebble floors belong to an ancient technique that persisted throughout the Mamluk and later on the Ottoman architecture where pebbles were used to cover khans' galleries and outdoor passages. The pebbles were collected from the nearby sea or river and laid with lime mortar directly on well-rammed earth or a layer of sand/clay.

In *Beiruti houses*, pebble floors were used as a punctual outdoor and garden feature. Somewhat rare, the patterns were designed in two colors, black and white.

PATHOLOGICAL PROBLEMS

Mechanical breakdown - structural deterioration (296, 297)

Lacunae and big loss: loss of individual or big areas of pebbles that got dislocated and lost over time due to wear and weathering.

Detached pebbles: result from a poor bond with the bedding mortar as well as the deterioration and the loss of cohesion of the bedding mortar. After the detachment of one pebble, adjacent pebbles are at risk because of the loss of the lateral support provided by the detached pebble.

Deteriorated pebbles: identified as cracks and fracture. These are characterized by the general cracking of the pebbles due to thermal expansion and weathering. This phenomenon also occurs in pebbles adjacent to lacunae.

Alteration – deposition

Surface soiling and staining: Pebble floors collect dust, leaves, and other airborne debris which necessitates frequent cleaning.

Human intervention: The concrete backing with cementitious bedding mortar and grout could contribute to latent deteriorative factors such as alkali-silica reaction—which is a particularly damaging expansion of silica in the presence of water and alkali cement.

Moisture staining: This is caused by inadequate drainage (mainly water runoff) and heavy exposure to rainwater.

Vegetation and bio growth: This is a result of exposure to humidity and shade.

RESTORATION AND CONSERVATION METHODS

The unavailability of the original constituents can be a major constraint in the restoration of original pebble floors (collecting pebbles from the seaside or from river beds is prohibited).

However, industrial processed pebbles can be used (these are small pieces of leftover stones and marble are processed in a rock tumbler and come out as pebbles).

Cleaning

This process will be completed by manually removing particulate soiling and debris from the interstices of the pebbles with thin bamboo sticks, small brushes, and using a small vacuum cleaner to collect the debris.

Reintegration of loose pebbles

- Find replacement pebbles that match as closely to the original ones as possible (dimensions, colors, etc.)
- Once the adjacent loose pebbles are out, make sure to get the remaining soil and debris out of the space left behind.
- Pour the mortar in the empty cavity, installing the pebbles.
- Make sure it completely dries before re-grouting.
- Make sure to have adequate drainage for water runoff.

Re-backing and over-grout

- Voids beneath the pebbles can either be injected with weak, lime-based grout without removing the pebbles or filled with dry sands/aggregates. This ensures that ground bearing is reinstated without damaging the floor.

296


297


GUARDRAILS, PORTALS AND FENCES

Mazen Haïdar

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Wrought iron works

The guardrails

The earliest examples of wrought iron guardrails and staircase railings date back to the late Ottoman period. Visible in corbelled balconies and exterior staircases, these examples are characterized by rhythmic vertical bars. Ornamentation in these early works was often limited to the addition of semicircular, or S-shaped scrolls bent at varying degrees and grouped into heart-shaped pairs. The reduced thickness of the curved forms, which does not exceed 4 mm, facilitated the cold bending process. Strong similarities among the designs circulated during this period in various Lebanese and regional cities suggest an intuitive production, where the knowhow and techniques transmitted between generations prevail over any other creative solicitation. Even though it occasionally appeared in bourgeois residences of the late 19th century, it was not until the 1920s that French inspiration in wrought iron works gained popularity. Thanks to the distribution of specialized catalogs during this period, motifs like the flower basin and others with Art Deco inspiration emerged and were locally reproduced by master ironmongers.

In examples prior to the arrival of cement, the structure of the wrought iron railing rests on vertical posts with a cross section of 4 cm. These posts are bolted to the lower part of the slab by means of a flat iron support. They are sealed with molten lead within holes cut in the stone to the dimensions of the vertical element (300). Horizontal bars, bent up or down in an "L" shape, are riveted to both sides of the vertical posts (300). The slender rods, flat bars and scrolls are first fabricated separately, and then connected to each other by riveting (301, 302, 303). Fastening collars connect lighter cold-bent elements such as volutes and the supporting bars of the staircase, while balcony handrails are connected by means of "L" shaped notches (304). Towards the end of the 1920s, the execution and assembly techniques of wrought iron structures experienced a turning point with the introduction of electric welding. Initially, this new technique coexisted with traditional fixation techniques; the production of a solid panel, rather than a series of separate elements, reduced the process of mechanical assembly to merely fixing the product onto vertical posts anchored in the concrete slab. The exclusive use of welding eventually appeared in high standing projects around the mid-1930s and spread quickly due to its easier production.

In corbelled balconies, the stability of the guardrails is intrinsically linked to that of the structure they are attached to. The breaking of the marble slab or the shattering of the concrete systematically weakens the wrought iron structure (305). This endangerment can also be triggered by external hostile factors that cause oxidation, corrosion of the material, and degradation of the original riveting system. Such issues are apparent in most of the buildings that have been deprived of maintenance.

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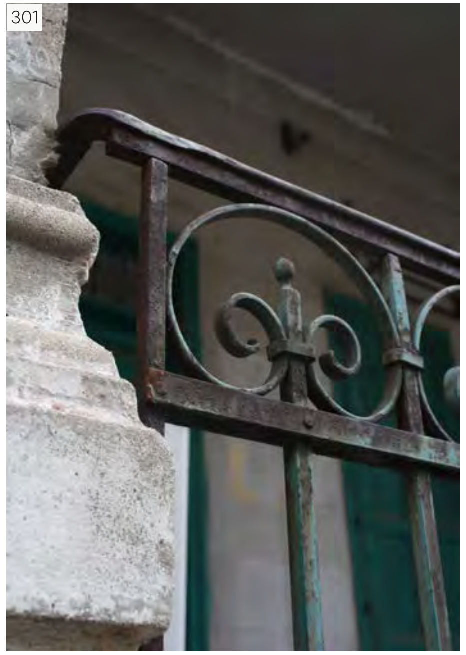

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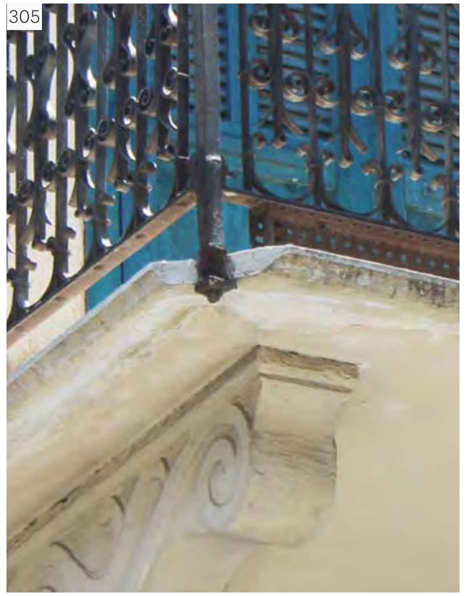

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The portals and entrance doors

At the turn of the century, grand portals giving access to a terrace or a private garden were mostly present in bourgeois residences. They can also be found in some of the Mandate period's buildings, located on plots that were not saturated by the built environment. Up until 1920, and before the widespread use of reinforced concrete, these two-leaf portals were framed by a decorated "Furni" stone structure (306). Other examples with larger dimensions appear in the grand, honorary entrances of buildings from the late Ottoman period. Composed of two or four leaves, the latter can be surmounted by an articulated motif based on volutes. The upper part gradually leaves its crown in favor of a straight or rounded shape with simple protruding elements. A look at the transformative practices initiated by residents reveals a tendency towards a closed and secured entrance area. This is developed from the moment of the portals' installation. Driven by necessity, the inhabitants added perforated or flat iron sheets to block small and large openings in the structure and avert access to the portal's lock from the street (307). In addition, this measure protected the entrance area of the building or the ground floor from the gazes of passers-by and prevented littering. In concurrence with this closing-up phase, safety locks, that did not exist in the original structure, were added. Growing insecurity will eventually prompt the installation of new steel lever clasps with padlock holders.

After guardrails, buildings' entrance doors with one, two, or more leaves were one of the most common wrought iron structures in town. In examples prior to the mid-1930s, entrance doors rarely exceeded 1.40–1.60 m and can sometimes be limited to one meter or less. The delimitation of the access door is mainly marked by the projected ornamentation made of stone or molded concrete. The opening can be further marked by a geometric articulation ranging from the simple semicircular arch to the more elaborate stepped opening in constructions inspired by the Art Deco movement. The absence of glass in the entrance doors underlines the permeability between the exterior and the interior of the building. The addition of the transparent material will not be generalized effectively until the mid-1940s. With a few exceptions, the production of building entrance doors before that date, was largely limited to wrought iron that guaranteed security and privacy at the entrance. The dimensions of entrance gates underwent considerable change during the 1930s as we witness the widening of access doors and openings, while ceiling heights gradually decreased.

In addition to oxidation and corrosion problems of wrought iron works, further types of deterioration include the loss of ornamental objects, like rosettes integrated into the doors' bases or other utilitarian elements like handles.

The fences

In Beirut, wrought iron fences are visible in several public and religious buildings as well as bourgeois residences. Generally, they consist of a stone parapet, or concrete blocks of varying height, surmounted by a series of pilasters and wrought iron grids with a straight or convex top. Their function can vary from protective structures of private gardens to separation elements marking boundaries between certain passages and adjacent properties. In terms of form, the metal structures of the fences, in most cases, resemble the entrance gate, and until 1920-1925, they were characterized by simple, vertically rhythmic configurations. However, some of the more elaborate examples reveal certain inspirations carried out from steel exporting countries to Beirut's port, such as France or Belgium. A few publications, like Henri Grave's La Ferronnerie published in 1881, Paris, included several surveys and represented important indicators of such transmissions in the late 19th century. Wrought iron fencing works, similarly to gates and entrance doors, were subject to continuous renewal due to waves of Art Deco inspiration that nourished the architectural scene of the mandate period. Fences from 1860-1925 reveal some dating clues that can be summed up by the coupling method of modules and the geometric definition of each module's upper part. In addition to both those indicators, the assembling techniques used, such as welding or riveting, are key dating elements for works from the turn of the century. The oldest works are sequenced by stone pillars and embedded at the base of stone parapets. They consist of repetitive round or square bars surmounted by spears that formed a straight, convex, or concave top. The lower parts of the first examples are ornamented with circles or volutes introduced at the square intersections of vertical and horizontal axes. As of the 1930s, bourgeois buildings with security walls witnessed a reduction, and even elimination, of masonry or reinforced concrete pillars. Subsequently, to ensure a similar stability, the structure in these late examples is reinforced by introducing wrought iron fence pillars.

The main problems with fences are similar to those encountered in other wrought iron works, like corrosion. The latter causes some ornaments or other horizontal elements to become loose and fall down. While this degradation is common to all wrought iron works, problems such as tilting are particularly evident in fence grids. Typically caused by a push exerted on the fence's upper part, the deformation can weaken the embedment of the metallic body in the wall, thus requiring the rehabilitation of the entire assembly.

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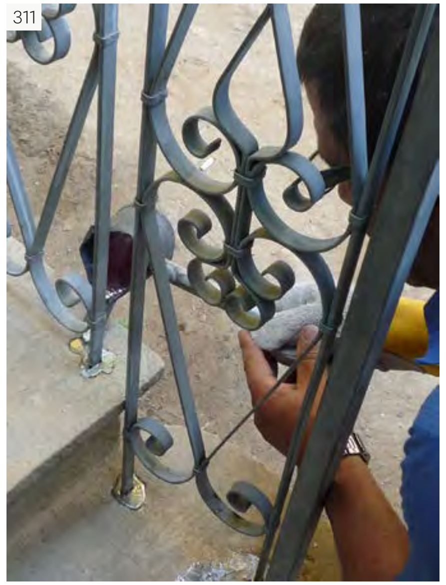

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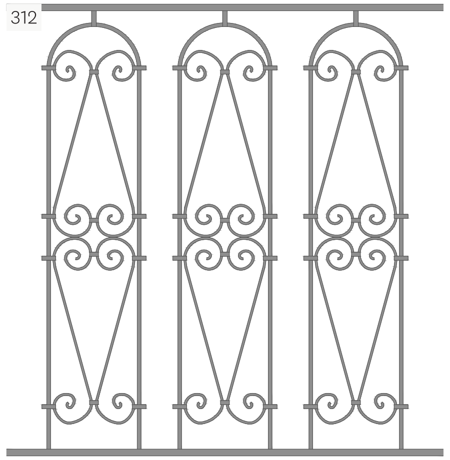

Restoration and conservation methods

The restoration of guardrails and other wrought iron structures can be divided into three categories which provide solutions to:

- Surface degradation of wrought iron elements

  The repair of corroded components and treatment against rust begins with stripping. Depending on each case, this operation can be approached on an ad hoc rather than global basis, giving priority to the most degraded areas.

- Complete deterioration or loss of structural elements

  Integration of new elements should be strictly limited to heavily damaged parts. The replacement of degraded structural elements such as the bases of doors or the vertical posts of guardrails should be favored over the substitution of decorative elements.

- The weakening of the structure and anchoring points

  Stabilizing the insertion points of guardrails, stair railings, window grills or fences requires careful synchronization with other operations such as the repair of balcony slabs or masonry consolidation. When old embedding systems, such as the sealing of the guardrail's vertical posts, is not adopted, it is important in the restoration project to respect the same spacing between the lower horizontal bar and the level of the slab.

Although the objective is to maintain the original appearance of each element, slight deformations and partial breakages of decorative components can be considered inherent to their history. Following this logic, they do not require specific replacement. The same stands true for the treatment of distortions dating back to the war, provided that this type of deformation is shown in solid iron bars and that the outline of these gaps is not dangerous to the touch. Similarly, additions such as perforated sheets in doors and gates can, in turn, benefit from a conservation treatment provided that they are in good condition.

Cast iron works

The use of cast iron in Beirut is limited to certain high-standing residences of the late 19th century. It is mainly visible in some external guardrails and staircase railings and its elements are recognizable due to the absence of sharp angles in their volume. Unlike wrought iron works, the latter are indeed characterized by a certain continuity between their facets. While this feature gives them a more pleasant feel at the edges, their surfaces maintain a rough appearance due to traces of sand grains found on execution molds. Furthermore, railings or guard rails made of cast iron are often characterized by a very heavy composition that combines floral motifs or animal shapes along with more abstract ornaments. The large number of details in such small elements contributes to establishing an image of solidity to the object.

The complexity of form in cast iron works suggests an execution technique that is much more manageable than that of forging. Cast in molds, the alloy of iron and carbon allows the emergence of more elaborate designs. While the firm guardrails offer a great resistance to compression, this cast iron assembly is not very resistant to traction. Different kinds of mechanical stresses can cause cast iron structures to break rather than twist, unlike iron elements which bend and deform. This explains the fragmentation of such elements in Beirut's bourgeois houses that suffered from the impact of bombs during the war or the port explosion of 2020.

Although the repair of cast iron elements requires specialized expertise and attention, it is nonetheless possible, if not recommended. This operation begins with the recovery of the broken fragments and re-composing them. Once collected, the fractured parts can be joined together by welding, and the missing details can be reconstructed with molds, taking similar patterns of sound parts as a reference.

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314

SERVICES

Fadlallah Dagher

Fadlallah Dagher

315

Most of the features described here are no longer in use. Modern comfort has taken over. However, these features are of consistent historical value and are important, as well as architectural features, that help identify the building's date of construction.

Water wells

"…And of water We have made every living thing…" (The Holy Qur'an, The Prophets Sura, Verse 30).

Beirut: literally "the wells," from be'erot, plural of be'er "well." (Online Etymology Dictionary)

Understanding Beirut's geographical position and geology is key to understanding its long history. From Mount Lebanon in the east, the Beirut River (*Nahr Beirut*) flows down the valley of Hammana. It used to flood the plains around the Beirut peninsula. Water makes its way down to the Mediterranean Sea through cavities in the soft marl clay soil from the area of *Ras el Nabeh*. In the old town of Beirut, water was stocked in cisterns and distributed by public fountains (*sabîl*). Water wells were also dug deep to catch the streams running underground. When the city started expanding outside its walls after 1840, farms and villas were built on lands where a private well would supply water for irrigation and domestic use.

These wells were the only sources for the supply of domestic water until the development of the public water supply network to Beirut from *Nahr el Kalb* through Dbaye at the turn of the century. Most of the 19th century villas and houses that survived the urban expansion still enjoy their wells in their garden today. Sometimes, these wells are located inside the houses (probably following the extension of the building's footprint).

Description (315)

The well is a vertical circular shaft with a diameter of 80 to 100 cm approximately, dug from top to bottom. The perimeter is clad out of sandstone with holes left to climb down and up the shaft during digging, as well as for further cleaning and maintenance. The depth of the well is relevant to the depth of the running stream. The average depth to reach the water table is 12 to 15 meters. However, evidence of depths reaching 30 meters have been observed on the edge of the hills and cliffs. The top of the shaft is framed in Mansourieh limestone.

Condition

The wells are mostly out of use nowadays, and urban authorities have failed to consider such resources as relevant. They have not been properly surveyed nor documented or protected despite their high environmental value. The few remaining wells are endangered mostly due to neglect and pollution or obstructed by the recent construction of deeper underground parking under modern buildings in the wells' surroundings.

Inspection and maintenance

Wells can be visually inspected by opening the cover; the presence of running water will be seen from atop.

- In order to clean the bottom of the well from rubble, debris, or dirt, workers will go down the shaft using the side step holes provided in the stone. They shall be fixed to ropes or belts and be equipped with an oxygen bottle and mask for safety.
- A sample of water will be collected and sent for analysis in a specialized laboratory. The potential use of the water will be determined accordingly.
- The shaft leads to the running water stream. It is not a tank to collect water. One should not try to caulk it. The sandstone perimeter shall not be plastered, as it allows for under surface water to filter into the well.

Water tanks and cisterns

Some large villas were equipped with vaulted underground cisterns to store water collected from the roof. Built in sandstone, these water tanks were caulked by a lime and marl plaster (*houwwara*). It is advised to deliver the rainwater falling on the rooftops to these cisterns and to add an overflow pipe.

Kitchens

A designated room for the kitchen was introduced after 1870. This room was vaulted in order to avoid fire, and its floors were tiled in Mansourieh ochre limestone ("Furni"). In the most ancient buildings, the kitchen was added to the structure coupled with a "Turkish toilet," flanking the south-east corner. In more recent structures (after 1880), it was integrated within the plan, always at the south-east corner to benefit from proper ventilation (since prevailing winds (*shard*) in Beirut blow from south-west to north-east). The position of the kitchen, flanked versus integrated, is an important indication to date the building.

Sinks (316)

Early kitchens were equipped with monolithic sinks carved in Mansourieh ochre limestone, fixed to a corner of the room. More recent sinks and worktops in Carrara marble were implemented around 1920.

Ovens (317)

Primitive wood and charcoal ovens carved out in pieces of solid Mansourieh limestone assembled next to each other are still observed in some houses.

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Sanitary systems

Up until the second half of the 19th century, the new villas and houses in Beirut were not equipped with proper sanitary systems. The population enjoyed the use of public baths (*hammam*) up until the end of the 1920s.

Primitive domestic sanitary systems (described below) were abandoned with the introduction of the modern water supply and waste-water public networks (318) during the 20th century. However, the traces of these obsolete systems have survived and can still be observed in many houses.

Toilets and septic tanks

After 1870, following the 19th century Ottoman *tanzimat* and its building code, *toilets à la turque* were implemented next to the kitchen areas on the south-east corner of the building. The sewage was directed through pipes (made of carved stones or terracotta) to a vaulted septic tank built either under the structure or adjacent to it. These septic tanks collected the wastewater from the kitchen sink and had to be regularly cleaned out.

Washbasins

Individual marble or limestone washbasins (*jorn*) were provided in rooms for daily use (321). These basins were filled with water extracted from the well. At the turn of the century, and thanks to the implementation of the water public network, fixed washbasins equipped with copper taps within a wall niche framed in marble were installed next to the dining rooms, toilets, and kitchen areas (320). Wood-fired water heaters (*'azan*) were installed as of the 1920s (323).

318


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321

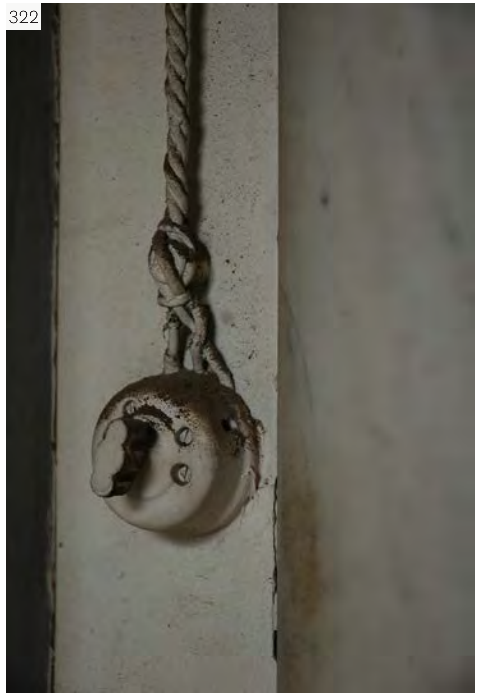

Gas pipes

Prior to the introduction of electrical power, some prominent villas were fed by the public gas network for lighting the chandeliers. Remains of thin copper pipes can sometimes be detected, hidden between the sandstone walls and the plaster layer or circulating in the timber roof space and feeding the rooms below.

Electrical equipment

Primitive electrical installations are still often visible. Indeed, the wiring was not embedded in the walls: the twisted copper wires coated with linen (*ketten*) were fixed on hooks made of bone or white porcelain mounted to the walls and ceilings (322). They connected rotary switches and round outlets to the pendant lights. The equipment's materials varied over the periods: wood and bone first, then galalith in the 1920s, bakelite in the 1930s, and porcelain after 1940.

Apart from the wells and cisterns, all other features can only be looked at as witnesses from the past with historical and/or aesthetic value. It is recommended to document and preserve them as such.

322


323


BEIRUTI GARDENS

Jala Makhzoumi

BEIRUTI GARDENS

Jala Makhzoumi

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House gardens in Beirut appeared as the city grew outside the medieval city wall in the late nineteenth century. There was no space in the dense fabric of the walled city for gardens. Nor was there a need. The city was surrounded by verdant landscapes. Dirt roads lined with prickly pear (*subbeir*) led out of the city gates into mulberry plantations, weaving through olive orchards and solitary oak copses. Further away, along the municipal boundaries of present-day Beirut was Beirut's pine forest.

The neighborhoods that sprouted outside the city walls in Zukak al Blat, Tabareez, Saifi, and Gemmayzeh adopted the central hall, detached house typology. Houses were built not wall-to-wall, but at the center of the property. The land surrounding the building became the first house gardens. Natural resources, scarcity, and climate dictates favored a productive garden, where beauty and usefulness combined as in the village house garden, *'hakura'*—a hybrid orchard/garden. The description of paradise in Abrahamic religions embodies this conception; God planted "every tree that is pleasant to the sight and good for food" and ensured that "a river" flows out of Eden "to water the garden" (Genesis 2). The colloquial name for garden in Lebanon, *jneineh,* is a diminutive of *jenna,* Arabic for paradise.

Beiruti gardens borrowed the concept of garden/orchard. Regardless of size, they were characteristically 'full', often packed with fruit trees. The large gardens of Sursok and Bustros were exceptions. They were designed to emulate the Western-styled gardens we are quite familiar with today, in which the 'full' garden is emptied to make 'space' for the much-favored lawn. For the majority of *Beiruti* families, however, the deeply rooted values and practices of rural garden culture were favored. Their gardens were planted fully with productive trees, and not a single square meter was left unplanted. The tree shade ensured that the garden was deliciously cool and pleasant.

The full garden came to serve as a socio-cultural mediator, interfacing private and public, and offering both spatial and visual separation to the central hall (*dar*) household. It provided owners the advantage of seeing their visitors as they approach the house from within the interior without being seen.

Diversity in tree species is another cultural preference of the *Beiruti garden*. It is a matter of pride to the household that their garden has one-of-every kind. A diversity of fruit trees is evident in the description of paradise: "Does any of you wish that he should have a garden with date palms and vines and streams flowing underneath, and all kind of fruit" (Sura II, Baqara). The choice of garden trees included citrus, pomegranate, mulberry, fig, grape vine, and myrtle. Grapevines were trailed on a pergola, *areesh*, or on a parapet, and enjoyed not only for the variety of grapes they produced, but also for the young leaves, *wara' areesh,* an ingredient of culinary recipes in Lebanon and the region. With time, new fruit trees were introduced into the garden. Loquat (*akidunya*), avocado and date palms, as well as ornamental trees, Jacaranda and Frangipani, *fitna,* became hallmarks of a *Beiruti* garden. The garden harvest was often shared with neighbors and used to make preserve and sherbets. Herbs and vegetables added to the diversity.

A potager garden, with parsley and mint, spring onions, and radishes readily available for the kitchen was complemented with tomatoes and peppers depending on the size of the garden. Chicken roamed freely, surviving on earth worms and kitchen waste and ensuring a regular supply of fresh, organic eggs and—when need arises—fresh meat.

Scent was important in the garden. The delicious, night fragrance of the *Cestrum nocturnum*, locally known as *kolonia,* and the ever-present jasmine trailed over the wooden portals leading to the garden. The delicate white flowers of the jasmine were strung into fragrant necklaces. There might have been roses and flowering bulbs, like narcissus, planted in pots to preserve water and be transported from shaded to sunny parts of the garden and vice versa.

At the heart of the garden is the water fountain, or *the birkeh*. The fountain was both ornamental and functional. It served as a reservoir to secure enough water to irrigate the plants when needed, namely in the summer, while also offering a pleasant sight and the refreshing sound of water droplets splashing in the heat.

The *Beiruti* garden was very much an ecosystem, the diversity of plant selection offered habitats to a range of insects. Bumble bees and butterflies circled the garden, serving as pollinators—a role taken over by moths attracted to the fragrance of night flowers. Bats were present, feeding on moths and caterpillars. The water of the *birkeh harbored* dragonflies and damselflies.

The *Beiruti* garden was perfectly aligned with present day awareness of the need for nature in our cities and of the role of biodiversity and efficient utilization of available resources—now referred to as sustainable development. The garden was ecologically constituted, climatically adapted and biologically diverse; its multifunctional space both efficient and beautiful, a place where children and grownups celebrated the complexity and beauty of nature.

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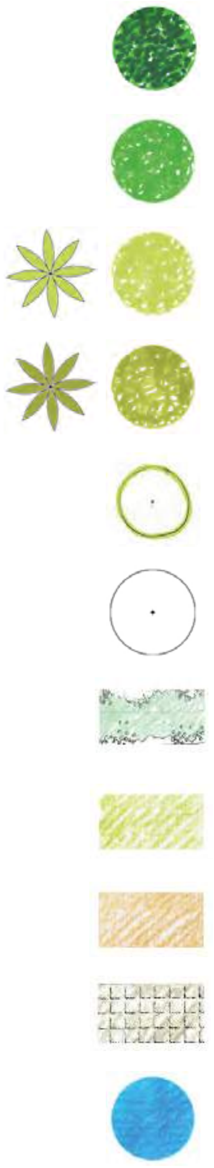

Mediterranean Trees
Almond; Laurel; Myrtle; Olive

Foliage Trees
Araucaria; Ficus Sycomorus; Ficus Elastica; Ficus Retusa Nitida; Palo Verde

Ornamental Trees
Bauhinia Variegata; Crape Myrtle; Flamboyant; Frangipani; Jacaranda; Fan Palm

Fruit Trees
Citrus; Loquat; Pecan; Mulberry; Avocado; Date Palm; Guava; Pomegranate

Shrubs
Cycas Revoluta; Gardenia; Datura Species; Hibiscus Rosa-Sinensis; Japanese Timber Bamboo; Oleander; Sword Fern; Yucca

Spontaneous
Tree of Heaven

Climbers
Bougainvillea; Climbing Roses; Common Ivy; Honeysuckle; Jasmine; Grapevine

Groundcover
Dichondra Grass

Bare Soil

Paved
Stone Pavers; Concrete Pavers

Water

328

328: Garden plan, Rmeil 320

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330

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