CONSERVATION PROBLEMS OF WALL PAINTINGS WITHIN THE ARCHITECTURAL HERITAGE

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Abstract: *The Armenian legislation is currently protecting and preserving architectural monuments, archaeological sites, and minors' artistic forms of art like xač'k'ars. Unfortunately, there are several cases of precious wall paintings preserved inside religious buildings (Tat'ev, Lmbatavank', K'obayr, Mastarà) being damaged during architectural monument restoration. In recent years, there has been a lot of interest in study, conservation, and restoration of wall paintings in Armenian churches; however, there is one terrible reality to report: the neglect and abandonment of the protection and safeguarding of visible wall paintings for many bureaucratic and logistical reasons, as well as reasons for complete indifference for the destiny of the frescoes. A significant illustration of this negative attitude is the chapel of the Armenian monastery of K'obayr. After many years of abandonment, the Armenian Ministry of Education, Science, Culture and Sport made a move and began a campaign of studies and restorations in collaboration with the Polytechnic of Milan, to restore the buildings and wall paintings. Restoration work on the K'obayr chapel has been put on hold since 2013 due to inadequate administrative administration. As a result, the chapel's single nave's double-pitched roof, which is incomplete has remained exposed for the past 10 years, and rainwater infiltration formed a lovely part of the wall paintings. Our four years of endless reports and reminders have yielded nothing. The purpose of this article is to show once again, that the wall paintings in Armenian churches are historical monuments that must be safeguarded and are an inseparable key component of each existing church's monumental architectural heritage; consequently, they must be protected.*

Keywords: *K'obayr, Mastarà, Lmbatavank', Axt'alà, Karmravor, Art'ik..*

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Introduction

There are limited references in Armenian architecture studies to wall paintings preserved in churches and templets that were created immediately after the church was built or later. Architecture and wall painting art are inseparable values, and one compliments to the other [1-3]. The Armenian church is a volumetric and geometrically secluded and mysterious environment created by a masterful combination of stone constructions. The wall paintings that survived on the internal walls, were made by using lime, sand, and mineral pigments to convey the ideas and commandments of spiritual values. The union of these two beautiful forms of cultural expression gives power and meaning to the spiritual structure, making it the cradle of Christianity's conservation and spread. The prevalence of wall paintings in churches, their depictions, painting skills, and color solutions reveal an important yet unexplored part of Armenian culture. According to our research, there were at least three regions in Armenia with wall-painted churches: the northern area, bordering Georgia (Kiranc', Khučap, K'obayr, Hałbat, 10-13th century); the central area - on the slopes of Mount Aragac (Lmbatavank', Art'ik, Mastarà, Koš, T'alin, Aruč, 7th century); and the southern area - bordering Iran (Surb Hovhannes, Surb Astvacacin, Surb Sargis, all in Mełrì, 17-18th century). A preliminary study of the wall paintings preserved in the churches of these three regions revealed their differences as well as their exceptionally high artistic value. In the Armenian highlands, many churches have been built and painted since the early days of Christianity. Many wall-painted churches in Ani's capital require a separate investigation

(Tigran Honenc‘, Sant Savior, and the Cathedral). The study of the numerous fragments of wall paintings that survived to this day, both from the early Christian and mature Middle Ages, is possible only because they have been preserved and restored.

The historian Vrtanes Kertogh in his treatise «Յաղագս պատկերամարտից» (About Iconoclasts) [4,5], written in the 7th century, exhaustively illustrates the presence of wall paintings in numerous churches of the time and the use of natural mineral pigments as well as pigments of vegetable and animal origin in the design they created. There is inadequate knowledge of the subject because of a lack of studies due to the large number of abandoned historical monuments on Armenian territory. On the one hand, the almost complete indifference of Soviet scholars in an atheist country, particularly for reasons of inappropriate illegal usage of monuments such as kolkhoz grain warehouses, has promoted the degradation and definitive loss of many pictorial fragments preserved in various churches in the territory of the Republic of Armenia. All wall paintings in Armenian churches are little studied for a variety of objective and subjective reasons: wall paintings are erroneously considered to have no local origins, and frescoes are painted by foreign artisans (Byzantines, Syriacs, Georgians, and Franks). We are convinced that painting and architecture are one and single, indivisible thought and that the design of the church and its interior decoration highlight full and harmonious work. There is presently no census and no complete catalog collecting all of Armenia's pictorial heritage [6]. Without this, it is impossible to study, conserve, restore, and produce a catalog of wall paintings in Armenian churches. The fundamental issue is insufficient attention from the government, religious institutions and local population. There is an absence of valorization and appreciation to recognize the value of this great cultural heritage. The lack of knowledge of those people who make decisions is also a major issue. I would like to present our testimony through examples of what happened to us while we were on our mission in Armenia from 2012 to 2022.

Materials and Methods

Our research and work have led to unbelievable outcomes that are evident with the naked eye. As previously stated, the products used for cleaning, phasing, grouting, consolidation, mortar restoration, and wall painting were chosen as the classics utilized in Italy because they were all restored with the consent of the authorities that protect the monumental and visual heritage so well-renowned around the world. The methodology for restoration was developed by the School of Restoration in Italy and is used in Veneto. The decades of professional expertise and the results produced in Venetian churches and palaces show the accurate use of conservative restoration methods used on numerous medieval murals executed in Italy and applied to wall paintings in Armenian churches.

Literature review

We have published numerous articles and four books on wall paintings in Armenian churches:

- Dadivank Revived Miracle.
  Authors: Karen Matevosyan, Avet Avetisyan, Arà Zarian, Christine Lamoureux, Armenian, Russian and English book (with Blessing of Primate of the Artsakh Diosece of the Armenian Apostolic Church Archibishop Pargev Martirosyan), Victoria Foundation, Yerevan, 2018, ISBN 978-9939-1-0690-8.
- The Restoration of the Wall Painting in Several Armenian Churches of First Christian Ages.
  Authors: Arà Zarian, Christine Lamoureux, Armenian and English book (presentation of Patrick Donabédian also in French and Italian), Tigran Metz, Yerevan, 2018, ISBN 978-99941-0-945-6.
- Haghbat- Restauro Conservativo Dei Dipinti Murali Del Secolo X, X-Xiii Nella Chiesa Del Santo Segno, 976-991.
  Authors: Christine Lamoureux, Arà Zarian, Armenian and Italian book (presentation of Seyranoush Manoukian), Tigran Metz, Yerevan, 2019, ISBN 978-99941-0-981-4.

- Dadivanh – La Conservation-Restauration Des Peintures Murals Datées 1297 Dans L'église Kathoghike Construite En 1214.
  Authors: Arà Zarian, Christine Lamoureux, Armenian and French book (presentation of Antonia Arslan), Tigran Metz, Yerevan, 2020, ISBN 978-99941-0-945-6.

Armenia's current legislature protects and preserves architectural monuments, archaeological sites, and small forms of decorative art, such as *xačʻkʻars* [1]. Unfortunately, there are several examples of magnificent frescoes kept inside religious structures that have been substantially lost during the process of restoring architectural monuments (Tatʻev, Fig.1, Lmbatavankʻ, Fig.2, Kʻobayr, Fig.3, Mastarà, Fig.4). Despite recent interest in the conservation and restoration of wall paintings in Armenian churches, there is a negative reality to highlight that leads to the abandonment and neglect of the protection and safeguarding of traces of wall paintings and frescoes for various bureaucratic and logistical reasons. A significant illustration of this negative attitude is the chapel of the Armenian monastery of Kʻobayr, which, after many years of abandonment, when Georgian academics took action to define the monument of Georgian culture (because of the existence of several inscriptions also in Georgian), Armenia's Ministry of Education, Science, Culture and Sport has acted to launch a campaign of studies and restorations in collaboration with the Polytechnic of Milan to restore the building and wall paintings [7]. The work on restoration of the Kʻobayr chapel has been halted since 2013 because of administrative inefficiency. As a result, the incomplete double-pitched roof (1.25 m^2 of slabs missing and the tip of the pitch is 7 ml) of the chapel with a single nave has remained exposed for the last 10 years, and rainfall infiltration has greatly increased the number of wall paintings (Fig.5). Our frequent reports and numerous reminders, which have lasted four years, have led to nothing, and the precious wall paintings are being lost daily. In 2022, we presented an elaborate detailed project (also available in English) to the international scientific commission specializing in the sector of monumental art of the Ministry of Education, Science, Culture, and Sports of the Republic of Armenia for the cleaning, consolidation, and conservative restoration cycle of wall paintings in the chapel of the Kʻobayr Monastery (88 pages, with photos, drawings, analyses, and so on) (Fig.6). The Commission provided some observations and suggestions for project improvements, which we considered. In 2023, we sent the completed project with all relevant components to the Ministry in Yerevan, requesting a date for the new presentation. This response was unexpected. The communication pointed out that the double-pitch roof, which had been left unfinished for 10 years, needed to be finished first. The Commission-approved roof design was now out of date and needed updating by a professional architect (Fig.7). My application was rejected because my authorization license was considered expired. I am the author of approximately 25 restoration projects of religious buildings in Armenia, including Vorotnavankʻ Monastery, Makʻenyacʻ vank' Monastery, churches in Makaravankʻ, Dapnocʻ vankʻ, Hacʻarat, Solak Mayravankʻ, Kotʻavankʻ, Teł, and others. In 10 years, only a small part of the roof could be completed, and we now must wait another few years for them to find a designer and funding. Our proposal to design and fund the works was rejected. Due to water infiltration and the negligence of the owner, 50% of the wall paintings have been lost.

The competent authorities displayed the same indifference in the case of Haričavank, a symbolic monument of medieval Armenian architecture, where the few fragments of the depiction of Hodegetria cannot be salvaged and preserved since a small piece of the roof has not been maintained and waterproofed (Fig.8). The Ministry has said that unless the roof situation is fixed, it will be impossible to propose a project to restore wall paintings, which will disappear in the meantime. We have been requesting this minor intervention for three years, which might be done in a single day by using specific materials to waterproof the link between the gavit's roof and the Mother Church's roof (Fig.9). Although the Haričavankʻ monastery is the property of the Holy See of Eǰmiacin, our project for cleaning, consolidating and conserving the remains of the wall painting must be

[1] The RA Law on the Preservation and Use of Immovable Monuments of History and Culture and the Historical Environment, Yerevan, 1998.

presented both to the Ministry's Scientific Commission and the Holy See's Commission of Architects. The issue is that one rejects the other while we await the project's presentation (Fig.10). We proposed an intervention on our initiative to waterproof the external covering above the wall of the internal painting. We are awaiting communication to leave for Yerevan and present our proposal, for which we are willing to invest the necessary funds. We did not receive a single invitation during the entire year of 2023.

Fig. 1. *10th-century wall paintings of the main altar of the Saints Peter and Paul church in the Tatev monastery complex before and after restoration of the church*

Fig. 2. *Depicts the process of removing historical plaster from the southern dome of the Saint Stephen Protomartyr Church in Lmbatavank to clean the walls, as well as our discovery of a 7th century mystical illustration in 2024*

In the Mother Church of Art‘ik, where the dome does not exist, in 2017, a section of the fresco cycle in the main altar from the 7th century was restored (Fig.11). For the best possible conservation of the restored paintings, we asked for the construction of a small provisional cover of the K‘obayr type to be built, but it was never made. The wall paintings are now practically outside, in the open air (Fig.12).

Fig. 3. *Due to the poor restoration of the roofing of the Kobayr chapel, as well as the infiltration of rainwater throughout the decades, high-value frescoes of the 12th century were lost*

In 2019, in Hałbat Monastery, a UNESCO World Heritage Site, we restored the wall paintings in the main altars, which had significant rainfall infiltration in the southeastern part due to the leaning external gallery (Fig.13). We notified all required authorities and obtained permission to begin soil excavations and waterproofing. When the wall paintings were restored, the Archbishop and Dean of the Diocese of Gugarac‘ Sepuh Č‘ulĵyan passed away, and everything stopped. I wrote, sent letters and contacted the Holy See of Eĵmiacin, but nothing came from it. A waterproofing project was proposed by removing the soil layer for permanent intervention; however, construction work was stopped due to the solution of a temporary cover made of sheet metal taken from the Rectory fire. For the past four years, rain has infiltrated and washed away parts of paintings from the third register of the main altar of the Holy Sign church restored by us. The indifference and lack of care for this important Armenian heritage, as in the case of a *xač‘k‘ar* installed in the masonry inside a church, is considered a historical monument and therefore protected and conserved, but the mural painting on the church's wall no. After 4 years, rain still fell on the sheet metal retrieved from the rectory fire (Fig.14).

In 2017, we discovered the remains of wall paintings on the southwest corner of the church of Saint John Baptist in Mastarà. After completing the research and studies, we presented the cleaning, consolidation, and restoration project to the Armenian Ministry of Education, Science, Culture and Sport, and it was authorized and approved. While doing the cleanup operation, we discovered that after the church reopened to the faithful state in 1993, during the Soviet period, this church was adapted to a grain warehouse, and metal tools were used to eliminate the mortar lade, seriously damaging the remains of fresco fragments hidden under the mortar (Fig.15). Toward the end of the 18th century, during the occupation of Armenia by Tsarist Russia, a wooden mezzanine was built in the church of Mastarà, in the western apse, to house the choir after the church's conversion to an Orthodox rite. The fresco was damaged during the construction, and the wooden structure covered a part of the Holy Knight that we discovered. In 2017, we presented the project sketch to the Ministry of Culture to detach the staircase from the wall and complete the fresco (Fig.16). I never got a response.

In 2016, we cleaned, consolidated, and restored the fresco cycle of the Surb Astvacacin church in Karmravor (Fig.17). In 2018, at our own expense, we decided to prepare illustrative panels with photos and texts in Armenian and English, as well as explanations of the various QR code works. The panels have a metal frame and are printed on rigid PVC (Fig.18). After preparing all the panels, we rented a vehicle and took them to all the churches. In 2021, we reported that the illustrative panel in Karmravor was destroyed with the intention of obtaining metal profiles and building a plate for lighting candles hidden behind the *xač'k'ar* (Fig.19). This was because it was no longer possible to light candles in the church to protect the restored frescoes. My project included building a new external altar layout for candle lighting by the faithful, together with the reconstruction of the portico destroyed in the 1990s. An entirely free idea was never considered (Fig.20).

In 2020, we presented an elaborate project for cleaning, consolidation, and conservative restoration of wall paintings on the west wall of Axt'alà Monastery, 10th century (Fig.21). The proposal was rejected by the Republic of Armenia's Ministry of Education, Science, Culture, and Sports, justifying the need for the drum and dome to be restored first (the project has been ready for 10 years, but no financing has been found). The drum and dome collapsed in the nineteenth century and were replaced in the Soviet period with a wooden cylinder roof to protect the interior from bad weather and rain. The frescoes on the internal walls of the Cathedral are protected from infiltration, and there is no impediment to their restoration.

Between 2015 and 2017, we conducted research, analysis, and

Fig. 4. *Damaged parts of the 7th century frescoes on the walls of St. John Baptist Church in Mastara, caused by Soviet plastering and its removal in the 1990s*

surveys and presented a project for the cleaning, consolidation, and conservative restoration of two mural paintings in the Katʻołikè church of the Armenian Monastery of Dadivankʻ in Arcʻax, dating from the 9th to the 18th centuries, commissioned by the Ministry for the Protection of Monumental Heritage and Tourism Development of the Republic of Mountain Karabax. The two frescoes from 1297 represent the following scenes: on the north wall, "The stoning of Saint Stephen Protomartyr" (Fig.22), and on the south wall, "The Granting of Patriarchal powers to Saint Nicholas the Wonderworker" (Fig.23). After the second war in Karabax and before the handover of the Armenian Monastery of Dadivank to the Azeris in 2020, the Armenian authorities decided to remove the frescoes to avoid vandalism by the occupiers (Fig.24). The Armenian operators initially canceled all our restoration work from 2014 to 2017 and then removed the frescoes, damaging them (Fig.25). Our requests to see the wall painting fragments removed from Dadivank were refused and never accepted. We intend to collaborate to restore wall paintings and display them to the public. We hope that the opportunity to achieve this goal will be created.

Fig. 5. *The bad condition of the Kobayr chapel's roof*

Fig. 6. *Ara Zarian and Christine Lamoureux's 2021 project to clean, repair, and conserve the frescoes of the Kobayr chapel, waiting for the gable roofs to be restored*

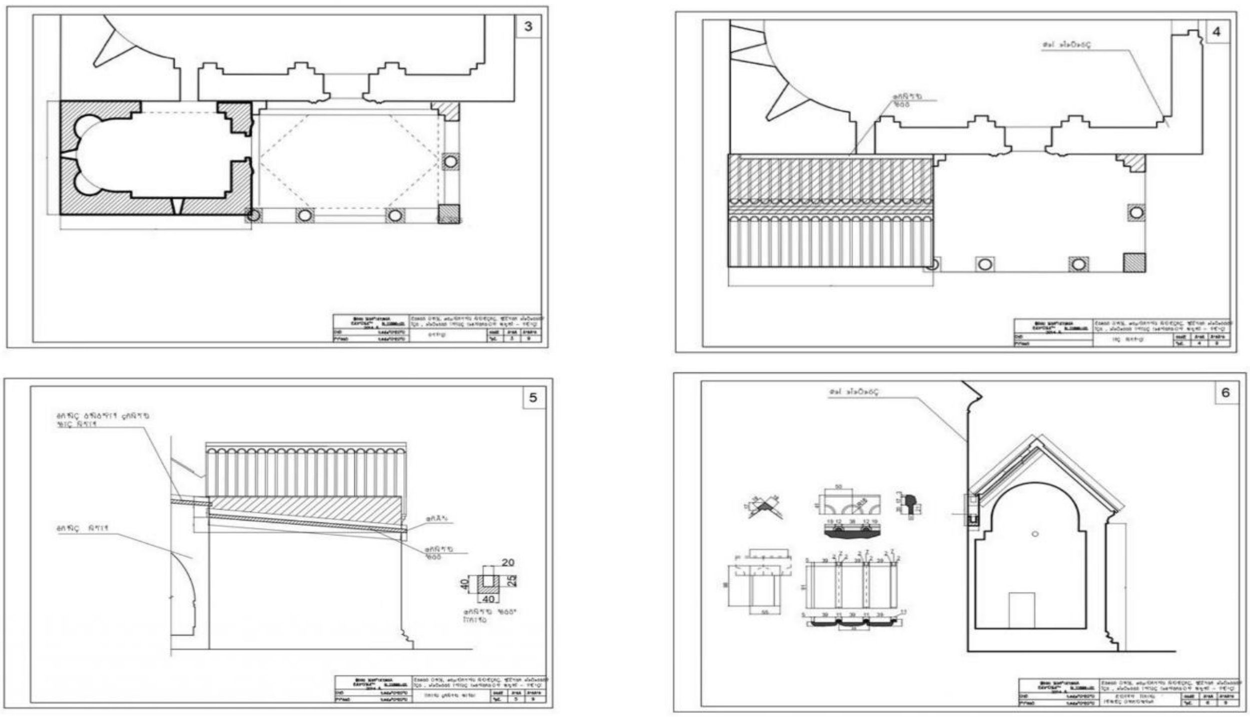

Fig. 7. *Architect Gor Mikayelyan's restoration project for the Kobayr chapel roofs was proposed in the 1990s but never implemented*

Fig. 8. *Fragments of a mural painting dated 1235 were found on the upper part of the entryway to Holy Mother of God Church from the Harich Monastery*

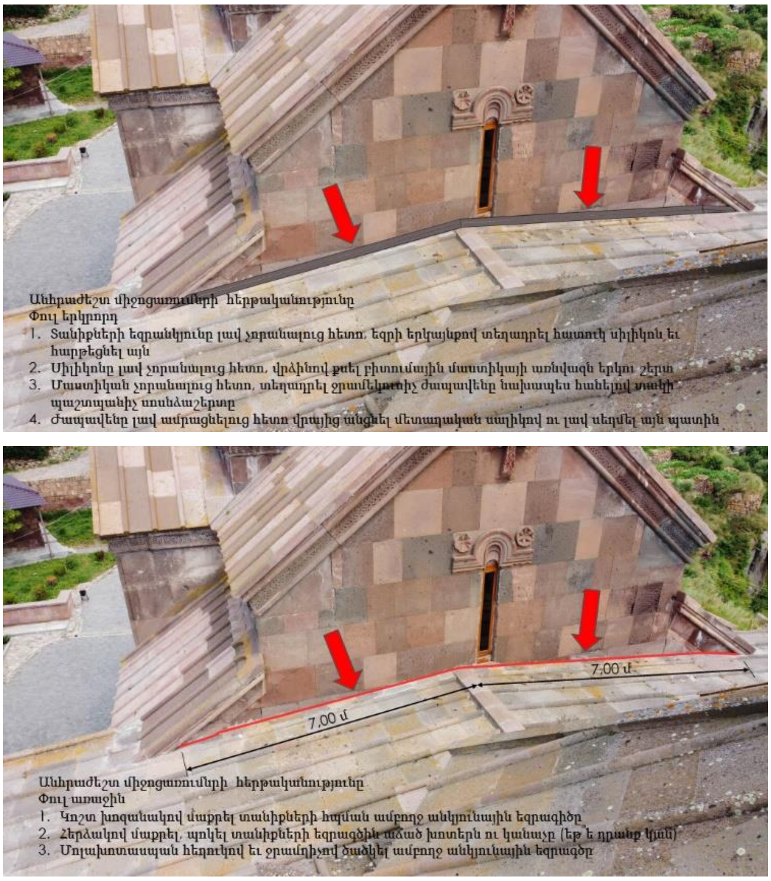

Fig. 9. *Architect Ara Zarian's proposal for waterproofing the gable roof of Harichavank courtyard in 2021 is awaiting approval from the Mother See of Holy Etchmiadzin*

Wall paintings in Armenian churches are historical monuments that must be preserved and are an inseparable part of the monumental architectural heritage of each existing church.

Results and Discussion

Between 2012 and 2019, the wall paintings in the Armenian churches underwent conservative restoration, consolidation, and cleaning. The authors also mentioned the results of the absence of local professionals with fresco restoration experience and knowledge, as well as the lack of interest from the authorities and the lack of expertise. The materials, techniques, and procedures used for the interventions on the wall paintings in the churches of Artzakh and Armenia are the same as those used during the restoration of frescoes in churches in the Veneto region in Italy. Over the

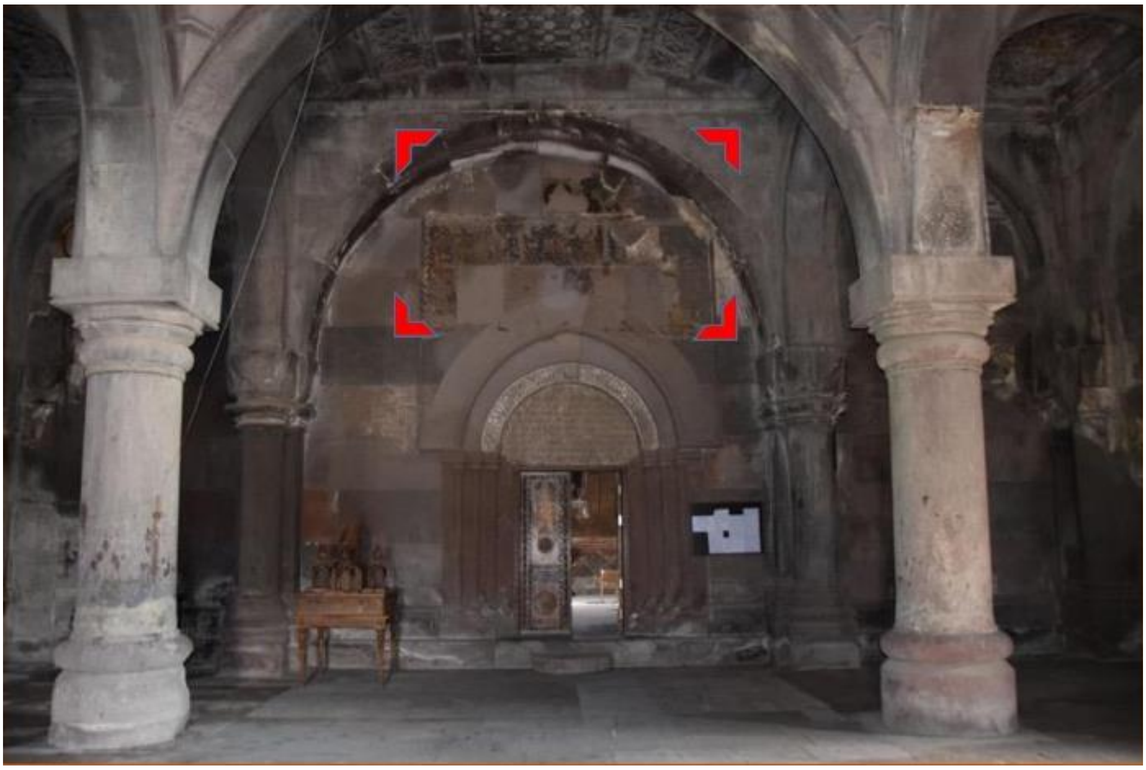

Fig. 10. *Ara Zarian and Christine Lamoureux's project to clean, maintain, and restore the Harichavank frescoes, approved by the RA Ministry of Education, Science, Culture, and Sport in 2024, is now awaiting approval from the Mother See of Holy Etchmiadzin*

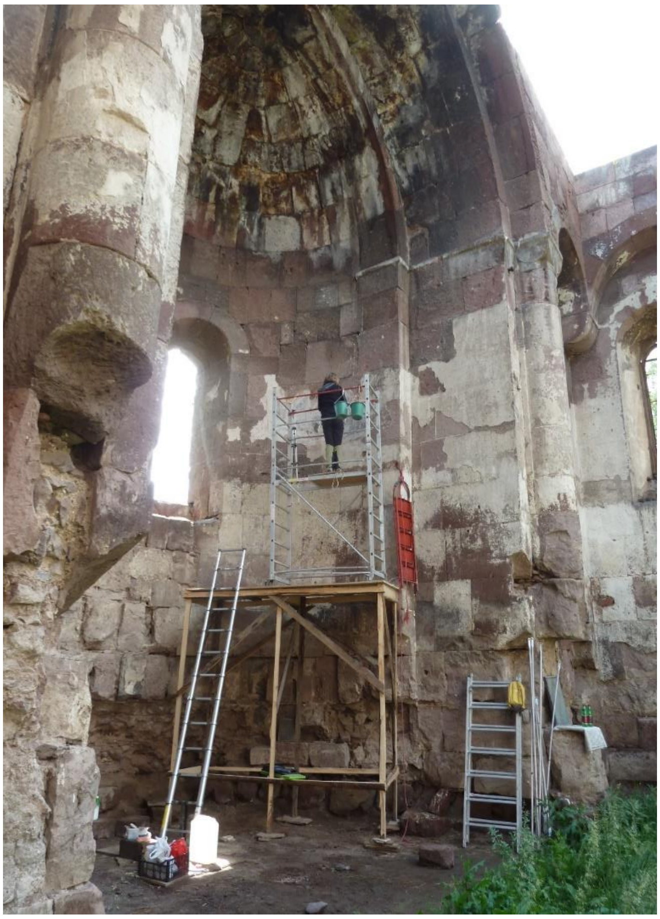

Fig. 11. *The restoration of a section of the 7th-century fresco preserved on the south wall of the main altar at St. George Cathedral in Artik*

course of a professional career spanning approximately 35 years, they restored approximately one hundred frescoes after being hired and approved by religious organizations as well as the province of Veneto's Superintendence for Heritage Cultural Institutions. The technologies, materials, and applications that the Minister of Culture, Science, Education, and Sports of the Republic of Armenia sought during the 2022 session of the International Scientific Commission are clearly visible across this time frame. These insights were considered and used to make changes and improvements to the restoration and conservation projects that would be presented shortly.

Discussions about the usage of novel nanotechnology materials, which have yet to be tested but are commercially marketed by the companies that create them, require time, which is insufficient. It was determined to employ traditional approved and proven materials, which have demonstrated great effectiveness and long-term durability, with at least 30 years of evidence of nontolerance to environmental changes. In any case, we decided to use next-generation materials for future work in Armenian churches.

Fig. 12. *The same mural after restoration in 2016*

Fig. 13. *A general view of the Haghbat monastery complex from the southeast*

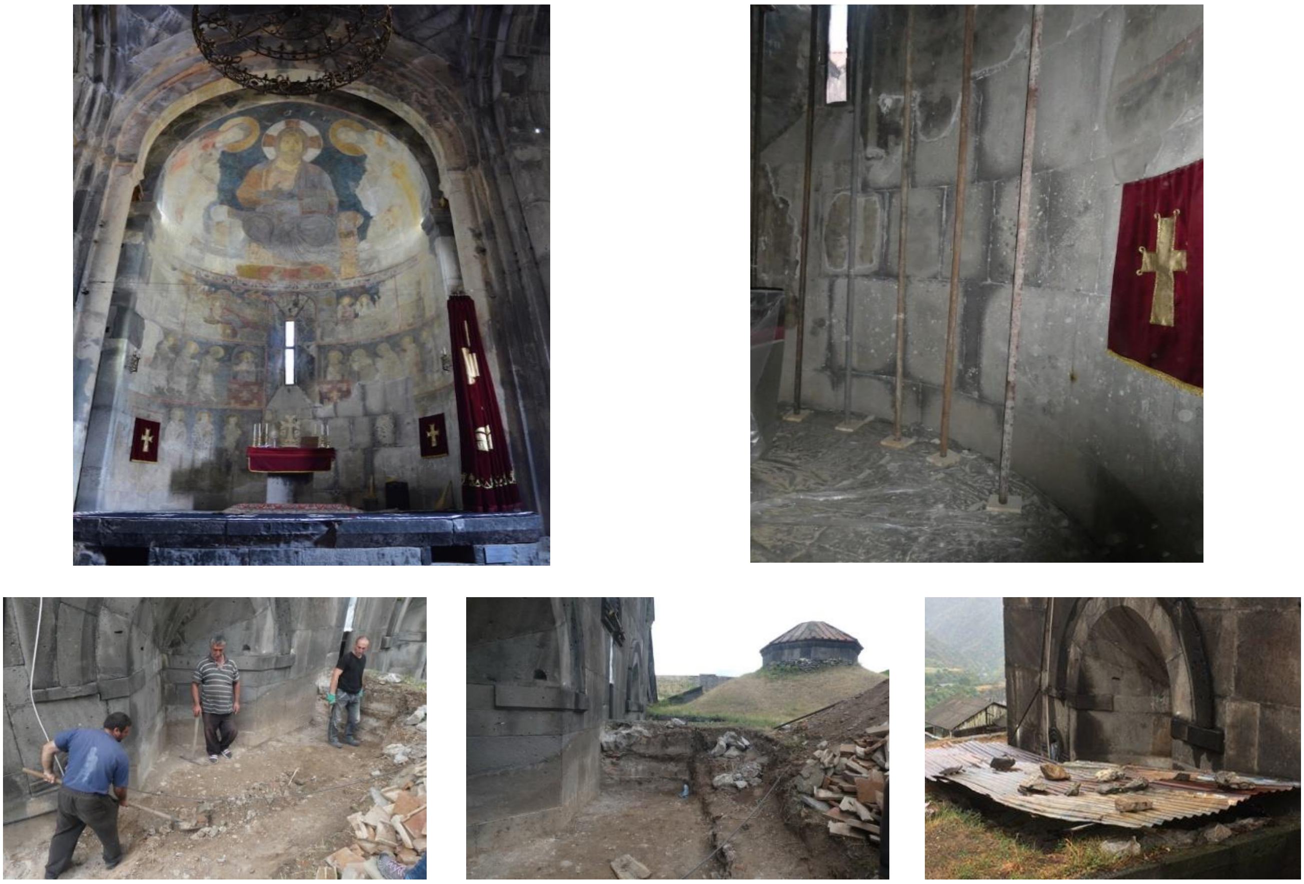

Fig. 14. *The damages caused by humidity to the wall of the mural painting restored by Ara Zaryan and Christine Lamoureux in 2019 of the main altars of the Holy Sign Church of the Haghbat Monastery complex, as well as the necessary measures and the unfinished status as of today*

Fig. 15. *An example of the brutal destruction of the fresco remnants discovered in 2015 by Ara Zaryan and Christine Lamour of St. John Baptist Church in Mastara*

Fig. 16. *The fragments of a fresco from the 7th-century can be found on the church's southern wall beneath the wooden wheels of an 18th-century lodge. Ara Zarian and Christine Lamoureux restored the wall painting in 2016*

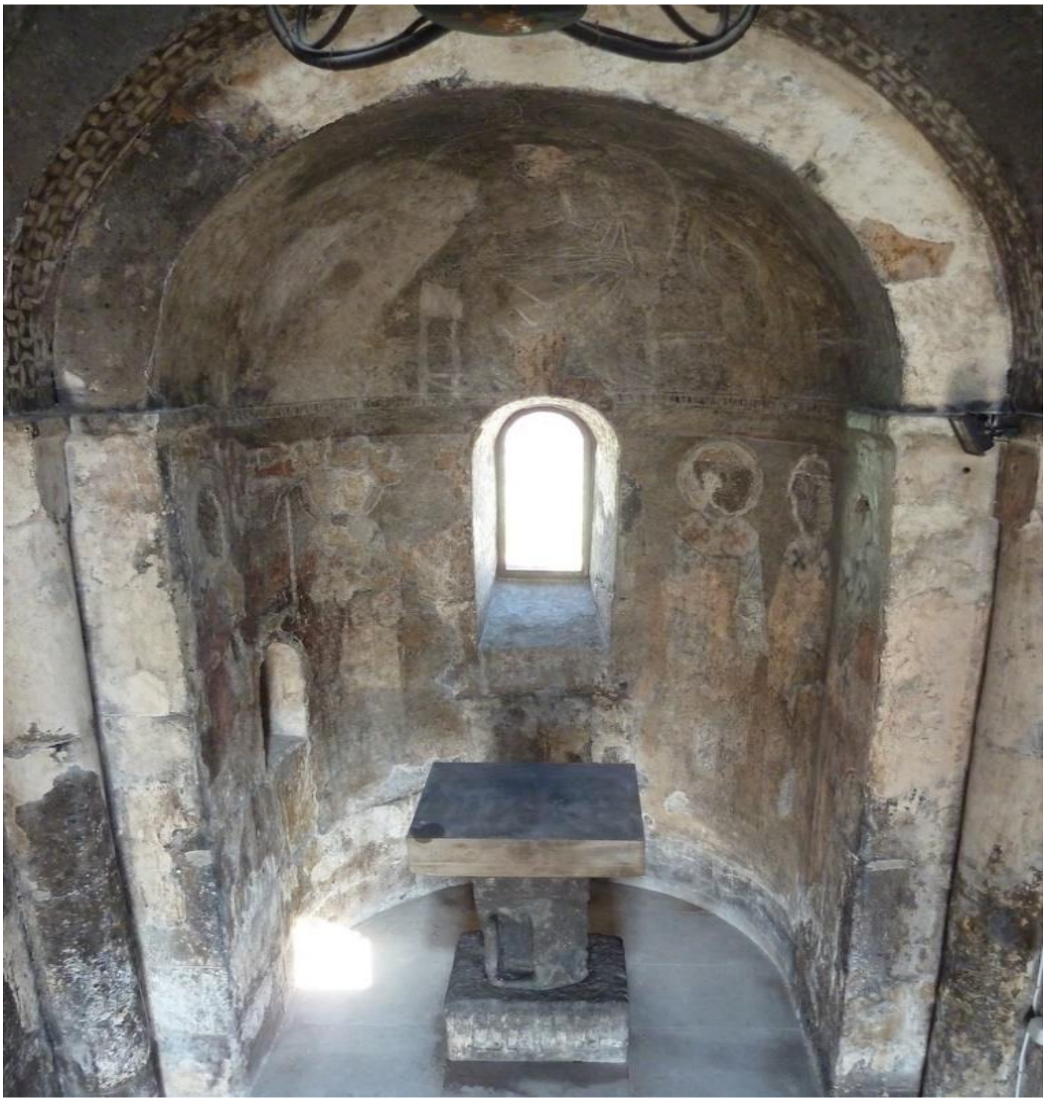

Fig. 17. *After completing the works of cleaning, fixing, and conservation restoration of the frescoes on the main altar of St. Holy Mother of God Church of Karmravor in 2016*

Conclusion

Fig. 18. *The process of preparing bilingual explanatory panels near the frescoes restored by us*

1. In Armenia there is no complete inventory of church wall painting fragments and scenes.
2. Without any knowledge of the monumental heritage, it is impossible to improve and legalize cultural heritage.
3. In Armenia there is no school of wall painting restoration and the few specialists who study, conserve, and restore wall paintings are often criticized.
4. Based on the examples presented above, it can be concluded that political and religious authorities do not pay adequate attention to the protection of pictorial heritage in Armenian churches due to a lack of professional training in the field.
5. We propose a rethink and thorough study to maintain what little survives of the beautiful wall paintings in Armenian churches.
6. We offer our expertise in creating a thorough catalog of all wall paintings in Armenian churches funded by the government or benefactors.

Fig. 19. *2022, after destroying the Crimson's explanatory panel and building a pool of candlelight from its metal rods*

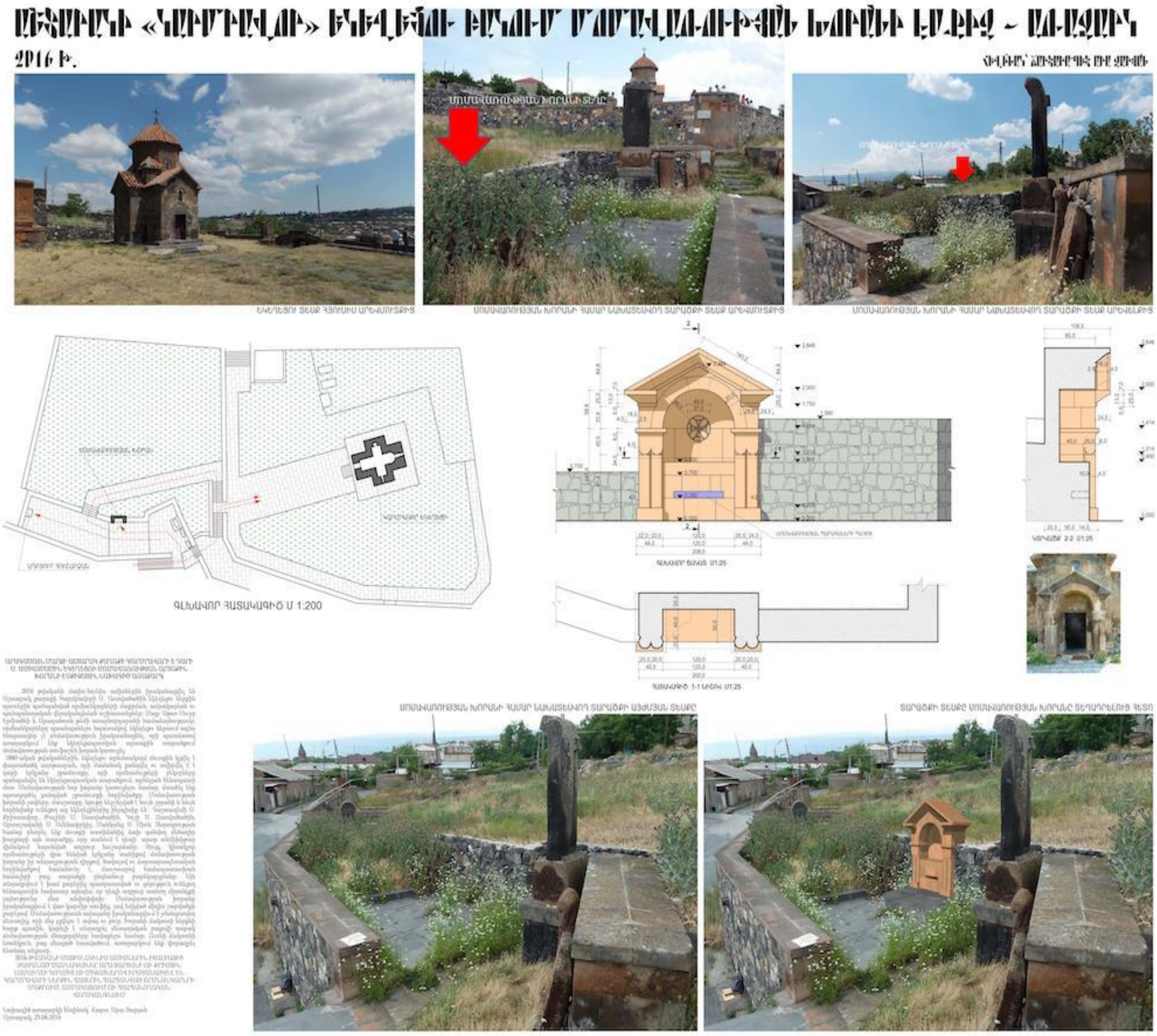

Fig. 20. *After restoring Karmravor's murals, architect Ara Zarian proposed the unrealized candlelight altar project*

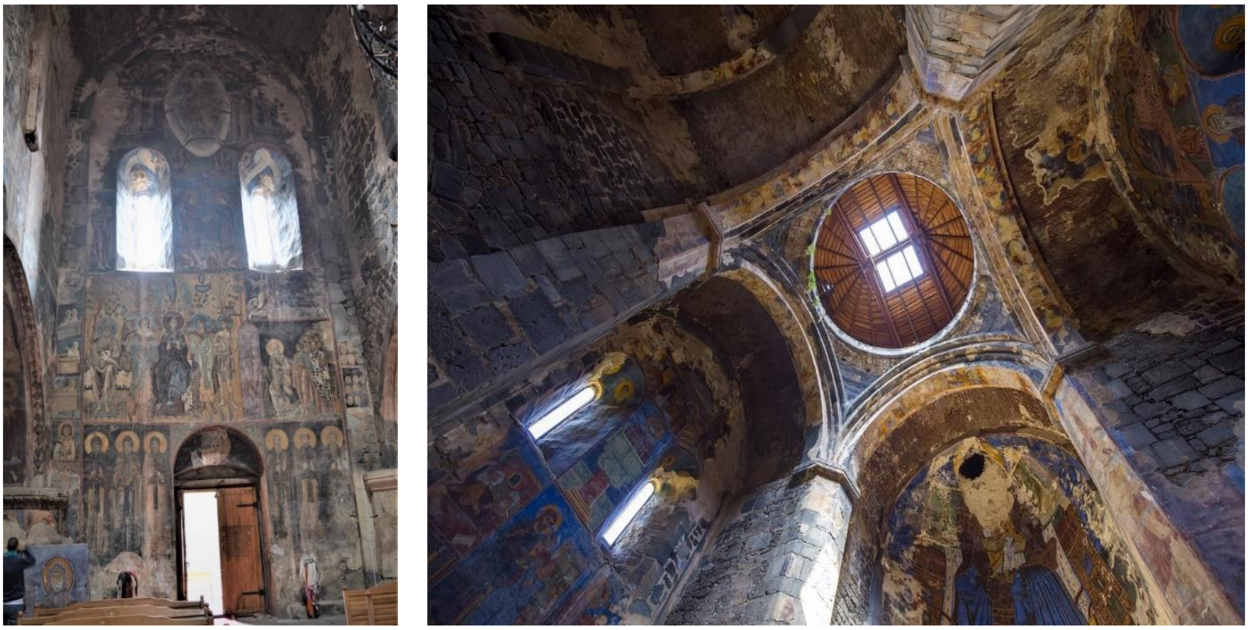

Fig. 21. *The interior walls of St. Holy Mother of God Church at Akhtala Monastery are completely frescoed, dating from the XII-XIII centuries*

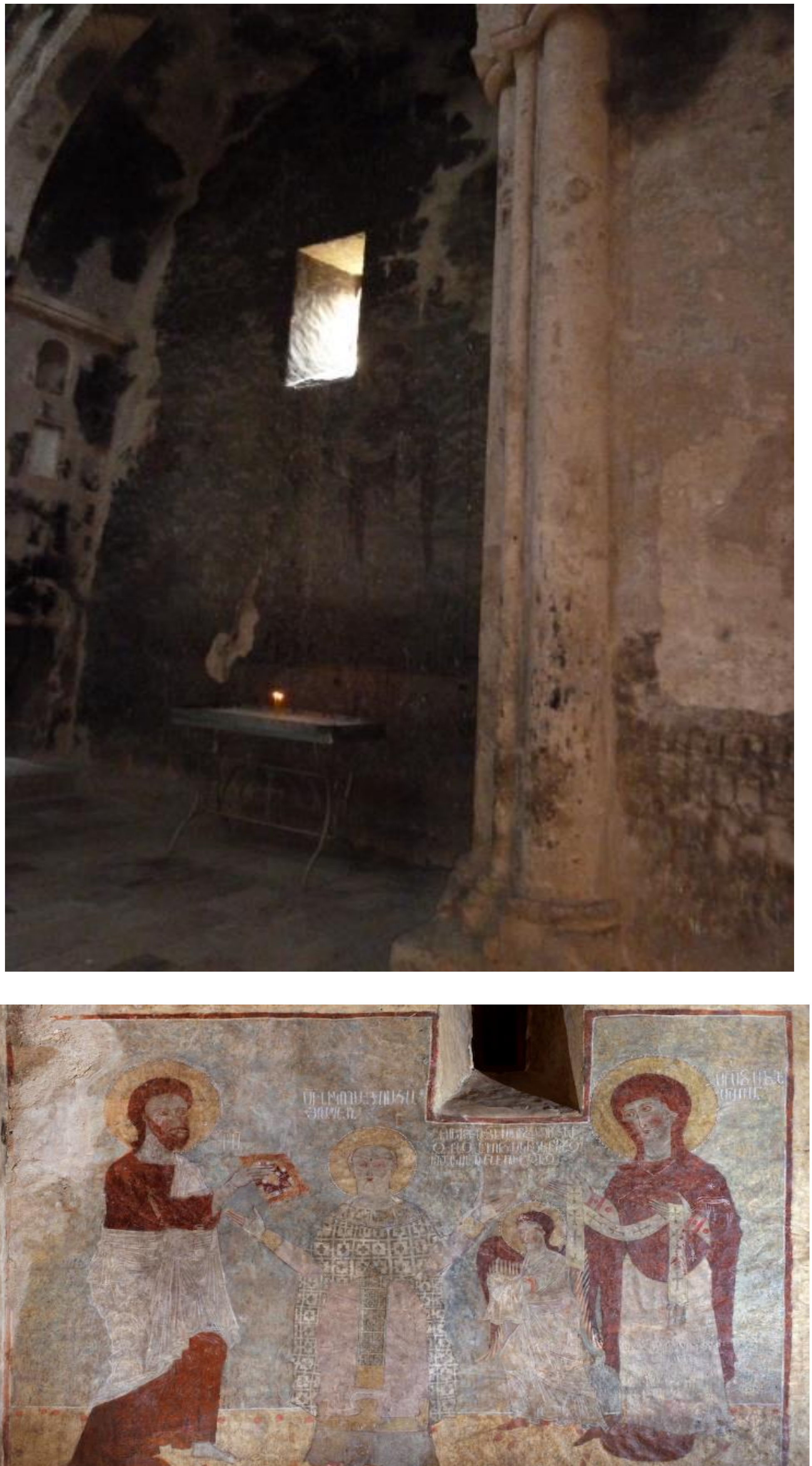

Fig. 22. *Before and after restoration of the 1297 mural on the south wall of the Cathoghike Church of St. Holy Mother of God in Dadivank Monastery by Ara Zarian and Christine Lamoureux from 2015 to 2017*

Fig. 23. *Before and after restoration of the 1297 mural on the northen wall of the Cathoghike Church of St. Holy Mother of God in Dadivank Monastery by Ara Zarian and Christine Lamoureux*

Fig. 24. *2022, after demolishing the mural on the northern wall of the Cathoghike Church of St. Holy Mother of God*

Fig. 25. *Dadivank Monastery Cathoghike St. Holy Mother of God Church, the mural is being removed from the wall for the safety of it*

Conflict of Interest

The author declares no conflicts of interest.

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AGHVANK ARCHITECTURE IN SCIENTIFIC LITERATURE

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Abstract: *In recent decades, articles on Aghvank architecture have been published in scientific literature, showcasing notable differences from materials published before the 1970s. These newer publications present conflicting results and conclusions, reflecting diverse scientific approaches. As a result, the Azerbaijani scientific community portrays the entire Christian culture of Artsakh, particularly its architecture, as a component of the Aghvan heritage. This paper comprehensively reviews existing scientific materials on Aghvank architecture, spanning publications from both the Soviet and post-Soviet eras, as well as compares the articles authored by Azerbaijani scholars with those that have been written in foreign languages and published in periodicals. After conducting research, it is evident that Azerbaijani historians have increasingly attempted to claim the Christian culture and architecture of Artsakh as their own over the past 40 years. This has led to a loss of objectivity and scientific approach towards existing materials and methods. The study aimed to show the dynamics of the "scientific study" of Azerbaijani architecture, the editing of the "new history" of the medieval culture and architecture of Aghvank in the Caucasus in recent decades, to highlight the main contradictions evident in the results of research by Azerbaijani and foreign scientists. Today, in the context of the occupation of the entire territory of Artsakh and its architectural heritage, such a discovery is becoming increasingly important.*

Keywords: *Artsakh, Bun Aghvank, Aghvank architecture, Sudagilan, Mamrukh, Nyugdi.*

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Introduction

Currently, Azerbaijan has militarily occupied the entire territory of Nagorno-Karabakh, which historically belonged to Artsakh, forcibly displacing the Armenian population that has resided in Artsakh for centuries. It is noteworthy that, until the 1920s, there was no mention of a nationality known as Azerbaijan among the people of the Caucasus [1]. Azerbaijan now faces the significant challenge of crafting a "history" to justify all its actions against the Artsakh population. Under these conditions, it is vital to consider how the existing architecture in Azerbaijan was presented from the beginning of the 20th century to the present day. The works of Russian and Soviet historian, archeologist, and Caucasologist I.P. Sheblikin [2], Soviet art critic, researcher of Near and Middle East architecture L.S. Britanitsky, and Soviet art historian, orientalist, and academician B.V. Weimarn [3] on Azerbaijan's medieval architecture, which were published until the 1970s, were examined.

Special attention was paid to the works of Azerbaijani scientists Mikael Huseinov, Sadikh Dadashev [4-6], Vagab Salamzadeh, and Kamil Mamedzadeh [6], which were published *pre-1970s and post-1970s*, comparing the content and methodological changes that developed in the last few years.

Russian archaeologist, ethnographer, and anthropologist Viktor Shnirelman and American scientist, Caucasologist, specialist in Armenian and Caucasian Aghvan history Robert Huysen also referred to Aghvan architecture and culture in the territory of Azerbaijan. And, certainly, the studies of the Russian archaeologist, art critic, and historian Anatoly Jacobson on the Armenian architecture of Artsakh are vital.

This study compares the aforementioned works from recent years with the studies conducted by non-Azerbaijani scientists during the same period, highlighting the modernity and novelty of this research.

This article aims to uncover the falsehoods which the scientific community of Azerbaijan–consistently attempts to present as new scientific findings and discoveries to the world under the state's patronage and in strict accordance with the prescribed task. Now, it becomes more problematic when the scientific world of Azerbaijan, deprived of healthy scientific criticism, is seeking to justify its persistent occupation policy toward Armenians, Armenia, and Artsakh. This issue is particularly pressing today, especially considering that the cultural heritage crafted by the Armenians remains entirely unprotected in Artsakh and is in a highly endangered condition in Syunik.

Materials and Methods

The Azerbaijani scientific community now portrays Aghvank architecture, especially cult architecture, as an inherent component of Azerbaijani architecture. Consequently, to provide a comprehensive overview of studies on Aghvank architecture, the scientific literature on Azerbaijani architecture was examined and analyzed.

The analysis of scientific studies and publications, depending on the period and the authors, was chosen as a method for the research. Two main stages were considered for comparison. The first stage includes publications from the 40s to the 70s of the XX century. The second stage comprises publications from the period of political independence and free scientific activity in Azerbaijan, which covers the period from the 70s to the present day.

Results and Discussion

Caucasologist Ivan Sheblikin conducted the first scientific study on Azerbaijan's history, culture, and architecture [2]. This study presents descriptions of Azerbaijan's main architectural monuments in the XI–XIV centuries and provides a brief overview of the architecture preceding that period. The work describes numerous monuments: castles, palaces, tombs, and palace structures, which were documented and studied in the 1930s. There is not even a hint of a Christian structure here. The latter are not considered structures and monuments of Azerbaijani architecture. Moreover, nothing is said about the medieval monasteries and churches of Aghvank.

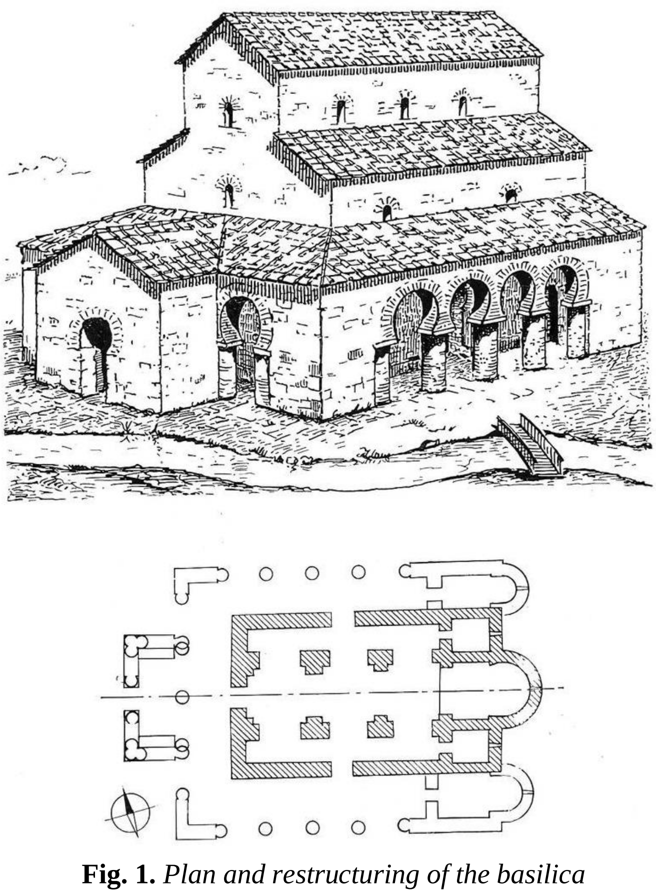

Fig. 1. *Plan and restructuring of the basilica temple near Kum village*

The second significant work on architecture within the territory of Azerbaijan was published in 1947, under the editorship of S.A. Dadashev and M.A. Huseinov [4]. The first part of the book focuses on the period predating the 11th century. Authored articles include "The Architecture of Azerbaijan until the 5th Century BC" by N. Gorchakova, K. Mel, and P. Sheblikin; "Monuments of the Kum and Lekit Settlements" by P. Baranovsky; and "8^{th}-11^{th} Century Monuments" by P. Sheblikin. Of particular significance in the book is Baranovsky's article, which presents, for the first time, the early Christian basilica temple of Kum village on the left bank of the Kur river in the Kakh region of Azerbaijan (Figs. 1,2), as well as the round temple of Lekit village in the same region (Fig. 3) [4].

Fig. 2. *Kum, general view of the basilica from the southwest and outer colonnade*[1]

In 1948, the Academy of Architecture of the USSR released a book titled "Architecture of Azerbaijan" [5,6], under the authority of S.A. Dadashev and M.A. Huseinov. Here, Aghvank is mentioned only in the introduction, in two sentences: "In the Roman era, the state that occupied the territory of Azerbaijan was called Albania. There is a mention of the Albanian cities in Ptolemy (first half of the 2nd century)" [4].

Russian historian and orientalist Kamilla Trever studied the history and culture of Aghvank. Her work "Outlines of the History and Culture of Caucasian Albania, IV century BC - VII century AD" was the first generalizing work dedicated to the issues of the history, socioeconomic relations, and material culture of Aghvank. In the section concerning the architecture of Aghvank [7], the monuments of Kum and Lekit villages are discussed, citing the results of Baranovsky's studies. The ruins of the early medieval church and adjacent buildings discovered by R.M. Vaidov during the excavations of Sudagilan in 1949 near Mingechaur, on the city's left bank (Fig.4) [8], are only briefly touched upon in the discussion. Nevertheless, the broken stone inscriptions in the church ruins [9] allows to date it to the 7th century [10].

The literature also mentions the chapel built near the village of Nyugdi in the Derbent region of Dagestan at the place of martyrdom of St. Grigoris, where St. Grigoris Church is located [11].

In 1968, the book "Architecture of Azerbaijan XVI-XIX centuries" was published by the publishing house of the Academy of Sciences of the Azerbaijan SSR, authored by A.V. Salamzade and edited by M.A. Huseinov. The first chapter of the book delves into cult structures, where not a single word is mentioned about Christian cult structures, particularly Aghvanic and, as is often presented now, Udi cult structures [12].

[1] https://commons.wikimedia.org/w/index.php?curid=109991412

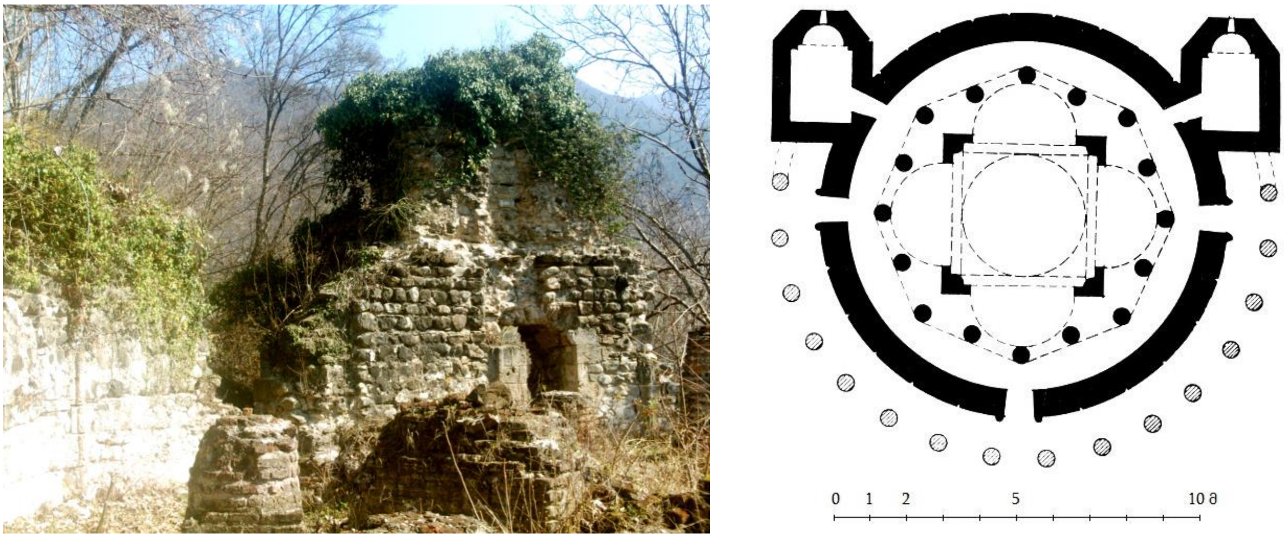

Fig. 3. *General view and plan of the ruins of the Round Temple in Lekit village*[2]

From 1966 to 1977, the Civil Construction and Architecture Committee under the USSR's Ministry of Construction, in collaboration with the Research Institute of Theory, History, and Prospective Problems of Soviet Architecture, released the 12-volume "History of World Architecture." This monumental work is the most extensive and authoritative publication of the professional literature in this field [13]. The architecture of Azerbaijan is presented in the 6th chapter of the 8th volume [14]. The first sub-chapter is about the architecture of Azerbaijan in the IV-VII centuries [11]. "Monuments of Christian religious construction are the nearby basilica in Kum village and the round temple in Lekit village" [14]. The text describes the basilica of Kum village and the rotund temple of Lekit village in great detail. It also mentions the relationship between these structures and the similar religious structures of the same period in Armenia, Georgia, Syria, and Byzantine. None of the following chapters discuss Christian architectural structures as a part of Aghvani or Azeri architecture.

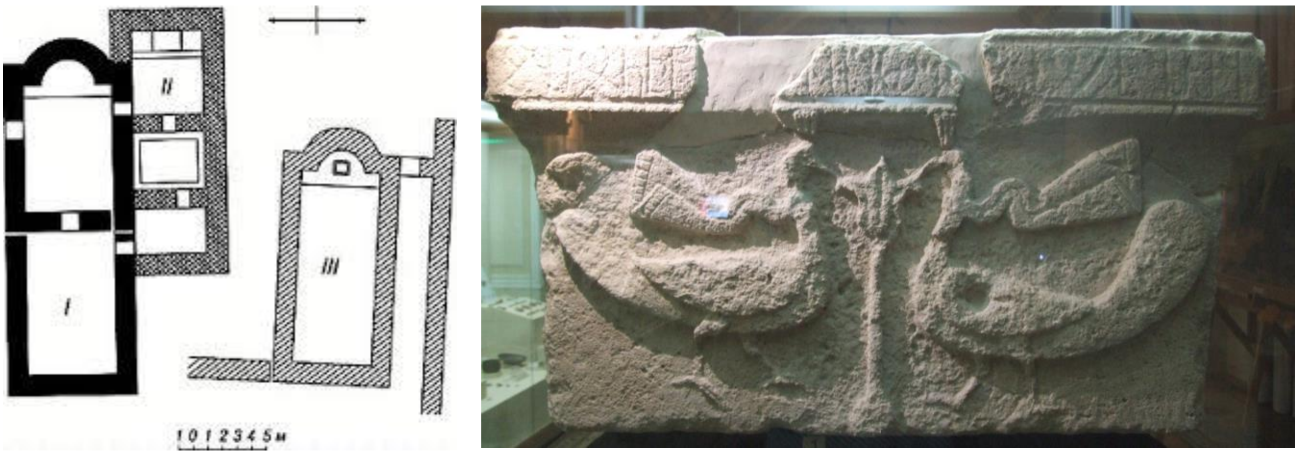

Fig. 4. *Plan of the foundations of the Sudagilan church complex*
(I-VII-IX centuries, II-VIII-IX centuries, III-V-VI centuries) and headstone

R.B. Geushev, a scholar from Azerbaijan who has studied the history of Aghvank, argues that the Gandzasar monastery is not Armenian but Aghvanic [15]. In 1978, Geushev defended his doctoral thesis in Tbilisi, titled "Christianity in Caucasian Albania," and subsequently published it [16]. The scientific novelty of the topic is: "The scientific novelty of the work lies in the fact that, to the best of the available capabilities, for the first time in a monographic plan a relatively complete history and history of the material culture of Christianity in Caucasian Albania is given as a natural part of the Azerbaijani people history" [16]. Here, the

[2] https://xn--h1ajim.xn--p1ai/index.php?curid=16909099

first attempt is made to own the monastic monasteries of Artsakh and Utik, declaring them aghvanic, regardless of the period and region. "The map of the distribution of monastic buildings in Azerbaijan shows that almost all bishoprics had several monasteries. Albanian monasteries were also built outside Albania" [16].

In the following years, Azerbaijani scientific thought exhausted its studies into the history and theory of Aghvank architecture itself and set a task to present the culture, architectural structures, and monuments on the right side of the Kur River as Aghvanic.

Soviet orientalist Zia Buniatov played an important role in this issue, providing the historical basis for the privatization of Armenian religious structures. The primary focus of the scientific debate has shifted from the reliability of scientific evidence and research to plagiarism and deliberate mistranslation of literary sources.

Soviet and Russian archaeologist and ethnographer Victor Schlimerman has deeply studied the Armenian-Azerbaijani conflict with its cultural and political issues. Speaking about the activity of Azerbaijani scientists, led by Z. Buniatov, distortions of historical materials and sources, he notes: "Another way to downplay the presence of Armenians in ancient and medieval Transcaucasia and belittle their role is to republish ancient and medieval sources with notes, replacing the term "Armenian state" with "Albanian state" or other distortions of the original texts. During the period of the 1960s-1990s, numerous reprints of primary sources were published in Baku, which academician Z. M. Buniyatov was actively involved in.

However, in recent years, when discussing ethnic processes and their role in the history of Azerbaijan, Azerbaijani authors sometimes generally avoid discussing the appearance of the Azerbaijani language and Azerbaijanis there, leading the reader to believe that they have existed there from time immemorial. Hardly Azerbaijani historians did this solely out of their own free will; they were likely influenced by the orders of the party and government structures of Azerbaijan" [17].

Soviet archeologist, art and architecture history researcher A.L. Yakobson has published many articles and works on Armenian architecture and, in particular, Gandzasar Monastery [18]. Speaking about the Gandzasar monastery, he mentions its belonging to the Armenian architectural school and strongly criticizes its Albanianization. "It is not clear why the authors needed to distort the semantic and artistic content and origin of the Armenian medieval decorative art, easily and mindlessly "connecting" it either to the art of Albania, which did not exist at that time (and in the authors' understanding, to the art of Azerbaijan), or directly to the art of Azerbaijan. Our summary is short. It is with regret that we have to admit that the article by D. A. and M. D. Akhundov is biased in its meaning and spirit. This kind of article, in our opinion, can only disorient the reader" [19].

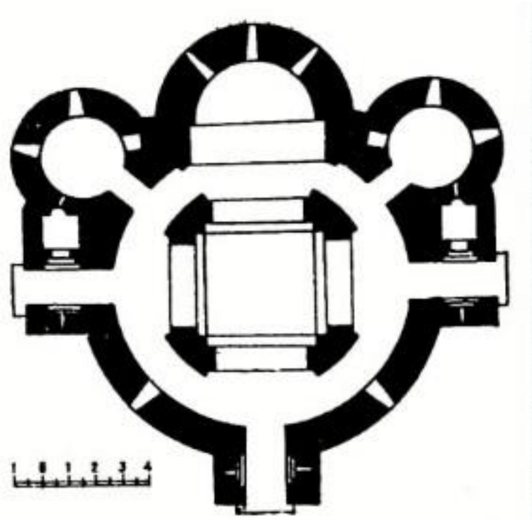

Fig. 5. *A medivial Christian round church near the village of Mamrukh in the Zakatala region of Azerbaijian*

Azerbaijani scientist G.S. Mammadova defended her doctoral thesis on the topic "Cultural Architecture of Caucasian Albania" [20] and, in 2004, published the monograph "Architecture of Caucasian Albania" with an additional edition [21]. In her research, the author also describes the round church near the village of Mamrukh (Fig. 5), expanding the influences that the Aghvanian, namely Azeri architecture left on the neighboring countries. The third chapter of the book talks about the Aghvank architecture of the 8th-10th centuries. Here, the author separates the architectural style of the Syunik school from the Armenian school and associates it with the influence of Aghvank. "However, the architecture of Caucasian Albania cannot be complete without religious structures on the territory of neighboring countries in areas historically associated with Caucasian Albania. In Syunik, roofing slabs replaced tiles earlier than in other areas. The trumpet arch was preserved here for a long time as the most effective design for changing from the base square to the drum. These and other features distinguish the architecture of Syunik from the Armenian one" [21]. The author unequivocally classifies the monastic complexes and religious structures of all later centuries, including Gandzasar, Khutavank, Amaras, Dadivank, and other monasteries, to the "Aghvanic" school of architecture, accusing Jacobson of partiality and unprofessionalism [21].

In these years, another thesis has been defended with similar topicality and goals. Candidate of architecture A.T. Salimova in 1998 defended a thesis titled "The creative roots of the Emergence of the cult ritual architecture of Caucasian Albania". From 1993 to 1996, she participated in several conferences and published articles on the aforementioned topic in Baku (Fig. 6) [22].

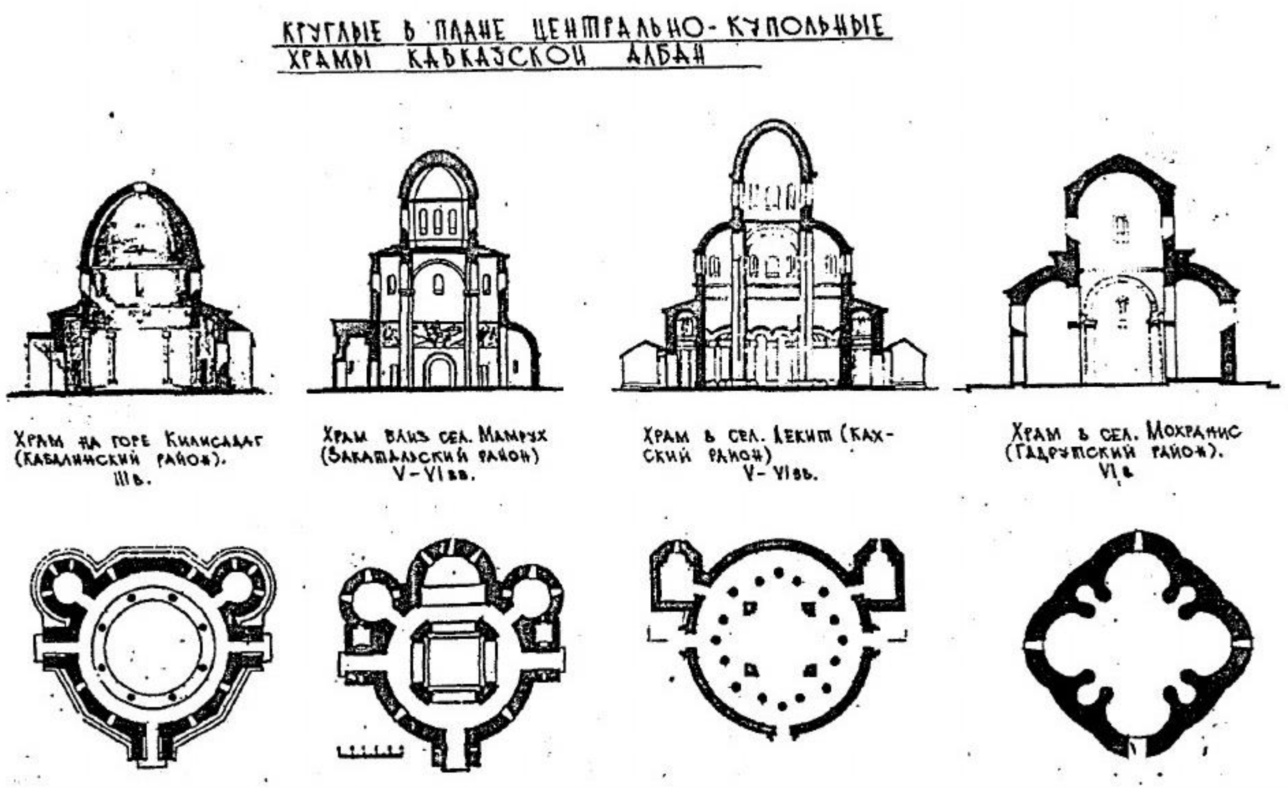

Fig. 6. *A list of all churches from A. Salimova's thesis, where the church of Mokhrenes village of Dizaki, which is clearly different from the first three churches, is presented as an aghvanic*

Azerbaijani historian, doctor of historical sciences, and professor F. Mamedova is also one of the researchers of the history and culture of Aghvank in the Caucasus. In 1986 her monograph "Political History and Historical Geography of Caucasian Albania" was published [23], which was strongly criticized both by scientific experts [24] and Azerbaijani scientists. Shnirelman considers her the main propagator of the "Albanian myth" [17], and Azerbaijanis, in the person of Yaghub Makhmudov, director of the History Institute of the National Academy of Sciences of Azerbaijan, consider her a "traitor to the fatherland" and "Armenian spy" for including Great Haik on the "Aghvank and neighboring countries" map[3].

Mamedova herself states that Heydar Aliyev personally demanded from F. Mamedova that every book published by Armenians be subject to scientific criticism[4].

[3] Albania or Atropatena? How they “compose” the ancient history of the Caucasus Archival copy dated January 6, 2014, on the Wayback Machine. "Echo" (Baku), No. 76 (1316), April 29, 2006.

[4] "Echo" newspaper, No. 76 (1316), April 29, 2006: "Armenians published 15-19 books a year, and Heydar Aliyev demanded scientific criticism for each book. So I began to untie the Armenian knot. One map is considered 4 years of work by a scientist. And I have 7 such maps. I thought that I would be praised for these maps but it turned out to be the opposite... ".

In 2005, her book "Caucasian Albania and the Albanians" was published, in which Mammadova albanianizes not only Eastern Armenia but also Kilikia, its people, kings, clergy, their spiritual culture, literature, jurisprudence, and material values [25].

The modern American scientist, Caucasologist Robert Huysen, also studied the history of Armenia and Caucasian Aghvank [26]. Speaking of the theory of literature related to the topic, he notes the unreliability of many historical publications from the Soviet period. «Scholars should be on guard when using Soviet and post-Soviet Azeri editions of Azeri, Persian, and even Russian and Western European sources printed in Baku. These have been edited to remove references to Armenian and have been distributed in large numbers in recent years. When utilizing such sources, the researchers should seek out pre-Soviet editions wherever possible». Unfortunately, Azerbaijan behaves barbarically with the cultural values that cannot be owned, such as cross-stones. The Azerbaijani government has not yet found a way to take possession of them (Figs. 7,8)[5].

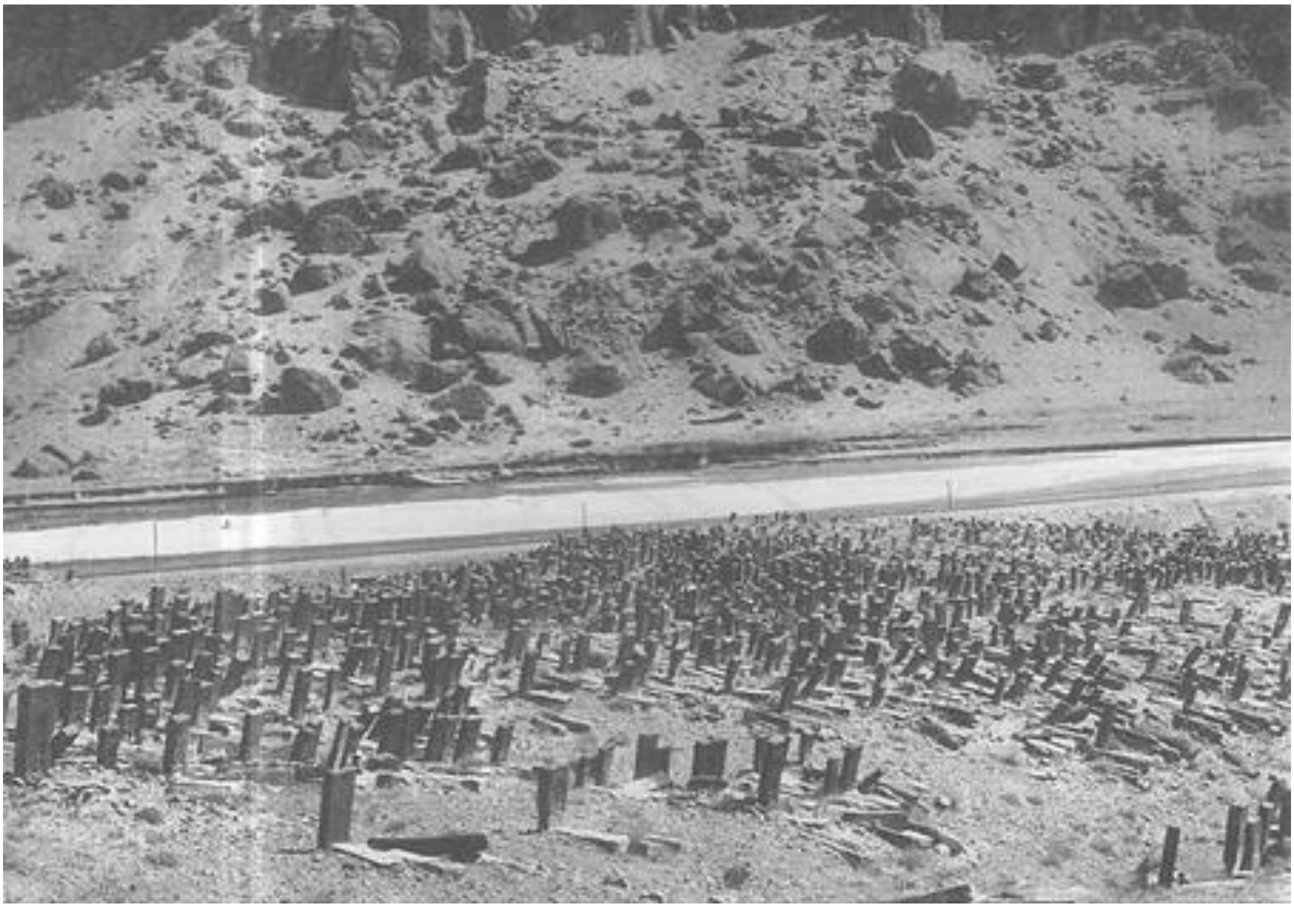

Fig. 7. *Jugha cemetery before destruction*

Fig. 8. *Satellite images of the cemetery taken on 23.09.2003 and 28.05.2009. The shadows from the cross-stones are no longer visible*

[5] High-Resolution Satellite Imagery and the Destruction of Cultural Artifacts in Nakhchivan, Azerbaijan https://www.aaas.org/resources/high-resolution-satellite-imagery-and-destruction-cultural-artifacts-nakhchivan-azerbaijan

Conclusion

Research on the culture and architecture of Aghvank remains a subject of great interest, with different points of view being expressed in various scientific studies. In this article, we reviewed and compared studies carried out mainly by Soviet scientists before the 1970s with the articles written after that period. Our analysis showed that:

1. It should be noted that in the materials published before the 1970s, the architecture of Aghvank was only represented by early Christian monuments that were found on the left bank of the Kur River in Aghvank itself. As a result, it was not considered a part of Azerbaijani architecture. These articles were written by both Azerbaijani and Russian scientists.
2. In the 70s of the 20th century, a new wave began when Azerbaijani authors not only included the entire culture and architecture of Artsakh and Utik in Aghvan architecture but also blamed those scientists who denied that the mentioned monuments belonged to Aghvan, that is, to Azeri.
3. After the collapse of the Soviet Union, during the political and scientific independence of Azerbaijan and the following years, scientific theses are being defended in Azerbaijan, where the trends of privatization of Armenian architecture are acquiring so much momentum that an attempt is already being made to alienate Syunik from Armenian culture, as well as the architectural schools of Kilikia.
4. Powerful state patronage in scientific policy has been condemned by Russian and Western scientists as unscientific and false approaches.
5. The authorities of Azerbaijan persistently and continuously establish a scientific foundation to support the implementation of a well-developed strategic plan aimed at occupying Armenia.
6. All the monuments in Azerbaijan that cannot be privatized (cross-stones, churches, and settlements) are at risk of vandalism and destruction.

Conflict of Interest

The author declares no conflicts of interest.

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CALCULATION FEATURES OF VERTICAL SETTLING TANKS FOR HEAVY METAL - CONTAINING WASTEWATER TREATMENT

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Abstract: *The article discusses the treatment of wastewater containing heavy metal salts before releasing it into natural water bodies or the urban drainage system. The focus is on environmental protection, human health, and the potential for recovering valuable metals from wastewater. A vertical settling tank was selected for its cost-effectiveness in treating metal-containing acidic wastewater. The article provides a general method for calculating these settling tanks during reagent sedimentation, which can be used to remove various types of heavy metal salts. For this purpose, all calculations related to the use of reagents (their quantities, volumes of reagent storage, solution tanks, and neutralization chambers) were conducted in advance. Additionally, corresponding chemical equations for the reagents and various acids, as well as the equations for the reactions occurring between the reagents and heavy metal salts, were formulated.*

Keywords: *salts of heavy metals, neutralization reactions, hydroxide compounds, wastewater, vertical settling tank.*

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Introduction

Industries involved in the chemical and electrochemical treatment of metals are among the most harmful to the environment. The discharge of wastewater containing poorly treated heavy metal ions into natural water bodies causes significant environmental damage, and the release of such untreated wastewater into water bodies must be entirely prevented [1-3]. Consuming seafood from such water bodies is fraught with dangerous consequences for humans, leading to severe diseases of the nervous system, blood vessels, heart, and liver [4-6]. It should also be noted that various technological processes in metalworking plants consume large amounts of water[1,2]. Therefore, the development of new or improved methods for deeply purifying this contaminated water is highly relevant from an environmental perspective[3] [7]. Deep purification will not only improve the ecology of the surrounding environment but can also serve as a source for obtaining a number of valuable metals [8-13].

Wastewater containing heavy metal ions, including valuable non-ferrous metals, is currently treated using various methods [14-18]. Electrochemical methods, based on physical chemistry, electrochemistry, and chemical technology, involve separation and conversion processes or a combination of both.

These methods are quite complex, and the mechanism and rate of each stage depend on many factors, which are difficult to ensure simultaneously.

Materials and Methods

The calculation methodology is based on reagents' interactions with acids and heavy metal salts. This method includes equipment calculation that neutralizes acidic metal-containing wastewater and a generalized calculation of the vertical settling tanks intended for their purification.

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[1] Water management in the steel industry. https://worldsteel.org/wp-content/uploads/Water-management-in-the-steel- industry.pdf

[2] Properties and Uses of Steel and Stainless Steel in Water Treatment Systems. https://3amakina.com/properties-and-uses-of-steel-and-stainless-steel-in-water-treatment-systems/

[3] Methods of wastewater purification from heavy metal ions (in Russian). https://www.vo-da.ru/articles/ochistka-ot-tyazholyh-metallov/metody-ochistki

In metalworking plants, various technological processes consume a substantial amount of water. Developing new or improved methods for extensive purification of this contaminated water is highly relevant from an environmental standpoint. Deep cleaning not only improves the surrounding area's ecology but can also help recover several heavy metals.

Currently, there are several methods used to clean wastewater with heavy metal ions, including precious non-ferrous metals. These methods, like electrochemical techniques, rely on the principles of physical chemistry, electrochemistry, and chemical technology. They mainly involve separation, transformation processes, and complex combined methods. Furthermore, the mechanism and speed of each stage are affected by numerous factors that are challenging to achieve simultaneously.

Calculation of vertical settling tanks and auxiliary structures

The work aims to extract valuable non-ferrous (and other) metals from the wastewater using the most commonly practiced reagent method. This method includes neutralization processes and redox reactions in which heavy metal ions are converted into hydroxide compounds and the resulting sludge is dewatered. If necessary, the pH value of the effluent is adjusted after purification[4,5] [19-21].

The article presents a generalized method for calculating vertical settling tanks for reagent settling, which can be used to remove all types of heavy metal salts. The choice of reagent settling in vertical settling tanks is justified by the relatively small quantities of these industrial wastewater. Settling tanks are particularly well-suited for extracting iron from industrial effluents, given that iron is the Earth's fourth most abundant chemical element (4.5-5%). It's important to note that in most iron-containing industrial effluents, the pH exceeds 8.3, leading to the prevalence of Fe^{3+} in the water over Fe^{2+}.

The efficiency of extracting insoluble Fe^{3+} as precipitated flocs of $Fe(OH)_3$ can be improved by pre-aerating the effluent. For this purpose, a pre-aerator can be designed as a separate unit, integrated, or attached to the vertical settling tank. To accurately calculate the selected vertical settling tanks, initial calculations of all equipment involved in the averaging and neutralization of these effluents need to be conducted [22-24].

The calculation is carried out in the following order:

1. Calculation of the reagents used,
2. Calculation of reagent facilities,
3. Calculation of solution tanks,
4. Calculation of settling tanks.

In our previous section, we outlined the formulas that result from the interactions between various reagents and acids (Table 1), as well as the formulas that arise from the interactions between reagents and heavy metal salts. We also took into account the molecular masses of the substances involved in these reactions (Table 2). The following sequential calculation approach is universal and allows for the calculation of the consumption of the specific reagent used for purification from specific salts of heavy metals. Since the flow of industrial wastewater usually varies over shifts (sometimes even within quite large limits), together with the neutralization installation, a built-in averager was also provided (Fig.1).

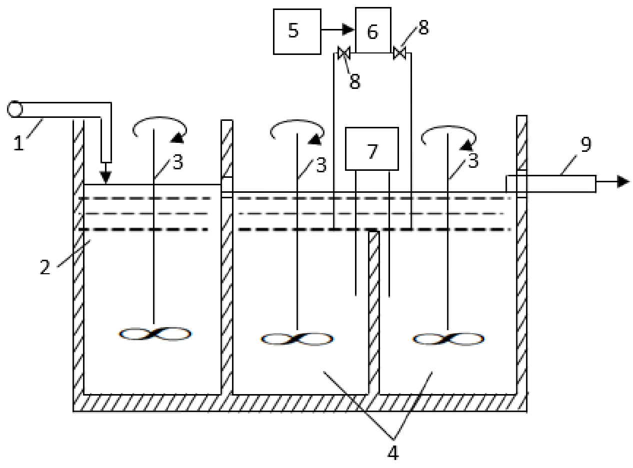

Fig. 1. *Scheme of the installation for averaging structure blending plant and wastewater neutralization*

1. acidic waste supply, 2. low-equalization basin, 3. mixer with mechanical drive, 4. neutralization chamber, 5. dispensable alkaline solution tank, 6. dispenser, 7. regulating pH meter, 8. valve, 9. neutralized drain into settling tank, 10. hole, ensuring the flow into the neutralization chamber

[4] Modern methods of water purification from heavy metals (in Russian). http://elib.bsut.by/bitstream/handle/123456789/6112

[5] Removal of heavy metals from water (in Russian). https://www.ecoindustry.ru/user/skruber/blogview/2053.html

Industrial acid wastes, through pipeline (1) enter the averaging chamber (2), where they are mixed with a stirrer (3) and through hole (10) enter the neutralization chambers. (4). At the same time, the alkaline solution from the supply tank flows into the dispenser (6) and, with open valves (8), is sent to the neutralization chambers. There, with the lowered indicators, the indicator of active hydrogen ions is regulated by the provided pH meter (7). Next, the neutralized wastewater is sent to the settling tank through pipeline (9). Note that mixer with mechanical drives are also used in the wastewater neutralization process.

Table 1. Molecular masses of the most frequently occurring salts of heavy metals in industrial wastewater

Name of heavy metals salts	Chemical formulas of heavy metal salts / molecular masses	Chemical records of metals / molecular masses
Iron sulfate	$FeSO_4$/152	Fe/56
Iron sulfate	$Fe_2(SO_4)_3$/400	Fe/56
Nickel (II) sulfate Nickel(II) chloride	$NiSO_4$/155 $NiCl_2$/130	Ni/59
Copper sulfate Copper (II) chloride	$CuSO_4$/160 $CuCl_2$/135	Cu/64
Zinc sulfate Zinc chloride	$ZnSO_4$/161 $ZnCl_2$/136	Zn/65
Lead (II) chloride	$PbCl_2$/178	Pb/207
Tin(II) chloride	$SnCl_2$/190	Sn/119

Table 2. Reaction equations between various reagents and acids

CaO	$H_2SO_4 + CaO + H_2O = CaSO_4 + 2H_2O$ 98 56 18 136 36 $2HCl + CaO + H_2O = CaCl_2 + 2H_2O$ 73 56 18 111 36 $2HNO_3 + CaO + H_2O = Ca(NO_3)_2 + 2H_2O$ 126 56 18 164 36 $2H_3PO_4 + 3CaO + 3H_2O = Ca_3(PO_4)_2 + 6H_2O$ 196 168 54 310 108
$Ca(OH)_2$	$H_2SO_4 + Ca(OH)_2 = CaSO_4 + 2H_2O$ 98 74 136 36 $2HCl + Ca(OH)_2 = CaCl_2 + 2H_2O$ 73 74 111 36 $2HNO_3 + Ca(OH)_2 = Ca(NO_3)_2 + 2H_2O$ 126 74 164 36 $2H_3PO_4 + 3Ca(OH)_2 = Ca_3(PO_4)_2 + 6H_2O$ 196 222 310 108
Na_2CO_3	$H_2SO_4 + Na_2CO_3 = Na_2SO_4 + H_2O + CO_2\uparrow$ $2HCl + Na_2CO_3 = 2NaCl + H_2O + CO_2\uparrow$ $2HNO_3 + Na_2CO_3 = 2NaNO_3 + H_2O + CO_2\uparrow$ $2H_3PO_4 + 3Na_2CO_3 = 2Na_3PO_4 + 3H_2O + 3CO_2\uparrow$
$MgCO_3$	$H_2SO_4 + MgCO_3 = MgSO_4 + H_2O + CO_2\uparrow$ $2HCl + MgCO_3 = MgCl_2 + H_2O + CO_2\uparrow$ $HNO_3 + MgCO_3 = Mg(NO_3)_2 + H_2O + CO_2\uparrow$ $2H_3PO_4 + 3MgCO_3 = Mg_3(PO_4)_2 + 3H_2O + 3CO_2\uparrow$
$CaCO_3$	$H_2SO_4 + CaCO_3 = CaSO_4 + H_2O + CO_2\uparrow$ $2HCl + CaCO_3 = CaCl_2 + H_2O + CO_2\uparrow$ $2HNO_3 + CaCO_3 = Ca(NO_3)_2 + H_2O + CO_2\uparrow$ $2H_3PO_4 + 3CaCO_3 = Ca_3(PO_4)_2 + 3H_2O + 3CO_2\uparrow$
Dolomite $CaCO_3 \cdot MgCO_3$	$2H_2SO_4 + CaCO_3 \cdot MgCO_3 = CaSO_4 + MgSO_4 + 2H_2O + 2CO_2\uparrow$ $4HCl + CaCO_3 \cdot MgCO_3 = CaCl_2 + MgCl_2 + 2H_2O + 2CO_2\uparrow$ $4HNO_3 + CaCO_3 \cdot MgCO_3 = Ca(NO_3)_2 + Mg(NO_3)_2 + 2H_2O + 2CO_2\uparrow$ $4H_3PO_4 + 3CaCO_3 \cdot MgCO_3 = Ca_3(PO_4)_2 + Mg_3(PO_4)_2 + 6H_2O + 6CO_2\uparrow$

Note: In reactions with slaked lime and quicklime, molecular masses are also given.

Table 3. Reaction equations between various reagents and metal salts

CaO	$FeSO_4 + CaO + H_2O = Fe(OH)_2\downarrow + CaSO_4$ $ZnSO_4 + CaO + H_2O = Zn(OH)_2\downarrow + CaSO_4$ $CuCl_2 + CaO + H_2O = Cu(OH)_2\downarrow + CaCl_2$ $NiCl_2 + CaO + H_2O = Ni(OH)_2\downarrow + CaCl_2$ $Fe_2(SO_4)_3 + 3CaO + 3H_2O = 2Fe(OH)_3\downarrow + 3CaSO_4$ $NiSO_4 + CaO + H_2O = Ni(OH)_2\downarrow + CaSO_4$ $ZnCl_2 + CaO + H_2O = Zn(OH)_2\downarrow + CaCl_2$ $CuSO_4 + CaO + H_2O = Cu(OH)_2\downarrow + CaSO_4$ $SnCl_2 + CaO + H_2O = Sn(OH)_2\downarrow + CaCl_2$ $PbCl_2 + CaO + H_2O = Pb(OH)_2\downarrow + CaCl_2$
$Ca(OH)_2$	$FeSO_4 + Ca(OH)_2 = Fe(OH)_2\downarrow + CaSO_4$ $ZnSO_4 + Ca(OH)_2 = Zn(OH)_2\downarrow + CaSO_4$ $CuCl_2 + Ca(OH)_2 = Cu(OH)_2\downarrow + CaCl_2$ $NiCl_2 + Ca(OH)_2 = Ni(OH)_2\downarrow + CaCl_2$ $Fe_2(SO_4)_3 + 3Ca(OH)_2 = 2Fe(OH)_3\downarrow + 3CaSO_4$ $NiSO_4 + Ca(OH)_2 = Ni(OH)_2\downarrow + CaSO_4$ $ZnCl_2 + Ca(OH)_2 = Zn(OH)_2\downarrow + CaCl_2$ $CuSO_4 + Ca(OH)_2 = Cu(OH)_2\downarrow + CaSO_4$ $SnCl_2 + Ca(OH)_2 = Sn(OH)_2\downarrow + CaCl_2$ $PbCl_2 + Ca(OH)_2 = Pb(OH)_2\downarrow + CaCl_2$
Na_2CO_3	$FeSO_4 + Na_2CO_3 + H_2O = Fe(OH)_2\downarrow + Na_2SO_4 + CO_2\uparrow$ $ZnSO_4 + Na_2CO_3 + H_2O = Zn(OH)_2\downarrow + Na_2SO_4 + CO_2\uparrow$ $CuCl_2 + Na_2CO_3 + H_2O = Cu(OH)_2\downarrow + NaCl + CO_2\uparrow$ $NiCl_2 + Na_2CO_3 + H_2O = Ni(OH)_2\downarrow + 2NaCl + CO_2\uparrow$ $Fe_2(SO_4)_3 + 2Na_2CO_3 + 3H_2O = Fe(OH)_3\downarrow + 3Na_2SO_4 + 3CO_2\uparrow$
Na_2CO_3	$NiSO_4 + Na_2CO_3 + H_2O = Ni(OH)_2\downarrow + Na_2SO_4 + CO_2\uparrow$ $ZnCl_2 + Na_2CO_3 + H_2O = Zn(OH)_2\downarrow + 2NaCl + CO_2\uparrow$ $CuSO_4 + Na_2CO_3 + H_2O = Cu(OH)_2\downarrow + Na_2SO_4 + CO_2\uparrow$ $SnCl_2 + Na_2CO_3 + H_2O = Sn(OH)_2\downarrow + 2NaCl + CO_2\uparrow$ $PbCl_2 + Na_2CO_3 + H_2O = Pb(OH)_2\downarrow + NaCl + CO_2\uparrow$
$MgCO_3$	$FeSO_4 + MgCO_3 + H_2O = Fe(OH)_2\downarrow + MgSO_4 + CO_2\uparrow$ $ZnSO_4 + MgCO_3 + H_2O = Zn(OH)_2\downarrow + MgSO_4 + CO_2\uparrow$ $CuCl_2 + MgCO_3 + H_2O = Cu(OH)_2 + MgCl_2\downarrow + CO_2\uparrow$ $NiCl_2 + MgCO_3 + H_2O = Ni(OH)_2\downarrow + MgCl_2 + CO_2\uparrow$ $ZnCl_2 + MgCO_3 + H_2O = Zn(OH)_2\downarrow + MgCl_2 + CO_2\uparrow$
$MgCO_3$	$FeSO_4 + MgCO_3 + H_2O = Fe(OH)_2\downarrow + MgSO_4 + CO_2\uparrow$ $ZnSO_4 + MgCO_3 + H_2O = Zn(OH)_2\downarrow + MgSO_4 + CO_2\uparrow$ $CuCl_2 + MgCO_3 + H_2O = Cu(OH)_2\downarrow + MgCl_2 + CO_2\uparrow$ $NiCl_2 + MgCO_3 + H_2O = Ni(OH)_2\downarrow + MgCl_2 + CO_2\uparrow$ $ZnCl_2 + MgCO_3 + H_2O = Zn(OH)_2\downarrow + MgCl_2 + CO_2\uparrow$
$CaCO_3$	$FeSO_4 + CaCO_3 + H_2O = Fe(OH)_2\downarrow + CaSO_4 + CO_2\uparrow$ $ZnSO_4 + CaCO_3 + H_2O = Zn(OH)_2\downarrow + CaSO_4 + CO_2\uparrow$ $CuCl_2 + CaCO_3 + H_2O = Cu(OH)_2\downarrow + CaCl_2 + CO_2\uparrow$ $NiCl_2 + CaCO_3 + H_2O = Ni(OH)_2\downarrow + CaCl_2 + CO_2\uparrow$ $Fe_2(SO_4)_3 + 3CaCO_3 + 3H_2O = 2Fe(OH)_3\downarrow + 3CaSO_4 + \uparrow 3CO_2$ $NiSO_4 + CaCO_3 + H_2O = Ni(OH)_2\downarrow + CaSO_4 + CO_2\uparrow$ $ZnCl_2 + CaCO_3 + H_2O = Zn(OH)_2\downarrow + CaCl_2 + CO_2\uparrow$ $CuSO_4 + CaCO_3 + H_2O = Cu(OH)_2\downarrow + CaSO_4 + CO_2\uparrow$ $SnCl_2 + CaCO_3 + H_2O = Sn(OH)_2\downarrow + CaCl_2 + CO_2\uparrow$ $PbCl_2 + CaCO_3 + H_2O = Pb(OH)_2\downarrow + CaCl_2 + CO_2\uparrow$
Dolomite $CaCO_3 \cdot MgCO_3$	$2FeSO_4 + CaCO_3 \cdot MgCO_3 + H_2O = 2Fe(OH)_2\downarrow + CaSO_4 + MgSO_4 + 2CO_2\uparrow$ $2ZnSO_4 + CaCO_3 \cdot MgCO_3 + H_2O = 2Zn(OH)_2 + CaSO_4 + MgSO_4 + 2CO_2\uparrow$ $2CuCl_2 + CaCO_3 \cdot MgCO_3 = 2Cu(OH)_2\downarrow + CaCl_2 + MgCl_2 + 2CO_2\uparrow$ $NiCl_2 + CaCO_3 \cdot MgCO_3 = Ni(OH)_2\downarrow + CaCl_2 + MgCl_2 + CO_2\uparrow$ $Fe_2(SO_4)_3 + CaCO_3 \cdot MgCO_3 + 6H_2O = 4Fe(OH)_3\downarrow + 3CaSO_4 + 3MgSO_4 + 6CO_2\uparrow$ $2NiSO_4 + CaCO_3 \cdot MgCO_3 + 2H_2O = 2Ni(OH)_2\downarrow + MgSO_4 + CaSO_4 + 2CO_2\uparrow$ $2ZnCl_2 + CaCO_3 \cdot MgCO_3 + 2H_2O = 2Zn(OH)_2\downarrow + CaCl_2 + MgCl_2 + 2CO_2\uparrow$ $CuSO_4 + CaCO_3 \cdot MgCO_3 + 2H_2O = Cu(OH)_2\downarrow + CaSO_4 + MgSO_4 + 2CO_2\uparrow$ $2SnCl_2 + CaCO_3 \cdot MgCO_3 + 2H_2O = Sn(OH)_2\downarrow + CaCl_2 + MgCl_2 + CO_2\uparrow$ $2PbCl_2 + CaCO_3 + MgCO_3 + 2H_2O = 2Pb(OH)_2\downarrow + CaCl_2 + MgCl_2 + 2CO_2\uparrow$

Reagent consumption (G) is determined by the following formula:

$$G = K_r \cdot Q\left(\sum aA + \sum bB\right)\frac{100}{c}, \quad \frac{kg}{day}, \qquad (1)$$

where $K_r = 1.1...1.3$ - reserve coefficient; Q - daily flow rate, m^3/day; A and B - respectively concentrations of acids and salts of heavy metals; $a = \frac{m}{n_a}$ - specific consumption of the reagent used for acid neutralization, kg/kg; m and n_a - the molecular masses of the reagent and acid, respectively; $b = m/n_m$ - specific consumption of the reagent used for the precipitation of heavy metal salts; n_m - molecular mass of heavy metal salts; $C = 40...70\%$ - content of the active substance in the reagent used.

The area of the reagent stock is determined by the following formula:

$$S = \left(Q \cdot ts\right)/h \cdot p, \ m^2, \qquad (2)$$

where $ts = 30\,\text{min}$ - reserve time; $h = 1.5...2.0\,\text{m}$ - the height of the reagent layer, $\rho = (1...1.2)\,t/m^3$ - specific gravity of the reagent.

Having the surface, we select the dimensions of the storage (width and length).

The volume of supply tanks (W_t) is determined by the following equation:

$$W_t = \frac{G \cdot C}{n_s Z}, \quad m^3, \qquad (3)$$

where $n_s = 4...6$ is the number of solutions obtained per day; $z = 4...6\%$ - solution content.

For the volume, we can select the number of tanks (at least two) and their dimensions. The consumption of the reagent solution is determined by the formula:

$$q_r = \frac{1000 \cdot n_s \cdot W_s}{86400} = \frac{n_s \cdot W_s}{86.4}, \quad l/\text{sec}. \qquad (4)$$

We also determine the total consumption of wastewater (q_t) and reagent solution by the following way:

$$q_t = q + q_r = \frac{Q_s}{86.4} + q_r, \ l/\text{sec}. \qquad (5)$$

Mixer volume (W_m) is determined by the formula:

$$W_m = \frac{60 \cdot q_t \cdot t_m}{1000} = \frac{q_t \cdot t_m}{16.7},$$

where $t_m = 5$ min is the mixing time.

For the volume, the diameter and height of the mixer are determined. Usually, we accept one mixer and its dimensions (diameter and height). The volume of the neutralization chamber is determined by the formula:

$$W_n = \frac{q_t \cdot 60 \cdot t_n}{1000} = \frac{q_t \cdot t_n}{16.7}, \ m, \qquad (6)$$

where $t_n = 30$ min is the required time to neutralize the flow.

Taking two neutralization chambers, we get $W_1 = \frac{W_n}{2}$ and the sizes of each of them.

The calculation of settling tanks begins with determining their diameter (B) using the following formula:

$$D = \sqrt{\frac{4qt}{\pi \cdot Vn_{st.t.}}}, \ m. \qquad (7)$$

where $V \leq 0.2$ mm/sec - the rate of wastewater in the settling tank; $n_{st.t.}$ – the number of settling tanks, which is advisable to take a multiple of 4, taking into account the fact that $D \leq 9.0$ m.

The height of the deposition zone is determined by the formula:

$$h_{set.} = 3.6 \cdot t_{st.}, \tag{8}$$

where $t_{st.} \geq 24$ is the duration of suspension deposition.

We determine the dry matter content (M) in the accumulated slag using the formula:

$$M = \left[K_s \cdot \frac{100 - C}{C} \left(X_1 + X_2 + X_3 + y_1 + y_2 - 2 \right) \right] \cdot Q, \quad kg / day, \tag{9}$$

where $X_1 = \sum a \cdot A$ - reagent consumption for the neutralization of acids contained in 1m^3 of wastewater, kg/m^3; $X_2 = \sum b \cdot B$ - reagent consumption for the precipitation of metal salts contained in 1m^3 of wastewater, kg/m^3; $X_3 = \sum \frac{m_h}{n_m} \cdot B$ - the amount of hydroxyls that are formed from the metals contained in 1m^3 of wastewater (m_h is the molecular mass of hydroxyls); $Y_1 = \sum \frac{m_s}{n_a} \cdot A$ - the amount of insoluble salts formed during the acid neutralization, kg/m^3; n_s - the molecular mass of insoluble salts; $y_z = \sum \frac{m_s}{n_m} \cdot B$ - the amount of salts formed during reactions between reagents and salts of heavy metal, kg/m^3; z – solubility of calcium sulfate ($CaSO_4$) in water. If $y_1 + y_2 - 2 < 0$, then the negative value of the expression is neglected.

We determine the volume of sludge (W_{sl}) using the formula:

$$W_{sl} = \frac{M}{10(100 - p)}, \quad m^3 / day, \tag{10}$$

where $p = 86...88\%$ is the moisture of the sludge.

We determine the settling tank conical part volume using the formula:

$$W_C = \pi \cdot D^3 / 24, \ m^3. \tag{11}$$

Taking the angle of inclination of the settling tank conical section to be 45^0, we obtain the height of the conical part – $h_{c.q.1} = D/2$.

We determine the settling tank cylindrical part volume (W_C) using the formula:

$$W_C = \frac{W_{sl}}{n_q + 1} - W_c, \ \text{m}^3, \tag{12}$$

where $n_q \geq 2$ is the estimated number of settling tanks.

We can also determine the height of the cylindrical part using the formula:

$$h_c = \frac{4 \cdot W_C}{\pi D^2}, \ \text{m}. \tag{13}$$

Taking the height of the neutral part $h_1 = 0.25$ m, we determine the depth of the settling tank (H):

$$H = h_w + h_c + h_{con} + h_1, \ \text{m}, \tag{14}$$

where $h_W = 0.5$ m is the height of the side wall from the drainage level.

The diameter of the central part of the vertical settling tank (Fig.2) is determined by the equation:

$$\frac{Q}{3.6 \cdot W_c} = n_r \cdot \frac{\pi d^2}{4}, \tag{15}$$

where Q - wastewater consumption, m^3/day,

n_r - the estimated number of settling tanks.

The diameter of the central pipe in mm is determined from equation (16):

$$d = \sqrt{\frac{4Q \cdot 1000}{\pi \cdot n_c \cdot V_c \cdot 86400}}, \text{ mm.} \tag{16}$$

where $V = 30$ mm/sec - flow rate in the central pipe.

We also determine the length of the transition part of the central pipe (h_e) and its diameter (d_e) according to the condition $d_e = h_e = 1.35 \cdot d$, mm.

The diameter of the central pipe (d_1) is determined by the following formula:

$$d_1 = 1.3 \cdot d_e, \text{mm.} \tag{17}$$

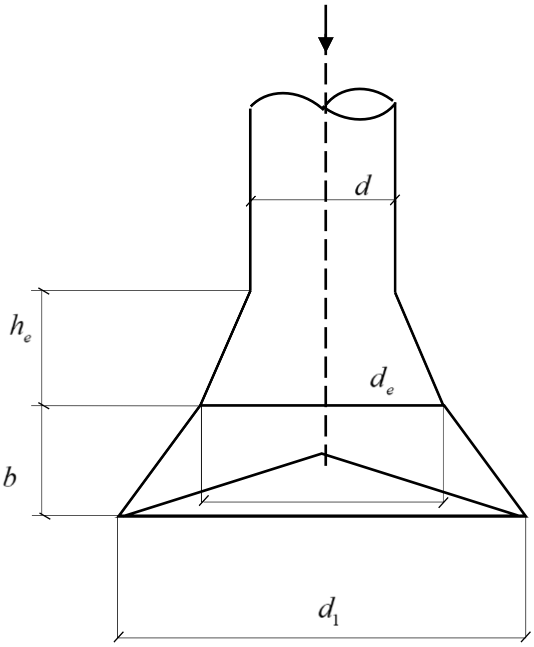

Fig. 2. *The central part of the supply pipe of a vertical settling tank*

After, we determine the length of the central pipe inserted-joint part using the formula:

$$\frac{Q}{3.6 \cdot V_s \cdot V_{s.p.p.}} = \pi \cdot n_c \cdot d_e \cdot b, \tag{18}$$

where $V_{s.p.p.} = 20$ mm/sec is the wastewater velocity at the splashing plate.

Taking into account the need for identical measurements of units, from equations (18) we get:

$$b = \frac{1000 \cdot 1000 \cdot Q}{864000 \cdot \pi \cdot n_c \cdot V_{s.p.p.}}, \text{ m.} \tag{19}$$

Conclusion

1. We have provided the necessary neutralizing reagents and all the appropriate equipment to neutralize industrial metal-containing wastewater, which can have an alkaline or, most often, acidic medium, during the treatment process.
2. A homogenizer is built into the neutralization chambers to reduce capital investments, simplify operations, and ensure accurate calculation of treatment facilities.
3. The suggested method allows for a detailed calculation of the vertical settling tank when removing various metal salts from acidic wastewater using specific reagents.
4. If necessary, wastewater that has been clarified in settling tanks can also undergo further purification, preferably through sand or dual-layer filtration. In all cases, a disinfection process is also planned after the purification process.
5. The sludge accumulated in the conical section of the settling tank can be transferred to sludge pads for dehydration and further extraction of valuable metals.

Conflict of Interest

The authors declare no conflicts of interest.

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HISTORICAL MEMORY AND VOLUMETRIC-SPATIAL COMPOSITION OF TSITSERNAKABERD MEMORIAL COMPLEX

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Abstract: *The erection of memorials and monuments plays an important role in the historical memory of humanity, self-recognition of society and awareness of the social nature of memory. From this point of view, we looked at the architectural-spatial environment of Tsitsernakaberd, the memorial complex dedicated to the victims of the Genocide, the organization of which is subject to the perpetuation of historical memory and is one of the manifestations of the preservation of national identity. It finds its parallels in world practice. The motivation for the construction of the memorial complex was the fiftieth anniversary of Yeghern. The Tsitsernakaberd hill has been completely culturalized, the landscape has passed through four conceptual lenses: "text", "arena", "performance" and "wound", achieving the harmony of hand-made and non-handmade. In the work, a complete examination of the architecture of the memorial complex was carried out by the method of comparative analysis of professional literature and personal observations. In conclusion, it can be said that the memorial dedicated to the memory of the Genocide victims, apart from its historical and artistic significance, is also a universal value and a sacred place for all those who consider human life as an absolute value regardless of nationality, religion or race.*

Keywords: *ethnic, memory, memorial, architecture, metaphor, monument, ideological, artistic, historical.*

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Introduction

The history of humanity is the story of the philosophical space-time connection of the Trinity of past, present and future. Throughout history, the concept of memory has been important, as it links this chain of unity. Memorial complexes have been created since time immemorial and preserve their traditionality till now as a materialized manifestation of human memory [1]. Memorial complexes play an important role in increasing the social awareness of collective memory, thus even today they are still being built in various forms [2].

However, since the late 19th century to the present, changes in the architectural composition of memorial complexes have altered the relationship between visitors and memorial complexes. Until the 19th century, monuments were simply built to perpetuate the memory of individuals or heroes, representing pictorial objects inaccessible and visible from afar, modern memorial complexes, on the other hand, allow the user to be widely involved in the memorial acts by touching, listening and participating [3]. Memorial complexes do not merely reflect ideas about the past, but confirm and insure the past. Becoming widespread around the world is, to some extent, a reference to the present, current political situations and circumstances, as collective memory is anchored in the present. Memorial complexes are part of the socio-political process which show how people value, discuss or heal historical wounds [4]. They also provide a sense of belonging and ownership among citizens, enhancing the touristic, economic and cultural value of the area.

The problem and the multilayered aspects of studying the structural features of memory have regularly been and are being touched upon by a number of scholars from all over the world [5]. As for the policy of commemorating the victims of the Great Genocide it has been addressed by Armenian scholars such as

Harutyun Marutyan, Karen Balyan and Levon Abrahamyan [6-8], considering the memory of the Armenian Genocide as one of the current pillars of the Armenian identity.

The Armenian Genocide has long gone beyond the position of being a purely Armenian tragedy and has entered the realm of world history. Certainly, the role of the Memorial Complex in this case was tremendous.

According to Harutyun Marutyan, "Memory and especially historical memory are among the most important elements that define the terms "ethnic community (ethnic)", "nation" and "national identity" [6].

The above-mentioned authors referred to the idea of memory, the genocide and the memorial separately. Some authors approached this question more superficially [9]. Therefore, this work is an attempt to present these three ideas on one plane, in a comprehensive way. Therefore, the aim of the research is to analyze the spatially organized materialized environment of the Genocide Memorial Complex, connecting it with the historical memory, as well as emphasizing the role of the landscape of the Memorial Complex and architectural composition in the application of architectural landscape elements in the urban area and the importance of realizing the user's sensory experience in the memorial space.

Methods and Materials

In the work, a complex examination of the memorial complex was performed, which was carried out by the method of comparative analysis of professional literature and personal observations. Archival documents and photographs were also used, which made it possible to restore important episodes related to the historical period of the Yeghern Memorial and the motivations for its construction.

Given the fact that the role of monuments and memorial complexes is great in historical memory, the self-recognition of society and the awareness of the social nature of remembrance, a number of scholars around the world now show a growing interest in memorial complexes and what the influence of construction, interpretation and disputability of a place or area in this process is.

From this point of view we have observed and studied the architectural-spatial environment of the Tsitsernakaberd Memorial Complex dedicated to the victims of the Genocide. The organization of the Memorial is subject to the perpetuation of historical memory, which greatly helps the nation to preserve the national identity created in the fusion of common experience and centuries-old culture.

The motivation for building the Memorial Complex was the fiftieth anniversary of the Genocide. And this Complex is the living expression and materialization of these fifty and more years of condensed terrible feelings and indomitable faith, which has gone beyond its historical and artistic significance and has become a holy place for all Armenians, and why not, for foreigners, for whom human life is an absolute value regardless of nationality, religion or race.

Armenian architects achieved all this as a result of deep analysis and long discussions, connecting the world classical experience with their national heritage. By studying the landscape through four conceptual lenses, which are "text", "arena", "performance" and "wound", they achieved a perfect harmony of the environment, and the entire Hill was culturalized.

From the foot of the Tsitsernakaberd Hill, the commemoration road rises to the ideological culmination, where the Memorial Complex erects. It is a set of three large monuments bearing theological significance: the memorial wall, the temple of eternity with the unquenchable fire in the center, and the memorial column.

In this paper, a complete examination of the Memorial Complex has been carried out by means of a comparative analysis of professional literature and personal observations.

From Memory to Memorial Complex

Since time immemorial, people have realized that nations or tribes simply cannot exist without memory, remembrance or ethnic memory. Consequently, megaliths, tombs and memorial columns like obelisks were built to materialize historical memory, which is the basis of national identity.

The great philosopher [10] perceives memory in a completely different way other than sensation or perception. Without the eye we cannot have the sensation of "blue", but through the eye we still do not have the memory of "blue" at all. For the eye now to give us that sensation, some blue object must appear in front of it. Architecture, or in this case, memorial complexes, serve as that "blue object" for the user. The perception brought to life by memory is considered to be new and in no case the preserved old one. A memory is something that can be re-imagined, and it does not mean that the imagination can become alive once again. Something that appears once again is different from the imagination itself. "I remember"- means I am experiencing something once again that no longer exists. I connect the experience of the past with my present life. This refers to every memory. So, of course, no feeling is wasted, as the soul preserves it as a memory, while the spirit draws from it whatever can enhance its abilities and its bio content.

If the spirit stores the intangible treasures or more precisely the intangible culture, the architecture transforms the intangible culture into an already visible, tangible, material culture, filled with the ideology, aspirations and heroism of the national spirit. Here already physical parameters, types of feelings, and social goals are combined in memorial complexes, making the memory of war or atrocity a part of public life, a celebration of the past or a commemoration of the past. The forms of significance of memorial complexes are influenced by reinterpretations of political history that reinforce, contradict or emphasize the status of the past events.

Results and Discussion

The Term Genocide and the Motivation to Build the Memorial Complex

The Genocide was the state policy of mass deportation and extermination of the Armenian population in Western Armenia, Cilicia and other Armenian-inhabited areas of the empire, as well as in Eastern Armenia, of the Ottoman Empire and the Kemal government during the First World War (1914-18) and the following years. It is characterized as the first genocide of the 20th century. This was an unprecedented tragedy that happened to Armenians. This undeniable fact is stubbornly not accepted by the Turkish government. Following the latter, many states of the world keep their eyes closed against the reality.

The term Genocide was defined and popularized in 1944 by a Polish lawyer of Jewish origin, Professor Raphael Lemkin. The Armenian Genocide carried out by Ottoman Turkey in 1915 also corresponds to this definition. According to Lemkin, Genocide is not only the physical annihilation and elimination of a national or religious group, but also the destruction of its national-spiritual culture. It is worth mentioning that this Genocide continues up to now. In the territories occupied by Azerbaijan, many memorial complexes are being physically destroyed and desecrated with the aim of destroying the collective and historical memory of the ethnic group (memorial complexes dedicated to those who died in World War II and Artsakh War I in Talish Village of the Republic of Artsakh)[1].

Rituals, customs, myths, shared historical memories and traditions are ways and actions to bind members of a nation and define their relationships. And since our national understanding of the past is always a tool for solving current problems, it was important to present the collective memory in the form of a monumental structure [11], which was implemented in the case of the Tsitsernakaberd Memorial Complex.

The motivation for building the Memorial Complex was the half-century anniversary, when people were powerless to bear the silence and indifference of others. And it was an absolutely spontaneous demand and eruption of ethnic memory.

The Genocide has never been forgotten, but for many years it has outwardly been silenced. This was conditioned by the fact that the spread of any national ideology was prohibited in the Soviet Union. However, on the eve of the 50th anniversary of the Genocide, the entire Armenian nation, especially the youth, as well as the Government of the Republic were preparing for that sad anniversary.

[1] https://monumentwatch.org/.

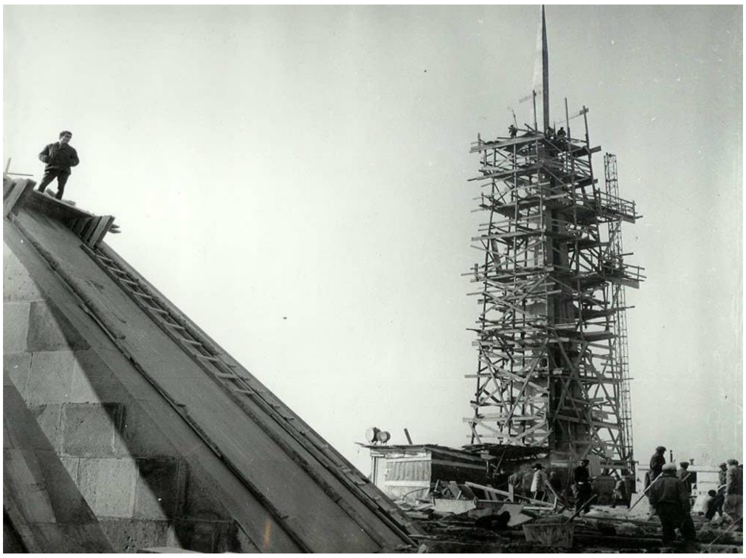

Fig. 1. *The Construction process of the Tsitsernakabert Memorial*

Fig. 2. *First Secretary of the Central Committee of the Communist Party of Armenia (CPA) Anton Qochimyan lights the unquenchable fire of the memorial*

On December 13, 1964, the 1st Secretary of the Central Committee of the CPA Ya. Zarubyan sent a letter of justification to the Central Committee of the Communist Party of the Soviet Union on officially celebrating the 50th anniversary of the Genocide, with the list of envisaged events. Based on the Decree of the Council of Ministers of the Armenian SSR dated March 16, 1965, the program and conditions of the republican tender for the construction of the monument commemorating the victims of the Great Genocide were published in the newspapers. On April 24 of the same year, a solemn meeting was held at the Yerevan Opera House, during which the beginning of the competition was officially announced. 78 projects were submitted to the Competition. A prestigious committee consisting of 12 people chose the project with the code "Flag of the USSR", the authors of which were A. Tarkhanyan and S. Kalashyan. 776.800 rubles were allocated for the construction, and "Yerkimshin" trust was chosen as the contractor. Initially, the official opening ceremony of the Memorial Complex was envisaged on April 24, 1967, but was later changed on November 29, the day of Sovietization of Armenia (Figs. 1,2).

The Volumetric-Spatial Composition of the Memorial Complex

After all, what is Architecture?

To enclose a part of space within certain boundaries. To give body, form and life to that space. To convey to it our physical and spiritual movement. Also to surrender to it and participate in the life of the Whole through a balanced, unobtrusive and harmonious structure. To be one and live a complete, full life with structure. When the structure, symbolizing us, is weight and symmetry, our consciousness is no longer blurred, it returns to its center, national self-awareness and ethnic memory, then it spreads and radiates. The free movement of the body, unfettered breathing and mental satisfaction are the three impulses that form true architecture [12].

Here, with the Tsitsernakaberd Memorial Complex, our architects found the body, form and life that should express and preserve the historical destiny of the nation.

According to the researchers, the construction of the memorial complex, which essentially meant recognition of the fact of genocide by the Soviet government, should at the same time extinguish the wave of the national movement in Armenia. Therefore, the monument symbolizing the genocide could not be located in the center of Yerevan, near the main square or the opera, in order to avoid mass visits. Therefore, the

Tsitsernakaberd hill was chosen for the construction of the memorial, in a remote, undeveloped, very inaccessible place in Yerevan.

Tsitsernakaberd Hill is located on the right bank of the Hrazdan River-in the western part of the capital and has an area of 132 hectares. After planting trees, it turned into a park, and was chosen as the site for the Memorial Complex. Studies show that the measurement of physical elements and the user's sensory experience are best taken into account when designing the Memorial landscape. It is ideal for the commemoration and the space provided. Simpler forms of the composition and symbolic messages allow users to more easily interact and understand the concept and purpose of the Memorial Complex.

Tsitsernakaberd Hill has been completely culturalized, the landscape has passed through four conceptual lenses [13,14], as is usually or traditionally done in the case of memorials: "text", "arena", "performance" and "wound", reaching the harmony between anthropogenic and naturogenic.

From the foot of the Tsitsernakaberd Hill, the commemoration road rises to the ideological culmination, where the Memorial Complex erects. Along this entire road, radio receivers are placed that play spiritual or national music (especially on Memorial Day), as if to commemorate the innocent victims. And this "liturgy" immediately cuts off the visitors from the busy daily life of the city, allowing them to immerse themselves into the arms of history, to awaken the ethnic memory, to review their present and, why not, not to get bored after a rather long ascent. Similar elements in memorial complexes (water, color, music, plants, scents, furniture, fire) are tools that architects use to create certain sensory impressions in memorial complexes [3]. We can consider this as the first successful element that guides visitors inside the Memorial Complex.

Inside is the Memorial Complex which erects as a set of monuments with three major theological meanings: the memorial wall, the temple of eternity with the unquenchable fire in the center, and the memorial column (Fig.3).

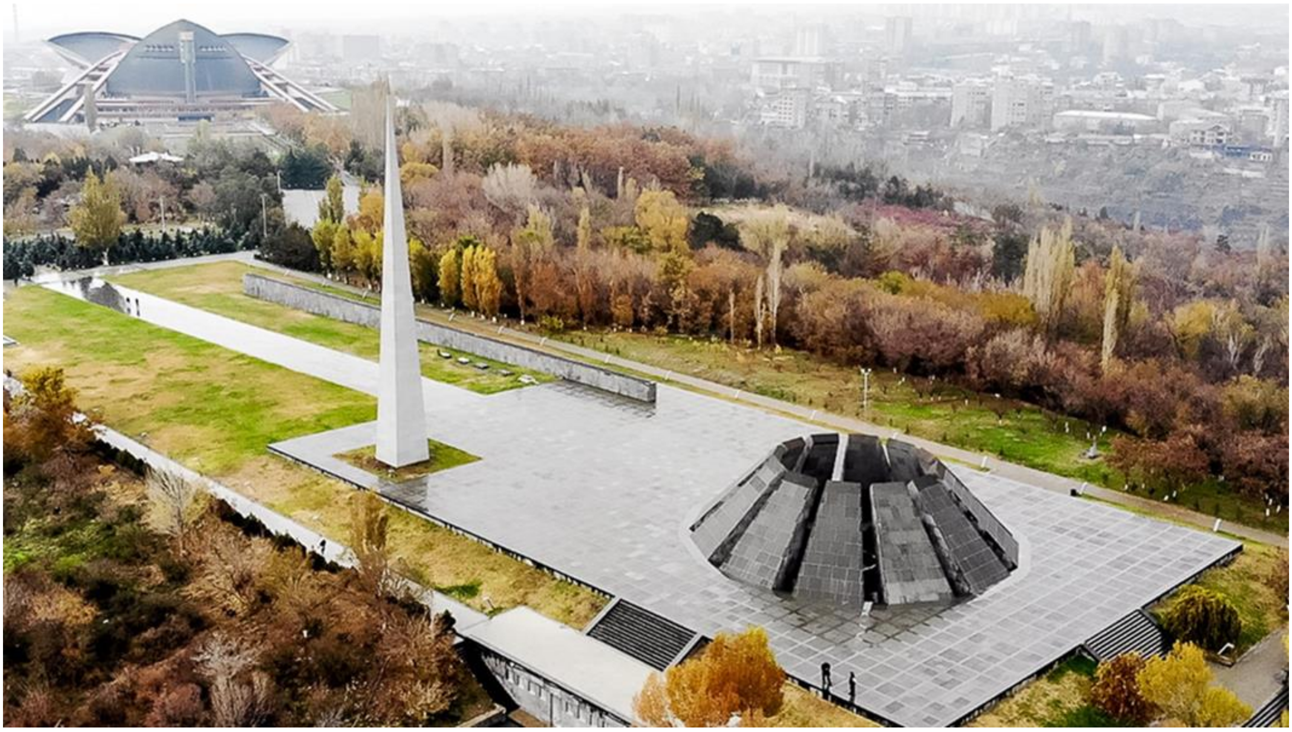

Fig. 3. *General view of the Memorial from the South*

The names of the locations, where the atrocities took place, are engraved on the hundred-meter-long memorial wall. This text metaphor symbolizes the ratification for historical events. Since 1996, the jars of soil taken from the graves of those who raised the voice of protest against the Armenian Genocide have been buried on the opposite side (Fig.4).

Fig. 4. *The wall where the names of the main towns affected by the Armenian genocide are engraved*

Fig. 5. *Twelve slabs grouped in a circle protecting, 1.5 meters deep, the "eternal flame", a sign of mourning*

The Memorial Hall is located in the performance metaphor: the 12 basalt chamfered pylons bowed to the unquenchable fire, forming a cone-shaped structure with an open volume, symbolize the tomb of the victims of the Great Genocide, where the ritual ceremonies are performed, and the unquenchable fire located in the center is the expression of the "unhealed wound".

The Temple of Eternity consists of 12 stone slabs. The number 12 is chosen based on geometrical laws, however the people consider that these columns symbolize the 12 largest states in Western Armenia (Fig.5).

In the arena metaphor, the 40-meter memorial column rising to the sky is a symbol of the national revival of the Armenian people (Fig.6).

The Armenian Genocide Museum-Institute[2,3,4]

The museum building summarizes the organization and ideological integrity of the spatial environment. Apart from museum-related functions, it also seems to museumize historical memory with documents (Fig.7).

[2] Armenian Genocide Museum-Institute. Activity, Yerevan. http://www.genocide-museum.am/arm/structure.php
[3] Armenian Genocide Museum-Institute. Genocide, Yerevan. http://www.genocide-museum.am/arm/genocide.php
[4] Armenian Genocide, Yerevan (in Armenian). https://hy.wikipedia.org/wiki/%

Fig. 6. *The erect monument symbolizes rebirth*

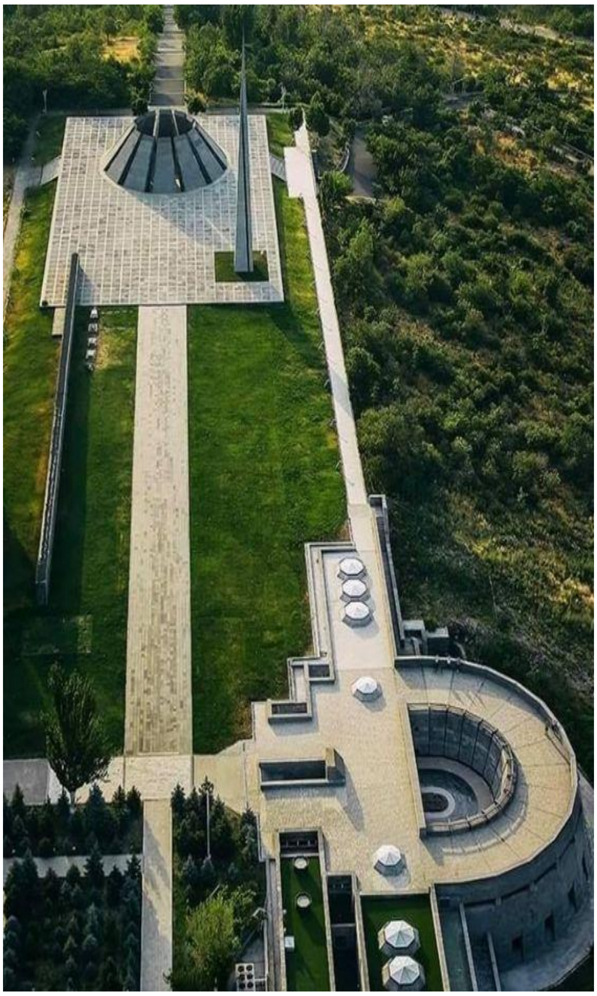

Fig. 7. *The Armenian Genocide Museum-Institute*

This scientific-cultural institution is located in the southwestern part of the Memorial Complex and occupies an area of 2000 square meters. It has an inner courtyard, the words of witnesses of the first Genocide of the 20th century are engraved on the 12 faces of the basalt wall. Among them are Henry Morgenthau, Fritjof Nansen, Anatole France, Jacques de Morgan, Valery Brusov and others. The map of Western Armenia with an area of 45 square meters was carved on the wall of the Hall, on which the places of massacre and displacements are marked. In 1995-2013, the exhibition materials were presented in the 3 halls of the Museum, mainly in the form of documents, copies of photo documents, ancient press and literature dedicated to the Hamidian massacres, the immolation of Adana and the Armenian Genocide. The Museum has a cinema hall, a scientific library, archival funds and offices (Figs. 8,9).

Fig. 8. *Inside the museum*

Compared to the Monument, the propaganda value of the Museum is incomparably greater [15].

Such sensitive sites have also become pivotal for diplomacy between friendly countries, mostly in the form of state visits that include promises that such atrocities will never happen again [16].

Fig. 9. *Display in the information centre*

Conclusion

In this research, an attempt was made to show how a properly organized architectural volume-spatial composition can best contribute to the preservation, strengthening and perpetuation of collective memory. And one of the important prerequisites for the survival of the nation is the collective memory.

Having subjected the component parts of the memorial to a deep analysis, we have come to the following conclusions:

1. The examination of the Yeghern monument complex clearly reveals the ideological content of the ensemble and the interconnectedness of form-creating elements.
2. The area has been completely culturalized.
3. In accordance with the classical traditions of Armenian architecture, the unity of hand-made and non-hand-made is noticeable.
4. Yeghern Memorial stands as a stone witness of historical memory in the spatial support of Yerevan and has become one of the symbols of the city.

Thus, the results of the work can be useful for researching and raising new, heroic, constructive memories within the framework of both architectural heritage and modern architecture.

Conflict of Interest

The authors declare no conflicts of interest.

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GREEN ROOF RETROFITTING IN ALGERIA BETWEEN SUSTAINABILITY AND SEISMIC VULNERABILITY

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Abstract: *Installing green roofs in urban areas is a sustainable practice towards the ecological transition, they offer many advantages with regards to reducing energy consumption, mitigating the urban heat island effect, managing runoff ...etc. In order to propagate this technique, green roofs have to be installed on the top of existing buildings, which can increase their vulnerability during seismic events. The present paper aims to evaluate the impact of green roof retrofitting on the seismic performance of a collective housing in Algeria. To this end, the finite element method was adopted to investigate the seismic-related parameters according to the Algerian seismic regulations. The studied reinforced concrete building is located in the district of Constantine (northern east of Algeria). It was found that the presence of concrete walls, recommended by the Algerian seismic regulations, increases the rigidity of the building, which reflects positively on the building's natural period and displacements. As for the stress-related parameters, the reduced normal force does not increase much; however, a significant increase in the shear forces at the base due to green roof implementation was observed. It was also found that adding a green roof contributes more to the stabilizing moment than to the overturning one during an earthquake event. Hence, in the studied context, the presence of load-bearing concrete walls offers certain positive effects on green roof installation with regard to the seismic performance. Nevertheless, a thorough seismic investigation should be performed before installing green roofs on the top of existing collective housing in Algeria.*

Keywords: *green roof, seismic performance, finite element, ecological transition.*

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Introduction

Climate change effects raise concerns about improving and protecting the environment, especially in urban areas. Innovative eco-friendly practices, like green roofs [1-3], are a key tool towards achieving an ecologically functional land cover in cities. As a planning strategy to face the climate challenges in urban centers by improving the environment quality, green roofs implementation is an important green technology that hosts vegetation in a specially designed substrate [4,5]. The history of green roofs in many cultures goes back thousands of years ago [6]. However, the appearance of the modern concept of green roofs took place in the 20th century, adopted in construction in Germany, and then in Northern Europe, North America, and other Asian countries [7]. Over the past decades, extensive green roofs have been considered as a valuable tool for sustainable development [8]. The environmental and economic benefits due to the thermal regulation capacity of green roofs have resulted in accelerating research and practice of this technique [8,9]. Green roofs offer other advantages for sustainable buildings and cities, including: improving air quality, mitigating the urban heat island effect, managing stormwater (by retaining and then slowly releasing rainwater), preserving the ecological environment, improving sound insulation ... etc. [10-13].

In the Mediterranean region, green roofs are considered as a useful technique for sustainable urban stormwater management, as they compensate for man-made impervious surfaces by absorbing a certain amount of rainwater and slowly releasing the rest into the evacuation systems [14]. In summer, in the

Mediterranean region, green roofs improve energy efficiency and mitigate the urban heat island effect, which consequently reduces the environmental impacts [15]. Weather and vegetation types control the performance of green roofs [16]. The installation of green roofs is gaining more popularity for microclimate regulation, as they are closely associated with climate and the environment [17]. For the specific climatic conditions in the Mediterranean region, the installation of green roofs is a complicated operation as it faces many challenges, such as selecting appropriate vegetation, and designing for climate change [18]. Therefore, plant breeding and improved growing substrates are crucial in future green roof research [19]. The presence of grass on the roofs of buildings could potentiate the effect of trees and shrubs. On the other hand, species with greater sizes and biomass perform better in reducing water runoff, compared to species with smaller sizes and lower biomass [20, 21]. In order to promote biodiversity, green roofs should include different types of substrates, which allows for the creation of multiple microhabitats, which can eventually support a larger diversity of species than if they were uniform [22].

Algeria, like other northern African and Mediterranean countries, is facing many environmental challenges, such as desertification, drought, biodiversity loss, air and water pollution …etc. [23]. Although the installation of green roofs in Algeria is not yet widespread, there is a growing interest in this green practice in the country. The work of [24] reports that the implementation of green roofs and facades could transform the Saharan cities in the southern part of the country into an ecological urban environment. In another study carried out in the town of Jijel, in the northern east of Algeria, the results show that green roofs can be an efficient technique for improving the thermal performance of the surrounding microclimate, and also the energy performance of buildings in urban areas [25].

Green roofs offer great advantages when it comes to reducing urban heat island, regulating runoff, and enhancing the overall life quality...etc. However, in order to propagate its use, green roofs have to be installed on existing buildings, which raises concerns about its impact on the building structure. In regions where earthquakes are frequent, the vulnerability of a building when adding a green roof on the top is crucial. In literature, few authors have worked on the seismic behavior of buildings with green roofs [26-31]. However, in the seismic context of Algeria, and the Algerian seismic regulations, the impact of green roof retrofitting on the seismic performance of buildings was not tackled yet.

The present paper shed light for the first time on the seismic impact of green roofs retrofitting on collective housing according to the Algerian seismic regulations.

Materials and Methods

Brief introduction into the Algerian seismic regulations

Algerian seismic regulations [32] have evolved through the years, the actual seismic regulations: RPA 99 V2003 is considered the fifth regulation after RPA 81, RPA81 V1983, RPA 88, and RPA 99. The development of the Algerian seismic regulations took into account the progress in the research field, and the lessons learned from earthquakes in Algeria, such as those of Oued Djer (October 1988), Tipaza (October 1989), Mascara (August 1994), and abroad, such as Spitak / Armenia (1988), Sanjan / Iran (1990), Loma Priéta / California (1989), Northridge/California (1994), Kobe/Japan (1995), and Izmit/Turkey (1999). According to [32], the Algerian territory is divided into five (05) zones of increasing seismicity (Fig.1).

Zone O: negligible seismicity.

Zone I: low seismicity.

Zone IIa and IIb: average seismicity.

Zone III: high seismicity.

The Algerian seismic regulations [32] classify buildings according to their importance into four (04) groups, The minimum level of seismic protection granted to a structure depends on its destination and its importance with regard to the protection objectives. The classification aims to protect people, then economic goods and cultural aspects of the community.

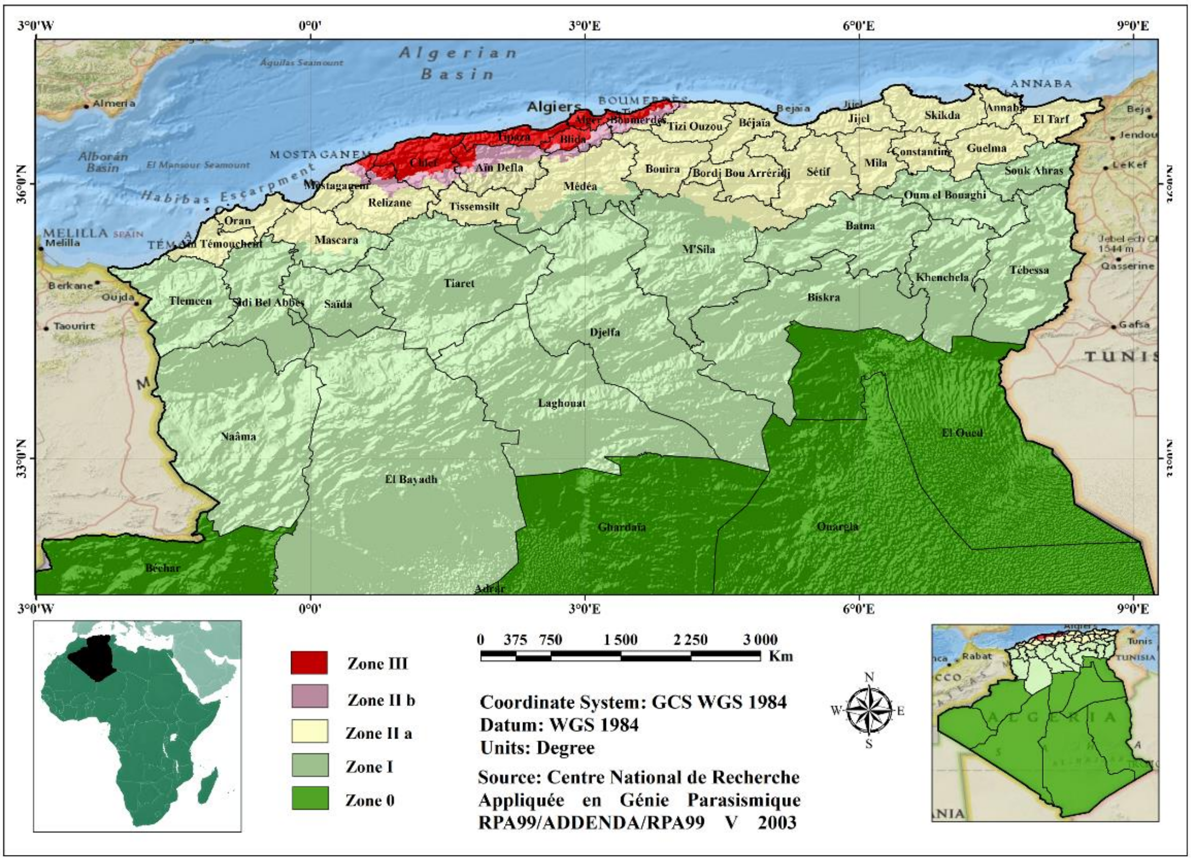

Fig. 1. *Seismic zones in Algeria [32]*

Group 1A: Buildings of vital importance.

Group 1B: Buildings of major importance.

Group 2: Common buildings or of a medium importance.

Group 3: Buildings of minor importance.

Accordingly, the Algerian seismic regulations give the following zone acceleration coefficients (Table 1).

Table 1. Zone acceleration coefficient [32]

	Zone			
Importance	I	IIa	IIb	III
1A	0.15	0.25	0.30	0.40
1B	0.12	0.20	0.25	0.30
2	0.10	0.15	0.20	0.25
3	0.07	0.10	0.14	0.18

As for the construction sites, the Algerian seismic regulations [32] classify them into four (04) categories based on the mechanical properties of the soil which constitute them.

Category S1 (rocky site): rock or other geological formation characterized by an average shear wave speed (VS) ≥ 800 m/s.

Category S2 (firm site): deposits of very dense sand and gravel and/or overconsolidated clay 10 to 20m thick with VS ≥ 400 m/s below 10m depth.

Category S3 (loose site): thick deposits of moderately dense sand and gravel or moderately stiff clay with VS ≥ 200 m/s below 10m depth.

Category S4 (very loose site):

- deposits of loose sand with or without the presence of layers of soft clay with VS < 200 m/s in the first 20 meters.

- soft to moderately stiff clay deposits with VS < 200 m/s in the first 20 meters.

The analyzed model

In order to assess the impact of green roofs on the seismic performance of collective housing in Algeria, a typical building is chosen as shown in Figure 2. This building is located in the district of Constantine (northern east of Algeria), which falls under the IIa seismic zone. The IIa zone was chosen because it covers a large zone in the northern part of Algeria extended from the east to the west, and known for its important population density. The building importance is classified according to the Algerian seismic regulations in group 2 (common buildings or of medium importance); this category contains buildings for collective housing or office use in which the height does not exceed 48m, other buildings that can accommodate a maximum of 300 people simultaneously, such as office buildings, industrial buildings …etc., and public parking lots. The chosen collective housing is built on a loose site (site of category S3 [32]).

The analyzed building is composed of six floors, each floor is composed of 4 apartments that share one staircase. The overall area of each floor is about 356m^2. The height of each floor is 3.06m, thus, the total height of the building is 18.36m. The cross section of columns varies between 1600 and 1800cm^2. As for the roof, it is inaccessible with a waterproof isolation covered by river gravel.

Fig. 2. *Picture of the analyzed collective housings*

The structural system consists of concrete load-bearing walls (15cm thick) and reinforced concrete (RC) frames. According to the Algerian seismic regulations [32], RC framed buildings with rigid masonry walls (rigid masonry walls are the common separation walls in Algerian buildings) must not exceed five (05) levels or seventeen (17) meters in seismic zone I, four (04) levels or fourteen (14) meters in zone IIa, three (03) levels or eleven (11) meters in zone IIb and two (02) levels or eight (08) meters in zone III. If the aforementioned heights are exceeded, buildings must include concrete load-bearing walls.

The bracing system consists only of concrete load-bearing walls, since in the studied model, the concrete load-bearing walls absorb more than 20% of the forces due to vertical loads [32]. As for the floor, it is made of a hollow block slab that transfers the vertical loads in the X direction. This later is assumed to be fully rigid, i.e., it transfers all the lateral loads to the bearing walls. Regarding the weight of the floors, it was calculated accounting for the hollow block slab and the materials used in floor covering, a value of 5.25 KN/m^2 is adopted for the studied case. In the present study, the compressive strength of the concrete is 25 MPa.

Since the building's roof is already equipped with water-proof isolation covered by river gravel, and the drainage system is already in place, the green roof is considered to be installed directly on the building, as demonstrated in Figure 3. The soil depth varied between 10cm (shallow green roof) and 50cm (deep green roof). The weight of the green roof is calculated using the saturated soil density (19 KN/m^3) and accounting for the weight of the plants as (0.45 KN/m^2). As for the live load, it is considered as maintenance load of 1 KN/m^2.

The building was modeled using the finite element code Robot structural analysis (Fig.4). A modal analysis was performed first, followed by a seismic analysis according to the Algerian seismic regulations. For the

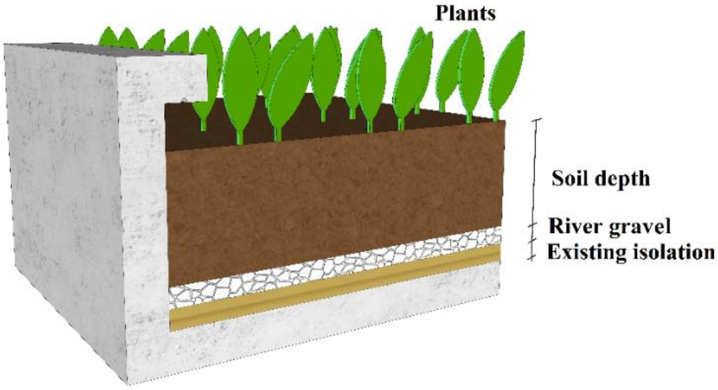

Fig. 3. *Schematic illustration of the green roof*

generation of finite elements, the nodes are generated at the intersection of vertical/horizontal bars. The tolerance of structure model generation for the analyzed model is 0.1mm. Regarding load-bearing walls, for the mesh generation, an element size of 0.5m was adopted. In this study, only the seismic performance-related parameters were analyzed.

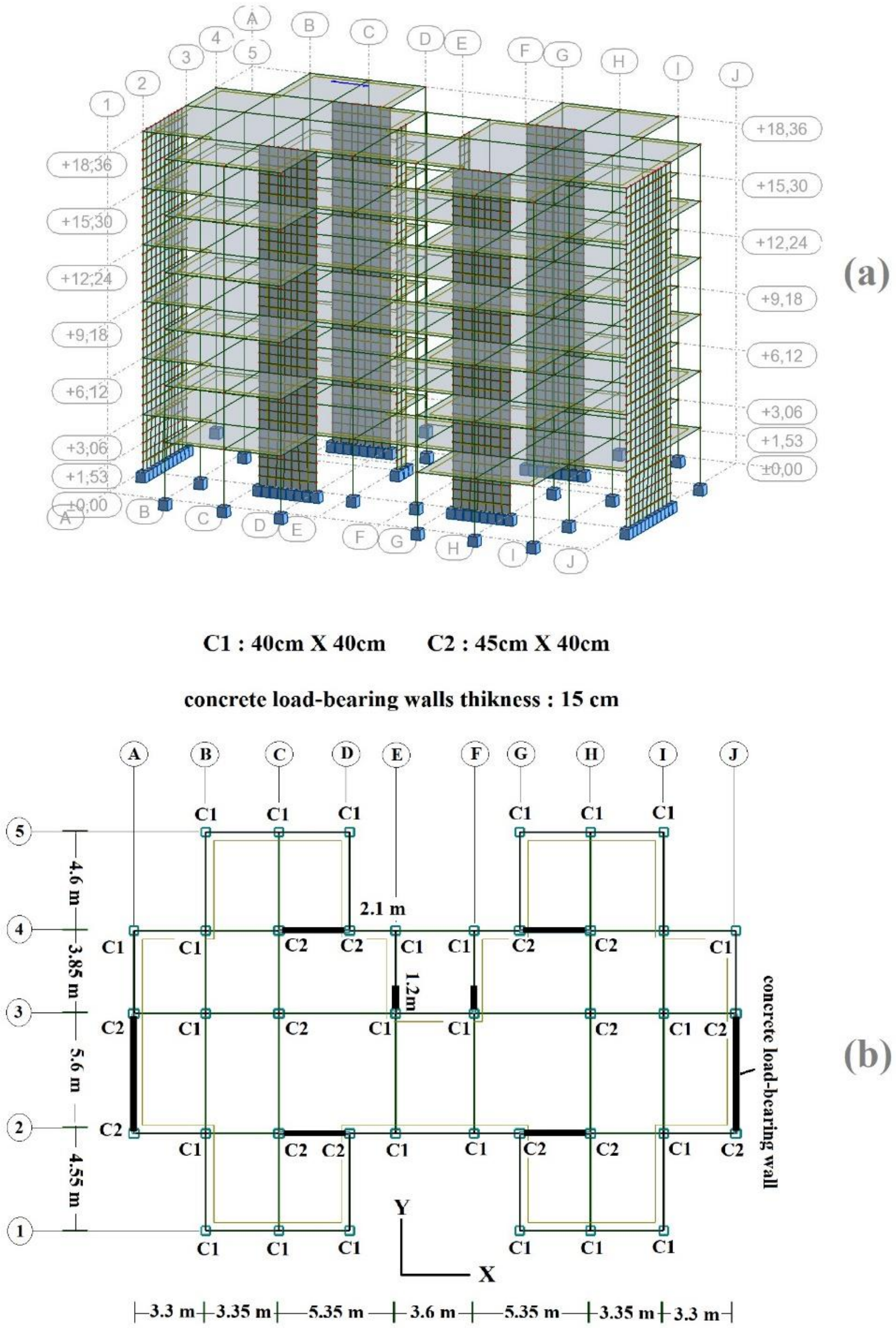

Fig. 4. *The 3D (a) and the building plan (b) of the analyzed numerical model*

Results and Discussion

In the present paper, the seismic performance of a collective housing with green roof retrofitting in Algeria is investigated according to the Algerian seismic regulations [32]. In order to assess the impact of green roofs on the seismic performance of this building, the natural period of the building, reduced normal forces in columns, peak storey drift, relative displacement, shear forces at the base, and overturning moment are investigated.

Effect of the green roof on the natural period of the building

It is meant by the natural period of a building, the time taken by it to undergo one complete cycle of oscillation. The value of the fundamental period (T) of the structure can be estimated from empirical formulas or calculated by analytical or numerical methods. The empirical formulas to use are as follows [32]:

$$T = Ct.hn^{3/4} , \tag{1}$$

h_n : height measured in meters from the base of the structure to the last level (n).
C_t : coefficient, function of the bracing system, type of separation walls. In this case study: "Bracing provided partially or totally by concrete load bearing walls, triangulated blocks and masonry walls" Ct = 0.05.
And:

$$T = \frac{0.09\, hn}{\sqrt{L}} , \tag{2}$$

where L is the dimension of the building measured at its base following the considered calculation direction. In this case, it is appropriate to retain, in each direction considered, the smaller of the two values given, respectively, by formulas (1) and (2).

In the present study, the soil depth of the green roof is varied from zero (building without green roof) to fifty centimeters (building with deep green roof), the period of building varies as plotted in Figure 5.

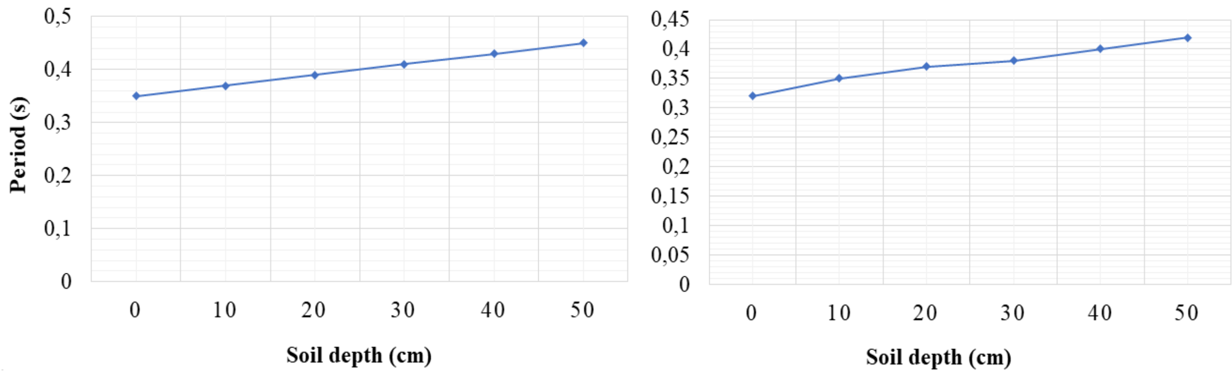

Fig. 5. *Analytical period of the structure in X direction (left side), and Y direction (right side)*

As plotted in Figure 5, the analytical period increases with the increase of the depth of the green roof in both X and Y directions (see Figure 4 for X and Y axes). As for the fundamental period calculated using formulas (1) and (2), they are 0.31s in the X direction and 0.38s in the Y direction.

For the X direction, the analytical period is greater than the fundamental one (0.31s) for all green roof depths, however, in the Y direction, the analytical period is less than the fundamental one (0.38s) for green roof depth less than 30cm and greater for green roof depths 40 and 50cm.

The tolerated analytical period should be less than 1.3 times the fundamental one [32]. In this case, less than 0.40s in the X direction, and 0.49s in the Y direction. For the present study, the periods in the building with 30, 40, and 50cm green roof depth in the X direction offered a greater period than that tolerated by the Algerian seismic regulations. Thus, for all the other configurations, the building periods obey the Algerian seismic regulations. This can be explained by the fact that the presence of load-bearing walls in the building contributes to a more rigid behavior of this later.

Effect of the green roof on peak storey drift

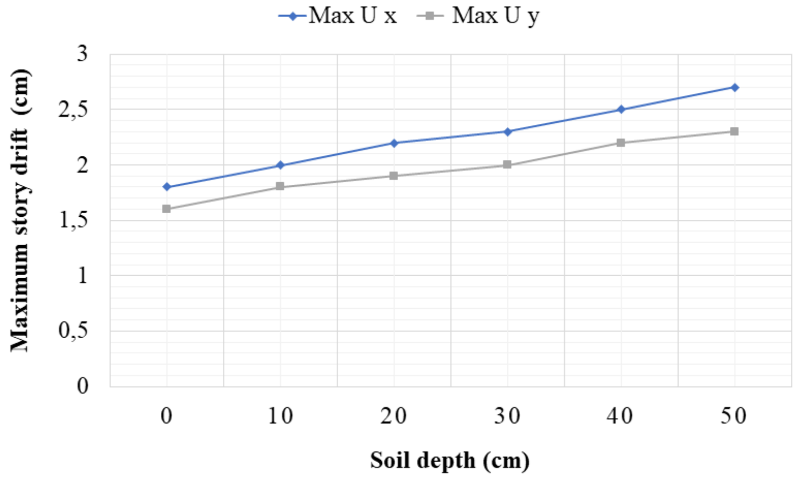

Fig. 6. *Variation of the maximum top storey drift with respect to the green roof soil depth in X and Y directions*

Adding more weight on the top of an existing building will logically cause the maximum storey drift to increase during an earthquake event. Thus, when adding a green roof to an existing building, it is important to make sure that the maximum storey drift at the top is not high enough to collide with the adjacent building.

In the present study, the maximum storey drift with respect to the green roof soil depth is analyzed as shown in Figure 6.

It is noticeable for both directions that the peak storey displacement increases with the increase of soil depth. In the X direction, the increase of top storey maximum displacement (Max Ux) between the building without green roof and the one with 50cm green roof is 0.9cm, and for the Y direction (Max Uy) it is 0.7cm. This increase is not very substantial due the presence of load-bearing walls.

Effect of the green roof on relative storey displacement

By definition, the relative displacement at level "k" with respect to level "k-1" is equal to:

$$\Delta_k = \delta_k - \delta_{k-1} \quad . \tag{3}$$

The lateral relative displacements of a storey relative to the storey adjacent to it, must not exceed 1.0% of the height of the storey unless it can be proven that a larger relative displacement can be tolerated [32].

In the present study, the relative displacement for each storey increases with the increase of the green roof's soil depth. The tolerated relative displacement should be less than 1% of storey height, thus less than 3.06cm, which is the case for all green roof soil depths (Fig.7).

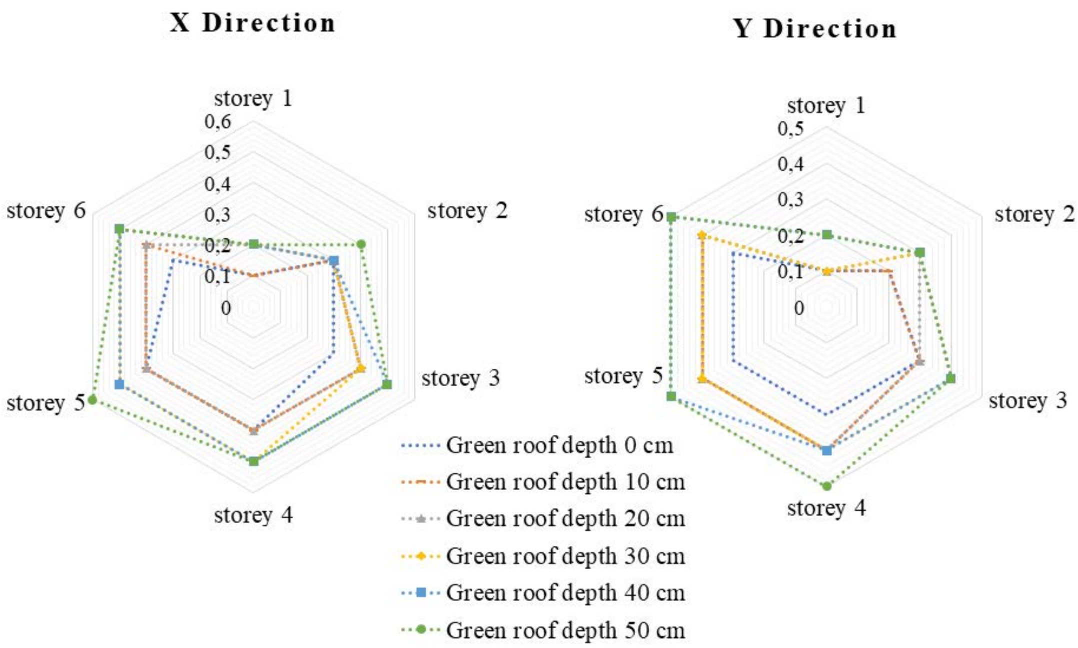

Fig. 7. *Variation of relative storey displacement (cm) with respect to the green roof soil depth in X and Y directions*

Effect of the green roof on reduced normal force

The reduced normal force is restricted in order to avoid or limit the risk of brittle failure under overall stresses due to the earthquake. The threshold for the reduced normal force in columns is 0.3. This later is calculated using the formula [32]:

$$\nu = \frac{Nd}{Bc.fcj}, \tag{4}$$

where Nd indicates the normal force applied on a column section of concrete during the event of an earthquake; Bc is the area of the column; fcj is the compression strength of the concrete (25 MPa).

As plotted in Figure 8, it is clear that the reduced normal force increases with the increase of green roof depth, however, for all soil depths, the reduced normal force is less than the threshold recommended by the Algerian seismic regulations.

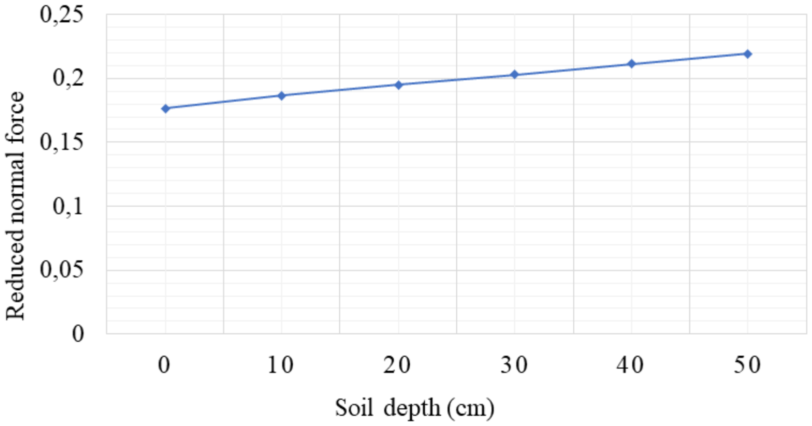

Fig. 8. *Variation of reduced normal force with respect to green roof soil depth*

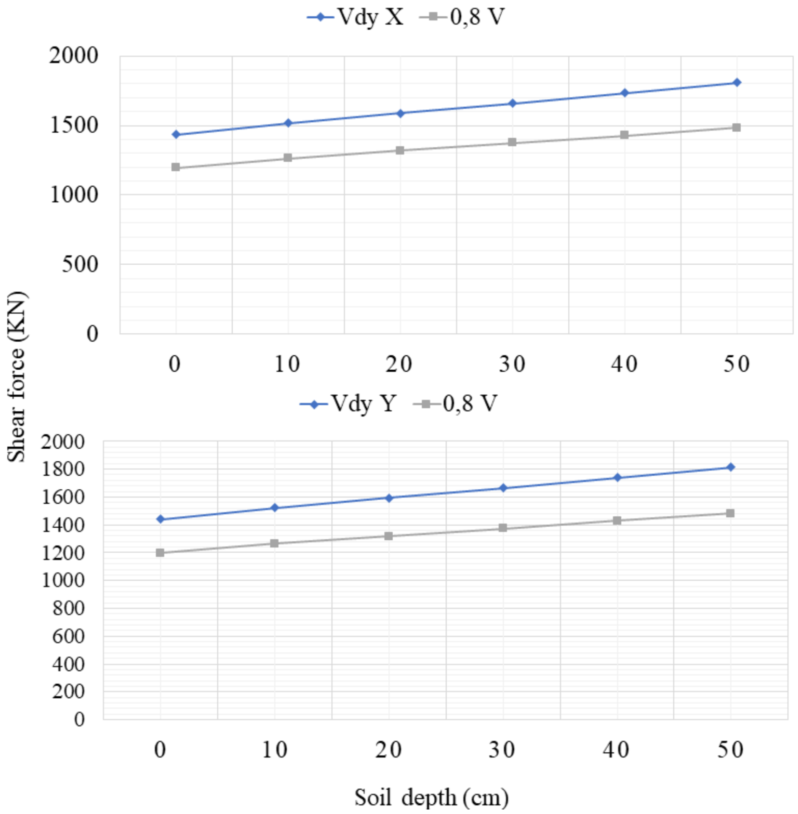

Fig. 9. *Variation of shear forces at the base with respect to green roof soil depth in X direction, and Y direction compared to 0.8 V*

Effect of the green roof on shear forces at the base

At the base of the structure, the resultant of the seismic forces (Vt) calculated by combining the model values must not be less than 80% of the resultant of the seismic forces given by the equivalent static method (V), for a value of the fundamental period specified by the appropriate empirical formula [32].

If Vt < 0.80 V, it will be necessary to increase all the parameters of the response (forces, displacements, moments...etc.) in the ratio 0.8 (V/Vt) [32]. Figure 9 shows the variation of shear forces at the base with respect to green roof soil depth in X and Y directions.

The total seismic force V, applied to the base of the structure, must be calculated successively in two orthogonal horizontal directions according to the formula [32]:

$$V = \frac{A.D.Q.W}{R}, \tag{5}$$

A: zone acceleration coefficient,
D: average dynamic amplification factor,
Q: quality factor,
W: total weight of the structure,
R: coefficient of the global behavior of the structure.

As shown in Figure 9, the shear forces at the base increase with the increase of soil depth. In both X, and Y directions, the shear forces for a building with the deepest green roof (50cm) are around 125% of that without a green roof, which represents a significant increase in the shear forces due to green roof implementation.

Effect of the green roof on overturning moment

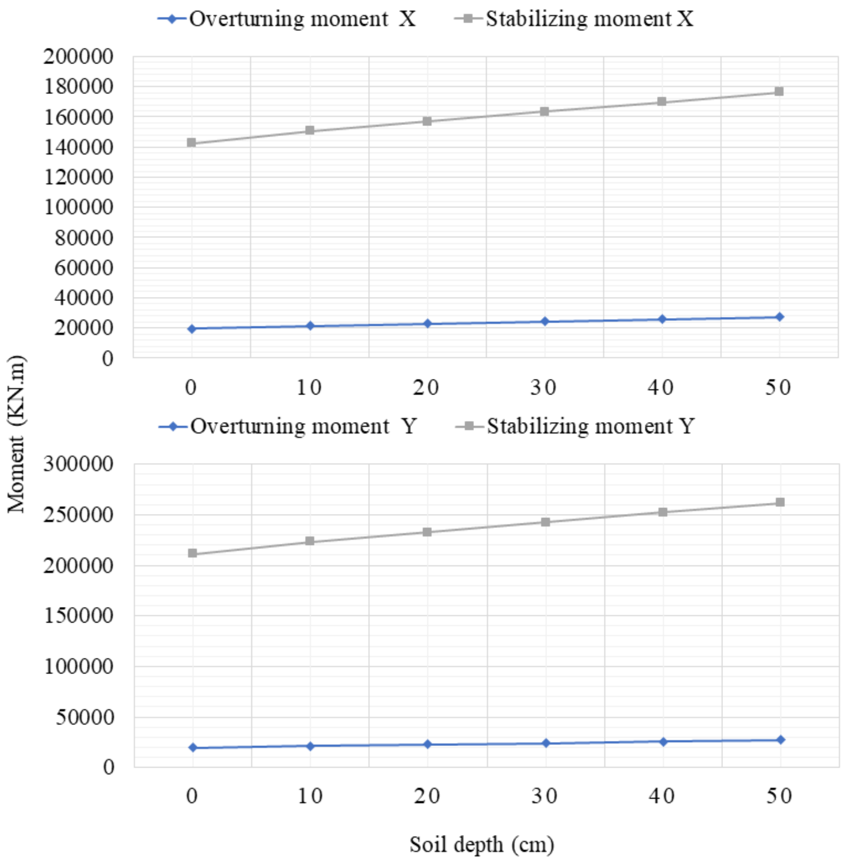

Fig. 10. *Variation of overturning and stabilizing moment in X and Y directions*

The overturning moment caused by an earthquake is an important parameter that must be included in seismic performance analysis. When it comes to green roofs, the weight of this later participates in both overturning moment and stabilizing moment. As shown in Figure 10, the stabilizing moment is much greater than the overturning one. Also, both overturning and stabilizing moments increase with the increase of green roof soil depth, however, the increase in the stabilizing moment is much significant, thus, adding a green roof contributes more to the stabilizing moment than to the overturning one.

Conclusion

Green roofs offer many advantages with regards to reducing energy consumption, mitigating the urban heat island effect, improving air pollution, managing runoff, increasing sound insulation, and preserving the ecological environment. All these qualities make green roofs a very sustainable technique for the ecological transition. However, in order to propagate this technique, green roofs have to be installed on the top of existing buildings, which can increase their vulnerability during seismic events. In this research, the seismic performance of collective housing with green roof retrofitting in Algeria is investigated according to the Algerian seismic regulations.

It was found that the presence of load-bearing concrete walls, recommended by the Algerian seismic regulations, has a certain positive effect on green roof installation with regard to the seismic performance. The presence of these walls increases the rigidity of the building which reflects positively on the building natural period and displacements, thus, even with the loads generated by the green roof installation, most of the displacement-related parameters remained obeyed to the Algerian seismic regulations.

As for the stress-related parameters, the reduced normal stress does not increase much, however, the shear forces at the base for the building with a deep green roof are around 125% of that without a green roof, which represents a significant increase in the shear forces due to green roof implementation.

Both overturning and stabilizing moments increase with the increase of green roof soil depth, however, the increase in the stabilizing moment is much significant, thus, adding a green roof contributes more to the resisting moment than to the overturning one.

In the studied context, the presence of load-bearing concrete walls offers certain positive effects on green roof installation with regard to seismic performance. Nevertheless, a thorough seismic investigation should be performed before installing green roofs on the top of existing collective housing in Algeria.

Conflict of Interest

The authors declare no conflicts of interest.

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TRANSFORMATIVE EFFECTS OF SALINITY ON SEBKHA SOIL PROPERTIES: UNVEILING STRENGTH, STRUCTURE, AND STABILITY THROUGH ADVANCED REMEDIATION STRATEGIES

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Abstract: *This study investigates the effects of varying salinity levels on sebkha soils, focusing on their physical, mechanical, and chemical properties. Soil samples were collected from Tin silt sebkha in Ain M'lila across three different seasons, resulting in high salinity soil (HSS), medium salinity soil (MSS), and low salinity soil (LSS). The grain size distribution curves reveal that 70% of grains in both HSS and LSS have diameters less than 60 µm, with LSS containing 19% more particles smaller than 20 µm compared to HSS. Unconfined compressive strength (UCS) measurements show a significant decrease from 1100 kPa in LSS to 200 kPa in HSS, with corresponding peak strains increasing from 2.3% to 4.7%. Chemical analysis indicates that pH decreases from 8.17 in LSS to 6.79 in HSS, reflecting increased soil acidity with higher salinity. SEM images demonstrate that higher salinity results in a denser soil structure due to salt cementation, whereas lower salinity soils exhibit more micropores. The study highlights the need for comprehensive models integrating these properties to enhance predictive capabilities and inform effective soil management. Future research should explore remediation strategies using additives to improve soil strength and stability, addressing the challenges posed by salt dissolution and soil degradation.*

Keywords: *salinity, sebkha soil, grain size distribution, unconfined compressive strength, soil pH, SEM analysis, soil remediation, predictive modeling.*

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Introduction

Problematic soils are globally prevalent and pose considerable challenges to civil engineering infrastructures, often leading to costly damage and structural failures [1, 2]. Among these, collapsible soils are particularly notorious due to their sudden loss of strength upon wetting. Houston et al. [3] identified collapsible soils as one of the most problematic geomaterials in the field of geotechnical engineering, and the study of their behavior is essential for designing foundations and other civil structures. Sabkha soils, a specific type of unsaturated collapsible soil, are particularly troublesome in arid and semi-arid regions [4-7]. Their high soluble salt content and low clay fraction promote the formation of a macroporous structure, where soil particles are loosely bonded [8]. Under dry conditions, the salt phases act as a cementing agent, stiffening the soil structure. However, exposure to water triggers the dissolution of these crystalline phases, destabilizing the bonds and drastically reducing the soil's strength, which can lead to catastrophic settlement or collapse [8].

In recent decades, researchers have increasingly focused on understanding the complex behavior of saline soils, given their widespread occurrence in coastal and desert regions. Ying et al. [9] observed that compaction properties remain relatively unaffected by varying salinities, primarily due to the low clay content, which limits the influence of salinity on the diffuse double layer. However, Li et al. [10] demonstrated that the higher the chloride content is, the more likely the agglomerates are to appear in the soil, altering its microstructure. Hafhouf et al. [11] further highlighted the vulnerability of sabkha soils to drying-wetting cycles, showing that prolonged leaching significantly reduces soil salinity from 16.3 dS.m-1 to 3.8 dS.m-1, with the corresponding soil strength decreasing by almost 50%, from 325 kPa to 175 kPa. Similarly, Modmoltin et al. [12] found that soil salts could mitigate some of the negative effects of organic matter on treated soils, while Li et al. [13] demonstrated that chloride salts weaken the mechanical properties, such as unconfined compressive strength, even if compaction remains largely unaffected. Moreover, Xing et al. [14] identified that chloride ions (Cl-) have the most detrimental impact on the strength properties of saline soils, followed by magnesium (Mg2+) and sulfate (SO42-), indicating that the chemical composition of salinity plays a pivotal role in determining soil behavior.

Despite these efforts, there remains a notable divergence of opinions in the scientific community regarding the effects of salinity, especially in relation to soil strength. Some studies report a stabilizing effect of certain salts, while others emphasize their destructive impact on soil cohesion and mechanical integrity [15-17]. These discrepancies are largely attributed to the complex interplay between different types of salts, which is often not fully accounted for in studies focusing on a single ion [18]. Furthermore, the role of microstructure is increasingly recognized as a critical determinant of macroscopic behavior. Foncea et al. [19] emphasized the influence of natural soil structure, classifying soils into macroporous and microporous categories, each with distinct permeability and strength characteristics. This highlights the need for a more integrated approach, combining both chemical and structural analyses, to fully capture the effects of salinity on soil performance [20].

The primary objective of this study is to address these gaps by investigating the combined effect of chloride and sulfate salts on the physical, chemical, and mechanical properties of saline soils. The research aims to provide a more comprehensive understanding of how varying salt concentrations affect soil behavior under different environmental conditions, particularly in relation to its strength, compaction, and permeability. Furthermore, advanced microstructural analysis using Scanning Electron Microscopy (SEM) will be employed to elucidate the interaction between salt phases and soil particles, linking microscopic changes to macroscopic behavior. By bridging the gap between microstructural and macrostructural analyses, this study seeks to offer new insights into the mechanisms governing the behavior of saline soils, particularly in complex environments where multiple salts interact. These findings will have practical implications for geotechnical design, offering strategies for mitigating the risks associated with saline and collapsible soils in infrastructure projects.

Materials and Methods

Soil samples were collected from the Tin silt sebkha in Ain M'lila using a hydraulic excavator, at a depth of 1 to 2 meters below the surface. This sampling was conducted during three distinct seasons: summer, spring, and winter, resulting in three different salinity levels: highly saline soil (HSS), moderately saline soil (MSS), and slightly saline soil (LSS). The classification of these salt-affected soils follows the guidelines established by the US Salinity Laboratory Staff [21]. After collection, the samples were air-dried, gently crushed using a plastic hammer to avoid contamination, and then sieved through a 2 mm mesh to remove larger particles.

Ying et al. [9] demonstrated that the salinity levels have an insignificant effect on the Atterberg limits of soils with low clay content. As a result, only the geotechnical characteristics of HSS are presented in Table 1, since variations in salinity did not significantly alter these properties for the other samples. The highly saline soil (HSS) was classified as Lean Clay (CL) according to the Unified Soil Classification System (USCS). The chemical composition of HSS, shown in Table 2, reveals the dominance of chloride (Cl-) and sulfate (SO4^2-) ions, with concentrations of 3585 mg/l and 4704 mg/l respectively, indicating the presence of halite and gypsum phases. According to Loyer (1991), the soil's pH of 6.79 classifies it as a neutral chloride-sulfate soil.

Table 1. The geotechnical characteristics of HSS

Soil parameters	Methods	Values
Liquid limit LL		34.00
Plastic limit PL	(ASTM D4318-00, 2000	17.300
Plasticity index PI		16.70
≤ 2 mm fraction (%)	(NF P94-056, 1996)	98
≤ 80 µm fraction (%)		68
≤ 2 µm fraction (%)	(NF P94-057, 1992)	3
USCS	(ASTM D2487-00, 2000)	CL

Regarding soil compaction characteristics, such as optimal dry density (δdopt) and optimal water content (wopt), it was observed that the salinity levels had a negligible impact, a finding consistent with that of Ying et al. [9]. Therefore, all three soil types—HSS, MSS, and LSS—were compacted at their respective optimum water contents, which remained constant across varying salinity levels. This consistency suggests that, despite significant chemical differences, the mechanical response of the soil to compaction is not strongly influenced by salinity within the studied range.

Table 2. The chemical composition of the soluble salt content of HSS

ECe ($dS.m^{-1}$)	Salinity ($g.l^{-1}$)	pH	Soluble salt content ($mg.\ l^{-1}$)						
23.2	14.84	6.79	Na^{2+}	K^{2+}	Ca^{2+}	Mg^{2+}	HCO_3^-	Cl^-	SO_4^{2-}
			2323	50	391.2	156.5	10	3585	4704

Results and Discussion

Granulometry

Figure 1 demonstrates the grain size distribution curves (GSDC) of sebkha soil across varying salinity levels, revealing the significant influence of salinity on particle size distribution, particularly within the silt grain range. The non-convergent trend between slightly saline soil (LSS) and highly saline soil (HSS) underscores the complex interplay between soil salinity and granulometry. For both LSS and HSS, approximately 70% of the particles exhibit diameters smaller than 60 µm, yet when examining finer fractions, the divergence becomes more apparent. For LSS, 57% of the grains fall below 20 µm in diameter, whereas for HSS, only 38% do, representing a 19% increase in fine particles for LSS compared to HSS.

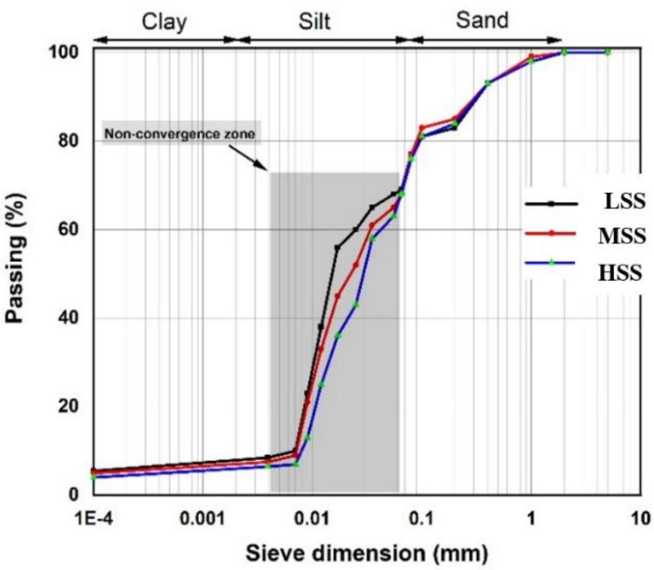

Fig. 1. *The grain size distribution curves of the three sabkha soils*

This variation can be explained by the presence of soluble salts such as halite (NaCl) and gypsum ($CaSO_4 \cdot 2H_2O$) in HSS [22]. These salts act as cementing agents between soil particles, especially within the silt fraction, due to the larger specific surface area of silt particles relative to sand grains [23]. The specific surface area is a critical factor in geotechnical engineering, as it dictates the degree of interaction between particles and binding agents. In dry conditions, halite and gypsum form strong crystalline bonds that stabilize larger aggregates, effectively reducing the proportion of fine particles. However, upon exposure to moisture, the dissolution of these salts weakens the interparticle bonds, leading to the disintegration of aggregates and an increase in the proportion of finer particles [24].

The impact of salinity on particle size distribution is closely linked to the microstructural properties of the soil. Silt particles, with their higher specific surface area, are more susceptible to salt cementation compared to coarser sand grains. This interaction leads to the formation of larger aggregates in saline environments, but when subjected to wetting-drying cycles, the breakdown of these aggregates results in a shift towards finer particle fractions. Such behavior is consistent with findings by Li et al. [13], who observed that increased chloride salt concentrations induce crystallization and flocculation, thereby increasing the proportion of particles greater than 2 μm. This suggests that chloride salts play a fundamental role in modifying soil structure through the crystallization of salt phases, leading to temporary stabilization that is disrupted during dissolution processes.

Furthermore, the differential behavior between HSS and LSS can be attributed to the chemical composition of the soils. HSS contains a higher concentration of soluble salts, which enhances the cementing effect between soil particles. These salts form a rigid matrix that holds the particles together, leading to larger aggregates and a reduced proportion of fine particles in dry conditions. Conversely, LSS, with a lower concentration of salts, exhibits less aggregation, resulting in a higher proportion of fine particles. The dissolution of salts in HSS causes the breakdown of these aggregates, thereby increasing the fraction of fine particles under moist conditions. This process is particularly relevant in sebkha soils, which experience fluctuating moisture levels due to environmental conditions, leading to cycles of salt precipitation and dissolution that significantly alter soil structure.

The presence of gypsum and halite in sebkha soils, especially in the silt fraction, is further supported by their high solubility in water, making them highly susceptible to dissolution. When exposed to moisture, these salts dissolve, weakening the soil's structural integrity and leading to a loss of cohesion between particles. This results in an increase in the proportion of finer particles, as previously cemented aggregates disintegrate. This behavior is critical for understanding the geotechnical performance of saline soils, particularly in regions where seasonal variations in moisture can lead to dramatic changes in soil stability.

Additionally, the limited clay content in the tested sebkha soil explains why the effect of salinity on the clay fraction is minimal. Clay particles, known for their plasticity and water retention capabilities, typically respond to salinity through changes in the diffuse double layer and interparticle forces. However, due to the low clay fraction, these effects are negligible in the current study, and the influence of salinity is predominantly observed in the silt fraction. Ying et al. [9] also noted that for soils with a low clay fraction, salinity has little to no effect on the Atterberg limits, further supporting the hypothesis that the observed behavior is primarily driven by interactions between soluble salts and silt particles.

In conclusion, the grain size distribution of sebkha soils is strongly influenced by salinity levels, with significant differences observed between LSS and HSS [25]. The cementing effect of soluble salts such as halite and gypsum plays a crucial role in stabilizing soil aggregates, particularly in the silt fraction, while the dissolution of these salts during wetting cycles leads to the disintegration of aggregates and an increase in fine particles [26].

Stress-strain curves of unconfined strength tests

The stress-strain curves presented in Figure 2 illustrate the results of unconfined compressive strength (UCS) tests for sebkha soils with varying salinity levels. The stress-strain behavior of these soils is influenced significantly by salinity, with a marked decrease in peak strength prior to failure across all samples. A key observation is that soils with higher salinity exhibit a more pronounced ductile behavior, meaning that peak strength is attained at larger axial strains as salinity increases. This relationship is crucial in understanding the mechanical performance of saline soils in geotechnical applications.

In saline soils with higher salt content, such as halite (NaCl) and gypsum ($CaSO_4 \cdot 2H_2O$), the solid salt phases within the soil skeleton begin to dissolve under certain moisture conditions. Halite, being highly soluble, dissolves rapidly upon contact with water, transforming solid particles into fluid phases [27]. This dissolution leads to a loss of cohesion between soil particles, thereby disrupting the soil structure and resulting in a softer, more ductile response under loading. The mechanical disturbance caused by the dissolution of these salt phases explains the reduction in strength and the shift toward greater ductility, as the soil becomes less capable of resisting deformation [4].

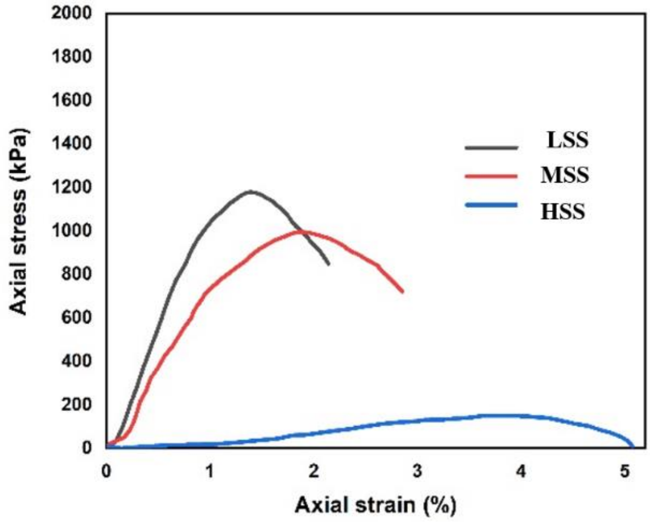

Fig. 2. *The stress-strain curves of compacted three sabkha soils*

In contrast, gypsum is less soluble compared to halite, which slows its dissolution process. However, even partial dissolution of gypsum can still contribute to the weakening of the soil matrix. The combined presence of these salts leads to a progressive softening of the soil, with increasing salinity exacerbating the degradation of the soil's structural integrity. As a result, the soil's capacity to bear loads decreases, which is evident from the stress-strain curves.

For the slightly saline soil (LSS), the dissolution phases are almost negligible due to the lower salt content. The low solubility of salts in LSS ensures that the soil structure remains largely intact, leading to a stiffer response during loading. This is reflected in the stress-strain curve, where the LSS displays a prominent peak at failure, indicating that the soil retains much of its original strength until a distinct failure point is reached. The pronounced peak in the blue plot (Fig. 2) represents this stiff behavior, as LSS maintains its cohesion and strength over a broader range of axial strain before failing suddenly, which is characteristic of more brittle materials.

The transition from stiff, brittle behavior in low-salinity soils to soft, ductile behavior in high-salinity soils can be attributed to the complex interplay between the dissolution of soluble salts and the resulting changes in the soil microstructure. As the salinity increases, the soil undergoes a shift in mechanical behavior from brittle failure, where the soil fractures and fails abruptly, to ductile deformation, where the soil continues to deform beyond the peak load without sudden failure. This behavior is indicative of the weakening bonds between particles, caused by the dissolution of salts [4].

The progressive ductile response with increasing salinity highlights the need for careful consideration of salinity in geotechnical design, particularly in regions with saline soils like sebkha environments. The softening of the soil structure due to salt dissolution can lead to significant settlement and deformation in engineering structures, particularly when subjected to loading over time. Therefore, understanding the stress-strain behavior of saline soils is essential for predicting their performance under real-world conditions, especially in areas where moisture fluctuations can exacerbate the dissolution of salts.

Unconfined compressive strength

Figure 3 illustrates the relationship between peak strength, axial strain, and salinity levels for sebkha soil samples subjected to unconfined compressive strength (UCS) testing. The peak strength (UCS) represents the maximum stress the soil can withstand before failure, while the slope of the stress-strain curve before failure indicates soil stiffness. Both the UCS and stiffness exhibit a decreasing trend with increasing salinity levels, highlighting the detrimental effect of salt content on the mechanical properties of sebkha soils.

For example, the UCS is only 200 kPa for highly saline soil (HSS), while it increases to 580 kPa for

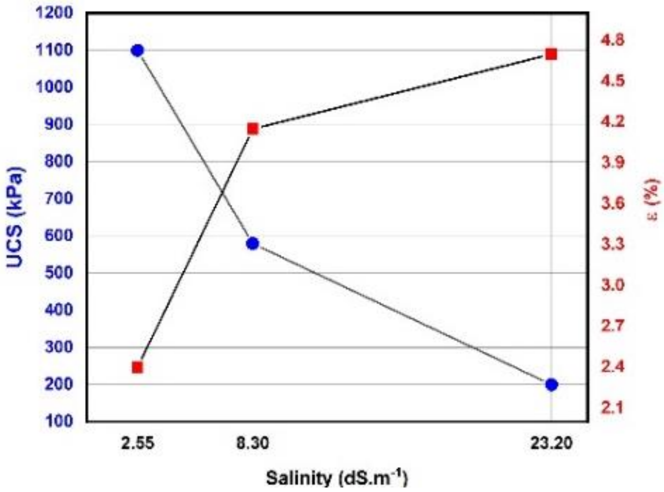

Fig. 3. *The peak strength and axial deformation of compacted three sabkha soils*

moderately saline soil (MSS) and reaches 1100 kPa for low salinity soil (LSS). These results suggest that salinity significantly weakens the soil structure, particularly in soils with high soluble salt content, such as halite and gypsum. The dissolution of these salts under certain moisture conditions compromises the integrity of the soil matrix, leading to a notable reduction in strength.

In contrast, the axial strain at failure exhibits the opposite trend. The strain at failure (ε) is much larger for HSS (ε = 4.7%) and MSS (ε = 4.2%) compared to LSS (ε = 2.3%). This inverse relationship between salinity and strain indicates that higher salt concentrations result in more ductile behavior, where the soil deforms more before reaching its failure point. The high ductility of HSS and MSS can be attributed to the dissolution of halite and gypsum, which causes the soil structure to soften and undergo greater deformation before failure. In LSS, however, the lower salt content limits the dissolution processes, resulting in a stiffer and more brittle response under loading.

The variations in UCS and strain between MSS and LSS are more pronounced than those between HSS and MSS, indicating that the reduction in salinity from 8.30 dS.m-1 to 2.55 dS.m-1 has a more substantial effect on the soil's strength and stiffness compared to the reduction from 23.2 dS.m-1 to 8.30 dS.m-1. This finding can be explained by the relative solubility of the salts involved. In highly saline soils, halite is the dominant phase due to its high solubility, and it dissolves more readily when exposed to water. In contrast, in MSS, gypsum becomes the predominant phase, which is less soluble and has a more significant impact on the soil's mechanical properties.

The presence of gypsum in MSS plays a critical role in both strength and stiffness. While halite dissolves rapidly, leading to a softer soil structure, gypsum's slower dissolution process allows it to maintain some cohesion and strength within the soil matrix. However, when MSS is exposed to leaching, the gradual dissolution of gypsum can lead to a significant reduction in soil resistance. This makes MSS highly susceptible to strength loss during wetting-drying cycles, posing a potential risk for civil engineering works in saline environments. In this context, field conditions involving MSS warrant closer attention due to the greater risk of structural degradation over time.

In summary, the UCS and stiffness of sebkha soils increase as salinity decreases, with LSS demonstrating the highest strength and lowest strain at failure. Conversely, the ductility of the soil increases with salinity, as evidenced by the larger strains at failure for HSS and MSS. The sharp reduction in strength and stiffness between MSS and LSS highlights the critical role of gypsum in soil behavior, particularly in environments where salinity levels fluctuate. Given these findings, MSS soils in particular should be carefully monitored and managed in geotechnical applications to prevent excessive weakening under environmental stressors such as leaching.

Chemical Analysis

Seasonal climatic conditions play a critical role in influencing soil salinity through mechanisms such as capillary action and evaporation. The solubility of different salt phases in the soil is contingent on the salt type and its degree of crystallization, as well as the inherent structure of the soil (Foncea et al.[19]). In the case of the sebkha soil under study, chloride salts are predominant. Chlorides are highly soluble, which means they readily dissolve in moisture and migrate to the soil surface via capillary forces and evaporation. This process leads to a reduction in soil salinity as the chloride content diminishes over time.

In contrast, gypsum, which is also present in the soil, exhibits a lower solubility rate compared to chloride [28]. Gypsum's dissolution is less pronounced under the same conditions, leading to a slower decrease in soil salinity. This differential solubility influences the overall chemical composition and pH of the soil, as reflected in the chemical analysis results [29].

Table 3 provides an overview of pH variations across different salinity levels. It is observed that as soil salinity increases, there is a corresponding decrease in pH, indicating an increase in soil acidity. This trend is attributed to the high concentration of chloride ions in the soil, which contributes to a more acidic environment. Specifically, the soil at the highest salinity level (HSS, CE = 23.2 dS.m-1) shows a significant drop in pH, reflecting the strong acidic influence of chloride salts.

Table 3. The chemical analysis of compacted three sabkha soils

CE ($dS.m^{-1}$)	pH	Salt content ($g.l^{-1}$)
23.20 (HSS)	6.79	14.24
8.30 (MSS)	8.03	5.31
2.55 (LSS)	8.17	1.29

Conversely, when salinity decreases from 23.2 dS.m-1 to 2.55 dS.m-1, there is a notable increase in pH from 6.79 to 8.17, resulting in a more neutral environment. This shift is indicative of the reduced impact of acidic chloride salts and the relative dominance of less acidic phases, such as gypsum, which contributes to the neutralization of soil acidity. The variation in pH values underscores the dynamic interplay between different salt phases and their impact on soil chemistry.

The impact of salinity on pH is more pronounced when transitioning from high salinity levels (e.g., 23.2 dS.m-1) to lower levels (e.g., 8.30 dS.m-1), reflecting a more significant change in soil acidity. In contrast, the pH variations between lower salinity levels (e.g., 8.30 dS.m-1 to 2.55 dS.m-1) are less dramatic, suggesting that the soil's chemical environment stabilizes as salinity decreases.

This chemical behavior has practical implications for managing saline soils in agricultural and civil engineering contexts. High salinity levels can lead to increased soil acidity, which may adversely affect plant growth and soil stability. Conversely, lower salinity levels are associated with a more neutral pH, which can be more conducive to plant growth and soil health.

Microstructural Analysis (SEM)

Figure 4 provides insights into the microstructural characteristics of sebkha soil samples analyzed via Scanning Electron Microscopy (SEM). The observations reveal significant differences in the soil microstructure corresponding to various salinity levels.

High Salinity Soil (HSS)

In Figure 4 (a), the SEM images of HSS illustrate the presence of well-defined crystalline salt phases. The soil's chemical composition, predominantly chlorine-sulfate, confirms that halite (NaCl) and gypsum ($CaSO_4 \cdot 2H_2O$) are the main compounds. Halite typically appears as white, platelet-like crystals, whereas gypsum exhibits a more random and varied morphology. These salt crystals contribute to a denser soil structure through their cementing action. The halite and gypsum crystals act as binding agents, creating a cohesive matrix of soil particles. The interlocking of these crystals with soil particles forms a robust network that enhances the soil's initial strength and stiffness. However, the stability of this structure is contingent upon the salt phases remaining intact.

Low Salinity Soil (LSS)

In contrast, the SEM images of LSS reveal a different microstructural arrangement. The lower salt content in LSS results in a less dense structure with more noticeable micropores between the soil aggregates. This porous texture is likely due to the reduced presence of soluble salts like halite and gypsum, leading to fewer cementing agents within the soil matrix. Additionally, the lower clay content in LSS may contribute to the more pronounced appearance of micropores, as the reduced clay fraction limits the overall cohesion and binding capacity of the soil [25].

The effect of salinity on soil microstructure is evident in the observed changes. Higher salt content results in a denser and more cohesive soil structure due to the cementing effect of halite and gypsum [25]. However, when the soil is exposed to water, the solubility of these salts comes into play. Halite, being highly soluble, dissolves readily upon moisture exposure, which disrupts the cementing bonds and weakens the soil structure. Gypsum, while less soluble, still contributes to structural changes over time. The leaching process, wherein salts are washed out from the soil surface, creates additional micropores and alters the particle arrangement, resulting in a more porous and less cohesive structure.

The dissolution of salts through leaching significantly impacts the soil's mechanical properties. As the cementing salts are removed, the previously bound soil particles are left with reduced cohesion, leading to a decrease in soil strength and stiffness. This shift in the microstructural arrangement highlights the importance of considering salinity and its impact on soil behavior in practical applications [30].

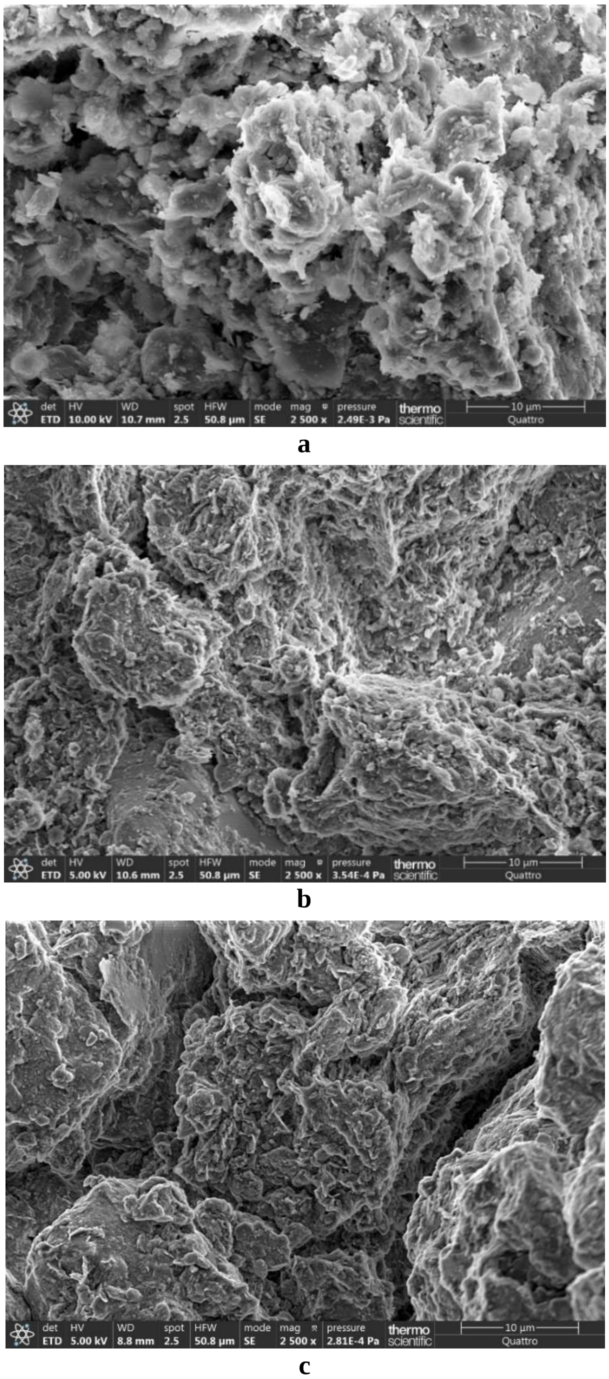

Fig. 4. *SEM of compacted three sabkha soils:*
a - HSS, b - MSS, c - LSS

Conclusion

The investigation into the effects of salinity on sebkha soils has yielded significant insights into their physical, mechanical, and chemical properties. The study reveals the following key findings:

- **Grain Size Distribution**: Higher salinity levels lead to a greater proportion of finer particles, with 70% of grains having diameters less than 60 µm. Specifically, low salinity soil (LSS) contains 19% more particles smaller than 20 µm compared to high salinity soil (HSS). This shift is attributed to the dissolution of larger aggregates in high salinity conditions, which increases the proportion of finer particles.
- **Stress-Strain Behavior**: Increased salinity results in more pronounced ductility and reduced peak strength. The unconfined compressive strength (UCS) decreases from 1100 kPa in LSS to 200 kPa in

HSS, while the peak strain at failure increases from 2.3% to 4.7%. This trend indicates that higher salinity softens the soil structure due to the dissolution of salt phases, disrupting soil cohesion.

- **Unconfined Compressive Strength (UCS)**: UCS decreases with increasing salinity, with values of 200 kPa for HSS, 580 kPa for medium salinity soil (MSS), and 1100 kPa for LSS. The maximum strain at failure also varies, showing higher strain in higher salinity soils. This reflects the impact of gypsum and halite on soil strength, with gypsum having a significant effect when salinity levels decrease.
- **Chemical Analysis**: The pH of the soil decreases with increasing salinity, indicating greater acidity. The pH shifts from 8.17 in LSS to 6.79 in HSS, highlighting the influence of chloride concentrations. The transition from high to low salinity also shows a shift towards a neutral pH environment.
- **Microstructural Analysis (SEM)**: Higher salinity soils exhibit a denser microstructure due to salt cementation. In contrast, lower salinity soils have a more porous structure with increased microporosity. The dissolution of salts under higher salinity leads to structural rearrangements, affecting soil strength and stability.

Future research should focus on developing comprehensive models that integrate the chemical, physical, and mechanical properties of saline soils. These models would enhance predictive capabilities, aiding in the design of effective soil management strategies. Additionally, understanding the effects of salinity on soil properties can inform remediation and stabilization techniques. Investigating methods to stabilize or improve saline soils with additives or treatments that counteract the negative impacts of salt dissolution could significantly enhance soil strength, cohesion, leading to more robust and sustainable management practices.

Conflict of Interest

The authors declare no conflicts of interest.

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A TYPOLOGICAL IDENTIFICATION OF THE LARGE HOUSING ESTATES OF 1950S IN ORAN. EXPLORING THE THREE - DIMENSIONAL APPROACH

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Abstract: *In Algeria, the city of Oran is home to around fifty large housing estates built in the 1950s-1962, designed according to ethnic diversity, amalgamated location between the city center and the surrounding suburbs accompanied by facilities with a metropolitan influence, also known as modern housing estates, witnessed a revolutionary trend never seen before in Algerian society in particular, living in shantytowns. However, they suffer fierce criticism associated with their monotony and similar design, leading to their stigmatization and marginalization. This article aims to identify typological diversity across three dimensions, architectural, urban and social, using ethno-architectural analysis, comparing inhabited surveys, semi-directive interviews and photographs to highlight the particularity and typological characteristics of a sample of large housing estates in Oran. The results obtained by this study reveal that the typologies vary according to the dimensional criteria raised, highlighting their diversity and richness.*

Keywords: *large housing estates, typologies, three-dimensional, ethno-architectural, inhabitant.*

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Introduction

With the influx of labourers, followed by the further expansion of family immigration [1] and the rise in Algerian families 77.3%[1], the housing problem started to manifest in 1946. Consequently, the construction of housing for the majority was initiated in the suburbs of Oran [2], leading to the emergence of the *'large housing estates'* a novel model of social housing mandated in 1949 [3] to be implemented across metropolitan France and the French colonies. A chance emerged to transform the city of Oran into a contemporary metropolis, by transitioning from unsanitary and unstable housing to innovative and comfortable dwelling, in line with the prevailing societal movement of that era. An innovative architectural style and a vibrant social environment emerged between 1950 and 1962, culminating in a significant milestone in Algeria's colonial housing history. Conceptualized as self-governing municipalities with cultural, health, educational, and economic amenities [4], these towns often resulted from a crisis that required public policy intervention. They were mostly perceived as catalysts for social and cultural change [5], but in other cases, they were seen as catalysts for social and cultural transformation. Initially, these towns appeared unaffected by the political system, which is prevalent in Western democracies like France and Italy but is exported by the metropolis to Algeria [6]. The housing stock primarily consists of dwellings constructed in the adjacent suburbs for the two separate populations, with a small number located in the central city.

Contrary to what we are used to hearing about a test laboratory, the large housing estates were first initiated in the French metropolis, the country of origin, before finally arriving in Algerian soil, the country of importation [7], designed by world-renowned architects such as Pouillon Candilis and Simounet, specialists in social housing, who carried out large-scale housing projects in the major Algerian cities (Oran-

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[1] DEMONTÈS Victor, L'Algérie économique: la population algérienne, t. 2, Algiers, Impr. algérienne, 1923, 498p. (based on data from Augustin Bernard's Enquête about habitation of algerian's indigènes (1921)); quoted by KATEB Kamel, Européens, "indigènes" et Juifs en Algérie..., op. cit., p.183).

Alger, Annaba), as well as major construction companies that were responsible for the territorial and technical development of several large housing estates, including the Algerian company Chauffour-Dumez and the Algerian company Léon Ballot, one of the factors that ensured the large-scale production of housing. The title of this period of cooperation is "The Algerian Saga" [8], the complexity of which is linked to the different contexts in which they were built [9].

However, from the 2000s onwards, fierce criticism seemed to be at its height, with all the large housing estates in Oran beginning to be seen as identical banal creations, the source of all the evils of society - delinquency, prostitution, theft, crime - a superficial and unscientific discourse that dragged on and stigmatized their development, or even delayed a possible heritage strategy, already envisaged in some cases overseas, witness to a social, urban and architectural history of a particular period that will not be repeated [10], an approach that illustrates this inscription of GEs in time [11]. The large housing estates in Oran are neither classified as heritage nor considered valuable architecture. This is due to the need to identify their diversity and uniqueness, some of which are hidden. This question raises concerns given its quantitative importance, which reaches 20% of the housing stock [12]. The vice-heritage approach has strengthened the protection of the architectural product as a whole, and the issue of conserving social housing is of greater concern to some agents of the architectural and heritage production space [13].

Through recent research into the future of this modern colonial architectural heritage, we want, using this article, to share the elements dissected to take account of the diversity of the four essential historical, social, urban and architectural dimensions, whose reflection on heritage should be given some limits based at least on its four headings [13]. Beyond the conclusions drawn from the typological diversity that we have gradually rediscovered through the ethno-architectural approach, the case study makes it possible to break with the criticisms of their repetitive monotony. A solid base of data has been developed to understand the concept of large Algerian housing estates better in order to make rational and objective decisions about their trajectory, which can be fulfilled and sustainable in the face of heritage approaches whose commitment begins first with identification, knowledge, protection, and enhancement [14].

In addition to proposing a reflection aimed at incorporating everyday, ordinary life into the heritage approach, this research on six large housing estates in Oran aims to alter the typically static perception of the banal, concealing immensely rich characteristics and activities... Reference [15]. The questions pertained to their relationship with their current residence and the modifications they had implemented before or during their relocation. The study residences were chosen using the quota sampling technique.

Materials and Methods

This research work is grounded on the empirical ethnoarchitectural approach, which allowed for direct field tests to confirm the previously formulated premise. Drawing on a representative sample of six exemplary large housing estates, volumetric, aesthetic, structural, and socially diverse features are examined despite variations in location within the city (city center/suburbs). An examination of the data acquired by an investigative instrument, including surveys, semi-structured interviews as the primary data gathering method, specifically intended to investigate responses to indirect enquiries [16], and images of exteriors, collectively known as "ethno-architectural surveys". This survey is a method that enables data collection with a quite reasonable degree of validity [17]. During the field study, criteria and sub-criteria were developed and organized into a typology to define the main geographical areas. Table 1 displays the primary criteria and sub-criteria for each dimension to determine the typologies of the large housing estates. It demonstrates their uniqueness, which aligns with an architectural component and a wider societal rationale [18] that can be considered a national legacy, seen as a contextual architectural heritage that fuses modern architecture with local architecture in large Muslim housing estates.

Table 1. Criteria and sub-criteria for large housing estates typologies (source: authors, 2023)

Architectural dimension	Urban dimension	Social dimension
The location of spaces (served, serving)	Perception	Dynamic social environment
		Daily activities such as the market
		religious festivals
Conviviality	layout	Income level
Defined surfaces	Size and shape	Education level
Degree of transformation		
Access to dwellings	Mode of access	Category of communal areas appropriation
		Behaviour
		Sociability
Window types	Number of dwellings	*Original inhabitants*

We are currently observing the third generation of residents in the various large estates, with a notable predominance of young residents aged 28, representing 50% of the sample, and middle-aged people up to 45, who make up 35%. Those aged 70 and over make up a smaller proportion, at 15%. The field survey included perspectives from all three generations (older people, adults and teenagers). It ensured balanced representation between genders (male/female) and between tenants and homeowners during the semi-structured interviews, which were organized at the time of the cell surveys and at the time of the national religious holidays, which began with key questions combined with secondary questions in order to clarify the purpose of the interview [19].

Case study

Oran has a strong identity, reflected in its rich and diverse architectural heritage. These traces of the past help to make Oran a modern city: Oran, on the contrary, is a city without suspicion, in other words, a completely modern city [20]. The large housing estates of the 1950s were created with the help of several project managers, a harmonization that bears eloquent witness to the joint efforts of these personalities. The work of locating and identifying the initial corpus of large housing estates from 1950-1962 is an essential stage that precedes the phase of selecting and analyzing large housing estates for a diversified typological identification (Table 2). To this end, two waves of large housing estate construction have been identified, showing the richness of their diversity.

The first wave (1950-1958) was marked by the architectural richness and monumentality of the large complexes, with conceptual variations in the flats depending on their purpose (Muslim, European). The complexes of this first phase also came closest to the principles postulated by the architects of the Athens Charter in 1933, with the integration of elements that "make up" modern comfort.

The second wave (1958-1962) was clearly marked by the sobriety and informality of the façades. This period coincided with the adoption of the "Constantine plan", when the effort was multiplied with singular creations by universally recognized masterpieces (Fig.1).

Table 2. Identification sheet for the six main case studies

Large housing estates	L.H.E 1	L.H.E2	L.H.E3	L.H.E4	L.H.E5	L.H.E6
Year of construction	1951-1957	1957	1956-1958	1955-156	1959	1954-1956
Architect	Pierre Jean Guth	Justin Marie	Henri Désiré Cantie	Justin Marie	Jean Bedeau Andre Gomis V.Mialy D.Roman	Fernand Pouillon
Owner	HLM company	Algerian Cooperative Society for Muslim Housing	Municipal Housing Office HLM	Algerian Cooperative Society for Muslim Housing	C.I.A[2] for C.I.LO.F[3]	HLM company
Housing category	H.L.M improved	Semi-urbain[4]	Million	Semi-urbain	Million[5]	H.L.M improved
Number of dwellings	580	376	602	254	520	614
Destination	Marine officers + civilian civil servants + workers from mainland France	Resettlement scheme for tenants of buildings in danger of collapse in the navy district	French social class	Algerian Muslims	Civil servants	Naval staff

1 L.H.E Dar Beida

2 L.H.E Sid el houari

3L.H.E Lescure

4 L.H.E la quiétude

5 L.H.E les falaises

6L.H.E Valmy

Fig. 1. *Photographic images of the six large housing estates of the case study (source: authors + Oran archive)*

[2] Algerian real estate financing.

[3] Housing company for civil servants.

[4] Semi-urban' housing, specific to Algeria, was introduced at the end of the decade. This was a "much simpler type (...) designed to provide a decent flat for those living in the casbahs or gourbis with limited resources" Guillopé. 2023, p. 516.

[5] The so-called "million-franc" housing scheme, envisaged from the summer of 1954, was introduced in November 2. Expected to cost one million francs, it was designed as an intermediate range between the Logécos, which many people found too expensive, and the "basic economic housing" (LEPN), also known as "standard economic housing". Decree no. 54-1120 of 10 November 1954 (JORF-LD, 16 November 1954, p. 10793; see also the opinion of the Economic Council in its meeting of 8 March 1955, reproduced in the appendix dedicated to Regulatory Texts.

Results and Discussion

Spatial configurations on an urban scale (recurring mass layouts)

The compositional analysis of the ground plans in our corpus reveals three recurring typologies that have been attempted in this selection. These typologies are focused on the criteria of orientations described as guiding principles of the ground plan and the layout, distribution, and assembly of these plans to the extent that they exhibit variations.

The Tower and bar model

This model is very much in line with the standard definition and the image that immediately springs to mind for these housing developments built in France. Comprising low-rise blocks and a tower of over 17 storeys with bars, the ensemble forms a central island affected by an internal courtyard. The designers propose to open up panoramic views towards the immediate environment from the volumes created; this large-scale composition has made it possible to acquire the maximum number of dwellings known as the "million operations" which is the size of the large-scale operation comprising 500 to 600 dwellings. The orientation of this typology is identical, most often N/S or E/W (Fig.2).

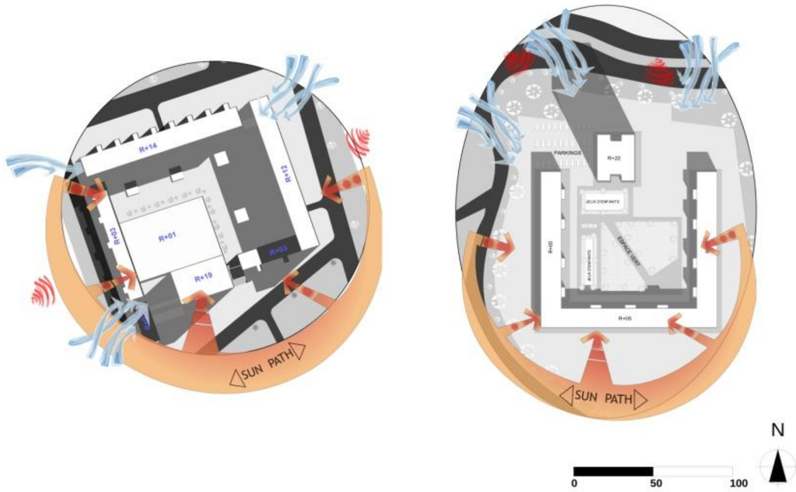

Fig. 2. *The mass plans of the Tower and bar model Lescure+Les falaises (authors, 2023)*

The pavilion model

The pavilion model accounted for a significant portion of our corpus (60%), comprising a sequence of bars with identical shapes that ran parallel or perpendicular to each other and varied in orientation. This resulted in an expansion of the range of house designs implemented. These developments are of medium to large scale, often consisting of 200 to 600 houses, with the concept occasionally integrated into some of the bigger compositions. Since the direction of the different low-rise blocks (R+5) and their distance around each other result in very low or nonexistent masking effects, the sunshine factor was a genuine worry. Thus, this design deviates significantly from the conventional design of major developments, which involves different orientations for all the buildings and a maximum of 2 or 3 "typical" structures of the same height and surface area that would be replicated to form the project (Fig.3).

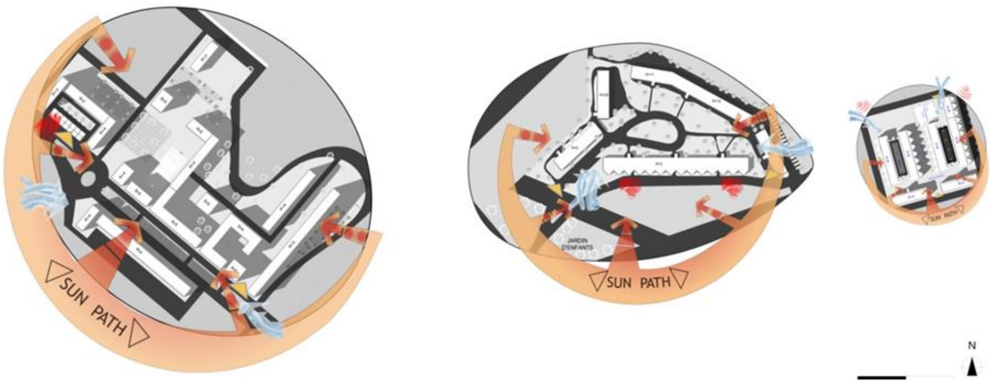

Fig. 3. *The mass plans of the pavilion model Valmy +Sid el Houari+La quietude (authors, 2023)*

The Hybrid model

The Hybrid model comprises a centrally situated huge structure, including a tower affixed to a long, curved bar, with equipment injected into the surrounding area from opposite sides of the plot. Three identical bars have been positioned at a locus in the northeastern direction. The northern side strip consists of two 4-storey structures strategically positioned to face about north and south, thereby maximizing the advantages of the winter sun and the summer sea wind (Fig.4).

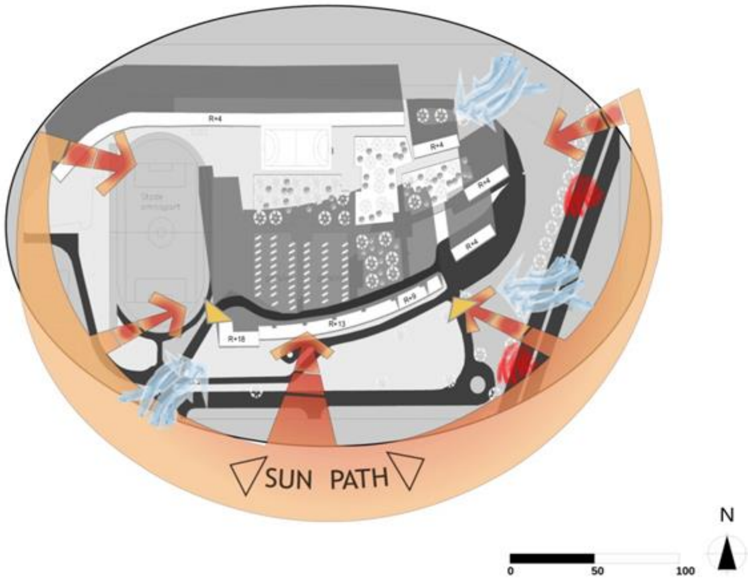

Fig. 4. *The mass plan of the hybrid model of Dar el Beida (authors, 2023)*

Spatial configurations on an architectural scale (plan of recurring dwellings)

The "Semiramis" plan [6]

This typology has found wide expression in Oran [21]. The characteristics of this type of flat are linked first and foremost to local requirements, as it was designed for the conservative indigenous population. Access to the different flats is via the corridor. The principle organization of the flat plan places the service spaces directly at the entrance. It pushes the service spaces to the rear, where the circulation spaces of Semiramis are less visually exposed, and the high walls preserve the inhabitants' privacy to a greater extent [22]. Unlike the spatial distribution of the concentric open-air courtyard found in the traditional Muslim house, this typology provides for separating the courtyard from the other spaces, thus losing its traditional organizational and structural role. The windows have been drilled into the walls on a reduced scale to maintain privacy and allow people to see without being seen (Fig.5).

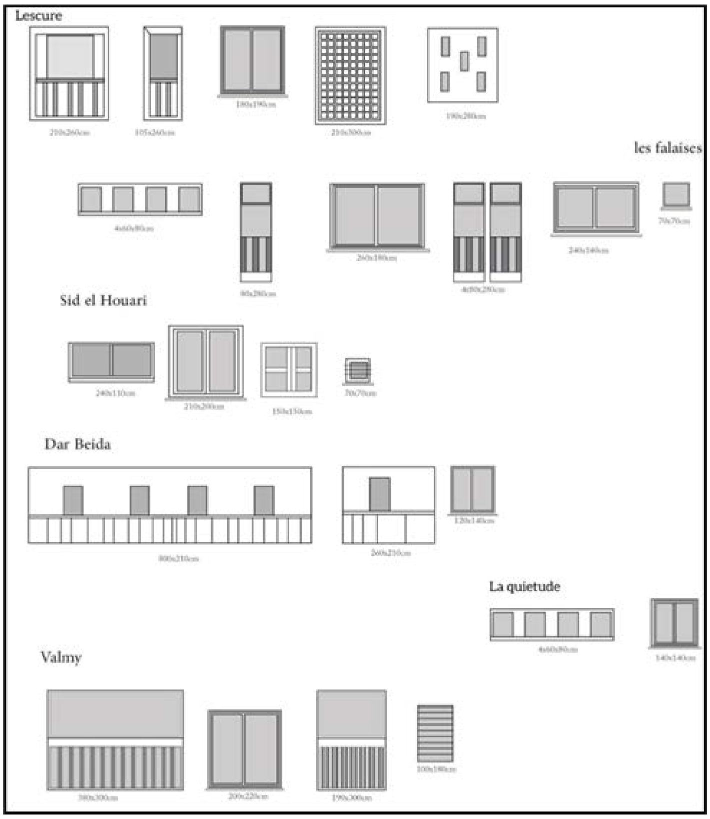

Fig. 5. *Survey of type of windows for each case study. Oran (authors, 2023)*

This type of housing, therefore, corresponds well to the desired objective: to provide affordable housing with a high level of modernity and comfort so as not to create a financial imbalance for the head of the family. The surface areas are identical in the two programmers', 2 and 3 rooms in the majority (T2=36.81m^2,

[6] Conceived by architect George Candilis, this is a model of social housing specifically created for the Algerian and Morocco people. It maintains a formal architectural layout resembling a tripod with pathways and incorporates a traditional courtyard at the back of the residence. The serviced areas are prominently displayed in large sizes.

T3=48.87m², T4=65.87m²), all of which face both sides of the building, so they benefit from a dual orientation that allows them to receive maximum light and sunlight. A single architect's design of identical accommodation for two different housing estates with the same purpose does not inspire any transformation or modification[7] (Fig.6).

Fig. 6. *Survey of a dwelling T2, T3, T4 of Sid el Houari and la Quietude. Oran (authors, 2023)*

Logécos plan[8]

This is a typology that first existed in the French metropolis and was transported to Algerian soil, keeping the same dwelling surface areas[9] T3 = from 48 to 67 m², 4P = from 53 to 68m, established by a decree of 16 March 1953 "Dwellings must have electric lighting and equipment, including at least an installed shower, a sink and a washbasin, WCs must be installed inside the dwelling; possible derogations (absence of existing technical networks" [23]. This type includes the large Lescure and Les Falaises developments, which were designed in an era of technical modernization but also with hygiene in mind [24]. Housing of the "economical and family" type will enjoy all modern conveniences and benefits from dual orientation. The living rooms face south and west and are magnificently exposed, while the kitchen is equipped with a drying rack to protect it from the sun, separate from the living room. The walls of the facades are made of white ashlar, pierced by large picture windows, a symbol of openness (Fig. 5). However, investigations and surveys have revealed two types of modification: additions to the landing and extensions to the kitchen, removing the drying room to acquire a few extra square meters. The second is the introduction of new interior spaces by adding partitions, given that the space is large. These two types of action, the first one privileges to exploit wasted space, while the second involves the independence of each space (Fig.7).

[7] The observations and interviews carried out in 2023 for this type of housing reveal no major changes to the housing, which results from a development designed to meet the needs and lifestyle of the local population from the outset.

[8] Economic and family, it is a type of housing managed by a low-rent housing organization (HLM), public or private, that benefits from partial public funding, direct (subsidy) or indirect, Dictionary la rousse2015 .la petite “economic” property (“Logécos” formula).

[9] Inter-ministerial order of 17 March 1953, art. 5 (JORF-LD, 18 March 1953, p. 2562).

Fig. 7. *Survey of a dwelling T3, of Lescure and Les falaises Oran (authors, 2023)*

Improved HLM plan

Pouillon is a prime example of this. In the Valmy housing estate, intended for the families of naval personnel on duty at the Lartigue naval air station, the flats have 1-5 rooms plus a kitchen, toilet and shower room. They all have a double aspect based on a North-East, North-West / South-East, South-West layout. The "day" and "night" areas are also clearly separated, with the living area first and the dining area at the back of the home. Adding a bedroom to the living room means we can choose between an extra bedroom or a larger living room. This housing configuration aims to offer households freedom in the layout of their homes. This is an example of an innovative architectural concept, reflected in the "flexibility to modify" of the plans, enabling flats to be converted, enlarged or reduced in size in the future without having to undergo major alterations. Despite the same purpose, the spatial distribution is well thought out and nuanced (Fig.8). No changes were made to the accommodation in these two housing estates, given the generosity of the space and the modern comforts.

Fig. 8. *Survey of a dwelling T3, T4 of Dar Beida and Valmy. Oran (authors, 2023)*

Spatial configurations on a social scale (the expression of inhabitants)

Based on interviews with residents and two years of observations, a proposal has been made for a social typology about the different areas of the large housing estates, broken down into three categories:

Discreet social housing

Discreet social housing includes the two major housing estates, Valmy and Dar el Beida (Fig.9), which are now inhabited by non-sedentary military families who are not native to the city of Oran. 80% of the interviewed population reported that the residents' experience is characterized by secrecy: "We cohabit but remain not acquainted with one other; this is due to the state's responsibility for the upkeep and administration of the large housing estate". They intend to depart for their extended family outside Oran during religious holidays. Veschambre argue that the appropriation of housing is associated with identity and symbolism, characterized by its tangible, consistent, and demonstrative implementation manner [25].

Fig. 9. *Communal spaces in the two large housing estates (Valmy, Dar Beida) (authors, 2023, 7 p.m.)*

Intense social housing

Lescure, la quietude, and Les Falaises housing estates are characterized by a vibrant and lively social life, which is highly valued for its distinctive influence on the intellectual development of the residents. The primary factor that led to the development of this typology is the significance of identity within the cohabitation of various categories of inhabitants who contribute to the formation of diverse values in acquiring and utilising shared areas. "We can see that the relationship between societies and their spaces, places, and territories has a strong identity dimension", Di Méo[10] observes (Table 3).

Table 3. Summary table of the survey carried out at the three locations (authors, 2024)

Criteria / Large housing estates	Dynamic social life	Income level	Level of education	Type of appropriation of communal spaces	Original inhabitants
Lescure	Strong	Low	Medium	Singular	70%
Les falaises	Strong	High	High	Authentic	85%
La quiétude	Strong	Low	Low	Modest	95%

The courtyards in the three large housing estates embody a unique act of appropriation by the inhabitants. This co-ownership IU enhances the reputation of the estates by fostering a positive utilization of the space and promoting a vibrant social life. This is evident not only daily but also during religious festivals when the courtyards serve as exceptional venues for appropriation (Fig.10). Most of the interviewed residents originate from the expansive housing estates, which have existed since the 1960s-1970s, following the departure of the French social class. However, a few residents of the quiet area have continued to live on the premises even after gaining independence. This can be attributed to their relatively low income and level of education, as is characteristic of the native population. Conversely, on the cliffs, many residents are productive farmers with a substantial income, which is seen in the genuine use of the community spaces[11].

[10] DI MÉO, Guy. L'identité: une médiation essentielle du rapport espace/société. *Géocarrefour*, 2002, p. 175.
[11] In 2022, the wali of Oran redecomposed LES FALAISES as the most robust and well-preserved huge ensemble in Oran.

Fig. 10. *Common spaces in the three main areas during festive religious events (Lescure, les falaises, La quietude) (authors, 2023)*

The social ghost

The observed and investigated realities reveal a typology of a large housing estate devoid of vitality and liveliness. This typology is not only influenced by its location in the old Oran (formerly a shanty town) with insufficient facilities and a cemetery that serves as an obstacle facing the large housing estate (Fig.11). Additionally, 70% of the interviewed residents do not hail from this area, resulting in a lack of identity value, nostalgia, and militancy. Consequently, the absence of appropriation of the various common spaces can be justified.

"*I have recently relocated to Oran, where I work and spend my days outdoors, so I am unfamiliar with the residents. The area is tranquil, with everyone confined to their peaceful residences. Even during periods of weakness, I choose not to venture outside to prevent potential conflicts with the inhabitants*". Extract from an interview with a 36-year-old male resident of Mascara town.

The absence of recreational spaces, street furniture, and diverse landscape elements, such as trees, vegetation, and tiny squares, elucidates the lack of vitality in SID el Houari, mirroring the loss of spirit among its inhabitants.

"Regrettably, our former residents, who were single families, have left this large housing estate, which met the standards of social diversity, justice, citizenship, equality, and solidarity. New arrivals value this type of housing more than residents born in the complex. I intend to maintain a pristine appearance, particularly in the courtyard where we interact socially". Extract from an interview with a 71-year-old man.

The analysis of the three-dimensionality of the six major housing estates revealed the identification of three distinct typologies of these estates based on clearly established criteria. The data collecting approach we will employ is "ethno-architectural surveys". Including urban typologies characterized by their size, shape, purpose, and number of residents, it is evident that the shapes were mostly varied by the tower block and bar type, facilitating the integration of green areas. Ultimately, various models that were preferred by the political figures of that era, namely the diverse project owners, extended outside the HLM office. Two other models were proposed: the pavillonnaire, characterized as an unstructured open urban model, and the hybrid model, which integrates the above-described models with a balanced urban layout and includes many amenities. A reimagined version of the traditional house, with the courtyard patio as the key organizational element, the "Semiramis" style is designed for the conservative Algerian populace, whose spaces are somewhat limited. The Logécos "economic family" low-cost housing model has surface areas that precisely match those of the metropolitan low-cost housing model. All three- and four-bedroom flats in this model are designed with a double orientation to ensure optimal sunlight exposure for the dwellings. In the spatial dwelling, an enhanced low-cost housing concept created by famous architects for navy personnel and their families, the east-facing bedrooms receive morning light. At the same time, the living spaces get maximum sunlight during the middle of the day. Conducting a comparative analysis of the facades has enabled the determination of the number of bay models associated with the intended use of the extensive complex. Within Muslim housing, the typical number of windows per project ranges from 2 to 4. Several expansive home developments within European housing, such as les Falaises, Valmy, and Lescure, feature a range of 3 to 6 distinct types of openings.

Fig. 11. *Common space in the large housing estate of Sid el Houari (authors, 2023, 11 a.m.)*

The extensive housing development's social structure was an essential factor in comprehending and analyzing it. Three social typologies, characterized by varying degrees of apparitional, discreetness, and liveliness, were identified. These typologies were examined based on how both native inhabitants and newcomers appropriated communal places.

Conclusion

Additionally, this study enabled the creation of typologies for large housing estates that go beyond the typical towers and bars commonly associated with them [26]. Contrary to popular belief, large housing estates are not uniform and standard but rather distinct from one another, shaped by the cultural background of the architect who designed them and by particular societal logic with diverse profiles (native, European, working class, etc.). In other words, these estates are architecturally tailored to the intended population, influenced by the introduction and inspiration of new ideas. A prime example is the "Semiramis" design, initially conceived by the architect Candilis in Morocco, drawing inspiration from the architect Justin Marie. It serves as a reflection and is an excellent example of modern architecture adapted to the local context. A comprehensive examination of the activities at the urban master plan level has allowed us to comprehend better the incentives and mechanisms implemented and the selection of building orientations, prioritizing solar gain for the whole building envelope. The diverse floor designs, characterized by their different sizes and shapes, rendered each project a distinct phenomenon. These tools are used to strategically design a well-defined area tailored to the operation's scale and function to establish a cohesive urban structure that aligns with the ideals of the contemporary movement.

Ultimately, considering the meticulous observations and extensive conversations with residents, it becomes evident that the social impact is unique across all major housing complexes. Some of the changes and positive appropriations made by the residents are highly intense, and their sociability plays a crucial role in establishing and sustaining the social impact. This highlights the development of a heritage, particularly through the appropriation of the space and the existing social practices. The non-sedentary population influences the discreteness of the premises. It can be observed that a majority of tenants dominate the social dimension, resulting in disrupted and less anticipated appropriations and sociability. Consequently, this directly affects the original social aspect of the large housing estates. Finally, the social ghost, characterized by its geographical position, has become a distinct social enclave and significant housing estate, isolated from the rest of the city. However, nowadays, the major housing estates in the suburbs have become fully integrated into the urban structure of the new city, except for those in the Intramuros. Consequently, many of its residents have left the area and been replaced by non-Oranians seeking employment in the big city.

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Conflict of Interest

The authors declare no conflicts of interest.

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