

Sustainable Construction Practices in Sahrawi Refugee Camps: Insight from El-Ayoun Camp, Algeria

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Introduction

The Western Sahara, a former Spanish colony, is a country on the western edge of the African continent. 1975, on the eve of Franco's rule and with the departure of the Spanish administration it was invaded by Moroccan and Mauritanian troops. Following a period of guerilla warfare between the local 'Sahrawi' population and the invaders, and the subsequent withdrawal of the Mauritanian army, Morocco has installed itself as an occupying force over the largest extent of the territory. The beginning of the warfare also saw the flight of tens of thousands of refugees over the border into Algeria, a historical ally of the Sahrawis, and the establishment of four refugee camps on Algerian territory, near the border zone. Since the 1970s these refugee camps have developed into some of the largest urbanized settlements within the Saharan Desert, now housing approximately 170.000 refugees amongst five camps. (Basel, 2011).

The central research question driving this study is: how can the housing conditions in Sahrawi refugee camps be improved to enhance sustainability and adaptability to local climatic conditions? Addressing this question is critical, given the fragile construction materials currently in use, which are ill-suited to the extreme deserted environment. By focusing on the Al-Ayoun camp as a case study, this research examines patterns of urban development, housing materials, and community preferences to uncover practical, scalable solutions.

The methodology combines field observations, technical evaluations, and interviews with residents and experts to analyze housing patterns and their resilience to environmental challenges. The findings highlight the community's evolving preferences for cement and red brick housing while identifying critical weaknesses, such as the reliance on zinc roofing. By proposing innovative approaches, including modern mud construction and enhanced material quality, this study aims to address both immediate and long-term housing challenges. This research provides insights that can be applied to other marginalized

and resource-constrained communities facing similar environmental and socio-economic challenges, ensuring broader relevance and impact.

The paper is structured as follows: Section 1 Introduction, Section 2 provides a literature review sitting the research within the broader discourse on sustainable construction. Section 3 outlines the methodology of this study. Section 4 explores the historical and urban context of the camps, while Section 5 presents the findings on housing patterns and materials. Finally, Section 6 discusses the innovative contribution of this study to the broader literature on sustainable construction and offers recommendations for sustainable and resilient housing solutions. In contrast, Section 7 is the conclusion.

Literature Review

Resilient Housing in Marginalized Resource-Constrained Settings: An Exploration of the Sahrawi Refugee Camps

The design of resilient housing solutions in marginalized and resource-constrained environments has emerged as a critical area of study, particularly in the face of sustainability and adaptability challenges arising from adverse climatic and socio-economic conditions. Resilience, in the context of urban housing and development, refers to the ability of a community or housing infrastructure to withstand and recover from adverse events or shocks, such as natural disasters, extreme weather events, economic downturns, or social disruptions. It involves the capacity to adapt, bounce back, and even thrive in the face of challenges (Enwin, & Ikiriko, 2024). This need is acutely felt in refugee camps, such as those housing the Sahrawi people in Algeria, where inadequate infrastructure and severe resource limitations necessitate urgent and innovative housing solutions that are both durable and economically viable.

Traditional and Modern Approaches to Housing

Mud-building presents itself as one of the most important solutions for the housing problem and sustainable development in our contemporary world, and one of the most important application elements connecting the architectural heritage with contemporary life. It is also one of the best means (Al Suliman, & Suliman, 2016). It also Mud-brick construction, prevalent in arid climates due to its thermal efficiency and affordability, offers a traditional solution; however, its vulnerability to extreme weather conditions necessitates modernization through the incorporation of additives like lime or cement (Groat & Wang, 2013). While transitioning to modern materials such as cement or fired brick enhances structural integrity, these options often incur higher costs and compromise thermal efficiency, ultimately marginalizing the most vulnerable populations (Braun & Clarke, 2006). Recent innovations have emerged from the synthesis of traditional methodologies with contemporary technologies. For instance, the utilization of

repurposed plastic bottles as building materials in Sahrawi refugee camps exemplifies a sustainable and cost-effective response to the scarcity of resources (World Habitat, n.d.). Furthermore, the integration of green roofs and dome-shaped designs can significantly improve thermal performance and resilience against extreme climate events (Braun & Clarke, 2006). Also, clay has excellent insulating properties because of its high thermal mass. It absorbs, stores, and releases heat very effectively, making the building interior cooler in summer and warmer in winter. This makes the internal environment more comfortable and reduces energy demand and associated carbon emissions (Kefas, Patrick, & Chiroma, 2007).

Challenges in Refugee Camp Housing

Housing conditions in refugee camps, particularly in the Sahrawi regions, are plagued by systemic challenges, including lack of urban planning, deficient infrastructure, and exposure to severe climate. Reports from UNHCR (2017) indicate the prevalent use of zinc roofing, which exacerbates heat accumulation and presents safety hazards during severe weather. The absence of sewage systems and inadequate drainage facilities further heighten health risks for the camp inhabitants (UN-Habitat, 2016). Refugees face harsh desert conditions and rely almost fully on humanitarian assistance to meet their basic needs (ACAPS, 2022).

Global Perspectives on Resilient Housing Solutions

Empirical evidence supports the successful integration of local knowledge with innovative technologies to bolster housing resilience across various contexts. Community-driven solutions in South Asia and Sub-Saharan Africa illustrate the feasibility of scalable and adaptive housing models tailored to local conditions (UN-Habitat, 2016). The increasing focus on climate-smart housing emphasizes the imperative of balancing economic viability, durability, and cultural congruence in addressing contemporary global housing challenges (World Economic Forum, 2023). The introduction of the concept of resilience into the housing sector has become an urgent need in the development of the performance of the housing system, to continue to meet the housing needs in the housing market through a set of that increase their resilience to risk. (Mansoor et al., 2023).

Contribution of the Current Study

This study aims to address the specific housing challenges faced in the Sahrawi refugee camps, a context often overlooked in academic discourse. It conducts a detailed analysis of four prevalent housing typologies—mud, cement, mixed, and red brick—identifying their respective weaknesses while proposing

forward-thinking solutions, such as the modernization of mud-brick construction techniques and alternative roofing options. These innovations are designed to tackle localized construction challenges while contributing to the broader discourse on sustainable housing practices in resource-constrained environments.

Building upon existing literature, this research prioritizes climate-adaptive and context-sensitive housing solutions. For example, Groat and Wang (2013) advocate for the melding of traditional construction techniques with modern materials to enhance both durability and thermal comfort. While strategies for resilient housing typically emphasize cost-efficiency and scalability in marginalized regions (Creswell, 2014), their adaptation for long-term refugee camp settings is still insufficiently explored.

By filling these gaps, particularly regarding the inadequacies of zinc sheet roofing in extreme heat (Yin, 2018), this research offers innovative, climate-responsive solutions. Integrating field observations, community preferences, and technical assessments, the study presents practical recommendations aimed at enhancing housing resilience and sustainability in the Al-Ayoun Camp. The findings significantly contribute to the growing body of literature focused on sustainable construction practices tailored to extreme climates and resource-limited settings.

Methodology

This study explores the housing conditions in the Sahrawi refugee camps, with a focus on the Al-Ayoun camp. The methods employed include field inspections, technical observations, photographic documentation, and semi-structured interviews with key stakeholders. These methods aim to comprehensively understand the challenges and opportunities for sustainable construction in the camps. Below is a detailed description of each method.

Field Inspections

Field inspections were conducted to assess the physical condition of the housing units in the camps. This involved systematic observation of structural integrity, material usage, and environmental adaptability. The inspections followed established protocols for on-site surveys in a resource-constrained environment. Specific attention was given to identifying vulnerabilities in existing structures and documenting variations in housing patterns.

Technical Observations and Photographic Documentation

Technical observations focused on evaluating the performance of construction materials and their suitability for the extreme desert climate. Observations were supplemented by high-resolution photographs, which served as visual evidence to support the analysis. Photographic documentation adhered to best practices in architectural research, ensuring that images captured critical details of building materials, roofing systems, and spatial layouts (Yin, 2018).

Interviews

The study conducted 20 semi-structured interviews with diverse stakeholders, including residents, engineers, and local authorities. Interviewees were selected through purposive sampling to ensure representation across different roles and perspectives. The selection criteria included experience with housing construction, familiarity with local challenges, and involvement in camp management. The interviews explored themes such as housing preferences, perceptions of material performance, and proposed improvements. To ensure reliability, all interviews were audio-recorded (with participant consent) and transcribed verbatim. Data were analyzed using thematic coding, following Braun and Clarke's (2006) framework. MAXQDA software was employed to facilitate systematic coding and thematic analysis, enabling the identification of recurring patterns and key insights.

Data Analysis

The collected data were analyzed using a mixed-methods approach. Qualitative data from interviews and observations were triangulated with quantitative data from field inspections to ensure validity. This approach aligns with Creswell's (2014) guidelines for integrating qualitative and quantitative methods in social science research.

Ethical Considerations

Ethical approval was obtained from the relevant institutional review board. Participants were briefed on the study's objectives, and informed consent was obtained before data collection. Confidentiality and anonymity were maintained throughout the research process. This comprehensive methodology provides a robust foundation for analyzing the challenges and prospects of sustainable construction in the Sahrawi refugee camps. By employing a combination of field-based and analytical techniques, the study ensures a holistic understanding of the subject matter.

Historical Background

a brief overview of the history of the Sahrawi movement provides context for the argument that follows. As the Spanish government prepared to abandon its protectorate of Western Sahara in November 1975, it secretly signed an agreement with Morocco and Mauritania aimed at establishing a tripartite administration of the territory. Morocco and Mauritania had competing claims to the Western Sahara, a region bordered on the north by Morocco, the northeast by Algeria, the south and southeast by Mauritania, and the west by the Atlantic Ocean. Just as Spain was preparing to withdraw, Morocco and Mauritania invaded the territory. Morocco took control of the northern two-thirds of Western Sahara, which it renamed its southern (or “Saharan”) provinces, while Mauritania seized control of the southern third.⁴ Meanwhile, the Polisario, established in 1973, won Algeria’s backing for its independence struggle and set up its headquarters in Sahrawi refugee camps located in an isolated region of the southwestern Algerian desert near the town of Tindouf. The camps are also home to the Sahrawi Arab Democratic Republic (SADR), the state-in-exile established by the Polisario in 1976 (Farah, 2008).

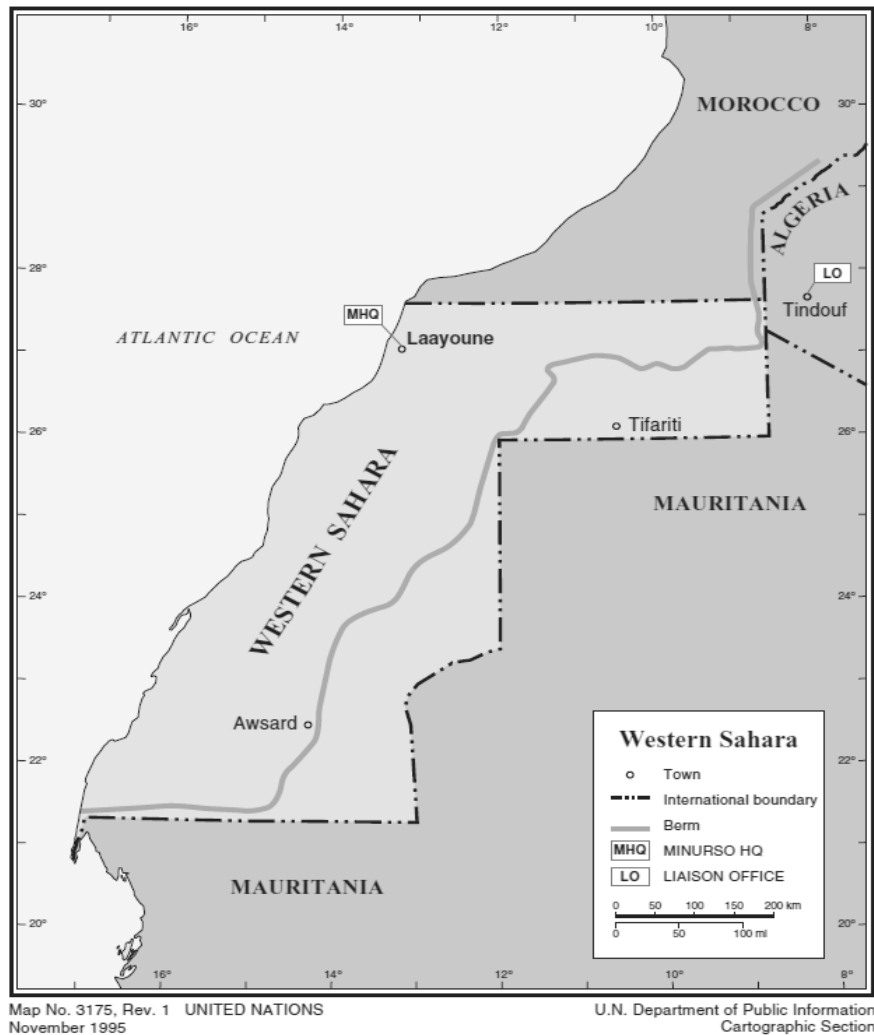
Figure 1: The location of Western Sahara in relation to Northwest Africa and neighboring countries



Source: Herz, 2015.

The Sahrawi refugee camps appeared in the Tindouf region in 1976, following the brutal Moroccan and Mauritanian invasion, after the tripartite agreement (Spain, Morocco, Mauritania) known as the Madrid Tripartite Agreement, which divided Western Sahara into a north under the control of Morocco and south under the control of Mauritania, in the condition of ensuring the interests of Spain in the region (phosphates, fisheries) (Bakr, 2004). Following the air strikes and the successive bombardment of the Moroccan air force on the one hand and the Mauritanian forces on the other hand, the Omdrayga area in Western Sahara for refugees fleeing from the northern regions, who would later flee to Algeria (Bakr, 2004). Most residents still live in modest tents or huts, do not have access to drinking water, and rely heavily on International humanitarian aid (Human Rights Watch, 2008).

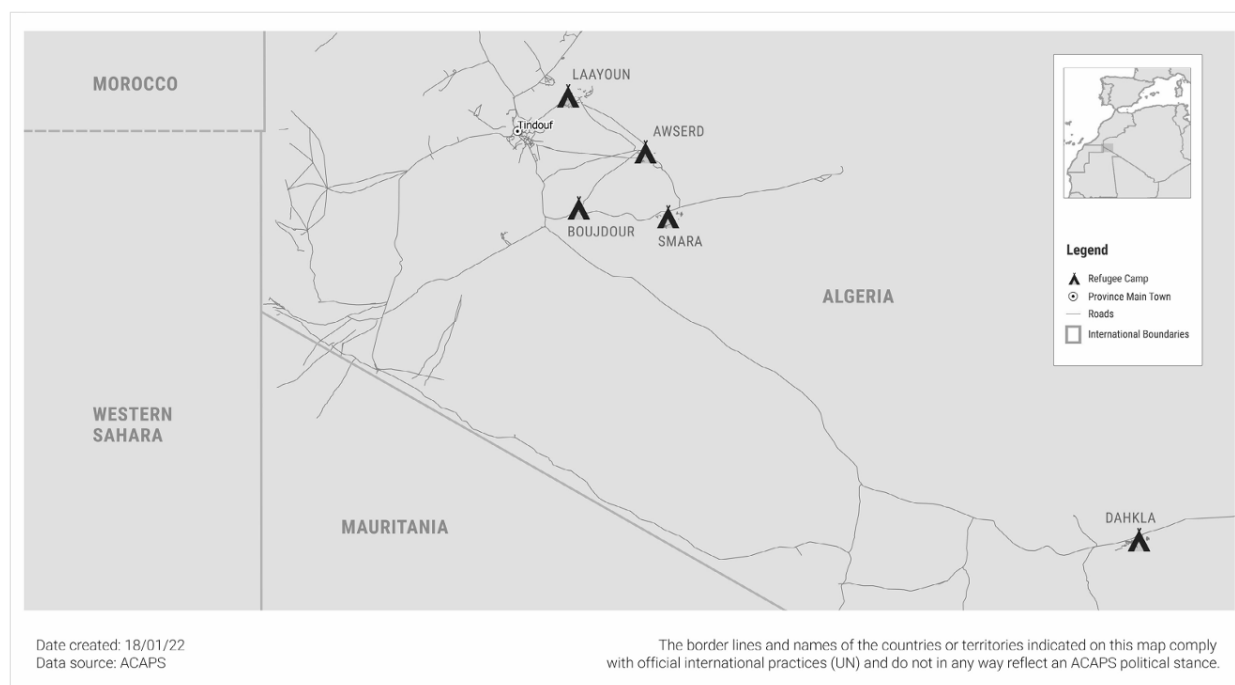
Figure 2: Western Sahara, its liberated and occupied parts, and the location of the refugee camps.



Source: Farah, 2008.

In March 1976, Sahrawi refugee camps were established in the southwest of the Algerian desert, precisely in the Tindouf border region with Western Sahara. These camps were named according to the regions from which refugees migrated to six camps that differ in population density according to the original region they displaced from (Nafea, personal Interview, 2019).

Figure 3: Western Sahara, its liberated and occupied parts, and the location of the refugee camps.



Source: ACAPS, 2022.

The first camp was established in Al-Subaiti, and then it was moved to its current location to be called the Smara camp it includes the displaced from the occupied Smara region. The Sahrawi refugee camps in the Tindouf region of Algeria include six distinct camps, each named after a significant location in Western Sahara to reflect the regions from which the refugees originated. Among these, the Dakhla camp houses refugees displaced from the occupied Dakhla region. This camp is one of the largest and plays a vital role in preserving the cultural and social identity of its residents. The Al-Ayoun camp, named after the Al-Ayoun area, similarly serves as a haven for those displaced from that region and is characterized by its size and the variety of housing types it accommodates. The February 27 camp, in contrast, is the least densely populated. Despite its smaller size, it remains an integral part of the network of camps, providing a quieter and less crowded environment for its residents. The camp of the martyr Al-Hafiz, also known as Al-Rabuni, serves as the administrative headquarters for all the camps. It houses various government institutions and plays a central role in coordinating humanitarian and administrative activities across the region. Each of these camps reflects the broader struggles and resilience of the Sahrawi refugee community, serving not only as places of refuge but also as centers for maintaining cultural continuity and social cohesion (Nafea, personal Interview, 2019).

Figure 4: Refugee tents after their displacement to the Tindouf area during the period 1975-1976.



Source: Media Archive Center of SADR ,2019.

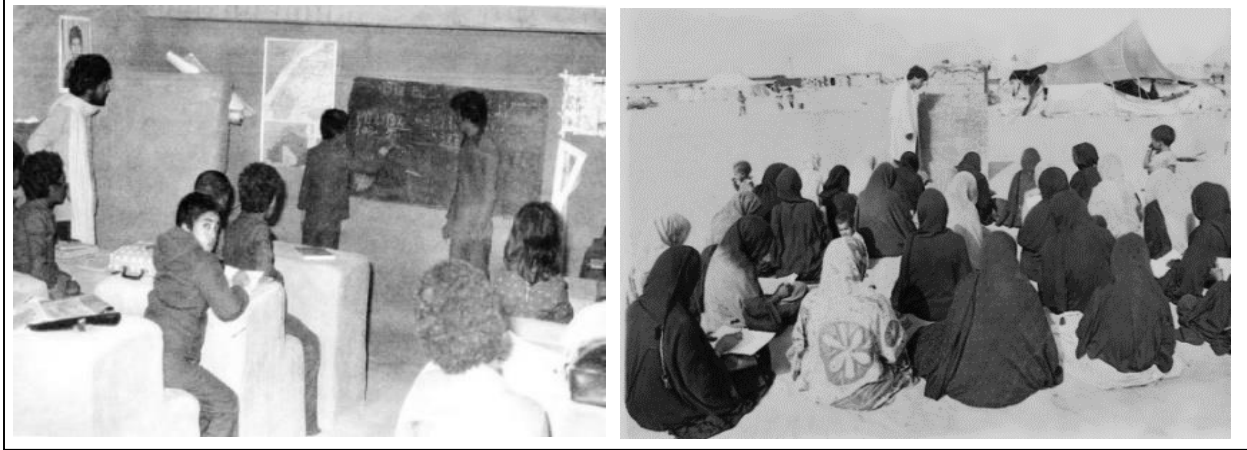
The population of the Sahrawi refugees living in the Tindouf camps is 173,600, according to an official report of the latest statistics conducted by the United Nations High Commissioner for Refugees (UNHCR) in January 2018. However, to better understand the population density, the total area of the camps must be considered. With the combined area of the camps being approximately 150 square kilometers, the average population density is around 1,157 people per square kilometer. This population is distributed among five camps as follows:

Table 1: Distribution of Sahrawi refugees in the Tindouf camps.

Camp	Population	Percentage
Smara Camp	50700	29%
Layoun Camp	50500	29%
Auserd Camp	36400	21%
Dakhla Camp	19500	11%
Boujdour Camp (February 27)	16500	10%

Source: United Nations High Commissioner for Refugees, 2018.

Figure 5: primary school and a literacy school in the refugee camps in Tindouf during the period 1976-1980.



Source: Media Archive Center of SADR ,2019.

El-Ayoun camp, on which this paper focuses, is located east of the city of Tindouf and is about 10 km away from it, and it is the closest camp to Tindouf. El-Ayoun camp is considered the second largest camp after Smara camp with about 50,500 refugees, according to the statistics of the United Nations High Commissioner for Refugees (UNCHR) for the year 2018. The camp occupies an area of about 24.93 sq. km.

The Urban Condition of El-Ayoun Camp

El-Ayoun camp consists of six districts randomly located in the area allocated to it. Each district contains four municipalities that are clustered together in a chess shape. The headquarters of the district is located in the center of these four municipalities, separated by wide main streets that intersect at the headquarters of the district. The headquarters of the district usually takes a circular shape to resist strong winds and prevent sand from accumulating on it. The headquarters of the department includes the central administration with all its offices and the offices of the representatives of the central directorates of the Wilaya (Directorate of Handicrafts, Police), In addition to local dispensaries affiliated with the district, as well as the headquarters of kindergarten (pre-school), the market surrounds the district's headquarters or what is known as Marsa on the edges of the wide main streets separating the municipalities, where the refugees get their daily needs, then rows of tents and mud buildings follow (Nafea, personal Interview, 2019).

This camp has not been provided with infrastructure networks since its establishment until today, as it is not provided with drinking water networks or sewage channels, and the roads there are unpaved, not to mention that they are equipped with rainwater drainage channels, which sometimes causes the spread of diseases among the population, and it is not equipped with electricity networks, which have become an indispensable necessity for the human being.

Housing in El-Ayoun camp has gone through different periods according to the political and economic conditions of its residents. They can be divided into four phases:

1976 to 1983: This period was the first breakthrough in assembling, organizing, and forming camps for refugees. This period was also characterized by assembling the blocks of the El-Ayoun camp and transferring the residents of the Adkhal area to Nabka, to complete the El-Ayoun camp with its six districts in November 1977. The reorganization and formation of the districts of the El-Ayoun camp, as well as the division of districts into municipalities. The chess shape was the dominant form in the planning of districts. As a Wilaya, El-Ayoun was not subject to an integrated planning that includes its districts and links them together, but rather the planning was at the level of the districts, not the Wilaya. Mud construction in El-Ayoun camp did not appear during this period except in hospitals, district headquarters, and the Wilaya headquarters, given the hope of returning home soon. As for the housing, the tent (Qaytun) was the only element and the multiple space for the refugees. The tent includes a kitchen, bedrooms, and a place to receive guests (Nafea, personal Interview, 2019).

1983 to 1994: Clay construction spread during this period. After the fifth anniversary of 1983, a government decree was issued to build kitchens for families in the February 27 camp (present-day Boujdour), with a rectangular shape of 2 x 3 meters, an area of 6 square meters, and a zinc plate roof. As a result, construction spread in the rest of the camps. The common pattern in that period in residential buildings was the construction of a large room 7x4 in addition to a kitchen 4x5 and a bathroom, in addition to the tent. These spaces are linked to each other by walls of mud brick (blocks) with a thickness of 20 cm that make doors in different directions. This space that links the areas is known as the yard (Haush), where the door openings of the room, kitchen, and tent main door go into the yard, while the bathroom is outside the collection. The predominant roof used for these mud buildings was cotton due to the lack of building materials and the spread of poverty among the population, except for public utilities, which were roofed with zinc sheets (Nafea, personal Interview, 2019).

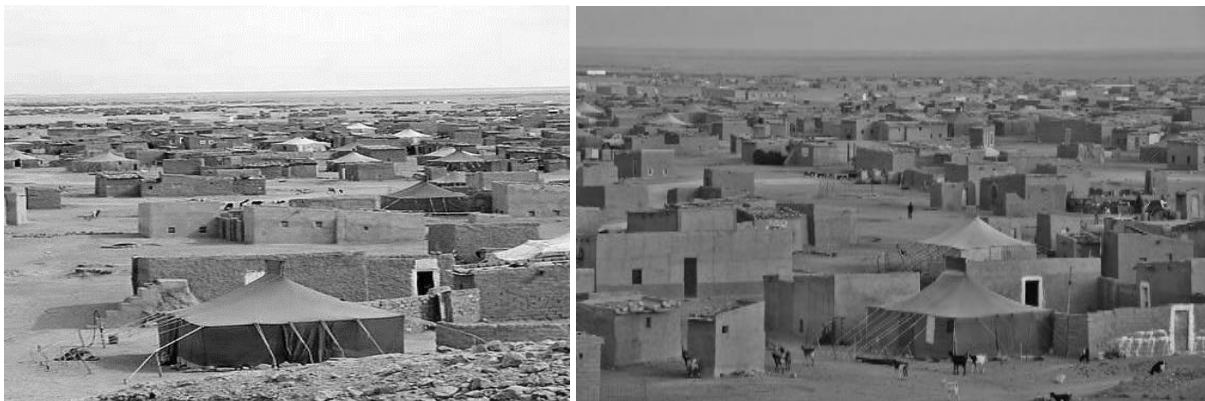
Figure 6: Laayoune camp in 1984.



Source: Media Archive Center of SADR ,2019.

1994 to 2006: One of the most important features of this period was the torrential rain that swept through the ElAyoun camp in 1994, which led to a major change in the urban planning features of the camp, as many mud houses were destroyed at the level of districts and municipalities, and some of the locations of the districts were changed, such as the Guelta district. The extinction of the features of the chess layout of the circles that was adopted before the 1994 torrent; to be replaced by islets of organic and irregular shapes, these islands are lined with twisting roads. Increasing population density, which led to the people's encroachment on streets and empty spaces randomly (anarchy in land use), and the growth and spread of districts and their interconnection with each other (Nafea, personal Interview, 2019).

Figure 7: Laayoune camp in 2005.



Source: Media Archive Center of SADR ,2019.

2006 to 2020: In previous times, construction was based on clay as the main material for building all the elements of the housing, including walls and external and internal cladding. However, this period was characterized by the emergence of cement block construction, especially after the heavy rainstorms swept into the camp in 2006 and demolished many mud houses and again the rains and storms in 2015 caused another catastrophe, resulting in the demolition of a huge number of houses. Thus, the idea is that buildings with mud is not suitable and have become outdated, and cement is being used instead of mud. (Nafeh, personal Interview, 2019).

Figure 3: Laayoune camp in 2018.



Source: The researcher, 2018.

Urban Problems in the Sahrawi Refugee Camps

The urban problems in the Sahrawi refugee camps reflect a range of systemic and infrastructural challenges that hinder sustainable development and quality of life. One of the primary issues is the spread of diseases and epidemics, which can be attributed to the lack of sewage networks and inadequate street drainage systems. These deficiencies create unsanitary conditions, posing serious health risks to the camp's residents (Herz, 2013; UNHCR, 2018). Additionally, the absence of organized urban planning has led to frequent family disputes over land boundaries. This lack of planning is further exacerbated by the absence of comprehensive urban development strategies over the years, leaving the camps vulnerable to disorderly growth (UN-Habitat, 2016).

Figure 9: Pictures of buildings from El-Ayoun camp after the 2006 rains.



Source: Media Archive Center of SADR ,2019.

The camps also face a rising prevalence of crime and social issues, which are compounded by inadequate law enforcement and overall instability within these communities. Unregulated exploitation of land has led to chaotic land use, diminishing the availability of space for future development. Public spaces and recreational areas, essential for fostering community engagement and providing psychological relief, are noticeably absent. Similarly, the lack of afforestation and green spaces contributes to an inhospitable environment, exacerbating the harsh living conditions in the desert (Yin, 2018).

Figure 10: Pictures of some buildings of El-Ayoun camp after the 2015 rains.



Source: the researcher 2015, & Media Archive Center of SADR ,2019.

Finally, the disorganized and sprawling layout of the camps poses significant challenges for establishing essential infrastructure in the future. The chaotic spread of buildings across large and irregularly spaced areas makes it difficult to implement cohesive networks for water, electricity, and transportation. Addressing these issues requires a comprehensive approach to urban planning, infrastructure development, and community management to ensure a more sustainable and livable environment for the Sahrawi refugees (Creswell, 2014; UNHCR, 2018).

Results: Patterns of fragile housing in El-Ayoun camp

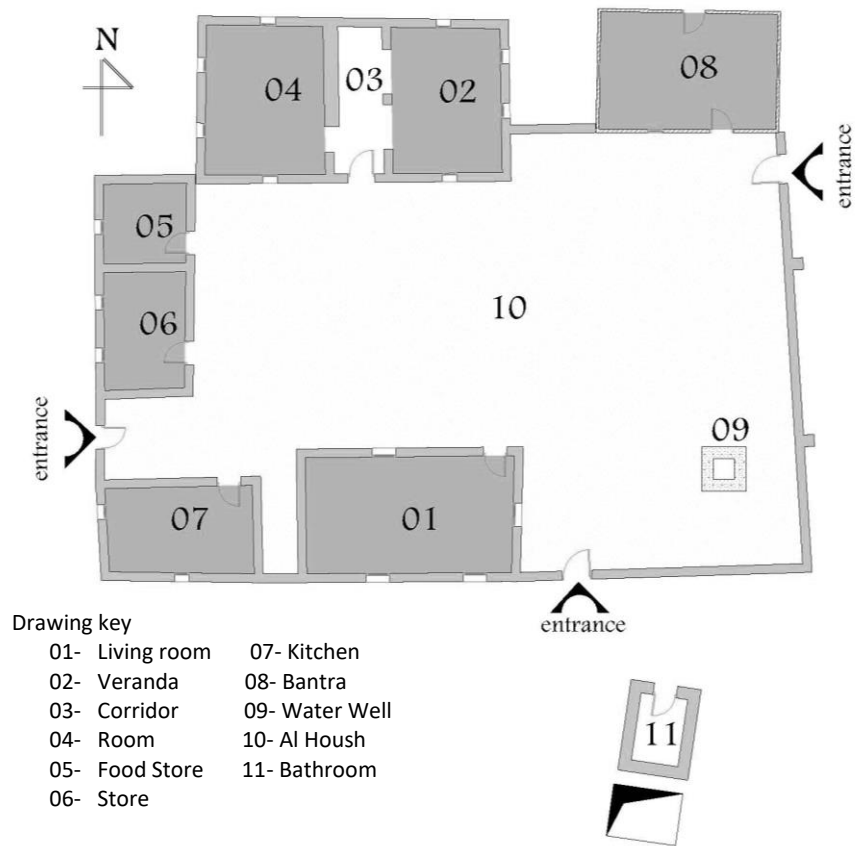
Housing in the camps can be divided into four main types depending on the main building material, and we have chosen samples from Al-Hagouniyah district in El-Ayoun camp: (i) muddy housing patterns, (ii) cement housing patterns, (iii) mud-cement housing pattern, and (iv) red brick housing patterns. We chose this division based on what was examined from the field of study and confirmed by the interview we had with the architect Moulay El Mahdi, where he says " Eng. Moulay El Mahdi: As you can see, this is now found in many houses, and this is the result of the fall of some parts in the previous rains of 2006 and 2015, which were built with cement instead of mud. some families build one or two rooms with cement to take shelter during heavy rains or build the whole house with cement or red brick, and this is according to the family's financial ability, mud houses are no longer feasible in resisting climatic factors, but in my opinion, it is not considered a solution to the problem of construction in camps. The roof of the Shinko must be removed first and replaced with other materials that are suitable in price and resistant to heat, on all types of housing built of mud or cement or mixed mud-cement, as well as red brick houses, as well as studying the walls and external openings and guidance or what is known as the cover. The architect of the building and the choice of everything that further improves the internal conditions of the building".

The mud pattern

The muddy housing pattern in the Sahrawi camps consists of different-sized rooms, a large kitchen, and a tent, in addition to one or two storerooms, one for food supplies and the other for clothes and household belongings, a bathroom (toilet) and a bathroom. Between them, there are walls of mud brick (block) with a thickness of 20 cm. Doors are made for it in different directions. This space is known as the yard (Haush), where the openings of the doors of the rooms, the kitchen, the tent (its main door) and the stores go into the yard while the toilet and the bathroom are outside the structure. This style is the oldest among the others.

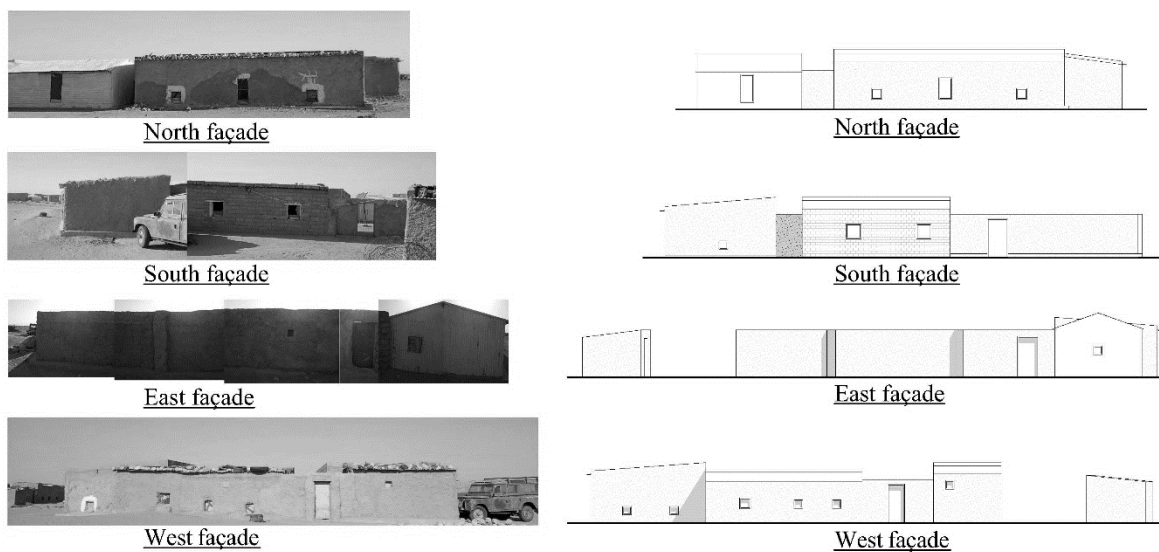
Building materials and techniques: The mud brick pattern in the camps relies on mud bricks (clay) as the main construction material for the building.

Figure 11(a): A detailed plan of a family's mud house in the Hagouniyah district, El-Ayoun camp.



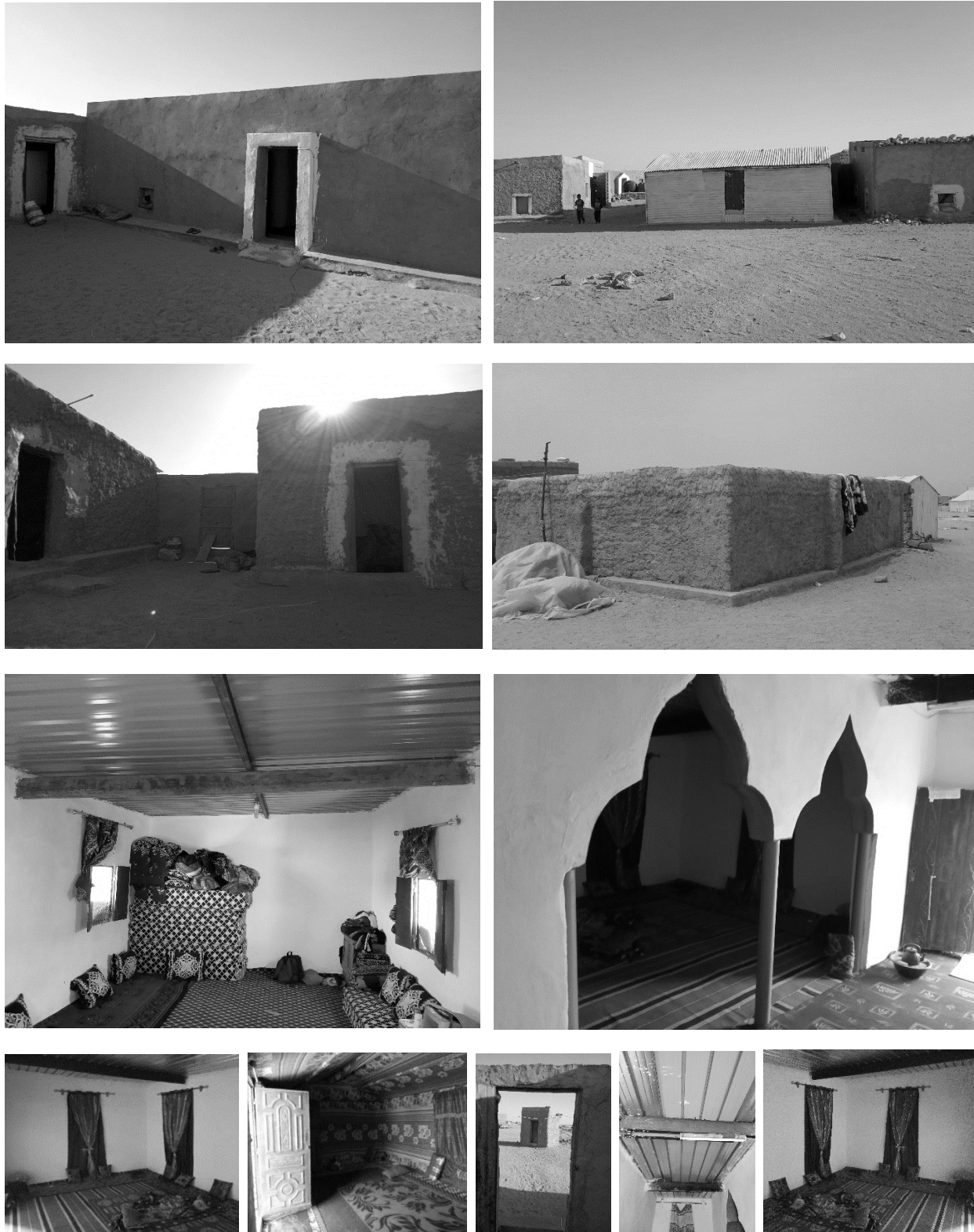
Source: The researcher, 2022.

Figure 11(b): Facades of a family's mud house in the Hagouniyah district, El-Ayoun camp.



Source: The researcher, 2022.

Figure 11(c): perspectives of housing from old Mud bricks covered with cement to protect it from Rain for a family in Al-Haguniyah District, Al-Ayoun camp.



Source: the researcher (2022).

Foundations: This pattern has no foundations, as the mud is directly lined up on the ground, and sometimes it is excavated by 20 to 30 cm, and sometimes the thickness of the first row is doubled to reach 40 cm to be the foundation of the building.

Walls: They are made of clay brick dried under the sun, with a thickness of 20 cm, and no other materials are added to it to increase its durability and resistance, and the process of selecting good clay.

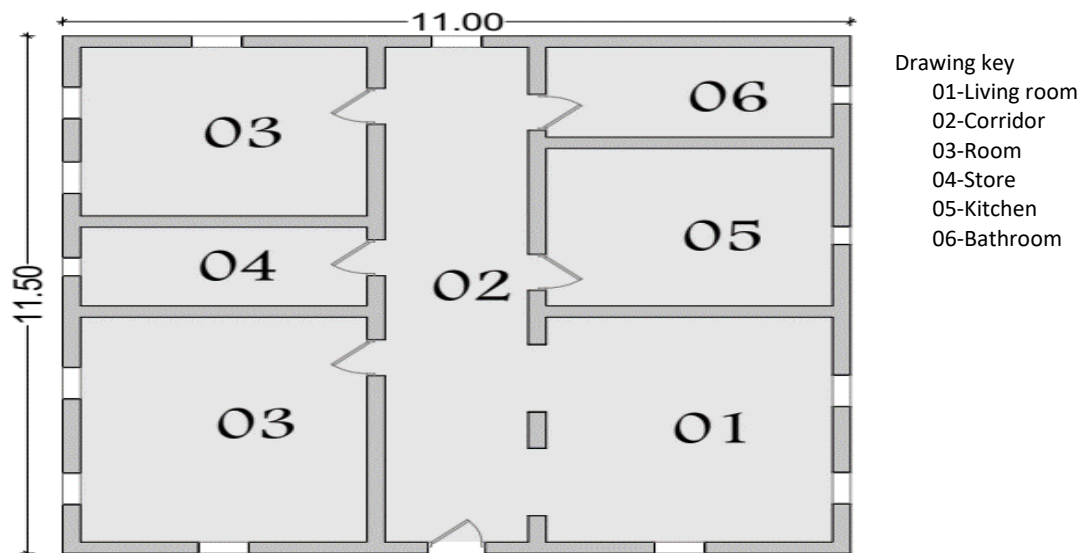
The roof: Shincro sheets are used as a roof for these buildings, which leads to a high temperature inside the room due to the rapid heat transfer of this material, and the roofs are supported by wooden or iron beams.

External openings: For windows: Usually the windows of this style are small and at a low height from the ground's surface from 20 to 40 cm, and their main material is iron, which makes them bridges to transfer heat into the house. As for the doors, they are also made of iron without thermal insulation layers. These doors are no less harmful than windows on the building in transferring heat.

The cement pattern

This type of housing spread after the torrential rains that swept the ElAyoun camp in 2006, and again in 2015 to demolish a huge number of mud houses and give a bad impression among the refugees about buildings with mud and its fragility in resisting climatic factors. This style is mostly a single block, unlike the previous one, where the house's spaces gather in one corridor. Usually, this style is devoid of the large yards found in the old mud style, but it takes small yards for ventilation and hanging the laundry.

Figure 12(a): Detailed plan and facades of a cement block house for a family in the Haqouniyah district, El-Ayoun camp.



Source: The researcher (2022)

Figure 12(a): facades of a cement block house for a family in the Haqouniyah district, El-Ayoun camp.



Source: The researcher (2022)

Building materials and techniques: This pattern depends on the cement material, whether on the level of walls or the level of external and internal cladding and floors.

Foundations: This type of foundation is usually made of cement, stone, or reinforced concrete, and this depends on the financial ability of the owner.

Walls: They are made of cement blocks with a thickness of 15 cm, supported by reinforced concrete columns in the corners of the building. The cement material formed for the walls causes an increase in the temperature of the house in the summer due to the speed of convection and vice versa in the winter, which makes the room an oven in the summer which causes some diseases (high pressure among the elderly, headache).

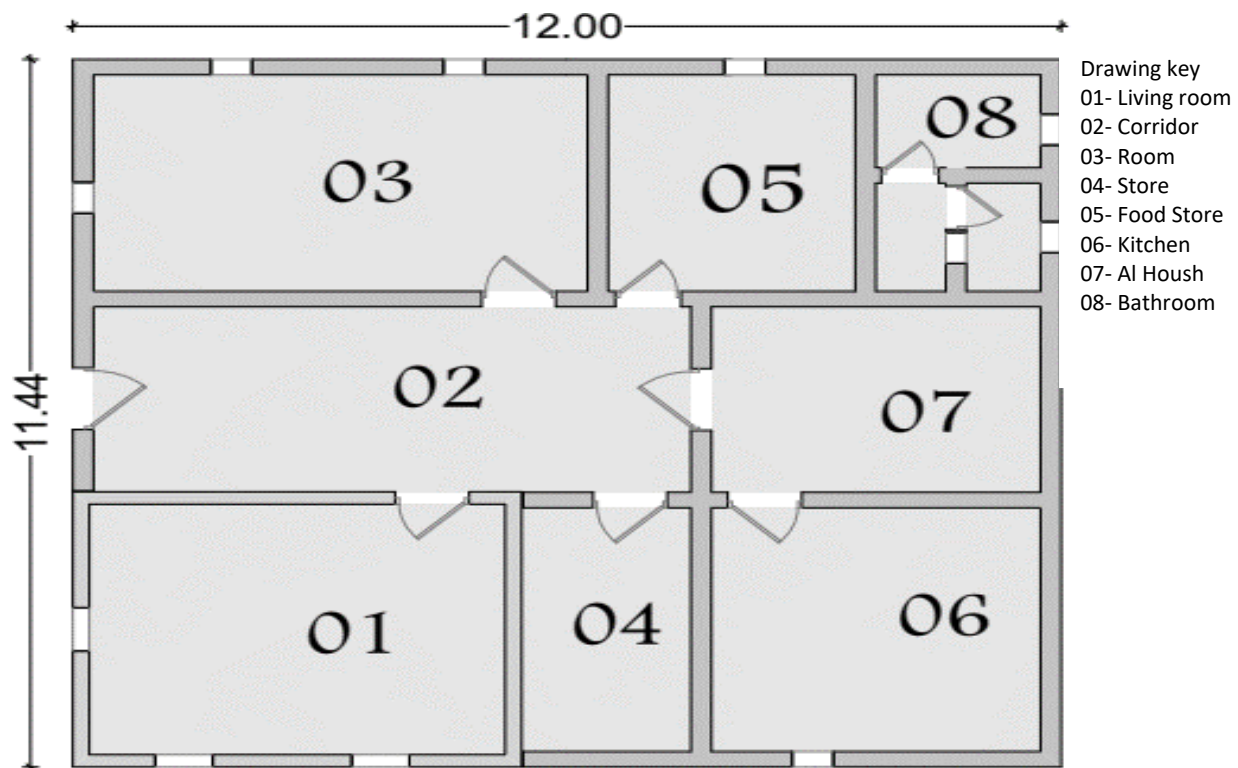
The roof: The roof of this style does not differ from the style before it (mud style), where it is roofed with chinko sheets supported by joists of wood or iron. These metal sheets are fixed with cement bricks or stones.

External openings: For windows: The windows of this style are of considerable dimensions (0.80 m * 1.00 m) and at a height of 1 m from the surface of the ground, and the main material for them is iron or aluminum, which makes them bridges to transfer heat into the house. As for the doors, they are also made of iron and often without thermal insulation layers. These doors are no less harmful than windows in transferring heat into the building.

The mud-cement pattern

This pattern is considered the most prevalent in the camp, which is the construction of some of the housing parts from mud and others with cement, and this is due to the financial inability to build the entire house with cement, or that the house was present, and the rain destroyed part of it to be rebuilt again but with cement bricks. This pattern does not differ from its predecessors of mud and cement patterns. Each part of it is subject to a pattern. The parts built of clay are subject to the mud pattern, and the parts built of cement are subject to the cement pattern, but it contains two types in terms of the distribution of voids (empties gathered in one block, and dispersed voids such as clay pattern).

Figure 13(A): A detailed plan of a mixed-type dwelling of mud and cement for a family in the Haqouniyah district, El-Ayoun camp.



Source: The researcher (2022)

Figure 13(b): facades of a mixed-type dwelling of mud and cement for a family in the Haqouniyah district, El-Ayoun camp.



Source: The researcher (2022)

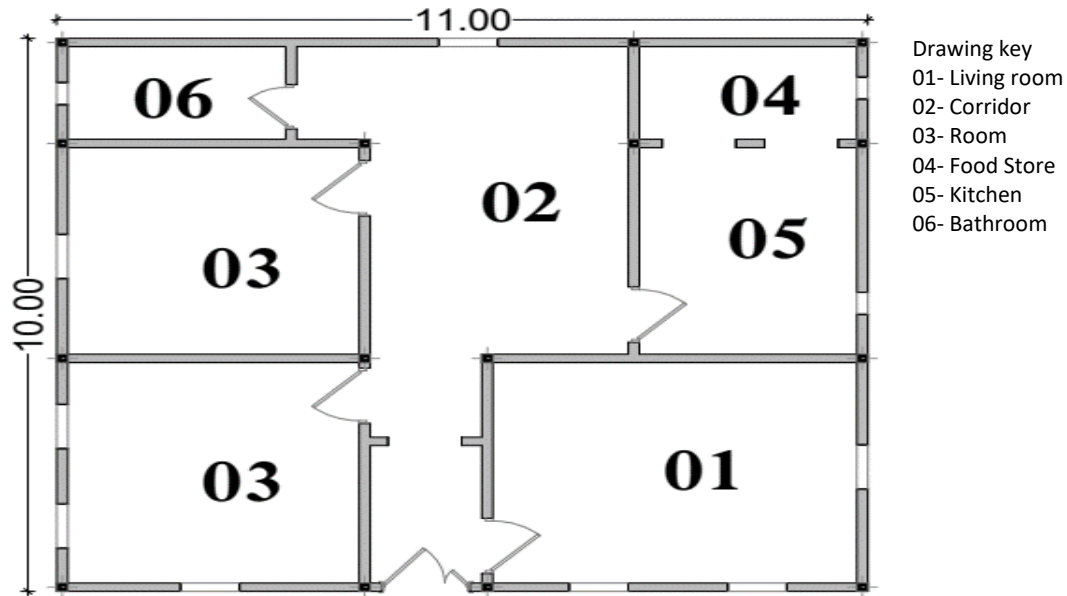
Building materials and techniques: This style of construction techniques and materials are subject to the previous two styles, and each part of it is subject to the style of its material.

The Red Brick pattern

This is the least widespread pattern in the camp, as it appeared after the 2015 rains that inflicted great losses on the camp, due to the lack of red bricks in the camp sometimes (because it is not produced inside the camps) and its high prices, and the majority of the labor force does not have sufficient experience in building with it, so they prefer to avoid it. This pattern is very similar to the cement pattern in terms of the distribution of spaces.

Building materials and techniques: This style depends on the Red Brick material on the level of the walls, while on the level of external and internal cladding and floors, it depends on Cement.

Figure 14(a): Detailed plan of housing from red bricks for a family in Al-Haguniyah District, Al-Ayoun camp.



Source: the researcher 2022.

Figure 14(a): perspectives of housing from red bricks for a family in Al-Haguniyah District, Al-Ayoun camp.



Source: the researcher 2022

Foundations: The foundations of this style are more robust than the previous styles so small bases of reinforced concrete are established for it, as well as beams to carry the walls. This style is more resistant and safer than the previous styles, but it is expensive.

Walls: They are made of red bricks with a thickness of 15 cm, supported by reinforced concrete columns and an upper beam linking these columns. As for the internal cladding of the walls, it is cementing mortar, and usually, the external facades are not treated.

The roof: The roof is a common element between all styles, so the roofing of this style does not differ from the previous styles and with the same technique as well.

External openings: For windows: The windows of this style are of considerable dimensions (0.80 m * 1.00 m) and at a height of 1 m from the surface of the ground, and the main material for them is iron or aluminum, which makes them bridges to transfer heat into the house. As for the doors, they are also made of iron and mostly without thermal insulation layers. These doors are no less harmful than the windows in transferring heat. This pattern shares the same external openings as the cement pattern.

Table 2: Shows the prevalence rate of each of the four types of residential buildings in the municipality of Azem Eshieh in Laayoune camp.

Number	Housing Pattern	Quantity
01	Mud bricks	48
02	Cement-mud bricks	308
03	cement bricks	90
04	Red bricks	05
Total		451

Source: The researcher (2022).

Comparison between patterns

The municipality of Adem Al-Shih (municipality 1) was taken from the Al-Haqooniyah district in Al-Ayoun camp as a sample to determine the prevalence rate of each of the previous patterns. The following table is a summary of the results of the study.

Table 3: The following table summarizes the strengths and weaknesses of each of the patterns explained above.

Housing Pattern	Foundations	Walls	The roof	External openings	Resistance to climatic factors			Environment	Cost	Safety
					Heat	Wind	Rain			
Mud bricks	fragile	fragile	fragile	fragile	good	weak	weak	friendly	low cost	not safe
Cement-mudbricks	strong	strong	fragile	strong	weak	weak	good	non-friendly	high cost	safe
cement bricks	fragile	fragile	fragile	fragile	medium	weak	medium	relatively friendly	average cost	not safe
Red bricks	strong	strong	fragile	strong	medium	weak	good	friendly	high cost	safe

Source: The researcher (2022).

Discussion and Recommendations

The findings from this study highlight the significant challenges faced by Sahrawi refugee camps in terms of sustainable construction, particularly in the Al-Ayoun camp. These results contribute to the broader discourse on sustainable construction in resource-constrained settings by addressing critical gaps in urban planning, material use, and architectural design. By integrating these findings with existing literature, this section demonstrates how the study provides actionable insights beyond the immediate case study.

The shift from mud-based housing to cement and red brick constructions reflects a global trend observed in the literature, where durability and modernity often take precedence over traditional practices (Groat & Wang, 2013). While these materials offer increased resilience, they also present new challenges, such as thermal inefficiency and higher costs. This aligns with studies emphasizing the importance of localized and context-sensitive construction practices (Yin, 2018). The reliance on zinc roofs further complicates housing conditions, as documented by previous research highlighting the thermal and safety issues associated with such materials in extreme climates (Braun & Clarke, 2006). Thus, this study reinforces the necessity of exploring alternative roofing solutions, such as domes or green roofs, to enhance thermal comfort and safety.

Moreover, the findings emphasize the importance of integrating sustainable construction techniques, such as modern mud-building methods, which are both cost-effective and environmentally friendly. This echoes existing literature advocating for the revitalization of traditional materials through contemporary techniques to balance sustainability with cultural relevance (Creswell, 2014). The community's resistance to mud construction underscores the need for education and awareness campaigns to shift perceptions and promote the benefits of these methods.

In addition to material and design considerations, the study's findings on urban challenges—including unplanned land use, absence of public spaces, and lack of infrastructure—highlight the need for comprehensive urban planning. This aligns with global frameworks emphasizing the role of urban design in improving the quality of life for displaced populations (UN-Habitat, 2016). The chaotic expansion observed in the Sahrawi camps mirrors challenges in other refugee settings, underscoring the universal relevance of the study's recommendations.

As such, this research not only addresses the specific needs of the Sahrawi refugee camps but also contributes to the broader understanding of sustainable construction in humanitarian contexts.

Conclusion

This study emphasizes the urgent need for sustainable and climate-adaptive construction practices in the Sahrawi refugee camps, especially in Al-Ayoun Camp. It identifies significant shortcomings in housing and urban planning and offers practical solutions like modernized mud construction, alternative roofing, and comprehensive urban strategies to tackle immediate issues such as thermal inefficiency and infrastructure deficits,

The study also introduces a resilience framework for sustainable living in resource-constrained settings, focusing on:

1. **Material Optimization:** Combining traditional materials, like mud bricks, with modern enhancements for better durability and thermal performance
2. **Architectural Innovation:** Using domes and green roofs to improve safety and thermal comfort in extreme climates.
3. **Community Engagement:** Involving residents in planning to encourage acceptance of sustainable practices.
4. **Urban Planning:** Prioritizing thoughtful layouts, public spaces, and essential infrastructure to enhance living conditions.

5. Scalability and Adaptability: Creating solutions that can be adapted to various cultural and socio-economic contexts.

By addressing these aspects, the study aims to improve living conditions for refugees and provide a model for sustainable housing in marginalized areas. Future efforts should integrate this framework into policy and practice, promote community-driven planning, and expand successful approaches.

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Legend of the Figures:

Figure 1: The location of Western Sahara to Northwest Africa and neighboring countries Source: Manuel Herz (2015) From Camps to City, Refugee Camps of The Western Sahara. ETH Studio Basel, Lars Muller Publishers.

Figure 2: Western Sahara, its liberated and occupied parts, and the location of the refugee camps. Source: Randa Farah, (2008). Refugee Camps in The Palestinian and Sahrawi National Liberation Movements: A Comparative Perspective. Journal of Palestine Studies Vol. XXXVIII, No. 2.

Figure 3: Western Sahara, its liberated and occupied parts, and the location of the refugee camps. Source: ACAPS. (2022). Sahrawi refugees in Tindouf, Briefing note 19 January 2022.

Figure 4: Refugee tents after their displacement to the Tindouf area during the period 1975-1976. Source: Media Archive Center of the Sahrawi Arab Democratic Republic, (2019).

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Figure 6: Laayoune camp in 1984. Source: Media Archive Center of the Sahrawi Arab Democratic Republic, (2019).

Figure 7: Laayoune camp in 2005. Source: Media Archive Center of the Sahrawi Arab Democratic Republic, (2019).

Figure 8: Laayoune camp in 2018. Source: The researcher, (2018).

Figure 9: Pictures of buildings from El-Ayoun camp after the 2006 rains. Source: Media Archive Center of the Sahrawi Arab Democratic Republic, (2019).

Figure 10: Pictures of some buildings of El-Ayoun camp after the 2015 rains. Source: the researcher (2015), & Media Archive Center of the Sahrawi Arab Democratic Republic, (2019).

Figure 11(a): A detailed plan of a family's mud house in the Hagouniyah district, El-Ayoun camp. Source: The researcher, (2022).

Figure 11(b): Facades of a family's mud house in the Hagouniyah district, El-Ayoun camp. Source: The researcher, (2022).

Figure 11(c): perspectives of housing from old Mud bricks covered with cement to protect it from Rain for a family in Al-Haguniyah District, Al-Ayoun camp. Source: The researcher, (2022).

Figure 12(a): Detailed plan of a cement block house for a family in the Haqouniyah district, El-Ayoun camp. Source: The researcher, (2022).

Figure 12(b): facades of a cement block house for a family in the Haqouniyah district, El-Ayoun camp. Source: The researcher, (2022).

Figure 13(a): A detailed plan of a mixed-type dwelling of mud and cement for a family in the Haqouniyah district, El-Ayoun camp. Source: the researcher, (2022).

Figure 13(b): facades of a mixed-type dwelling of mud and cement for a family in the Haqouniyah district, El-Ayoun camp. Source: the researcher, (2022).

Figure 14(a): Detailed plan of housing from red bricks for a family in Al-Haguniyah District, Al-Ayoun camp. Source: the researcher, (2022).

Figure 14(b): perspectives of housing from red bricks for a family in Al-Haguniyah District, Al-Ayoun camp. Source: the researcher, (2022).

Legend of the Tables:

Table 1: Distribution of Sahrawi refugees in the Tindouf camps. Source: United Nations High Commissioner for Refugees, (2018). Official Report: Sahrawi Refugees in Tindouf, Algeria.

Table 2: Shows the prevalence rate of each of the four types of residential buildings in the municipality of Azem Eshieh in Laayoune camp. Source: the researcher, (2022).

Table 3: The following table summarizes the strengths and weaknesses of each of the patterns explained above. Source: the researcher, (2022).

Appendix-01

Interview With Mohamed Nafea (former Minister of the Ministry of Construction and Reconstruction of liberated territories) on August 31, 2019. This interview was conducted in person.

Q: Mr. Minister, would you mind a brief overview of your history in the field of construction and camp planning.¹

A: I have had a long and extensive career in construction. Since 1960, I have worked as a builder and later as a team leader with Spanish workers during the Spanish colonial period in the Sahrawi territories. In 1966, I moved to Laayoune, the capital, to work there. After Spain withdrew from the region and the war began between the Polisario Front on one side and Morocco and Mauritania on the other, I fled the Sahrawi territories as a refugee and joined the ranks of the Sahrawi People's Liberation Army to liberate Saguia el-Hamra and Wadi el-Dahab in November 1975. I remained with the army units for two to three months. Due to my acquaintance with some leaders in the Front, I was selected as a construction supervisor and later appointed as the central director of construction in the refugee camps. After the establishment of the Ministry of Construction in 2004, I was appointed as the first Minister of Construction in the camps, a position I held until 2010. This is a summary.¹

Q: When was your first project or construction in the camps?²

A: My first project was to build a furnace in the liberated “Al-Mahbas” area, as there was an urgent need to build it. I built it from the remains of a clay building of the Spanish guards that was there. After completing it, I was transferred to the martyr Al-Hafiz (Al-Rabouni), and my first building was a garage (welding workshop).²

Q: In what year?³

A: In approximately 1975, after its completion, it was roofed with very simple materials.³

Q: What are the building materials used? We are interested in the building materials used, for example brick, palm leaves, meaning anything that was used in construction?⁴

A: The walls of the garage were built of brick (ordinary clay bricks), and as for the roof, empty barrels were used and cut into shinko pieces and the garage was roofed with them. Then a nursery was built in Rabouni (the martyr Al-Hafiz) as well.⁴

Q: When you were displaced to the region as a refugee, were there housing for refugees and were they organized for the residents, without talking about public institutions?⁵

A: There was only a tent, some people placed a partition in the middle of the tent to use part of it as a kitchen.⁵

Q: Regarding the urban planning of the camps, was there a specific layout in the distribution of tents? Linear, circular, checkerboard distribution. How was it?⁶

A: we interviewed some people who told us that the tents were randomly piled up on top of each other.⁶

Mr. Mohamed Nafea Q: You mean Umm Edreika camp?⁷

Researcher: No, I mean the Tindouf camps after people fled the bombing of the “Umm Adrika” camp. There were three camps, the Subaiti camp and... We are waiting for your answer to confirm or deny the information.⁷

A: For us, we started construction in the year 1975. When we wanted to transform a district or create a new district, we would make a plan for it in this form (he drew it roughly to convey the idea to us). The administration would be in the middle of the district with(nursery), and the administration would be in it. The hospital had police...etc. The administration was based in a tent with a large shed, which was in the 1970s and 1970s. (1976) Nothing else with a large square of stones around it.⁷

Q: Do you have pictures of him?⁸

A: No.⁸

Q: Can we find pictures of those camps?⁹

A: No, no, I don't think so, and God knows best.⁹

Q: At the beginning of forming the camp circles, what was the distance between the tent and the second tent?¹⁰

A: I think there was 12 meters between one tent and the other on all sides: north, east, west, and south.¹⁰

Q: Was the (tent) uniform for all families or not?¹¹

A: Yes, it was just a tent, There were also large tents distributed to departments such as the Crescent, schools, and hospitals as well.

As for the citizens, they are the same size and type, which is known to this day.¹¹

Q: When did clay brick construction appear and in what year specifically? almost?¹²

A: From the year 83 (1983) and above.¹²

Q: And for public institutions, when was it?.¹³

A: Since the beginning, approximately in 1975, there was the garage (welding workshop), then the (nursery), and then the transportation center. The construction was made of bricks and the roofs were made of barrels and wooden boards, and there was a special team to bring and prepare the roof materials.¹³

Q: Do you remember any of them?.¹⁴

A: Yes, the person responsible for them at that time was “Abbah Balali,” and the transportation center was built by “Aslough Al-Saghir.”¹⁴

Q: How was the formation of your brick dough? I mean, how was the dough (the mixture from which the bricks are made)? Was it cohesive and strong? What was your view of it?.¹⁵

A: In Rabouni (the martyr Al-Hafiz), there are areas with good clay and others are sandy. I used to ask them to bring hay or something that would help improve and strengthen the bricks or wood carpentry, but it was not available, so we took some wild plants such as “Asbat” and “Arkaba” and crushed them. When mixing them with the dough (brick mix), there was nothing available, which was very urgent.¹⁵

Researcher: A primitive stage.

Mr. Mohamed Nafea: Yes, primitive because it is a war phase. After several buildings in Rabouni, I was transferred to Dakhla (Laouina) in order to build a headquarters or facility for the Sahrawi Arab Democratic Republic congress.

Q: As for the Laayoune camp, when was it established and how was it formed?.¹⁶

A: It was over phases, as there were only three districts, and it was called “Al-Nabka,” and every time a new district was opened until the camp reached six in total, as is the case now. It is considered to have been established in stages, some districts in 1976, and some in 1977, and the refugees were transferred from the “Adkhal” camp, which was close to the Rabouni camp (the martyr al-Hafiz), to the “Al-Nabka” camp to complete the camp’s dairas.¹⁶

Q: Regarding the “Adkhal” camp (an area where there were refugees), is it the same as the Al-Ayoun camp or not?.¹⁷

A: Yes, they are the same residents. They were transferred from the “Adkhal” area to the place where Al-Ayoun camp is located today, and three new districts were formed. Where there were only three districts, it became six districts, and its name was changed from Al-Nabka Camp to Al-Ayoun Camp.¹⁷

Q: Who are the most important figures who contributed to planning the camp?.¹⁸

A: Yes, I mention among them “Abdelkader Talib Omar” (the current ambassador of the Sahrawi Republic to Algeria), but he participated greatly with me in planning the “Awsard” camp, as it was planned entirely by determining the locations of the district headquarters and the distance between each district and another.¹⁸

Q: What was the distance between the districts?.¹⁹

A: Yes, the distance between “Agwinit” and “Techla” (the names of the circles in the Awsard camp) was 400 meters, and between “Techla” and “Lakwira” was 500 meters, half a kilometer.¹⁹

Q: Regarding your formation of these districts and your design of the neighborhoods (each district contains 4 neighborhoods), what background did you have, the background that you had in planning?.²⁰

A: Organizing the tents in order to organize the population, so that the neighborhood (municipality) included 100 tents and was surrounded by a square of stones to define its borders. A new neighborhood was opened in the event of new refugee delegations and the number reached 100 families. But if The families are fewer, so the square (neighborhood boundaries) is opened and they are added to one of the neighborhoods, The neighborhoods are separated by wide streets that intersect at the district headquarters, which in turn includes the headquarters of the Sahrawi Red Crescent, where humanitarian aid, the police, the hospital, the club, and the education headquarters (nursery) are distributed.²⁰

That was part of the interview I had with Mr. Mohamed Nafea (former Minister of the Ministry of Construction and Reconstruction of liberated territories).

Appendix-02

Interview With Molay El Mehdi (an architect working in the construction sector in the camps) on December 05 ,2021. This interview was conducted in person.

Q: Do you mind a glimpse of your working life briefly in the construction sector in the camps.1

A: I obtained a bachelor's degree in 2014 and then a master's degree in housing in 2016 from Bechar University, Faculty of Engineering, and then I entered into work life as a consultant in architectural design and supervision as well. All the projects that we design in our office we follow up their implementation. We worked a lot with humanitarian organizations in the camps, which build and restore schools and hospitals and build houses for vulnerable groups of refugees.1

Q: I have some questions about construction in the camps. Could you help me answer them?.2

A: Go ahead.2

Q: From your point of view and according to your experience here, what are the reasons that made the camp residents tend to building with cement instead of clay?.3

A: it seems that the inability of mud houses to resist climatic factors, especially strong rains and floods, this is almost the biggest factor, for example, the rains of 2006 destroyed many mud houses, as well as the rains of 2015, especially in the Laayoune camp, and there are other factors such as the frequent need for restoration, so every two or three years you must do some restoration. Besides, in the view of the residents, mud houses have become old and traditional.3

Q: Is the cost of building with cement appropriate to the income level of camp residents?.4

Q: Building with cement is expensive for refugees, as here the income is very limited or does not exist sometimes, as most families depend on food supplies provided by organizations or expatriate family members in some countries.4

Q: Is the mud construction in the camps structured and planned or is it primitive and random architecture?.6

A: No, it was random in terms of the selection of the clay material from which the brick is made, as well as the one used in construction. Thick walls of 40 or 50 cm are not made, as is known in the world, and without foundations. In short, there are no features of mud buildings known in the world, construction in the camps is an exceptional case.6

Q: How luxurious is clay construction in terms of thermal factors (heat, cold)?.7

A: Excellent, The mud houses here are much better thermally than the cement-built houses, but both suffer from the Shinko roof, which raises the temperature in summer and cold in the winter and is dangerous during the wind.7

Q: In your opinion, what are the weaknesses of the mud construction in the Sahrawi camps?.8

A: The most important of which are fragility and inability to resist climatic factors, the lack of selection of clay material from the soil from which the brick is made, due to lack of knowledge, the large number of cracks due to salinity of the ground, the roof of the chinko that raises the internal temperature of the building as well as dangerous during the wind.8

Q: What are the positive aspects of mud houses?9

A: It has several advantages, including thermally excellent, low-cost, easy to build, and any refugee can build his own home.9

Q: Is combining clay and cement construction in the same building (mixed building) an ideal solution for the reality of refugees?.10

A: As you can see, this is now found in many houses, and this is the result of the fall of some parts in the previous rains of 2006 and 2015, which were built with cement instead of mud. some families build one or two rooms with cement to take shelter during heavy rains or build the whole house with cement or red brick, and this is according to the family's financial ability, mud houses are no longer feasible in resisting climatic factors, but in my opinion, it is not considered a solution to the problem of construction in camps. The roof of the Shinko must be removed first and replaced with other materials that are suitable in price and resistant to heat, on all types of housing built of mud or cement or mixed mud-cement, as well as red brick houses, as well as studying the walls and external openings and guidance or what is known as the cover. The architect of the building and the choice of everything that further improves the internal conditions of the building.10

Q: When did construction with cement in the camps start?.11

A: Almost after the 2006 rains, but in a small way, but after the 2015 rains, cement construction spread significantly, and on the other hand, the residents stopped building with clay almost completely.11

Q: Are cement materials available in the camps continuously and throughout the year?.12

A: Almost yes, except in some periods it decreases in the market and its price rises significantly.12

Q: How can camp residents be convinced of the need to preserve mud buildings and develop them to be more resistant to climatic factors and keep pace with the requirements of current life?.13

A: The issue is not easy, but it is not impossible. People rely on realistic examples that you see in their reality and we can embody them, if mud houses are built with correct standards and from treated clay with materials that increase its resistance to climatic factors and meet the needs of the population, then the residents will certainly imitate you because it is better thermally and less expensive, and it is architecturally beautiful if the facades are treated correctly.13

That was part of the interview I had with Molay El Mehdi (an architect working in the construction sector in the camps).

Appendix-03

Interviews with residents of Layoune camp on June ,2018. This interview was conducted in person.

Q: I have some questions about construction, I would like you to answer them.1

A: I don't mind, go ahead.1

Q: Why is there a reluctance of the population to build with mud, is it its inability to resist climatic factors (wind, rain, heat ...)?2

A: Frankly, mud construction is weak. Every time we build our houses, they are destroyed by the heavy rains that come unexpectedly, we are tired of the mud.2

Q: But is the cost of building with cement appropriate to the income level of camp residents?3

A: It is very expensive, but there is no solution, the mud is weak and the cost of renovation with almost every rain costs you a building with cement.3

Q: Are cement materials available in the camps continuously and throughout the year? Is it produced locally?4

A: In some periods there is a shortage. It is not produced locally, of course, even the city of Tindouf does not have cement factories rather comes from 800 km far away wilayas.4

Q: What is your view of the mud buildings in the camps built by prisoners of war, which lasted for decades?5

A: Good, but it also needs to be renovated every time.5

Q: Is the Sahrawi labor efficient in clay construction?6

A: No, you don't need experience, I built my house myself with the help of some friends and neighbours and no one has experience in the first place, building with clay does not need experience, all people can build with it.6

Q: How comfortable do you feel thermal inside the clay structure, and in winter is it warm?7

A: Cool in summer and good in winter, much better than cement.8

Q: If you want to build in the future, what will you build your house, and why?9

A: If I have money I will build with cement, will not fall because of rain, the only problem is that the wind ruins the roof, or it is hot in the summer, but can handle it with some patience.9

Q: Why did you choose to build with cement over clay construction even though the raw materials for clay construction are available in nature and at the lowest cost?10

A: Because it is stronger in the rain, You will suffer with the clay, during the rain you wait for the house when it falls on you or you run away from it to the tent, there is no solution.10

Q: But cost is lower?11

A: It doesn't matter. 11

Q: Is building with cement an ideal solution to the construction problems in the camps? And why?.12

A: I don't know, but it's better than mud.12

Q: In your opinion, what are the weaknesses of the mud construction in the Sahrawi camps?.13

A: weak, cracking, old.13

Q: What are the problems you suffer from in your mud house?.14

A: Many cracks in the walls, the salinity of the ground affects the walls, dangerous during rain, Shinko causes increased heat and dangerous during wind.14

That was part of the interview I had with residents of Layoune camp.