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Detailed shelter response profile Yemen

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DETAILED
SHELTER RESPONSE PROFILE

YEMEN

LOCAL BUILDING CULTURES FOR SUSTAINABLE AND RESILIENT HABITATS

1ST EDITION
SEPTEMBER 2022





Shelter Response Profiles (SRP) / Local Building Practices Profiles



BACKGROUND

The organisations backing this document (see back cover) have been working for several years on the elaboration and dissemination of an identification method for local building cultures and practices (LBC/LBP), especially regarding their potential to contribute to Disaster Risk Reduction (DRR), and also to shelter and housing responses in post-conflict situations. The aim is to facilitate the identification of the strengths and weaknesses of LBC/LBP and the opportunities they offer – in an adapted version if necessary – in housing reconstruction, retrofitting or improvement projects.

In doing so, it is essential to consider that families and communities often live in changing environments due to factors such as conflict, climate change, urbanization, globalization, and changing socio-cultural attitudes. Thus, even if local practices are meaningful, they are challenged, and it is still advisable to find locally manageable solutions and limit innovations so that they can be adopted toward sustainable development and increased local resilience capacity.

SRPs are part of a broader set of tools and documents. They are one of the activities of Step 1 *Understanding the context* of the Protocol Informing choice for better shelter (see link in the box “To find out more” below), developed by the “Promoting Safer Building Working Group” (Self-recovery) of the Global Shelter Cluster.



OBJECTIVES

SRPs have several complementary objectives:

- To help to recognise the importance of understanding a context before proposing any action or project.
- To favour the development of shelter and human settlements responses (preparedness, early-recovery or later phases linking with development stages) more focused on localization, reduction of climate change and environmental impacts, and promotion of self-recovery strategies.
- To help to better take into account the existing construction sector, natural and human resources, local knowledge, existing solutions and good practices, and local cultural and social practices such as existing DRR

knowledge, know-how and techniques at various scales (materials, building systems, house, compound, settlement organisation).

- To give a non-exhaustive overview of a country or territory: demographic, cultural, social and economic data; hazards, environment and climate change impacts; impacts of crises in the population; HLP issues; legal and institutional framework; construction sector, etc., and so to help orient practitioners in new contexts.
- To eventually become an advocacy tool for the shelter sector/cluster members, agencies, donors, or local authorities for more localized actions, facilitating self-recovery and communities’ resilience.



CONTENT AND SUGGESTIONS FOR USE

This document introduces reference data on local building cultures and sociocultural strategies that result in people’s resilience. It also provides evaluation criteria that can help in elaborating locally adapted project- strategies.

Context and details differ from place to place, and stakeholders benefit from the collected data to make comprehensive and accurate decisions. Thus, SRPs should not be considered exhaustive. They are just a first level of information that needs to be deepened through field analysis of the specific intervention context. Therefore, it remains essential to organize field surveys that will also allow exchanges with local actors and inhabitants on the constraints and potentials of their territories in terms of access to land, lifestyles, material and human resources, practices, knowledge and construction capacities.



TARGET AUDIENCE

Local, national, international, governmental, non-governmental and civil society actors that are involved in the prevention, preparedness and response to humanitarian crises

(disasters or conflicts) in the shelter, housing and human settlements sector.



HISTORY OF THE SERIES OF SRP

This publication is part of the series of documents: “Local Building Cultures for sustainable and resilient habitats”. Several documents have been produced after a disaster (Fiji, Ecuador, Haiti) or before a disaster strikes as a preparedness tool (Bangladesh, Tonga, Malawi). Two profiles have been elaborated for situations of both protracted crises and disaster contexts (Ethiopia and the Democratic Republic of Congo).

TO FIND OUT MORE

SHELTER RESPONSE PROFILES

<https://www.sheltercluster.org/promoting-safer-building-working-group/library/shelter-response-profiles>

PROMOTING SAFER BUILDING WORKING GROUP

<https://www.sheltercluster.org/working-group/promoting-safer-building>

PROTOCOL: INFORMING CHOICE FOR BETTER SHELTER

<https://www.sheltercluster.org/promoting-safer-building-working-group/protocol-informing-choice-better-shelter>

SELF-RECOVERY PROJECT (GCRF FUNDS)

<https://self-recovery.org/>

SHELTER RESPONSE PROFILES

[Fiji](#)

[Ecuador \(coast\)](#)

[Haiti](#)

[Bangladesh](#)

[Ethiopia](#)

[Democratic Republic of Congo \(southeast\)](#)

[Malawi](#)

[Tonga](#)

[Burkina Faso](#)

ABOUT TO BE RELEASED:

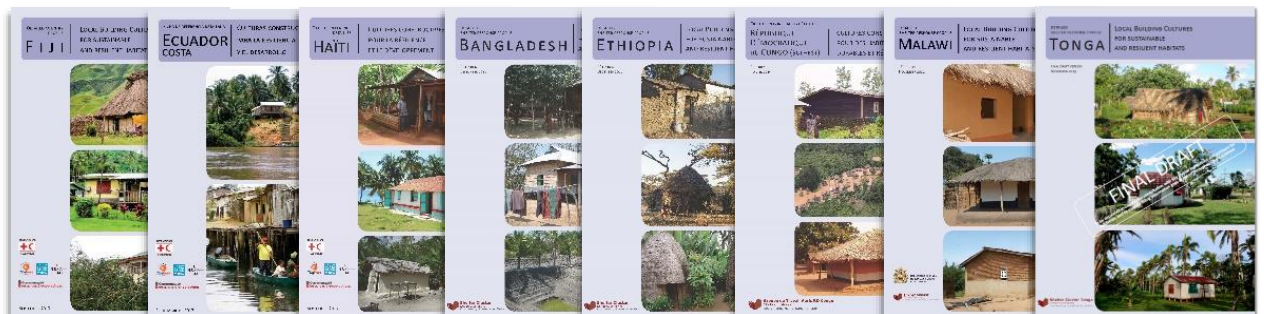
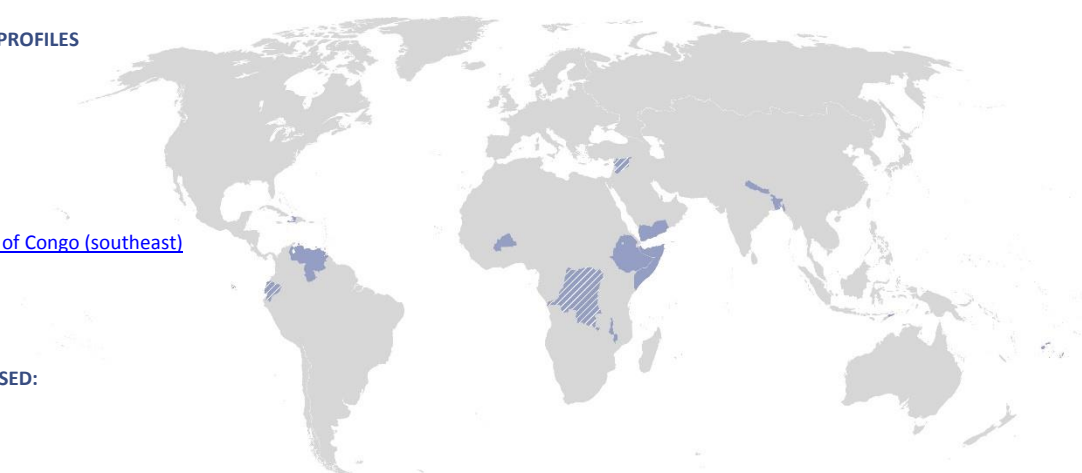
Venezuela

Yemen

Nepal

Somalia

Syria (northwest)



Cover photos (from top to bottom):

Reed House, Coastal Region CC Motohakone

Village in Sana'a Gov. stone masonry, cluster pattern ©CRATERre

Market place in Shibam, Highland; Hadramawt CC Motohakone

Foreword

YEMEN CONTEXT

The Republic of Yemen is a country in Western Asia located at the southern end of the Arabian Peninsula. It is the second-largest sovereign state in the peninsula. Yemen's capital city is Sana'a. As of 2022, the country's population is estimated at 31.9 million.

HIGH VULNERABILITIES

The country has been experiencing an armed conflict for over 7 years, causing tens of thousands of civilian casualties and displacing over 4.3 million people. Even though the current and recent ongoing cease-fire is cause for renewed optimism, Yemen is currently regarded as one of the world's most significant humanitarian crises. According to the UN's 2022 humanitarian need overview (HNO), 23.4 million people in Yemen are estimated to require humanitarian assistance in 2022, of whom 12.9 million are in acute need.

Natural hazards aggravate this crisis. They include torrential downpours and, in 2021, recurrent flooding causing deaths, injuries, displacements, and widespread damage to essential infrastructure, affecting at least 149,000 people. The country is also prone to desert locust infestations, depletion of natural water resources and natural woodlands, which significantly impacts the availability of housing material.

Yemen's economy has shrunk by half since 2015, with over 80% of the population living below the poverty line. Many Yemeni have been displaced for several years, some of which also have been displaced multiple times throughout the conflict. These conditions exacerbate existing vulnerabilities and accelerate the erosion of displaced persons' resilience, intensify needs, increase protection risks, and spur the adoption of negative coping strategies. Some of the highest levels of vulnerability are concentrated in about 2,358 self-

settled displacement hosting sites (Yemen has a no-camp policy) accommodating 1.55 million internally displaced persons (IDPs).

ADAPTED LOCAL BUILDING PRACTICES (LBP)

Yemen has a unique built heritage: apart from the famous historic urban centres of Sanaa and Shibam in Hadramawt, which are 2 outstanding examples of cities built with traditional construction techniques, high level building knowledge and know-how exist almost everywhere in the country and has been surviving for centuries.

However, in recent decades, Yemen has drifted away from traditional building techniques towards more modern ones, even though quality control and enforcement of building regulations are often lacking.

After 7 years of conflict, there is a pressing need for investment in housing and associated basic public services infrastructures: the Yemen Shelter Cluster estimates that in 2022, 7.4 million people in Yemen will require shelter assistance requiring a massive investment of US\$ 225 million. The protracted nature of the crisis implies a need for more durable housing solutions providing adequate accommodation for several years while returns to locations of origin are possible. The use of local building techniques and practices are deemed semi-permanent and less likely to give a perception of permanence, often aggravating landowners.

Local building practices are very much in evidence when you visit the 2,000 internally displaced person (IDP) sites dispersed across the country. IDPs have building skills and are using these techniques often with limited support to enhance their household shelter adequacy. Also, we need to enhance and expand this capacity as resources for widespread humanitarian responses are limited.



Amran, old city center – ©CRATERRE



IDPs site, Al Hudaidah Gov. – CC YFCA

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[1] Introduction

WHY LOCAL BUILDING PRACTICES ARE IMPORTANT TODAY *

All over the world, societies have managed to produce, adapt and develop their habitat according to their needs, interests, aspirations, preferences, availability, affordability and abilities, making the best use of locally available materials. Strategies developed take advantage of natural resources to protect against the destructive forces of nature and have always generated rich and varied knowledges at local levels.

(Re)discovering the intelligence of local architectures and analysing their associated practices is often very useful in the process of designing disaster-resistant architectures in line with build-back-safer principles, but also to adapt to contemporary lifestyles and their evolution, respect the local environment and culture and conform to the technical and economic capacities of local populations.



The well-known old walled city of Shibam, called the "Manhattan of the Desert" is a UNESCO World Heritage site in Hadramawt Gov.– CC Mavilimon3

Relying on, or at least getting inspiration from local knowledge, know-how, construction processes, and traditional means of organisation has proven to be very effective, as it favours:

- The implementation of solutions well adapted to local ways of life and the suggestion of viable improvements;
- The possibility to shelter many people quickly and cost-effectively while taking into account seasonality effects as well as factors like religious festivals and livelihood activities;
- Large-scale reproducibility of the improvements designed in continuity with local building cultures and an easy

access, both financially and technically, to the promoted solutions for non-beneficiaries.

- A positive impact on local economies as local skills and materials are fully promoted while also taking into account environmental concerns linked to the construction industry;
- Extensive short and long-term ownership by the beneficiaries through their participation in decision-making and project implementation processes;
- Empowerment of local populations through the recognition of the value of their existing capacities for building and the improvement of their resilience.

To develop a disaster-resistant architecture adapted to the local lifestyle, it is crucial to involve the beneficiaries, the local professionals and decision-makers from the very beginning of the recovery phase. Also, rebuilding is often necessary and can be very demonstrative and convincing; therefore, promoting appropriate repairs when possible may help achieve this goal. This way, the link between relief, recovery and development is enabled, so the long-term benefit of a shelter project is ensured. In addition to the supply of shelters, the project will have a higher level of resilience.

*The concept of Local Building practices and other key terms related to the topics addressed in this document are defined in Section [Key concepts](#), p.67.

YEMEN PROFILE: INFORMATION, DATA COLLECTION AND PRODUCTION

In October 2021, the Global Shelter Cluster (GSC) launched an expression of interest for Country level clusters to apply for support for the development of a Shelter response profile (SRP). The Yemen shelter cluster applied for this support.

In January 2022, a first workshop with all Yemen shelter cluster partners was held. Over the next few months, a focused working group was established involving the national and 5 sub-national cluster coordination hubs. Info graphics were gathered and shared with the editorial team. Several discussions were held with experts in the country, mainly the Shelter Cluster and its partners. Meetings were organised with the Shelter Cluster Strategic Advisory group and the national/sub-national coordination team. An informal discussion on local building practices was held at the hub

level with humanitarian partners. The sessions focused on the different human settlements in the regions, in urban and rural contexts.

Therefore, this profile was elaborated after a dedicated literature review of around 80 documents (see [Sources consulted to produce this document](#), p.68) and thanks to information collected during and after this process. The document has been reviewed by several international and Yemeni experts and shelter and housing actors in Yemen.

The strengths of local construction and practices, including a variety of hazard-resistant practices, compliance with shelter and settlement standards mainly pertaining to construction and environmental impact, taking into considerations disaster prevention, risk reduction, long-term environmental impacts mitigation measures, knowledge and experience developed by local communities that all have been identified, analysed and many of them validated over the years, and are here summarized and disseminated.

The document is intended to be a living one, and new contributions are highly appreciated.

ARTICULATION WITH THE YEMEN SHELTER CLUSTER STRATEGY

This profile explored localized shelter solutions for transitional shelters and permanent housing, which contributes directly to the shelter cluster strategy. It also presented local building practices and materials in shelter construction. It highlights how the local communities know best what materials work for their local environment, what shelter design is most appropriate for the culture and climatic context, and how to maintain shelters built in these ways.

The shelter cluster strategy emphasized the importance of using the highest quality and context-specific localized solutions. It also recommended community participation and ownership with a strong focus on shifting away from contractor-driven to owner-driven approaches.



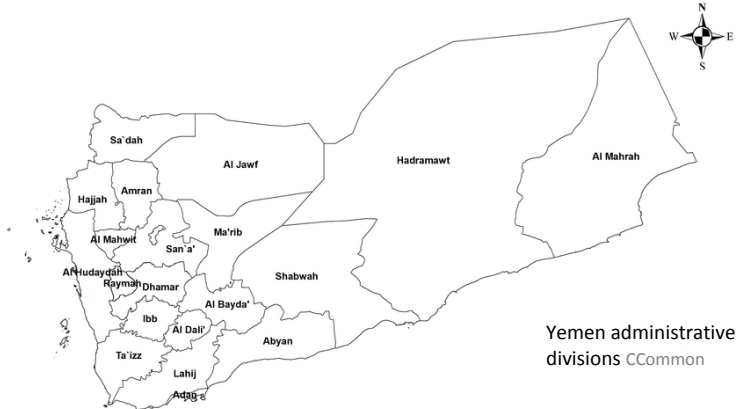
Earth bricks building with stone basement, Hadramawt Gov., Rakhia district, 2022 – ©YFCA

[2] Country profile

[2.1] GENERAL DESCRIPTION



– CC wikimedia



Yemen administrative divisions CCCommon



Relief map – CC vidiano.com

Government: Republic of Yemen

Capital: Sana'a

Administrative divisions: 19 governorates (*muhafazah*)

Within each governorate, municipal regions are divided into areas (*mantaka*). Non-municipal regions are divided into districts (*earthiriyah*).

Total land: 527,970 km²

Coast line: 2,400 km

Lowest point: Arabian Sea 0 m

Highest point: Jabal an Nabi Shu'ayb 3,760 m

LOCATION, PHYSICAL AND TOPOGRAPHICAL DATA

Yemen is a country on the south-eastern tip of the Arabian Peninsula, bordered in the north by Saudi Arabia, in the east by Oman, in the west by the Red Sea and the Babel-Mandeb, the strait that connects the Red Sea and the Gulf of Aden. Yemen shares maritime borders with Djibouti, Eritrea, and Somalia.

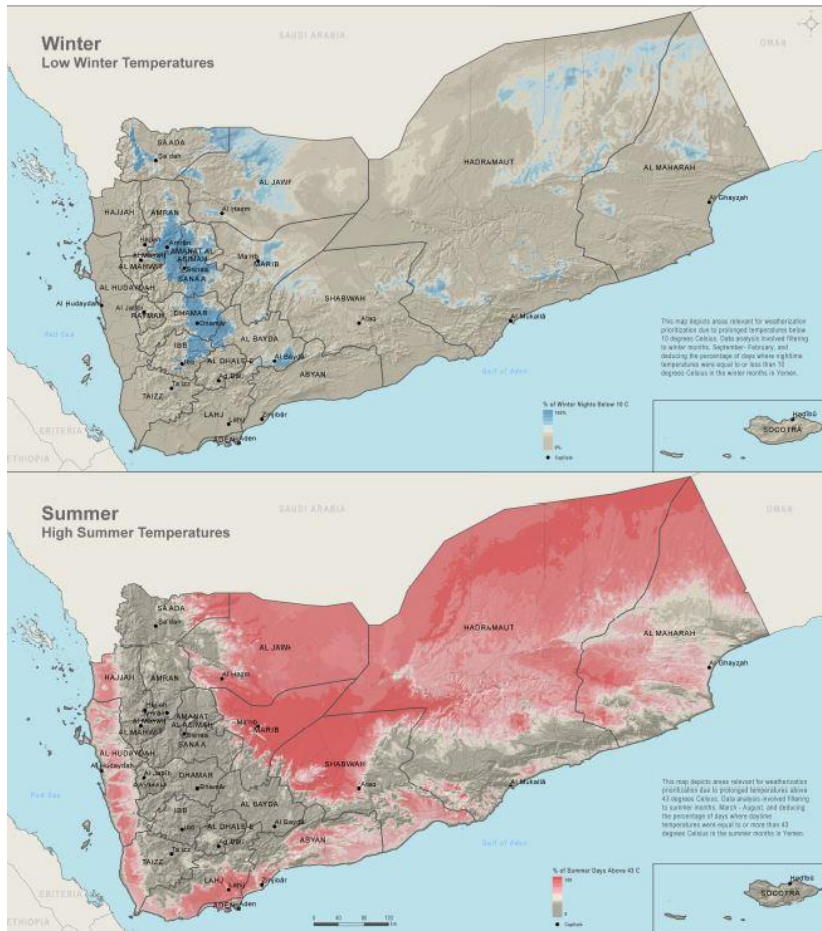


Topographical regions of Yemen – CC wikimedia commons

5 major land systems

- [1] The hot and humid coastal plain,
- [2] The temperate Yemen highlands,
- [3] The Yemen High Plateaus and Hadramawt-Mahra Uplands,
- [4] The interior desert
- [5] The islands.

DETAILED SHELTER RESPONSE PROFILE : YEMEN



Yemen weatherization map – sources: Shelter cluster, CCCM cluster and REACH initiative

CLIMATE

Rainfall regimes differ in the highlands and coastal areas, with relatively little rainfall in the country's centre. The annual frequency of rain days increases with elevation, with the mean number of wet days. Coastal areas receive 80% of the annual rainfall during the winter months, while rainfall in the highlands follows 2 distinct rainy seasons: the *saif* (April-May) and the *kharif* (July-September). The *saif* rains are governed by the northwest trade winds (entering the Red Sea Convergence Zone), while *kharif* rainfall is governed by mechanisms of the Inter-Tropical Convergence Zone. *Kharif* rains typically fall in short but heavy events¹.

PROTECTED AREAS AND WORLD HERITAGE SITES

Yemen has 3 World Heritage sites; Sana'a, Shibam and Zabid old cities. Many other heritage sites figure on Yemen's World Heritage tentative List and are damaged due to the conflict.

Concern for the country's cultural heritage was officially acknowledged in 1972 by the passing of the Law of Antiquities and Heritage and, with it, the creation of a government department to oversee the custody of the country's cultural heritage².

¹ (Nasser, 2010)

² (Varanda, 1994)

Climate

Yemen is a largely arid sub-tropical country where temperature depends primarily on elevation, and is determined, in the coastal areas, by the distance from the sea. Mean temperatures in the highlands range from below 15°C in winter to 25°C in summer, and in the coastal lowlands from 22.5°C in winter to up to 35°C in summer (World bank).

Wadis

Yemen does not have any permanent rivers, but does have numerous *wadis*, which are intermittently dry riverbed (Wikipedia).



Amran citadel entry gate – CC Motohakone

TO FIND OUT MORE

UNESCO-YEMEN
<https://en.unesco.org/galleries/heritage-risk-yemen>

[2.2] KEY DEMOGRAPHIC, CULTURAL, SOCIAL AND ECONOMIC DATA

TRIBES

↳ The Republic of Yemen is often described as one of the most “tribal” countries in the Middle East, if not the world. This statement reflects the fact that the vast majority of the Yemeni population, at least nominally, identifies as belonging to a tribal group³.

At present, there is general agreement that in Yemen, there are 5 major tribal confederations. The 2 largest are the Hashid and Bakil confederations, based in the areas north of the capital Sana'a, covering Sana'a, Amran, Sa'dah, Al-Jawf and parts of the Marib governorate. The next 3 largest confederations, Madhaj, Himyar and Kinda, are spread across the remaining areas of the country. In places, confederations intersect and overlap, while there are also regions with no strong tribal structures, such as Ta'izz in central Yemen and Aden in the south⁴.

ETHNIC GROUPS

↳ Main minorities and indigenous peoples: Zaydis (35 per cent), Muhamasheen 440,000-1.1 million (2-5 per cent), Isma'ilis (15,000), Jews (50)⁵.

Yemenis are overwhelmingly ethnic Arab and Afro-Arab. The black al-Muhamasheen ethnic minority does not belong to any of the 3 main Arab tribes in the country. It has been estimated to comprise 2-5 per cent of the population, though some community estimates the proportion close to 10 per cent⁵. For many years, including decades prior to the conflict, this group has suffered widespread discrimination, social exclusion and reduced access to public services⁶.

RELIGION

Demographic statistics for Yemen are unreliable, but nearly all Yemenis are Muslim. Next to a Shafa'i Sunni majority, there is a substantial minority of Zaydi Shi'as, mainly from Dhamar northwards. There are thought to be around 15'000 Isma'ilis in Yemen, concentrated in Haraz district near Sana'a⁵.

EDUCATION

Approximately 8.1 million school-age girls and boys need Education in Emergencies (EiE) assistance across Yemen. These include 1.65 million internally displaced children, 1.5 million children with a disability and minority groups who face challenges in accessing education. Conflict and continued disruption of schooling across the country and the fragmentation of the education systems have had a profound impact on the learning and overall cognitive and emotional development of nearly all the 10.1 million school-age boys and girls in Yemen. A pervasive issue in Yemen is a lack of teaching staff. Many have left the sector to seek other sources of income. Across the country,

↳ TO FIND OUT MORE

TRIBES AND THE STATE IN YEMEN
<https://sanaacenter.org/publications/main-publications/16156>

TRIBES IN YEMEN, ACAPS, 2020
https://www.acaps.org/sites/acaps/files/products/files/20200813_acaps_thematic_report_tribes_in_yemen_0_0.pdf

↳ Population distribution

It is important to distinguish between district size and population as often larger geographical areas are sparsely populated. An estimated 70 per cent of the population lives in the north of the country; the remaining 30 per cent lives in the south of the country. (OCHA, 2021)

Population: 29.83 million (2020)

Population density: 56.5 people per sq. km of land area

Poverty rate: 48.5 (2014)

Human Development index: 0.47 (rank 179, 2019)

Population growth: 2.3 (2020)

Gender Development index: 0.488

Languages: Arabic (92%), other (8%)

Religion: Shafa'i Sunni (65 per cent), Zaydi Shi'a (35 per cent) and Isma'ili Islam (an estimated 15,000 people)

Expected years of schooling: 8.8

Life expectancy: 66 years

Median age: 20.2

Fertility rate: 3.6/woman

Infant mortality rate: 60/1000

Health expenditures: 4.2% GDP

Physicians' density: 0.53 /1,000

Sources: Worldbank.org, undp.org, minorityrights.org

³ Acaps.org

⁴ sanaacenter.org

⁵ minorityrights.org

⁶ (OCHA, 2021)

functional schools suffer significant classroom overcrowding. The lack of qualified teaching staff is an ongoing problem. In addition, the risk of armed attacks or recruitment into armed groups at schools, widespread violence, and protection concerns were significant safety concerns for parents leading some to keep their children - especially girls - at home⁷.

HEALTH

The country has the highest maternal mortality ratio in the Arab region. Children are significantly affected by increasing rates of malnutrition. Poor coverage, lack of specialized staff, essential medical supplies and female doctors affect maternal health-seeking behaviour, particularly for the 75 per cent of Yemeni women in rural areas. Epidemics and other disease outbreaks are overburdening the weak health system⁷.

ECONOMY

The economy and the currency continued to collapse as foreign reserves were depleted, and the government was unable to subsidize food and other commodities for which Yemen is 90% import-reliant. It is estimated that 60% of the Government revenue comes from oil and gas exports. The depreciation of the rial and inflation were critical factors in driving up food prices in 2020. Yemen was already the poorest country in the Middle East before the escalation of conflict. Despite long-standing development challenges, progress had been achieved in key sectors by 2014. 6 years of conflict have reversed those gains. Between 40 and 60 per cent of the population now has limited or no access to basic services⁷.

GENDER

➤ Although Yemeni social norms have traditionally placed men as the source of family authority, years of war and upheaval are driving social change. A sudden change of roles among men and women has brought women to become fully responsible of their families, sometimes without any or limited prior experience in income-generating activities. There has been a 20 per cent increase in the number of female-headed households⁷.

Child marriage is often used as a way to seek protection from host communities and to relieve financial burdens. The common child marriage and the lack of education consequences of it plays a significant role in the incidence of gender-based violence (GBV). This practice continues to be a concern as a negative coping mechanism, as it is normalized by communities endorsed defining the age under 18⁷.

COMMUNICATION HABITS AND ACCESS TO INFORMATION

To be further completed

Currency unit: Yemeni Rial (YER)

GDP per capita (PPP): 1,594

Employment ratio: 33.1%

Skilled labour force: 29.7%

Unemployment rate: 13.6%

➤ TO FIND OUT MORE

WORLD BANK

<https://data.worldbank.org/country/yemen-rep>

UNDP

<https://www.hdr.undp.org/en/countries/profiles/YEM>

OCHA

<https://www.unocha.org/yemen>

UNHABITAT

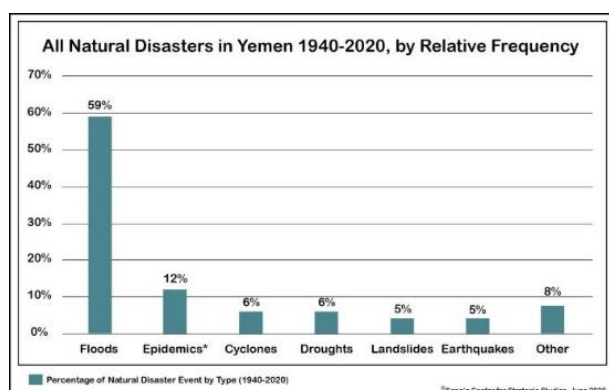
<https://yemenportal.unhabitat.org/>

⁷ (OCHA, 2021)

[2.3] RISKS, ENVIRONMENT AND CLIMATE CHANGE IMPACTS

- ☑ (FLASH) FLOOD
- ☑ EARTHQUAKE
- ☑ EPIDEMIC
- ☑ DROUGHT
- ☑ LANDSLIDE
- ☑ STORM AND HURRICANE
- ☑ VULCANO
- ☑ INDUSTRIAL RISK

Yemen faces multiple natural hazard risks and has experienced at least one disaster every year for the last twenty years. Climate variability is likely to increase and negatively impact agriculture, while the multiplication of extreme rainfall events increases the risk of floods. Famine risk, malnutrition risk, and cholera and covid19 risks also prevail⁸.



– Source data: EM-DAT, CRED / UCLouvain, Brussels, Belgium, www.emdat.be (D. Guha-Sapir), 2020-06-15; *Excluding COVID-19

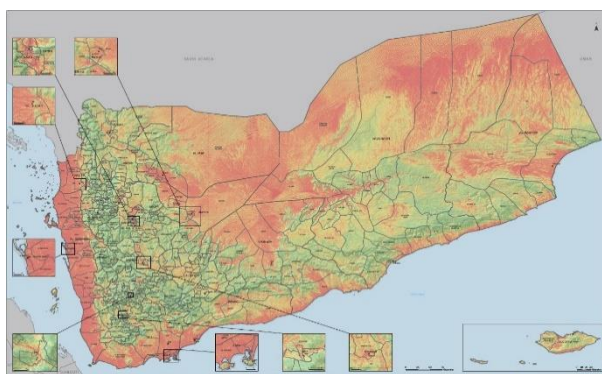


(FLASH) FLOOD

Floods are the most important and recurring disaster in Yemen and occur almost every year in Yemen. Major floods were reported in 1991, 1993, 1996, 1999, 2000, 2006 and 2008⁹.

Rainfall in Yemen is characterized by seasonally intense and short-lived heavy storms that often lead to flash floods with implications for soil erosion and the degradation of agricultural terraces. Occasionally, these floods have caused significant economic damage and loss of crops¹⁰. The heavy rains associated with a tropical storm in October 2008, for example,

brought 90 mm of rainfall over the course of 30 hours, as opposed to the usual 5-6 mm over the same period. This led to severe flooding in the Hadramawt and Al-Mahara governorates in eastern Yemen, resulting in over 70 deaths, the displacement of 25,000 people, and the destruction of over 2,800 houses. The overall damage from the flood was estimated at \$1,638 million. Due to their concentrated physical assets and population, floods in urban areas can result in very high losses; the average annual loss due to recurrent floods in Sana'a is estimated at US\$ 3.0 million¹¹.



Flood susceptibility in red – March 2020 – sources: reach, shelter cluster



EPIDEMIC

Since 2015, increased cases of diphtheria, polio and other diseases have all been reported, including dengue fever, which saw over 65,000 cases in 2020, affecting 69 per cent of the districts in Yemen. In addition, 2020 saw the declaration of a polio outbreak following reported cases of vaccine-derived poliovirus type 1 (cVDPV1) in the first weeks of August 2020, for the first time since it was eradicated in 2000¹².



DROUGHT AND DESERTIFICATION

Heavy rainfall is frequently followed by long dry periods that result in widespread drought, desertification and land degradation. Climate change may increase the length of these dry periods. Water stress is increasing, with groundwater reserves likely to be primarily depleted in 2 to 3 decades regardless of climate change, reducing agricultural output by up to 40 %. Yemen's water crisis ranks among the worst in the world. High aridity, fast-depleting groundwater reserves, and

⁸ Climate Risk and Adaptation Country Profile - Yemen (April 2011)

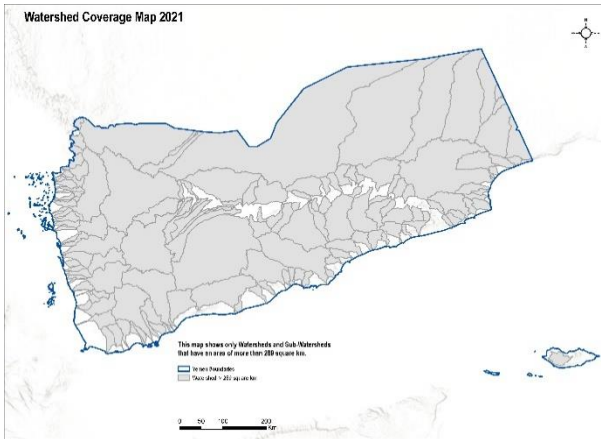
⁹ (Nasser, 2010)

¹⁰ thinkhazard.org

¹¹ GFDRR

¹² (OCHA, 2021)

projected risings in temperature indicate that stress on agricultural production will increase. Greater rainfall variability could result in prolonged drought periods. Drought caused the displacement of thousands of people from mountainous villages in 2009 for the first time in Yemen¹³.



Watershed coverage map (2021) – Sources: shelter cluster and REACH initiative



EARTHQUAKE

1982, 1991

Western and southern portions of Yemen are located in the seismically active zone between the Arabian and African tectonic plates, at risk of earthquakes. In addition, Yemen's mountainous terrain renders the entire country at risk of landslides. A vast majority of the urban poor is vulnerable to rockslide and landslide risks as they live in informal settlements that are typically on marginal and environmentally sensitive land¹⁴.



LANDSLIDE

Landslide susceptibility is classified as high. This means that this area has the rainfall patterns, the terrain slope, the geology, the soil, the land cover and (potentially) earthquakes that make localized landslides a frequent hazard phenomenon. Yemen's mountainous terrain renders the entire country at risk of landslides. It is difficult to determine future locations and timing of large rock avalanches, as these depend on local geological conditions and other non-climatic factors¹⁵.

¹³ (Nasser, 2010)

¹⁴ Climate Risk and Adaptation Country Profile April 2011

¹⁵ Thinkhazard.org

¹⁶ GFDR



STORM AND HURRICANE

In October 2008, Hadramawt and Al-Maharah governorates suffered substantial damage as a result of a tropical storm that is attributed to climate change¹⁶.



VULCANO

Yemen is located in one of the most active plate boundaries of the World - the triple junction made up of the Gulf of Aden, the Red Sea and the Eastern African Rift System. After 124 years of dormancy, the volcano that created the island Jebel at Tair, erupted on 30 September 2007¹⁷.



INDUSTRIAL RISK

Yemen also faces the real risk of a major oil spill with potentially dramatic implications for the population if maintenance of the FSO 'SAFER' tanker is not conducted urgently. The impact of a significant oil spill, if SAFER ruptures, sinks or explodes, would be catastrophic, and there is a limited national capacity to respond¹⁸.

CLIMATE CHANGE AND ENVIRONMENTAL ISSUES

↳ The Notre Dame Global Adaptation Index ranks Yemen among the countries least prepared for climate shocks and among the most vulnerable to climate change. As a result, impacts such as drought, extreme flooding, pests, changed rainfall patterns, increased storm frequency and severity and sea-level rise are increasing¹⁸.

Evidence that could be associated with climate change has already started to appear. Over the last decade, the annual average temperature over the country has been noticeably increasing. As a result, Yemen has experienced frequent droughts that caused food shortages, famine, and destruction of infrastructure and livelihoods¹⁹.

Drought, temperature variability, and changes in precipitation can lead to disastrous consequences for agriculture and food security. Climate change may imply a degradation of agricultural lands, soils and terraces, and desertification, which negatively affects agricultural incomes for local communities

¹⁷ ADRC

¹⁸ (OCHA, 2021)

¹⁹ UNFCCC

specifically and leads to national food insecurity as food production levels change. Furthermore, higher sea temperatures and the rise of the sea level are adversely affecting the coastal and marine environment resulting in coral bleaching and the disappearance of some fish species in the landed catch. In addition, the country's coastal areas are exposed to annual monsoon cycles, which have led in recent years to several hurricanes that have swept over the country and have had devastating effects on people, infrastructures and livelihoods.

↘ Yemen's water availability per capita is the lowest in the world. Groundwater extraction has exceeded the replenishment capacity, causing water depletion. It is anticipated that climate change combined with high population growth, inadequate agricultural development and policies as well as a lack of law enforcement to regulate water will result in high pressure on Yemen water resources. The overexploitation of groundwater resources and the rising sea level due to climate change will increase salt-water intrusion, especially in coastal aquifers. Desertification of agricultural land ranges from 3-5% annually²⁰.

DISASTER RISK REDUCTION MECHANISMS (DRR)

In 2005, the Ministry of Interior developed a National Plan for Disaster Management, but this plan does not address disaster risk reduction. The Environment Emergencies Unit in the Ministry of Water and Environment is in charge of risk reduction and has worked to set up a national platform for Disaster Risk Reduction in coordination with the UNISDR. However, there is no national policy for disaster risk reduction and, so far, only scattered and uncoordinated advances in implementing the National Plan for Disaster Management. Some projects, like early warning systems, have been established with funding by international organizations, but they have not been maintained when funding ended²⁰.

↘ TO FIND OUT MORE

RISK ADAPTATION COUNTRY PROFILE

<https://www.gfdrr.org/en/publication/climate-risk-and-adaptation-country-profile-yemen>

REPUBLIC OF YEMEN, NATIONAL REPORT, HABITAT III, 2016

<https://habitat3.org/wp-content/uploads/Yemen-National-Report-September-2016.pdf>

YEMEN ENVIRONMENT BULLETIN: HOW WEAK URBAN PLANNING, CLIMATE CHANGE AND WAR ARE MAGNIFYING FLOODS AND NATURAL DISASTERS, YASMEEN AL-ERYANI, 2020

<https://sanaacenter.org/publications/analysis/10346>

ENVIRONMENT COMMUNITY OF PRACTICE, GSC

<https://sheltercluster.org/group/11278/documents>

[2.4] REFUGEES, INTERNALLY DISPLACED PEOPLE (IDPS) AND RETURNEES



HUMANITARIAN CRISIS

Currently, Yemen remains one of the world's largest humanitarian crises and benefits from the largest aid operations. The crisis is the result of a brutal armed conflict that escalated over the last 6 years. It has caused tens of thousands of civilian casualties, the destruction of homes and infrastructure, displacing over 4.3 million people, collapsing the country's economy, and losing Yemeni income and livelihoods. As of July 31 2022, the overall number of registered Asylum Seekers and Refugees in Yemen stands at 97,614 individuals).

Women and girls are significantly affected by the ongoing conflict, deteriorating their socioeconomic situation, abjecting

their poverty, degrading their living conditions and causing distress in families with repercussions including various forms of violence and negative coping mechanisms such as child marriage and exploitation²¹.

↘ TO FIND OUT MORE

YEMEN HUMANITARIAN NEEDS OVERVIEW, 2022

<https://reliefweb.int/report/yemen/yemen-humanitarian-needs-overview-2022-april-2022>

YEMEN HUMANITARIAN RESPONSE PLAN 2022

<https://reliefweb.int/report/yemen/yemen-humanitarian-response-plan-2022-april-2022>

GLOBAL CONFLICT TRACKER, WAR IN YEMEN

<https://www.cfr.org/global-conflict-tracker/conflict/war-yemen>

²⁰ (Yemen National report, 2016)

²¹ (OCHA, 2021), 2022

[3] Description of local habitat

[3.1] OVERVIEW OF THE HOUSING SECTOR, ACCESS TO LAND AND INSTITUTIONAL FRAMEWORK

HOUSING SECTOR

↳ Driven by urbanization, demographic pressure and high inflation, the shortage of housing becomes dramatically high. However, supply-side policies and institutional frameworks in general and those addressing the housing needs of deprived and low-income families in specific have not yet been adequately developed. The country lacks an integrated national housing policy; consequently, housing finance schemes for deprived and low-income groups are not addressed²².

Most of the housing in urban Yemen is characterized by detached, individual houses. However, apartment housing is on the rise. From 1994 to 2004, the number of entrances found in multi-unit or collective housing blocks increased from 16.5-26.2% of the urban total²³.

The proportion of renting households considerably differs from one town to another. For instance, in Sana'a and Aden, 47.7% and 16.9% of households rent, respectively²⁴.

Before the current crisis, the percentage of "huts and shacks" was relatively low (approximately 2.3% in urban areas), but a substantial proportion of urban households lacked urban infrastructure. For instance, in 2004, 26% of urban buildings were not connected to any water supply network. This rate increased to 72% in rural areas²⁴.

Today, one of the main consequences of internal people displacement and the housing affordability issue is the mushrooming of squatter settlements and un-serviced peripheral neighbourhoods. This exclusion from formal housing services appears to be a growing concern in Yemen²⁵.

²² (Yemen National report, 2016)

²³ (last censuses, 1994-2004)

²⁴ (Al-Abed, 2014)

HOUSING, LAND AND PROPERTY ISSUE

↳ Land registration in Yemen is a critical issue, especially in urban settings. The strength of traditions of Yemeni social and cultural structures bind the current land practices followed by most people. A severe lack of trust in authority and lack of conformity to formal procedures exists, and this fosters hybrid systems and informal dealings²⁵.

The registration of land titles with the Land Registration Department in the General Authority of Lands, Survey and Urban Planning (GALSUP) is now a compulsory step in obtaining a building permit. However, in practice, registration rarely happens. For example, according to some estimations, 81.5% of construction in Sana'a happens without permits. One reason is that property transactions for both land and real estate are taxed at 3% of the sales value, due when the new owner registers the property on their name, which poses an obstacle to low-income families in particular. In addition, as a result of the widespread lack of official registration, disputes over land are widespread. Indeed, land disputes are estimated to constitute 30-50 % of all cases that appear before primary courts²⁶.

↳ MAIN ORGANISATIONS AND MINISTRIES INVOLVED IN SHELTER AND HOUSING:

- YEMENI ENGINEERS ASSOCIATION (YEA)
- GENERAL AUTHORITY OF LANDS, SURVEY AND URBAN PLANNING (GALSUP): LAND SURVEY, MAPPING, REGISTRATION. MANAGEMENT OF STATE LAND AND REAL ESTATE. URBAN PLANNING.
- MINISTRY OF PUBLIC WORKS AND INFRASTRUCTURE (MPI)
- MINISTRY OF PLANNING AND INTERNATIONAL COOPERATION (MOPIC)
- UN-HABITAT: <https://unhabitat.org/yemen>
- SHELTER/ NON-FOOD ITEMS CLUSTER: [HTTPS://SHELTERCLUSTER.ORG/RESPONSE/YEMEN](https://sheltercluster.org/response/yemen)

²⁵ (Yemen National report, 2016)

²⁶ (Sana'a City profile, 2021)

[3.2] ECONOMIC SITUATION OF HOUSEHOLDS AND ACCESS TO HOUSING

OVERVIEW OF THE ECONOMIC SITUATION AT HOUSEHOLD-LEVEL

Until the 70's, the population was essentially rural (more than 80%), producing coffee, qat and vegetables. There was very little difference between villages and small towns in terms of architecture, lifestyle or organization. Political elites lived in the cities, and tribal power was in the rural areas. The mass rural-urban migration started in the 90's onwards²⁷.

Nowadays, this internal migration is a key feature of Yemen's urban setting. Increased poverty rates in rural areas, absence of employment opportunities and other climate-related factors (water scarcity, drought, natural disaster, etc.) are considered the main reasons behind the growing trend of rural migration. Sana'a City is the main destination of internal migrants²⁸.

↳ It is worth noting that the recent armed conflicts lead to a "reverse" population movement from main cities (Sana'a, Aden and Ta'izz) to rural areas transforming them into hosting areas for Internally Displaced Persons (IDPs)²⁹.

ACCESS TO HOUSING

↳ Except for incidental resettlement, disaster relief projects and seldom public housing programs, all the housing production in Yemen is undertaken by the private sector, including private individuals. The private sector is estimated to carry out around 95% of the total housing construction.

The main issue affecting access to houses in Yemen is not the supply but the affordability of houses. Housing finance is undeveloped in Yemen. People build houses by saving money or getting family and friends loans. Commercial banks in Yemen give people fast loans but with complex mortgages and a high-interest rates. Therefore, the low-income group does not have access to these loans and cannot afford a house³⁰.

Most of these constructions occur in largely unplanned urban fringe areas, on disputed lands or land without known ownership as informal developments.

Before the civil war, housing overcrowding in urban areas was already alarming. Roughly 6,000 households in Sana'a and 9,500 households in Aden shared housing units, and between 50-75% of households in these cities live with more than 2 people in one room²⁸.

↳ TO FIND OUT MORE

DEVELOPING EFFECTIVE POLICY AND PLANNING IN YEMEN, DABBAS & Co, 2011

https://www.globalprotectioncluster.org/assets/files/field_protection_clusters/Yemen/files/HLP%20AoR/Developing_Effective_Policy_2009_EN.pdf

HUMANITARIAN RESPONSE: OPERATIONAL PRESENCE

<https://www.humanitarianresponse.info/en/operations/yemen/yemen-organizations-3w-operational-presence>

REPUBLIC OF YEMEN, NATIONAL REPORT, HABITAT III, 2016

<https://uploads.habitat3.org/hb3/Yemen-National-Report-September-2016.pdf>

SHELTER CLUSTER YEMEN – HLP WORKING GROUP

<https://sheltercluster.org/yemen/documents/draft-hlp-wg-tor>

UN-HABITAT – CITY-PROFILE OF YEMEN

<https://yemenportal.unhabitat.org/urban-profiles/>

URBAN HOUSING SUPPLY AND AFFORDABILITY IN YEMEN

https://www.researchgate.net/publication/351779306_Urban_Housing_Supply_and_Affordability_in_Yemen

²⁷ (Serageldin, 1982)

²⁸ (Yemen National report, 2016)

²⁹ (OCHA, 2021)

³⁰ (Alaghbari, 2011)

[3.3] ORGANISATION AND USE OF PUBLIC AND PRIVATE SPACES

► MAIN PATTERNS

↳ Forms of settlement vary but follow some common basic patterns. In the Tihama region, besides the harbour towns and fishing villages of the coastline, major settlements are near the trade paths of the middle region. The wadi basins concentrate on farming hamlets and villages like in the midlands of the western and southern mountain slopes. In the highlands, hilltops are preferred, whereas settlements surrounded by free-standing walls in the middle of the plains or against steep cliffs typify the northern and central plateaus. In the Mashriq, small settlements occur in wadis and around markets, but a significant part of the population is nomad or semi-nomad and lives in tents.

Communities live in scattered stone huts in transitional or unstable zones, but in general, even the minor settlements appear as tight clusters of buildings belonging to one or more separate but related nuclear family units. The word *bayt*, meaning house and patronymic lineage, is also commonly used for hamlets and villages. The cemetery and the mosque form part of the settlement from its early formation and may exist even in the smallest isolated hamlets. A few buildings, including a general store and craft and repair workshops, are often located at the entrance of settlements, even the smallest. Many settlements have communal agriculture facilities (threshing floors, places for the preparation of the dung fuel, animals' enclosures or stable and storage places for fodder.

The location of some facilities in the centre of a small village enhances the installation of other activities such as shops or tea houses. A place of this kind may represent an informal meeting point associated with leisure and specific occupational activities³¹.



Coastal plains

When descending towards the coastal plains, the habitat tends to decrease in height. In the valleys below 1,000 m altitude, the houses are often reduced to a stone cube and have only one floor above the stables³². In the area of Tihama, the people lived in round or square-shaped huts similar to the African villages along the Red Sea and facing Yemen, which confirms the permanent presence of culture and trade between Tihama and east Africa. Traditionally, the walls of earth or *al-Qusaib* plant (reed plant) were built as a fence to protect the village from the outside. Today, cement is progressively replacing earth³³.

The reed houses of Zuhra, in the northern part of the Tihama, are grouped in villages around a white mosque. Sometimes, several related huts are concentrated in a single protective enclosure. Nowadays, cement block houses mix with reed houses³².

³¹ (Varanda, 1982)

³² (Golvin, 2013)

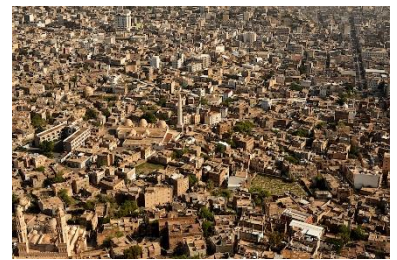
³³ (Ahmed, 2020)

↳ Yemen architecture

Yemen has a varied environment. In each area, one finds human settlements design and architecture adapted to the climate and to the locally available resources.



Cluster pattern, Sana'a Gov. – ©CRAterre



City of Ta'izz – CC Rod Waddington

↳ High tower house pattern

Tower houses as an architectural type derived from watchtowers and from agriculture necessity:

Centers of habitation were seldom situated on valuable agricultural land but were concentrated on outcrops above the valley floor or on slopes and hillsides that were too steep or rocky for agriculture. Therefore, buildings with small footprints were a necessity, leading to a vertical orientation in vernacular architecture (Kotnik, 2005).



The mountains and the highlands

Traditionally, villages group their dwellings on heights overlooking the region. They are examples of organically entangled settlements. This arrangement results from the interaction of traditional nuclear and extended family patterns, land tenure patterns and site requirements. Tower houses as an architectural type derived from watchtowers. They were often strategically placed on slopes or long lines down the middle of *wadis*. Isolated farmhouses were rare. More commonly, buildings were clustered for mutual protection to form small villages³⁴.



Village, Haraz mountains – CC Rod Waddington

► RURAL VS URBAN HABITATS

Yemeni towns are usually concentrations of high houses slightly more sophisticated in structure and decoration than rural houses, though remaining similar. From a reasonably dense centre, the houses merge into the scattered informal settlement at the edge of the town³⁵.

Traditionally, there was not a large gap between buildings erected by the very rich as symbols of power for themselves or the religious establishment and the modest dwellings of their subjects. Small village streets may, thus, not differ much from those of the neighbourhoods of large towns. The "urban" value of their form is owed, first of all, to the visual impact of the height of the buildings but also to features such as connections between houses bridging over the streets, occasional widenings that punctuate labyrinthine paths, etc³⁶.

↘ Today, the geographical dispersion of the Yemeni population is one of the main features of the country. This has implications on various levels, most notably on service provision and accessibility. The under-developed state of road infrastructure is one of the main factors causing the isolation of rural people, limiting their access to services and economic opportunities and hampering the movement of people and goods³⁷.

Urban development

↘ Changing lifestyles are reflected in the type of construction that affects the building verticality. First, as rural centres become more urbanized, the land along the roadside becomes more attractive, resulting in a horizontal building extension³⁸.

As the land's value increases further in relation to the rise of urbanization, we return to a more intensive exploitation of the land, with high buildings and steep streets, so characteristic of the old city of Sana'a. Then things take another turn with lower structures growing on the outskirts of the city (urban sprawl) which again comes from the increasing costs of land and increased security³⁸.

³⁴ (Lewcock, 1986), (Gazzard, 1986), (Varanda, 1982)

³⁵ (Lewcock & Serjeant, 1983)

³⁶ (Varanda, 1994)

³⁷ (Yemen National report, 2016)

³⁸ (Serageldin, 1982)



Urban population: 37.3%

Villages: approx. 40,000

Urban centres: 3,642

Major urban areas, population:

Sana'a: 1,937,451

Al Hudaydah: 617,871

Ta'izz: 615,222

Aden: 550,602

Ibb: 234,837

Dhamar: 160,114



IBB, urban dispersion – @sub-national hub, shelter cluster

↘ TO FIND OUT MORE

URBAN PROFILING YEMEN –
UN-HABITAT

Sa'ada
Sana'a
Al Hudaydah
Taizz
Zinjibar
Al Hawtah
Aden



<https://yemenportal.unhabitat.org/urban-profiles/>

Like other Islamic cities, Sana'a has a cohesive urban tissue organised around markets, mosques, residential neighbourhoods, hotels, etc. Residential areas are separated from the commercial sectors with gates. In Sana'a, as in the other Yemeni cities and some rural areas, vertical buildings (multi-story houses) are dominant and form residential communities³⁹.

Sana'a exemplifies the co-existence of a variety of new typological concepts. Generally, development is heralded by 1-storey commercial frontages in main streets as much as in small streets. Upper floors may be added later⁴⁰.

► TRADITIONAL CONDITIONS OF USE OF HOUSING

Household profiles

Yemeni houses are generally built for one nuclear family. In the case of several households, each one occupies a floor, thus constituting an autonomous cell⁴¹. Commonly, however, rooms are added to the father's house, and several agnatic families (patrilineal descent) are accommodated in the same building, each one having a private area and sharing certain communal rooms. In the largest families, the parents live with the eldest son; they never live alone. The best rooms are usually reserved for the eldest and the youngest. Each family unit has its kitchen whenever possible⁴².

↳ **Typological changes are occurring, even though the nuclear family house still prevails in buildings of flats in urban areas. In cities and the countryside, extended families still live in isolated houses as long as there is enough space for family members⁴³.**

Gathering room

Houses generally have a reception room (*Al-Diwan*) for formal occasions and large gatherings. The *Al-Diwan* is the largest room in the house. Its width is limited, as in the other rooms, by the span of the 3 to 4 m long wood beams usually available, but its length may be that of the house, possibly 12 metres or more.

Large houses may have more than one *Al-Diwan*, and when not used for its intended purpose, it can double as a household storeroom or seasonally as a sleeping room. Spare rooms, a bathroom and even a kitchen may exist on the same floor as the *Al-Diwan* and be reserved primarily for guests⁴⁰. As more than one family may live in one house (sons and their wives), they may share one kitchen and one *Al-Diwan* with their parents⁴³.

Family rooms

Sleeping rooms also double as sitting or dining areas. In general, no room is solely designated for meals, which the family may take in any room, hallway or pantry - but never in the kitchen. Small formal groups of guests may eat in the main sitting room; large groups eat in the *diwan* and hallways. Couples may share a room, but it is common for a woman with children to occupy a separate room from her husband. Usually, the bedroom space is used according to the social situation. Single brothers

³⁹ (Ahmed, 2020)

⁴⁰ (Varanda, 1994)

⁴¹ (Golvin, 2013)

⁴² (Varanda, 1994)

⁴³ (Sub-national hubs, 2022)

↳ Household composition

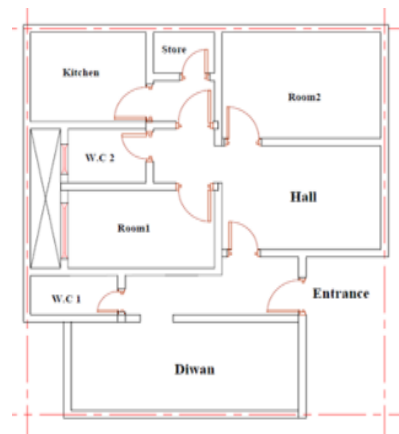
Extended family (father, mother, children, grandfather, grandmothers, uncles, aunts) live in one house, or family plot. In some places, compact settlements like clusters still exist for extended and groups of clans and tribes. They live together for a long time with access to livelihoods (sub-national Shelter cluster Yemen, 2022).



Sana'a, gathering room at the top of the tower house – CC Rod Waddington

↳ Al-Diwan

It is the room used for the principal events of the family's life: weddings, births and funerals. It is also the room where the owners of the house would sleep in case the house is crowded (Varanda F., 1994).



Division of public and private spaces in Yemenite houses – source: Ibb shelter cluster hub data

can share one bedroom. In a polygamous situation, each wife has her room and sometimes her kitchen. The eldest man and woman have the best and second-best rooms for personal use and as their private receiving and sitting rooms, although children sometimes take precedence.

Family sitting rooms are known in different regions as *ghurfa*, *al istiqbal ghurfa*, *al majTnu'a* or, commonly in Sana'a, as the *mafraj*. *Mafraj* and *mandhar* are both words that are used to designate the uppermost isolated room with the best view. Whatever it may be called, this room usually is the realm of the oldest man and is the most decorated with the finest coloured glass fanlights and the best objects displayed. It is the room especially chosen for *qat* chewing by small groups⁴⁴.

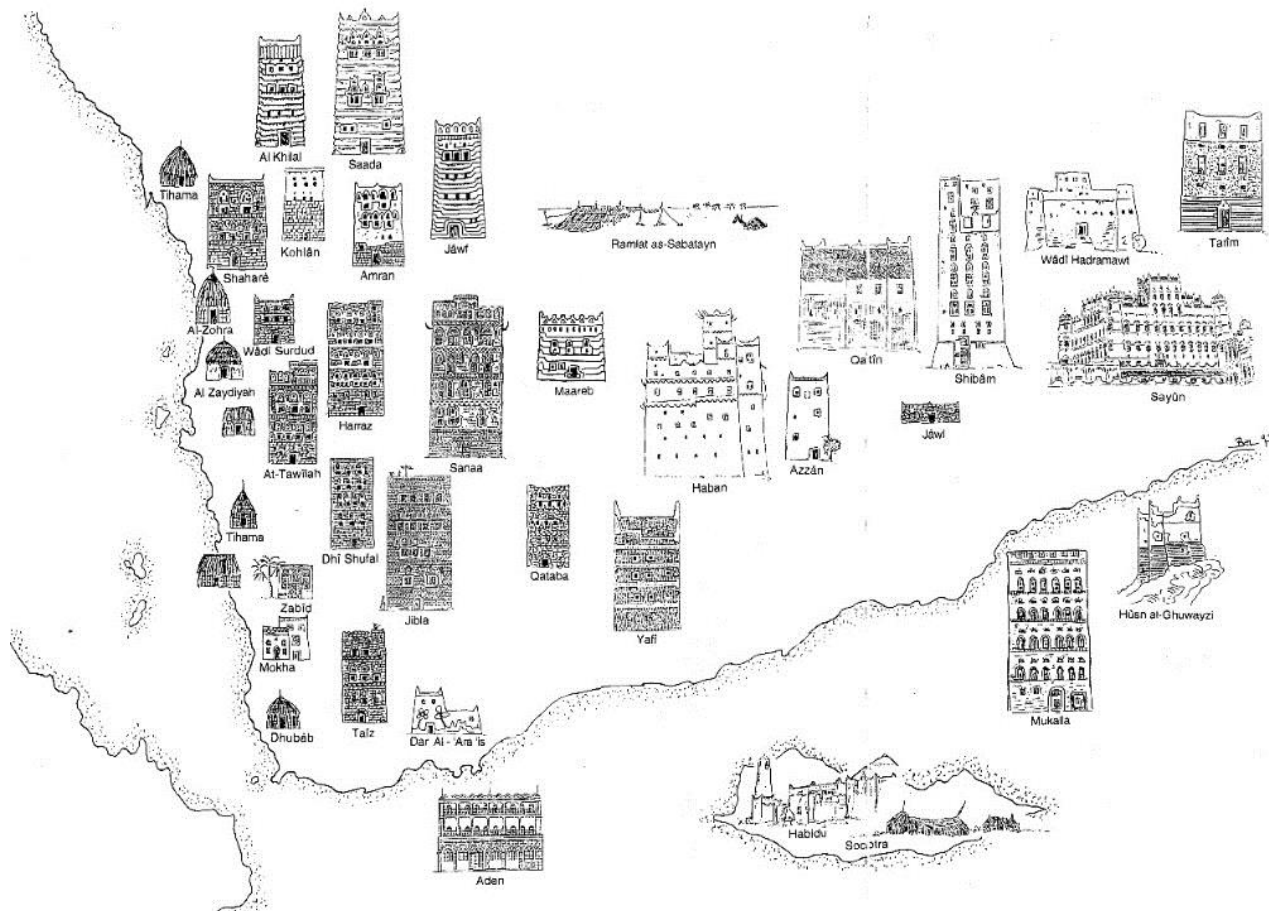
House interiors

Interiors of the houses in the Hadramawt region contain virtually no furniture; pillows and carpets are the furnishings. Because everyone sits on the floor, window sills are at floor level. Wood poles are inserted diagonally between the walls near the ceiling for storing mattresses and blankets overhead. Recessed niches, randomly placed, give character to otherwise bare walls and are sometimes decoratively painted⁴⁵. Simple niches in the walls are an economical way to keep items safe from children and dust – from the floor⁴⁶.

➤ **Housing expansion**

The family's economic situation plays the largest role in determining the type of expansion and the number of rooms per floor. In addition to the bedrooms, kitchens and bathrooms, house expansions include dining rooms and settings outside the house for receiving guests and outsiders. More extensions are built for livestock and their food besides the shelters. Stores are also made to keep stocks and cereals used throughout the year⁴⁴.

► **HOUSES TYPOLOGIES**



Main traditional architecture by region of Yemen- ©Editions Amyris - L'art des bâtisseurs - José-Marie Bel www.editionsamyris.com

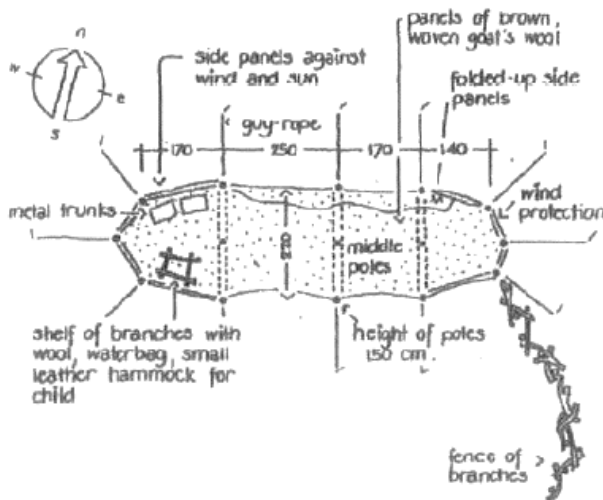
⁴⁴ (Varanda, 1994), (Sub-national hubs, 2022)

⁴⁵ (Jerome, Chiari, & Borelli, 1999)

⁴⁶ (Bonnenfant, 2000)

NOMADIC TENT

The nomads' tent, typically seen on the lower Eastern slopes, consists, in its simplest form, of a frame of branches or stakes covered with woollen rugs. Surrounding trees and shrubs provide additional shade areas and places to hang utensils, extra rugs and occasionally a crib. Sometimes only women and children sleep inside the tent, while the men sleep on open ground. More elaborate forms, in the grand tradition of the Arabian deserts, are described by Steffen: a frame of upright wooden poles, topped by carved mastheads, is anchored to the ground with ropes and covered with woollen strips, up to twenty metres in length and one metre in width, carefully sewn together. The sides of the tents can be left open or hung loosely to allow the circulation of air and smoke from the inside fireplace. Blankets and rugs are used to cover the ground. One end of the tent, reserved for the bed, personal effects and household provisions, is often reinforced with additional rugs as protection against the wind and heat. Cooking utensils, clothes and other household implements hang from pegs on the poles or the guy ropes. Adjoining the tent is a yard surrounded by a fence of thorn scrub and branches to enclose sheep, goats and cattle. A small shed beside the tent serves for the storage of water. As they progressively replace camels, four-wheel-drive vehicles and petrol drums are situated next to the Bedouin tents⁴⁷.



Nomad tents at Ghrija – ©Fernando Varanda

1-STOREY HOUSE: THE REED HOUSE

The simplest type, known locally as *'ushash*, reed houses are found throughout Tihama and appear in round and quadrangular plan forms. This type is a one-storey house built with reed and earth and contains living rooms, places for animal breeding and stores. These houses often do not have windows and are ventilated from the top of the ceiling. Generally, these dwelling units consist of several units disposed around, accessible through a high-walled yard (*hawsh* or *hawya*)⁴⁸. They often have an interior gypsum plaster covered with decorations.

⁴⁷ (Varanda, 1994)

⁴⁸ (Ahmed, 2020) and (Varanda, 1994)

Yemeni houses can be classified into 4 types:

- NOMADIC TENT
- REED HOUSE/BRICK HOUSE
- 1/2-STOREY HOUSE
- MULTISTOREY HOUSE

In Yemen, there are buildings under construction, buildings built in recent decades and others 200 years ago. One is not always able to see the difference.



Tents for nomads and IDPs in hosting sites Al Jawf – ©Sad'ha sub national hub Shelter cluster Yemen



Round reed houses, Tihama – ©Niklas Holmstrom



Round reed house layout in high-walled yard – ©Fernando Varanda

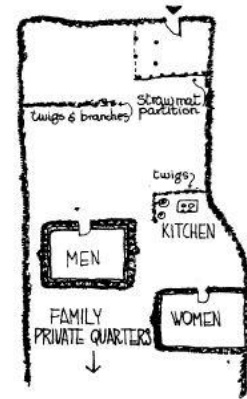
A cooking place (*mawfan*) is usually found outdoors in the yard, one enclosure often roofless for ablutions and latrine, another enclosure or covered unit for agricultural or fishing implements and another enclosure for animals. A wall-less covered area (known as *barud* in northern Tihama) is commonly foreseen for informal gatherings and *qat* chewing, doubling as a sleeping area on the hottest nights. Many compounds have their own well⁴⁹.

➤ The standard rule for reed and brick houses is of easily extended compounds containing one or more sleeping/sitting units.

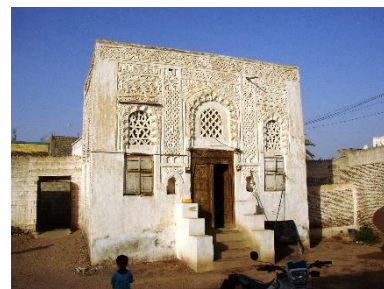
½-STOREY WITH COURTYARD: THE BRICK HOUSE

The brick houses, built with fired bricks, are found from north to south of the Tihama but predominate in the central/southern areas, in the towns of Zaydyia and Zabid. Brick houses are usually one-storey structures, though houses with 2 storeys do exist in the larger cities⁴⁹.

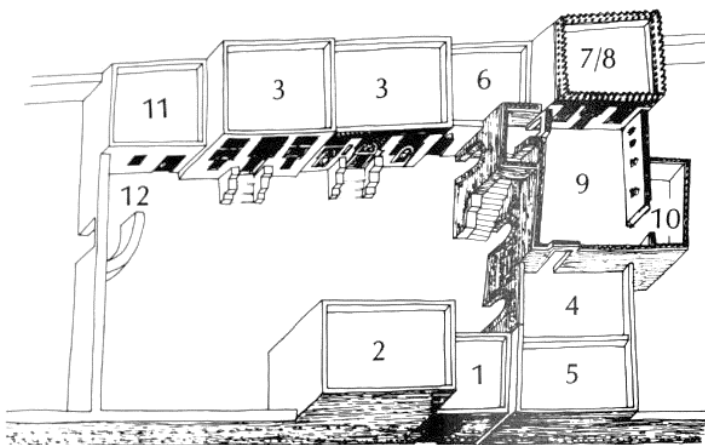
The spatial organization of the brick house is similar to that of the reed houses. Compounds are made of high (4 or 5 m high) one-room quadrangular structures, raised from the ground at the height of 2 or 3 steps and opening onto a central yard. A covered entrance hall with masonry or wood benches is characteristic, kitchens are generally indoors, and great emphasis is usually given to the main reception room (*usha* or *liwan*). A covered space open on the sides and occasionally arcaded for sitting/sleeping during the hottest periods is equivalent to the *barud* found in reed houses. These structures may be aggregated into continuous volumes along the compound wall and allow for limited expansion in height with isolated rooms and high parapeted courts on the roof, accessible by external stairs. The plan of the rooms is often modulated on the dimensions of the Tihama bed - an average 1.75 x 90 cm and 70 cm high. The compound walls are also relatively high, on average 3 metres. In Zabid, when the ground floor is used for non-residential purposes - perhaps a warehouse or shop the residential part could be above it, accessible by external stairs and with the rooms opening onto a higher central hall with a surrounding clerestory for light and air⁴⁹.



Rectangular reed house layout within the high-walled yard – ©Fernando Varanda



One-storey house, fired brick, Zabid – ©UNESCO



Axonometric of a brick house in Hays – ©Fernando Varanda

AXONOMETRIC OF A BRICK HOUSE in

Hays, the top room reached by an external stairs being an independent dwelling unit:

- 1. Entrance hall
- 2. Reception room (men)
- 3. Rooms (women)
- 4. *Sfaf*
- 5. Spare room
- 6. Kitchen
- 7&8. Storage with room above
- 9/10. Terrace, WC
- 11. Animals
- 12. Access to adjoining compound

⁴⁹ (Varanda, 1994)

1/2-STOREY HOUSE

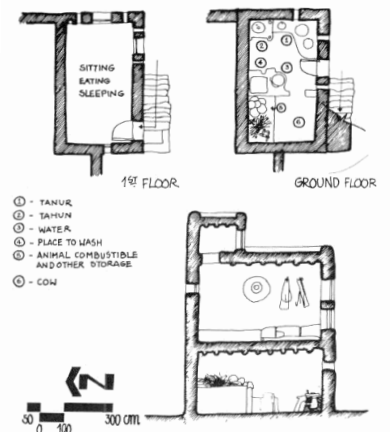
➤ A typical Yemeni house in the uplands and midlands has a basic structure consisting of 4 parallel walls, about 3 metres apart, and the length of available timber for roofs and floors. This is then supported on load-bearing walls. The climate dictates the orientation to ensure that living and sleeping rooms face south, with large windows to benefit from the warming sun in winter whilst the summer sun, being overhead, has not the same effect. The vast central space is used for many purposes, being, in effect, a covered courtyard. This is a standard solution for a house plan. Several floors can be added to this plan⁵⁰.

The shape of this house is adapted to natural features of the landscape or to other houses of the same type, forming clusters. The houses often have no windows, being lit and ventilated by holes in the roof.

Another type has 2-storey with an external stair to the living quarters on the upper floor. The ground level is used for storage and animals and sometimes contains the kitchen.

MULTISTOREY HOUSE: TOWER HOUSE

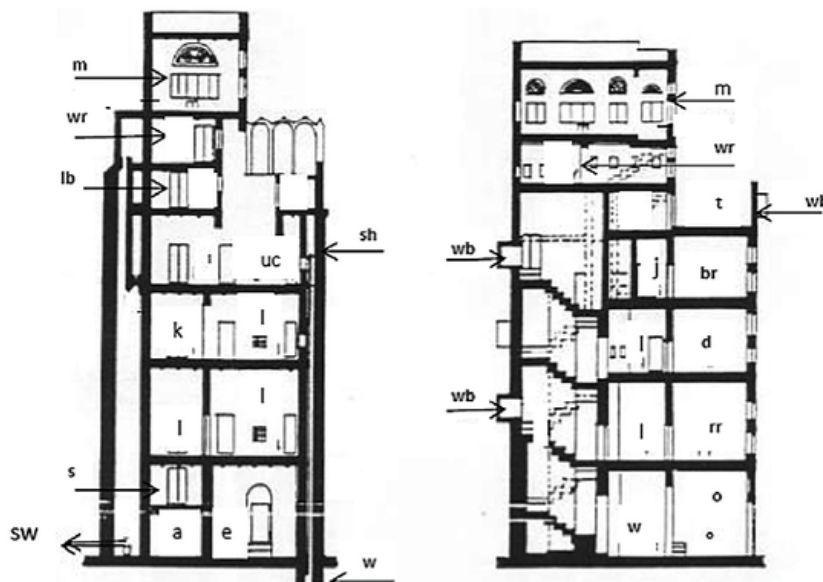
➤ High multi-story houses characterize traditional mountain architecture without an inner courtyard. One of the most impressive types is that of the capital Sana'a, built at an altitude of more than 2,300 m. These houses are known as "Tower Houses" - for the apparent similarities with the watch towers that exist all over the mountains.



Rubat al'Qa'lah, Yarim – © Fernando Varanda



2-storeys house, in Radaa – ©CRAterre



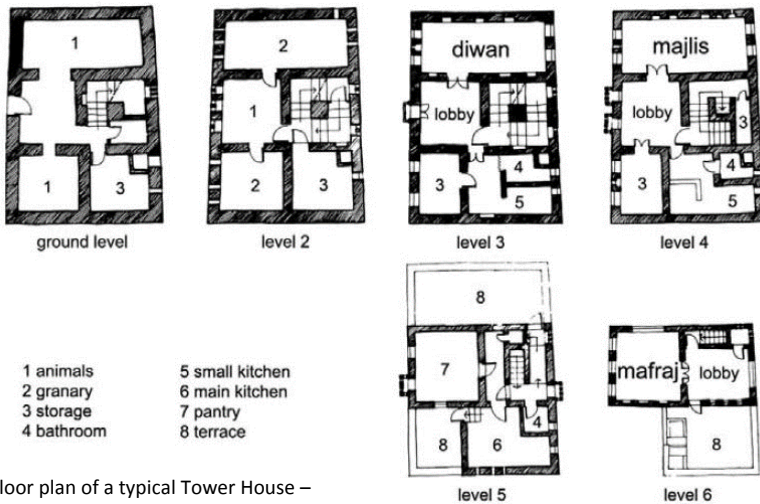
Tower house in Sana'a City – © Fernando Varanda, after (Ahmed, 2020)

SPATIAL ORGANIZATION OF THE MULTI-STOREY HOUSE IN SANA'A CITY.

- e : entrance
- a: animal's stalls
- s: store
- swr: sanitary waste room
- w: water well
- d: diwan
- k: kitchen
- uc: upper court
- sh: shaft
- lb: lavatory/bathroom
- wr: women's room
- m: mafraj
- o: loading mounting animals
- rr: reception room & business
- br: bedroom
- t: terrace
- j: grain and fruit store

⁵⁰ (Matthews, 1985)

In the central and northern highland plateaux, the "Tower House" plan may be circular or quadrangular, elsewhere, the quadrangular plan predominates. The various floor levels are articulated around the continuous staircase, running from the ground to the rooftop. The house grows in height as the family increases.



Floor plan of a typical Tower House –
©Fernando Varanda, and after Kotnik

↳ The main room on the fourth level is the *majlis* for women, a large reception room where women can meet for formal conversation and entertainment. The central kitchen is placed on the same or next floor and is shared by all the wives.

↳ The top floor is reserved as an afternoon reception room limited in use to the owner of the house and his private guests (the *mafraj*). Kitchens and sanitary facilities tend to be at the higher levels but may be repeated on other floors, depending on the number of related families living in the same house⁵¹.

The arrangement of space is in superimposed zones. Space for animals and bulk storage is on the ground floor, the *harr*, with granaries and household storage on the first floor or mezzanine level. The ground floor could reach 6 to 7 meters in height in the past. In urban contexts, nowadays, the space allocated for the needs of farming is often replaced by shops or warehouses.

The reception and large gatherings room (*diwan*) are on the floor above the second floor, which sometimes incorporates family quarters. The rooms in which the family lives throughout the day begin above the third floor. Although a couple may share a room, it is common for a woman with children to occupy a room separate from her husband, as in some of the previous typologies. The most private part of the house is from the level of the *diwan* upwards, where the sleeping and sitting rooms can be found, such as dining areas, kitchens, pantries and bathrooms. Each floor has an unfurnished hall or lobby. This hall is the intermediate area between the stairs, where both genders circulate and the private rooms, where women, children and only the men of the family are allowed⁵².

⁵¹ (Varanda, 1994), (Ahmed, 2020), (Lewcock, 1986)

⁵² (Varanda, 1994)



Tower house built with earth Sana'a Gov. –
©CRAterre



Tower house built with stones, Sana'a Gov. –
©CRAterre

↳ TO FIND OUT MORE

TRADITION AND CHANGE IN THE BUILT SPACE OF YEMEN, FERNANDO VARANDA 1994
<http://theses.dur.ac.uk/5093/>

TRADITIONAL MULTI-STORY HOUSE (TOWER HOUSE) IN SANA'A CITY, YEMEN, ATTIA, AHMED S., 2020
<https://www.sciencedirect.com/science/article/pii/S1110016820300028>

[3.4] ACCESS TO WATER, SANITATION AND OTHER SERVICES

WATER

↳ Access to safe water and sanitation remains a high priority in Yemen which has the lowest water availability per capita globally, coupled with increased water scarcity and WASH-related diseases that have reached critical levels.

Water collection is a burden that falls on women and girls, and 39% of households report more than 30 minutes travel time. 80% of households do not treat water at home due to the lack of supplies. Over 17% of families rely on purchased or trucked water⁵³.

Water sources do not necessarily coincide with the main concentrations of the population requiring increasing supply for domestic and agricultural use⁵⁴.

The traditional system for distributing drinking water and general use relied on reservoirs, wells and dams⁵⁴. However, surface water now generally runs to waste. The construction and maintenance of storage and irrigation works are part of a forgotten craft. Open cisterns seen clean and active in the mid-seventies are now abandoned and full of rubbish. Modern flush toilets have upset the traditional patterns of water consumption and methods of waste disposal⁵⁵.

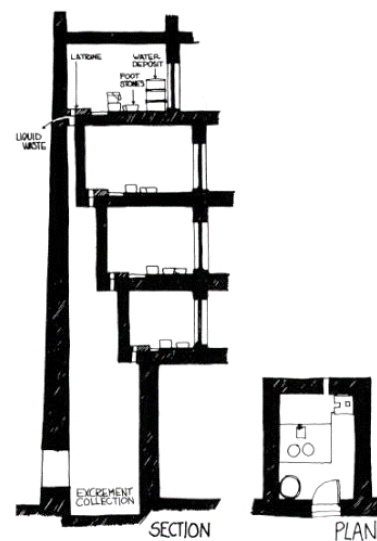
SANITATION

↳ Sanitation remains a major public health risk, with open defecation practiced by about 4 million people (13% of the population)⁵³.

Traditionally, bathrooms (*hammam*, *bayt al ma*) consist of a stone or earth latrine and a washing area with a shallow trough channelling liquid waste outside. Washing is done squatting with the feet positioned on 2 small quadrangular stones in front of which there is a higher cylindrical stone for the water basin. The washing area is either surrounded by a sill or slightly sunken so that the water runs to the hole from which urine is also drained out. A large water container is stored in the bathroom for the day's needs. Waterproofing with a skirting of polished lime plaster is frequent⁵³.

↳ Excess water ruins the traditional water drainage system, so the introduction of a domestic piped supply caused its demise⁵⁵.

In multi-storeyed houses, bathrooms are located as high as possible and when there is only one, it may be on the roof itself. The reason lies in the traditional waste disposal system. This consists of separating liquid from solid waste, the former going directly to the outside through a drain hole, either running down an impermeable surface rendered with water-resistant lime mortar or, particularly in earth houses, a drainpipe jutting out of the wall. Solid waste is dropped through a long shaft to a chamber on the ground floor, where it dries. In the past, it was collected as fuel for the public baths. Today, when it is reduced to ashes, it can be used as fertilizer. Additional bathrooms have parallel shafts to the same chamber. In the east and southeast, solid waste may fall down an inclined stone to the outside or a shaft not extending to the ground floor into an open container where it quickly dries⁵⁵.



Cut & plan of the traditional system of the faeces chamber – ©Fernando Varanda

The longer the drop, the safer the process, which worked very well in the Highlands climate at low population densities, but it depended on the lower social groups for waste collection.

⁵³ (OCHA, 2021)

⁵⁴ (Damluji, 1992)

⁵⁵ (Varanda, 1994)

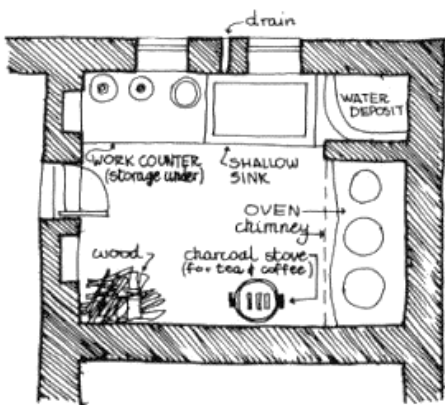
KITCHEN AND FUEL FOR COOKING

↘ Ventilation holes on the walls improve the ventilation of the kitchen a bit. In some examples, a whole part of the wall is multi-perforated with staggered stones or earth bricks⁵⁶.

The earth oven is lined with fired earth cones, open at both ends, accessed through the top, and a lateral hole at the bottom to withdraw ashes (*tannur*) is used for cooking. Both wood and dung cakes (*tikha*) are used as fuel. Food is prepared on a masonry worktop or on the floor. Washing is done in a shallow trough (*sahil*) lined with stone or lime plaster which may be raised but often is at floor level. At one end of the *sahil* a large ceramic water jar or deposit waterproofed with lime plaster exists, now often replaced by metal tanks⁵⁶.

In “Tower Houses”, the kitchen is usually located at the top of the house or on the terrace to protect the living quarters from smoke and odours. Still, this arrangement can vary, especially if several households (naturally closely related) live together. It is not uncommon these days to find kitchens on the upper floor, a development facilitated by the increasingly widespread use of modern devices⁵⁷.

Kitchens (*matbakh, dayma*) are the least attractive part of the house, being smoke-blackened rooms, bereft of comfort, poorly lit, and ventilated.



Example of a kitchen plan – ©Fernando Varanda

WASTE DISPOSAL

Only 9% of households report garbage collection through a public system⁵⁸.



Traditional water drainage system that can have severe impact on the earth building footings when the running water system is introduced that increases water consumption – ©CRAtterre



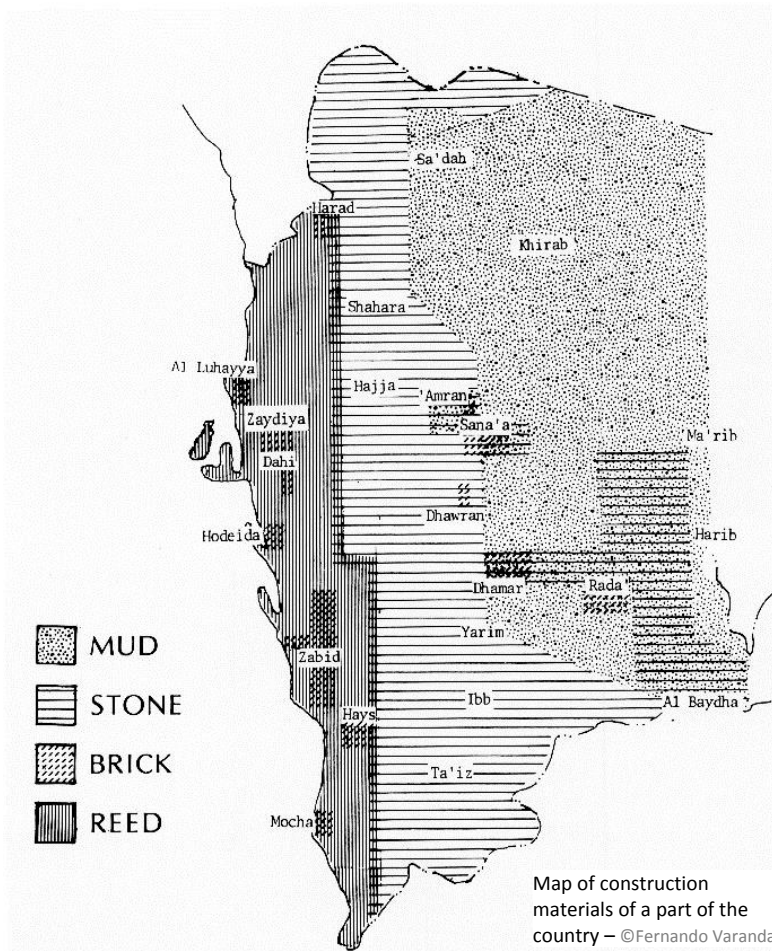
Water drainage system with pipes that requires a special attention to the wastewater drainage on the ground – ©CRAtterre

⁵⁶ (Varanda, 1994)

⁵⁷ (Golvin, 2013)

⁵⁸ (OCHA, 2021)

[3.5] CONSTRUCTION MATERIALS



↳ The architecture in Yemen is of the highest standard

Housing has been adapted to local climate conditions, locally available craftsmanship and local building materials.

As a result, different houses and technical models have emerged due to differences in topography, climate, construction systems and available building materials from one region to another.

↳ TO FIND OUT MORE

ENVIRONMENTAL PROFILE, YEMEN
Link GSC website (soon available)

↳ USE OF MATERIALS

Except for vegetal fibres used in the Tihama region, the traditional building materials in Yemen are raw or fired earth and stone for the wall structure; wood and earth for floors and roof structure; earth, lime and gypsum plaster for the rendering of exteriors and interiors; wood, alabaster and coloured glass for wall openings, and iron or brass for fittings. The used construction material is available in situ. Thus, earth construction is predominant in alluvial deposit areas and stone masonry in the rocky slopes.

→ Varied building solutions frequently occur in the same settlement or even in a single building⁵⁹.

EARTH BRICKS (ADOBE)

In regions with traditional earth brick (*madhar*) buildings, the know-how of making earth bricks comes from ancient times. Large earth-brick yards are located on the outskirts of towns, with more than enough room for the bricks to sundry. 16 workers can make 8,000 earth bricks per day. Soil is given or sold by farmers. According to local masons, the best soil (*zib'*) is excavated from a depth of 1 m. The topsoil is considered



Sun dried earth bricks – ©CRATERre



Sun dried earth bricks production – CC Motoshakone

EARTH BRICKS are moulded in wooden molds that vary in size according to the use and regional variations and form walls of at least 50 cm thick:

- 30 to 45 cm by 19 to 32 cm
- 8 to 9.5 cm deep

⁵⁹ (Varanda, 1994)

of poor quality because it contains salts from agricultural fertilizers. Regional knowledge is helpful to know the best earth. For example, in Hadramawt, 2 types of earth are considered: "hot" and "cool". While the "hot" earth is full of salts, the "cool" earth does not contain salts. In some other regions, masons collect suitable earth from around the date palms after the floods.

When preparing the mixture, the earth is wetted and mixed with chopped straw (*tibn* or *deyal*) to reduce the shrinkage and for reinforcement. In some places, dung is added. The straw is taken from the fields after the farmers' harvested and crushed wheat. The proportion of straw is determined by sight and feel, depending on the experience of the master. From 6 to 20 burlap sacks of straw can be mixed with one truckload of soil. As the house rises, wall thickness decreases, as does the floor-to-ceiling height⁶⁰.

The moulds are wetted, and the earth and straw mixture is dumped from a wheelbarrow into them. Often, sand or loose soil is sprinkled on the ground first to prevent the earth bricks from sticking. The earth mixture is smoothed by hand, and the edges are defined with the index finger or a knife. The mould is instantly lifted by a rope attached to one end, and the excess earth mixture is wiped off by hand. When necessary, it is wetted down again to prevent the earth from sticking to the sides. The moulds are made in the way that the projecting end nestles precisely into the newly made bricks, leaving the thickness of the wood only between each brick. The bricks are left to dry for a week and then stacked vertically. At this point, they are ready for use⁶¹.

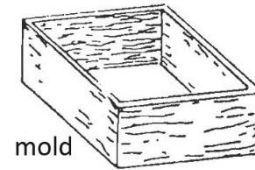
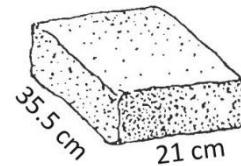
FIRED BRICKS

The fired bricks are shaped by hand in a mould and are cooked under fire of branches and cow dung. They are square, about 16 x 16 x 4 cm or 16 x 8 x 4 cm for the half-size. Fired bricks make wall thicknesses of about 34 to 42 cm. They are also used for characteristic brick decoration. In the Tihama, bricks of a more conventional oblong shape are made. Fired bricks are almost unavailable in the whole of Yemen⁶².

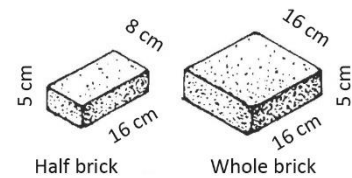
STONES

The geology of the country offers a great variety of stones for construction. In the past, stones were quarried on-site or from their immediate surroundings. However, stone quarried within sight of the road is now familiar: small slopes or rock outcrops provide a convenient resource for the limited demands of a small area, while larger sites satisfy almost countrywide need⁶³.

The stones are usually roughed out at the quarries, finishing being done by hand at or near the building site. But the escalation in the cost of labour is reducing the use of stone and causing the introduction of substitute materials. Large quarries producing 300 or more cubic meters of aggregate per day are equipped with trucks, bulldozers, and loaders. In the small quarries producing 50 cubic meters/day or less, the



Sun dried earth bricks – after Dereck Matthews



Type of Fired bricks in Sana'a. Other types are used in the Tihama – after Dereck Matthews

STONE SIZE:

The size of stones varies from one region to another, but often the depth of the stone is 20 cm or little more. The face varies from about 22 x 26 cm to 22 x 40 cm, 30 x 45 cm and 35x45 cm.

FREQUENTLY USED STONES ARE:

- Basalt:** a hard black stone used in foundation walls and footings;
- Volcanic Stone:** black or grey lava, famous for decorative use in facades around windows, arches and corners;
- Sandstone and Tuffite:** available in the highlands in a wide range of colors (yellow, red, green, grey) and used for load-bearing walls;
- Limestone:** a hard, heavy stone used mainly for foundations and infrequently for walls.

⁶⁰ (Matthews, 1985)

⁶¹ (Jerome, Chiari, & Borelli, 1999)

⁶² (Matthews, 1985) (Varanda, 1994)

⁶³ (Varanda, 1994)

technology level depends upon the available equipment but is generally more labour-intensive⁶⁴.

The type and precision of cut vary widely from one region to another according to inhabitants' wealth and available stone. To reduce costs, the more precise and time-consuming work is limited to the main façade. Stone floor tiles are produced in small workshops. They are produced in sizes varying from 40 cm square to 60 cm square. They are generally rough cut and uneven, with a thickness of up to 25-30 cm at the centre⁶⁵.

WOOD⁶⁶

Tamarisk, tanzania mangrove tree and acacia wood are commonly used as a beam to make the roof. Beams have a minimum section of 15 cm and spacing of 60 cm. Smaller wood beams are used to connect and fill the gaps between the girders. The beams have sections of 3-5 cm.

There is a shortage of indigenous building timbers, so imported timber of longer standard sizes is common.

↳ A higher risk for the wooden elements are termites; ceilings and wooden columns seem to have a high resistance in inhabited spaces, but windows and doors are vulnerable.

LIME

Limestone is abundant in Yemen. The burning of lime is a family tradition. Kilns (*furn*) are located outside the towns in remote areas. The kilns are keyhole-shaped in plan, or a domed chamber open to the sky. Fuel oil is added in an elongated firing chamber or arched opening. Limestone is collected from the wadi after the floods or from the mountains, broken into pieces and stacked⁶⁷.

GYPSUM

Gypsum is also baked in kilns, and the powdered product is sold in bags direct to the builders or in the *suq*. Gypsum is the raw material for producing *goss*, and it is currently produced in small-scale workplaces that are mainly located around Sana'a and Ta'izz. Gypsum is also mined for use in the cement manufacturing plant at Bajil⁶⁸.

Goss is a soft white plaster consisting of calcined gypsum, and its traditionally used as mortar in stone and brickwork walls in mountain areas where rainfall is light to moderate. The material is also used as a plaster inside the houses, sometimes carved for decoration or moulded to form a narrow shelf. The most characteristic use of the product is in the intricate perforated plaster carved screens or *quamaria*. These screens are decorated with stained glass (or sometimes coloured plastic) and are built-in above doors and windows. The plaster *quamaria* is surmounted by a protective

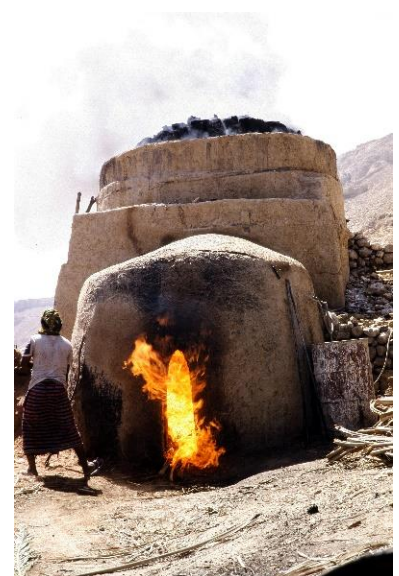


Wooden beams – ©YFCA

↳ Traditionally, wood functions in the buildings are:

A structure system: wood was used to create frames that support the structures of the building roofs, intermediate floors, staircases, sanitary duct systems and bridges between buildings.

A reinforcing material: wood branches, twigs and straw were used to support the roof coverings and reinforce the walls of earth buildings and cities defensive walls. (Al-Sallal, 2022)



Lime burning – CC Mtohakone

⁶⁴ (Miles & Ahmet, 1984)

⁶⁵ (Miles & Ahmet, 1984)

⁶⁶ (Al-Sallal, 2022)

⁶⁷ (Jerome, Chiari, & Borelli, 1999)

⁶⁸ (Varanda, 1994)

semi-circular arch and continues to provide a distinctive and attractive feature in contemporary Yemeni architecture. Goss is occasionally used for decorative external plastering (more frequently, as a window surround)⁶⁹.

CEMENT & CONCRETE

The only primary building materials industry in which the government is involved is cement. Ordinary Portland cement is now the most important construction material in the country. Local cement factories are located with fairly adequate geographical distribution inland and along the coast. Nevertheless, a frequent shortage of cement has constrained the construction industry's output and increased the already high prices of cement by 3-fold since 2001⁷⁰.

➤ All reinforcing steel is imported. Most of the structures designed by local engineers use readily available mild steel. Most contractors set up a reinforcement fabrication yard on the site, as there are no specialist steel stockholders who cut, bend, fabricate and deliver reinforcement cages.

The major construction companies engaged in projects requiring a large volume of concrete generally erect on-site automatic batching plants and bulk cement silos. These plants usually produce quality concrete with specified bearing strength, and testing facilities are available on large projects. There are also independent transit mix concrete companies in Sana'a and Hodeidah. On smaller sites, concrete is mixed in drum mixers or by hand. In rural areas, where structures are seldom more than one storey, concrete is usually placed by hand.

There are currently 8 integrated cement plants in Yemen⁷¹. However, there are numerous small yards throughout the country, with 2 to 5 workers producing from 300 to 600 standard blocks per day. The quality and bearing capacity of these blocks is very uneven. In many yards, the casting moulds are badly worn, the vibrating and compaction equipment is inadequately maintained, the raw materials are of variable quality, the wet cure is not followed, and the cement content is often reduced to save costs. There are large, automated concrete block plants in Sana'a and Ta'izz producing blocks of adequate dimensions and strength⁶⁹.



Building with cement blocks, Hadramawt Gov. Rakhia district, 2022 – ©YFCA

⁶⁹ (Miles & Ahmet, 1984)

⁷⁰ (Sultan, 2008)

⁷¹ <https://www.cemnet.com/global-cement-report/country/yemen>

CONCRETE BLOCKS are usually produced in the standard size of 20 x 20 x 40 cm.

➤ TO FIND OUT MORE

BUILDING IN YEMEN, MATTHEWS, DERECK, 1985-1996

<https://pure.tue.nl/ws/portalfiles/portal/4263106/340584.pdf>

<https://al-bab.com/commentary-yemeni-traditional-architecture>

TRADITION STEREOTYPES AND CULTURAL RESISTANCE THROUGH BUILDING FORMS: THE CASE OF YEMEN

<https://core.ac.uk/display/48578314?recSetID=>

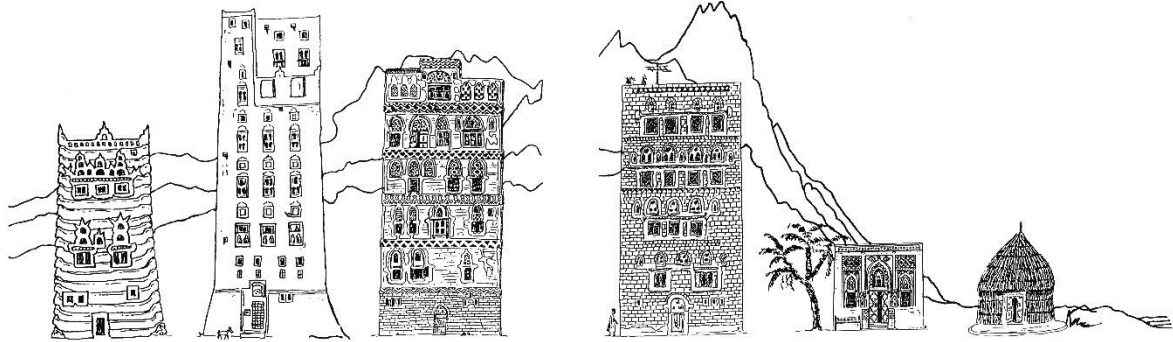
THE ARCHITECTURE OF EARTH: CONSTRUCTION AND REPAIR TECHNOLOGY IN HADHRANAUT, JEROME PAMELA & CO, 1999
https://www.researchgate.net/publication/269825587_The_Architecture_of_Earth_Construction_and_Repair_Technology_in_the_Hadramaut_Region_of_Yemen/link/550b74f60cf2855640971083/download

A CONSTRUCTION INDUSTRY IN TRANSITION, KULKANI, 1983
<https://www.archnet.org/publications/3607>

MODERN /TRADITIONAL BUILDINGS IN YEMEN AND SUSTAINABILITY, SULTAN & CO, 2008
https://www.researchgate.net/publication/256599703_Modern_Traditional_Buildings_in_Yemen_and_Sustainability

SHELTER METHODOLOGY FOR THE ASSESSMENT OF CARBON (SMAC) TOOL – GUIDE
<https://sheltercluster.org/environment-community-practice/shelter-methodology-assessment-carbon-smac>

[3.6] BUILDING TECHNIQUES



| Sa'dah | Shibam | Sana'a | Jibla | Zabid | Al-Zora |
|------------------|----------------------------|--|----------------------|--|--|
| Sa'dah, AL Jawf | Hadramawt | Sana'a region | Thula, Manakha | Tihama | Tihama |
| Cob wall | Earth brick, earth plaster | Stone, fired brick, earth brick, earth plaster | Stone, earth plaster | Earth brick, earth plaster, fire brick | Wattle and daub, reed, local fibres, earth plaster |
| 2-5 floors | 3-8 floors | 3-7 floors | 2-5 floors | 1 floor | 1 floor |
| 12-20m high | 30m high | 25-28m high | 20m high | 4-7m high | 5m high |
| 20-150 years old | 50-500 years old | 30-300 years old | 50-1000 years old | 30-300 years old | 20-30 years old |

Main traditional building technics of Yemen – ©Editions Amyris - L'art des bâtisseurs - José-Marie Bel www.editionsamyris.com

MULTI-STORIES HOUSE: FOUNDATIONS

Except for the Tihama reed houses, foundations and roofs are usually constructed along with similar principles. There are only minor technical variations in how each wall material is used structurally.

↳ All buildings have a rigid rock foundation, commonly of cyclopean stone, often from *wadi* boulders—a basalt basement with 2 or 3 courses above the ground. Foundations are dug until the solid ground is reached, the rule being "until the soil is too hard for the pick to enter". This means that foundations are 2 or 3 metres deep in alluvial soils and very shallow in rocky areas⁷².

The foundation may not be apparent, as is common in much of earth construction, or it may be raised to form part of the ground floor walling. This way, when the top floors are of earth, the ground floor may appear as a high stone foundation. Stone foundations continued to be used after the introduction of framed concrete structures with the concrete foundation beam bearing on the cyclopean stone⁷².

In earth construction, the stone foundation is built to act as a damp course in earth construction. The foundation is filled with soil and stones to create level platforms. At

↳ Main traditional construction types:

→ In the Tihama coastal region the walls may be of reed or entirely of fired bricks.

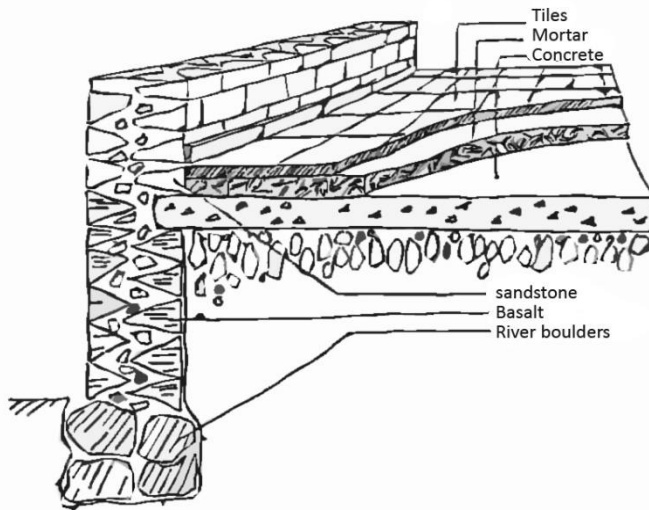
→ In the mountains and desert, the walls are commonly fired brick, stones, earth bricks or cob wall.

→ In the coastal lowlands windows have no glass, being fitted with timber grilles and shutters, the *mashrabiyyah*, permitting a cooling breeze to enter the building in such humid conditions.

→ In the uplands, high buildings have large glazed windows that benefit from the winter sun.

⁷² (Varanda, 1994)

40 cm, a wooden framework is added to knit the corners. Before the arrival of cement, ash was combined with lime putty to create a hydraulic mortar for foundations⁷³.



A typical section of foundation, wall and ground floor— after Miles & Ahmet



Earth walls on 1-storey basement, Amran – ©CRAterre

MAIN STRUCTURE

The principles of construction do not differ much from one house to another. They are imposed by the nature of the terraces and the ceilings, which use unsquared tree trunks as beams; a bed of branches laid across this framework, sifted and well-packed earth covered with a bed of plaster (*goss*). The use of local lumber limits the possibilities of the builders. Imported timber of longer standard sizes is now common.

The structure of a house is thus reduced to the 4 load-bearing walls of the facades and a transverse load-bearing wall parallel to the main facade. Of course, 2 transverse bearing walls can be found if the size of the house requires it, but rarely more. The stairwell, generally, uses one of the rear corners of the building, a large square pillar that can cross the whole building from top to bottom and then receives flights of steps. According to these various supports, the floors are distributed⁷⁴.

COB WALL (ZUBAR OR ZABIR)

One of the techniques in earth building is known as *zubar or zabir*. It is carried out by a team that forms the earth lumps into balls thrown up to the master mason standing on the wall; he places them in position, forming a layer all around the building⁷⁵.

The course is finished by being patted with a wood paddle. Cross walls are not finished at the same time; their intersections with the external wall are begun so that a critical vertical joint is avoided at the juncture of the walls. Each course is some 60 cm high and, in an average house, takes no longer than a day to build. The thickness of the walls on the ground floor is within the 60/80 cm range, depending on the intended height of the building. In external walls, each layer tapers slightly inwards so that its lower part oversails the top of the previous course. This helps to protect the wall face

Standard size

The width of the rooms is conditioned by the length of the available joists and beams from native species averaging 3m in length. So, the load-bearing walls cannot deviate beyond these dimensions, with rare exceptions.



Earth mix – ©YFCA



Chopped straw for the mixture – ©YFCA

⁷³ (Jerome, Chiari, & Borelli, 1999)

⁷⁴ (Golvin, 2013)

⁷⁵ (Matthews, 1985)

and joints from the rain running down the wall and emphasises the characteristic battered profile of these buildings.

In the northern and northeastern highlands, the corners of each course are raised, thereby restraining the courses and resisting any shearing action. A top coat of *malaj* - a plaster made of earth and animal dung - may or not be applied to the exterior of walls but is generally applied in interiors where it may also be finished with gypsum plaster. The size of the openings is conditioned by the form of the construction and tends to use small wood lintels rather than large arches. Windows and fenestrals are narrow, and the courses determine their height; multiple perforations rather than single-wide fanlights are therefore characteristic of the areas where cob wall predominates⁷⁶.

➤ The mixture is made of earth, water and frequently chopped straw and chaff branches. The mixture is covered by a plastic sheet and left for 2-3 days before use. The mix is done by walking and moving on the mixture. A foundation is often about 50 cm deep and must reach good soil and be filled with earth mixed with hay. The earth-course mixture is formed into balls with a diameter of 12-15 cm, and the builder throws the balls -medium power- from head level with both hands. Each earth-course has a height of one arm equal to 45 cm⁷⁷.

EARTH BRICK WALL (*LIBN*)

Sun-dried earth brick construction (*libn*) is widespread from the north to the south of Yemen. It predominates in the alluvial basins along the centreline of the country but also wherever earth is available. Even in areas where the stone is pre-eminent, earth bricks are used for secondary constructions, interior partitions and boundary walls. Associations of earth bricks with stones or fired bricks in the external walls identify local styles⁷⁶.

➤ As in cob wall construction, earth brick walls may be left exposed or surfaced externally with a plaster made of earth and animal dung (*malaj*). Unlike cob walls, both earth brick and fired brick buildings often employ arches to frame windows and doors⁷⁶.

Earth bricks form walls of at least 50 cm thick. They are usually covered with earth plaster outside and sometimes with gypsum plaster inside⁷⁸.

Earth bricks are stacked on the stone foundation in a running bond. Earth mortar is mixed from the same soil with a different kind of straw, a wild grass from the mountains cut in longer lengths. The thickness of the joints is roughly equivalent to that of the earth bricks; however, in the past, they were narrower. Courses are laid up to about 1 m and immediately earth plastered. The earth plaster is also made from the same soil and reinforced with short chopped straw in a greater proportion than used for earth bricks (4:1 earth/straw by volume). No more than one-storey is added

⁷⁶ (Varanda, 1994)

⁷⁷ YFCA, local and traditional building practices in Marib

⁷⁸ (Matthews, 1985)



Cob wall, construction site – ©YFCA



Cob wall, skilled mason – ©YFCA



Earth brick building, Shabwa Gov., Almarkha alsofla Dist., 2022 – ©YFCA



Earth brick masonry, Amran Gov. – ©CRAterre



Fired bricks, Al Hudaidah Gov., AlKhokha Dist. 2020 – ©YFCA

per year in order to allow complete drying. The process continues to the window sills, lintels, and ceiling/floor. At each stage, 2 months are required for drying. Finally, timber is placed horizontally in a diagonal manner, within the thickness of the earth brick wall, to reinforce the corners⁷⁹.

FIRED BRICKS (AJUR)

Fired brick walls (*ajur*) are best represented in the Tihama region and in and around the major towns of the central highlands: Sana'a, Damar and Rada. Nowadays, there is a limited amount of fired brick available for construction, and they are mainly used for architectural effects on a few new projects or for heritage restoration⁸⁰.

➤ **MIXED TECHNIQUES – EARTH BRICK (LIBN) AND FIRED BRICKS (AJUR)**

Another use of earth bricks is in conjunction with fired bricks for an external skin. This is more resistant to rain. Three courses of earth bricks equal 5 fired bricks. In the mountains, the walls are often a mix of fired brick and stone masonry⁸¹.

STONE MASONRY

After being transported to the site, individual blocks are shaped to produce a squared face, the rest of the block tapering inwards like a truncated pyramid when laid on the wall. The surface joints are as thin as 1 mm if the surface of the block is finished to a smooth cut. Joints on the external face may be set in either gypsum or cement mortar. The rest of the wall is usually in earth mortar. The internal finish is usually in a coat of earth mortar with gypsum mortar as the topcoat⁸².

➤ **Due to the shortage of skilled masons and generally low productivity, most major projects have eliminated stone as a load-bearing material. However, it remains popular as a facing to reinforced concrete frame structures. The exterior walls of high-income housing are often constructed in stone masonry, and local masons execute this work with great skill. The architectural appearance of houses is most appealing, but the labour and material cost is high, and only wealthy clients can afford mass stone masonry⁸³.**

There are also many different types of random rubble walling in Yemen, depending on the character of the locally available stone. Internal finishes are the same as for hand-cut stones wall. Externally the stone may be exposed with cement mortar or gypsum pointing or with an external rendering of cement and sand or earth mortar⁸².



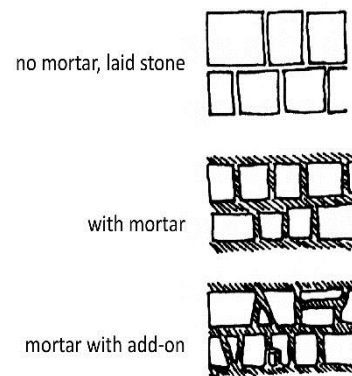
Stone masonry and earth bricks, Radaa – ©CRATERRE



Stone masonry, Aldhalea Gov., Damt District, 2022 – ©YFCA



Stone masonry, Sana'a Gov. – ©CRATERRE



Stone masonry – ©Editions Amyris - L'art des bâtisseurs - José-Marie Bel www.editionsamyris.com

⁷⁹ (Jerome, Chiari, & Borelli, 1999)
⁸⁰ (Miles & Ahmet, 1984), (Varanda, 1994)
⁸¹ (Matthews, 1985), (Varanda, 1994)
⁸² (Matthews, 1985)
⁸³ (Miles & Ahmet, 1984)

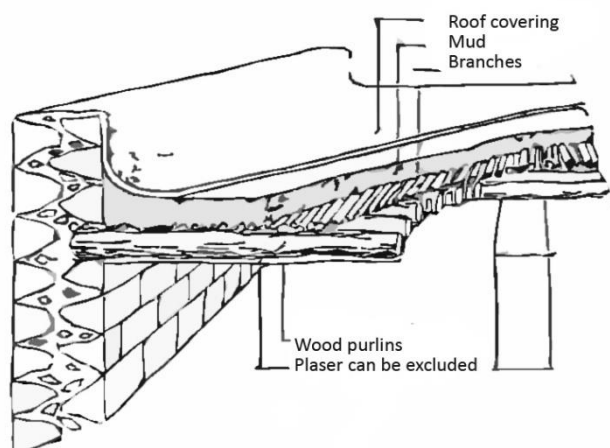
FLOOR AND ROOF

↳ Except for the reed houses on the Tihama coast, almost all buildings in Yemen have flat roofs. Traditional earth roofs and floors are supported on either unsquared tree trunks or imported timber.

Floors and roofs are constructed with a load-bearing structure of parallel beams (joists) closely spaced at a distance of 40 to 60 cm. In the mountains, twigs are spread between and covered with 2 coats of sifted, dampened and compacted earth. Some masters use the same earth for the walls and the roof. Others use a different type of earth and straw for the roof. The first coat of earth plaster is approximately 10 cm thick. A second coat is then applied, sometimes followed by 2 coats of lime plaster (*qadad*). The finished surface is polished with a stone 3 times separate. After 3 months, the surface is polished again and then whitewash is applied. If the traditional roof covering material is lime plaster, asphalt, terrazzo tiles and cement plaster are now widespread. Reinforced concrete roof slabs are also possible⁸⁴.

↳ Plastic sheet is often placed on the beams, under the 15 to 20 cm layer of earth plaster. This way of preventing water infiltration can have severe consequences for the wood and the roof's stability because it prevents moisture from escaping.

On the ceiling side, the twigs are surfaced with a mortar made of earth and dung (*malaj*), which, in all except the most remote or elementary buildings, is finished with the same gypsum plaster used for the walls. Full wood beams are used in elementary stone construction, but stone slabs replace the twigs and are left exposed on the underside. In the Tihama region, twigs could be replaced by a trellis of thin branches covered by palm leaf mats or by wood boards, sometimes forming painted ceilings. Imported timber of longer standard sizes is now common. Their standard form has resulted in a different type of ceiling, in which the wood beams are left exposed and only the flat parts in between are plastered. Today, floors generally are covered with cement floor tiles⁸⁴.



Traditional flat roof construction – after Miles & Ahmet



Floor on cob construction – ©YFCA



Zabid, traditional roofing – CC Tom Leiermann



Ceiling with earth plaster – ©Fernado Varanda



Ceiling with earth plaster – ©YFCA

⁸⁴ (Varanda, 1994), (Jerome, Chiari, & Borelli, 1999), (Miles & Ahmet, 1984)

RING BEAM AND CANTILEVERS

↘ Full wood strips (*basut*) embedded in the walls and running along the courses as a form of bracing for the masonry appear mainly in the southern half of the country, from Sana'a, through Dhamar to the Ibb province. The system was still in practice in the mid-seventies but the joists' positioning seemed a matter of formality rather than a real understanding of their function. The 1983 earthquakes sadly proved this to be the case⁸⁵.

The simplest cantilevers consist of carrying the wooden floor joists an average of 60 cm beyond the bearing wall face and building upwards from their extremities. This is a feature of many houses in the Jewish neighbourhood of Sana'a, but it is also widely observed elsewhere in the country. Later constructions use extended cantilevers made of imported timber. Cantilevered reinforced concrete balconies and floors are now often preferred in cities⁸⁵.



Cantilever in a building angle that widens street passage, Amran Gov. – ©CRAterre

PLASTER AND FINISHES

↘ Earth plaster (*malaj*) has been seen associated with the rendering of exteriors of earth buildings and with the ceiling and interior walls of all forms of construction. Only the more modest interiors of mountain buildings remain at that level, sometimes embellished by isolated or repeated simple motifs moulded in the clay. Interiors are otherwise finished with lime or gypsum plaster⁸⁵.

In Hadramawt, lime is used for plastering the exterior of the houses in the most vulnerable parts, the parapets and roofs. Lime plaster (*tarqa*) is proportioned 1:2, lime to sand. The sand (*batar*) is collected from the *wadi* after floods. The lime plaster is applied with a metal trowel or with bare hands to cover the earth plaster, which has first been wetted down and coated with a thin layer of fresh earth plaster. The finish coat is lime putty applied neat, to which coarse sand (*rashnah*) is immediately applied. This provides an excellent surface for white-washing (*rashah*), proportioned 1:2 (lime putty to water). The wealthy people also finish the exterior of their houses with oil-based painted decorations⁸⁶.

Lime and gypsum plasters were commonly used in the Tihama region and in the mountains to render interiors and exteriors of walls. The technique of lime plaster, known as *qadad* and applicable to stone or fired brick surfaces, is less current. Lime is used to create a highly polished, ceramic tile-like finish (*malas*) as a wainscot. Lime cream is used to make *malas*. Water is added to lime putty, then the mixture is forced through a muslin cloth to become like a cream, and the impurities are removed. The cream is applied neat to wet lime plaster with a metal trowel. The *malas* surface is said to improve with cleaning and age and to repel dust. Frequently, *malas* is painted decoratively. *Malas* are used in corridors, living rooms and bathrooms but never in the kitchen⁸⁵.



Shibam, renovation of an earth plaster – CC Tom Leiermann

Traditional lime plaster

Formerly fired lime was crushed and mixed with fine black gravel. Water was added and the mixture kneaded after the lime had "boiled". One layer of this plaster, after which small incisions were made on the surface. It was then beaten with a flat stone for one hour/day for a month, with thinner layers of plaster periodically applied. Patterns could be cut in the plaster while it was still soft. Finishing was with animal fat rubbed to polish, sometimes with alabaster powder. It would take a month to complete a room of about 10 m². (Varanda F., 1994)

⁸⁵ (Varanda, 1994)

⁸⁶ (Jerome, Chiari, & Borelli, 1999)

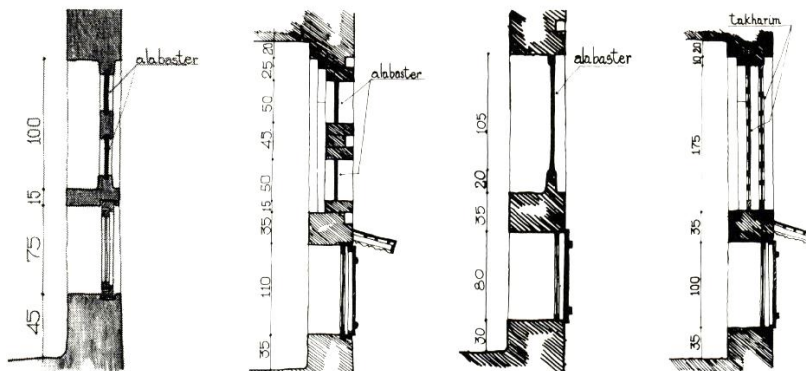
Gypsum plaster is a more effortless technique, but because of its lower resistance to weather, it is mainly used for the complete rendering of interiors. The plaster is prepared in buckets and, having turned into a pasty consistence the walls are covered with it using a float or bare hands. The final surface is smoothed by hand, with a large brush sometimes used for the first and last diluted coats. Unlike other techniques that suffered from the industrialization of building materials, gypsum plastering, carving and tracery have prospered⁸⁷.

↳ Walls of stone or fair-faced fired brickwork do not need external finish and do not require maintenance. But cement block walls are generally plastered and require regular maintenance⁸⁸.

In stone masonry, the internal face of stone walls is rough as the stones are generally uncut; it is usually finished with a thin layer of gypsum plaster covering the irregularities. This surface requires maintenance and repair⁸⁸.

DOORS AND WINDOWS

↳ The front doors made of wood are usually hidden by a small garden or an enclosed courtyard in front of the house, but sometimes they open directly onto the street. The windows are more complex: those of the lower rooms are narrow and low, with wooden shutters almost always closed or only half-open. They are square or slightly oblong. Those of the upper floors are designed in 2 parts, the *taqa* for ventilation and the *takhrim* for light⁸⁹.



Different types of windows, all divided in an opening and a fenestral –©Fernando Varanda

The first part of the 70 x 90 cm range is a lower rectangular window (*taqa*) provided with wood shutters or, even more simply, fixed wood bars for letting in air and light. The second part (*takhrim*) is an opening above, fitted with a fixed translucent element for additional light. Standard windows have a 2-leaf shutter set on the outer face of the window opening outwards⁸⁷.

Ventilation slits (*shaqus*) or additional fenestrals on each side of the window frequently complement this scheme. The window back is usually between 20 and 40cm allowing the occupants to look out while sitting on the floor. In the Tihama

⁸⁷ (Varanda, 1994)

⁸⁸ (Miles & Ahmet, 1984)

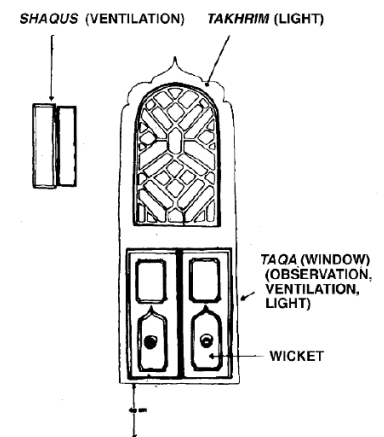
⁸⁹ (Golvin, 2013)



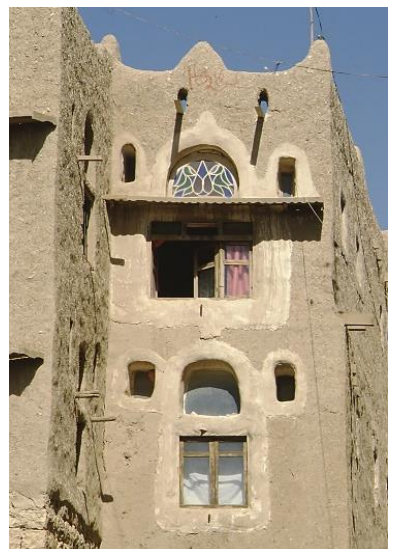
Earth plaster, inside – ©YFCA



Windows divided in a lower and higher part, Sana'a Gov. – ©CRAterre



Windows are usually formed by an opening lower section and a fenestral made by alabaster plates or gypsum tracery and colored glass – ©Fernando Varanda



Solar protection, Amran – ©CRAterre

region fenestrals or fanlights only appear in urban examples and particularly in the "Red Sea Houses"⁸⁷.

A local variety of hardwood, acacia, known as *tunub* - finished with mustard seed oil - is the preferred material used for traditional doors and windows. The increased dimensions for the opening sashes of the window needs the addition of grilles, not only as a form of external security but also, the sills being very low to prevent children from falling⁸⁷.

Rarer but more decorative are the *mashrabiyyah* or *kushk-s*. Entirely made of wood and always very finely worked, they differ from the masonry *shubbâk-s* in the way that they constitute a real protected living cell above the street. Women can stand in them, especially in the summer, to watch the street without being seen⁹⁰.

CONCRETE FRAME CONSTRUCTION

↳ Cement and reinforced steel are mostly imported, and the execution of reinforced concrete is often of poor quality for reasons such as lack of training, poor shuttering timber, aggregates of inferior quality, polluted water, inadequate compaction and poorly maintained concrete mixers. Except on large projects, concrete quality is rarely inspected by a qualified technician or engineer and facilities for concrete testing are not available⁹¹.

Concrete slabs became, in any case, a common way of building floors and roofs, justified mainly by the scarcity and high costs of timber. A mixed technique evolved, in which concrete columns existed only on the ground floor when wide contiguous spaces, such as commercial showrooms, were required, the rest of the building being of load-bearing walls braced with concrete ring beams and slabs. Other elements formerly made of wood - such as window and door lintels - were reproduced in concrete, regardless of the material in which the walls were built. When the walls are built of concrete blocks only, they are usually coated inside and outside with cement plaster⁹².

In the areas where cob walls are predominant, concrete blocks have been used not only to make new constructions but also for additional floors on existing buildings and to increase the number and width of openings. The blocks are laid on a reinforced concrete ring beam resting on the cob wall. Concrete also appears combined with stones and fired bricks. In Sana'a and Dhamar, hybrid techniques have been developed in which concrete blocks were used for the inner skin of walls faced with fired bricks or cut stones⁹².



Fired bricks and cob wall, Sana'a Gov. – ©CRATERRE

⁹⁰ (Golvin, 2013)

⁹¹ (Miles & Ahmet, 1984)

⁹² (Varanda, 1994)

↳ Concrete and cement block

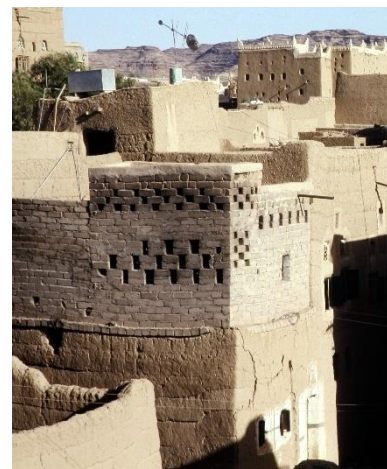
The imported style of apartment blocks from 2 to 5 floors, built in stages, with the steel rods exposed for future extensions, is frequent. The "modern" construction refers to city buildings and is characterized mainly by a reinforced concrete frame. The walls are made of concrete blocks with sometimes a local stone cladding, a kind of modern-traditional that is extremely expensive.



Earth bricks and cement blocks, Hadramawt Gov., Rakhia district, 2022 – ©YFCA



Stone masonry and cement blocks, Shabwa Gov., Rodhom dist. 2022 – ©YFCA



Cob wall and cement blocks, Sa'dah – CC Motohakone

[3.7] CONSTRUCTION: SEASONALITY, KNOW-HOW AND AVAILABLE SKILLS

SEASONALITY

↳ Many years ago, it would take 5 or 8 years to complete a house in earth construction. Today, an average-size home can take from 1 to 8 months to be built.

Earth brick building: construction is traditionally done in the winter since summers are too hot, and the dryness causes excessive cracking. Because buildings are constructed incrementally, masters work on more than one house at a time⁹³.

In Hadramawt, good weather throughout the year facilitates the construction process that can continue regardless of the season. In addition, since construction with earth brick takes place in stages (preparing the bricks, building walls, etc.), each separated from the next by a period of drying in the sun, construction stretches over a relatively long period⁹⁴.

KNOW-HOW AND AVAILABLE SKILLS

↳ In Yemen, working as a stonemason or bricklayer is regarded as an honourable pursuit and only members of the highest social class are engaged in these skilled handicrafts⁹⁵.

↳ The farmer is also a builder. Farmers build their houses with the help of their families and neighbours. Outside help was called in for technical details such as wood or plaster carving and, more recently, plumbing and electric wiring⁹⁶.

↳ The title of *usta*, the highest in the hierarchy, is not always hereditary; to obtain it, the patronage of a qualified *usta* requires practical experience. A young mason spends several years under the guidance and name of his master, who may be a parent or patron, until he can work independently and be allowed to engrave his name on a building⁹⁶.

Despite the loss of this tradition in the main cities, it seems that in certain medium urban areas the construction of a traditional house is still entrusted to professionals, involving a wide range of craftsmen, sometimes organized in guilds with varying

degrees of prestige, the passage from one guild to another being difficult. The responsibility for the whole building remains with the *usta*, the chief mason and contractor. He works either on a weekly wage basis for himself and his workers or as a contractor for a lump sum⁹⁶.

The construction of a stone wall, in Sana'a for instance, may entail the involvement of no less than 3 branches of the masons guild: the *usta*, being the chief mason, lays the external stone facings; the *thana* builds the interior face, and the *rassas* fills in the core with rubble and mortar made of earth and sometimes gypsum plaster. Unskilled day labour assists mainly in carrying the stones from where hewn stones are being shaped by the *muiaaqqis* depending on the position in the wall. The *mnwaqqis* is paid by the piece according to the shape and quality of the stone, and his wages are determined by counting the stones applied in each phase of the construction. This is a prestigious skill, although not equal in status to the *usta*. Terrazzo tiles became common and laying them introduced another specialist who was formerly responsible for applying water-resistant lime plaster⁹⁶.

The word *muhandis* is currently applied to a person with the skill to deal with equipment or machinery and is translated as engineer. It designates a plumber as well as a land surveyor, a structural engineer as well as an architect. A qualifying word may specify the profession, e.g. *muhandis ma'mari*, referring only to architects, but *muhandis al kahrab'a* means an electrical engineer as well as the electrician who fixes the fittings. The word *handasa* however deals directly with the notion of tracing lines or making drawings as part of the design operation⁹⁶.

The enterprises of earth bricks are usually relatively small, consisting of the following members:

| | |
|----------------------------|----------------------------|
| Ma'allium (or Usta) | Master Craftsman |
| Sikin | End Craftsman |
| Basir | Apprentice |
| Banana | 2 nd Apprentice |
| Amil bina | General builder |

Source: Deepa Mehta 2007

⁹³ (Jerome, Chiari, & Borelli, 1999)

⁹⁴ (Damluji, 1992)

⁹⁵ (Kotnik, 2005)

⁹⁶ (Varanda, 1994)

In Hadramawt, craftsmen travel throughout the region to practice their know-how. Like earth brick masonry, lime knowledge is typically passed down from father to son⁹⁷.

In 2007, a good master craftsman makes up to \$250 per month, annually more than 4 times the national income per capita, while an average craftsman will make about \$190 per month⁹⁸.

BUILDING PROCESS

↘ Stones are purchased at the quarry and brick at the kilns by an intermediary who delivers them either to the owner or the *usta*, if he is the contractor. The earth for earth buildings - whether in cob walls or in earth brick walls - is usually produced at the construction site, but there are still places where earth bricks are manufactured and sold to other construction sites⁹⁹.

To have a house built, the owner approaches the *usta* and tells him the kind of house he wants, perhaps using as a reference another house by the same mason or that of a neighbour. The *usta* then marks out the floor plan on the ground and explains how the rest of the house will be developed. Adjustments are then made, and the building proceeds to the first floor after obtaining the owner's approval. After that, the same procedure is repeated at each subsequent level⁹⁹.

Once the structural elements - foundations, walls and roofs - are complete, other craftsmen finish the building. First comes the plasterer, who is responsible for his team doing not only the work of rendering the walls and ceilings with gypsum plaster but also for carvings, shelves, and the tracery for the window fanlights. Finally, the carpenters arrive for the doors, windows and the ornamented board above the windows. Carpentry has always been costly, and houses are often left

without windows until the owner has enough money to order them⁹⁹.

Tools are only used when the hand itself cannot do what is intended. Thus, the man who builds a house in earth or surfaces it in plaster, shapes it with his bare hands. Even when tools like a trowel or a float are used, the hands follow to smooth and adjust. The farmer uses short hand tools to dig the ground, to thresh.⁹⁹



Watch tower with recently applied wall capping, cob wall technique, Amran Gov. – ©CRAterre

⁹⁷ (Jerome, Chiari, & Borelli, 1999)

⁹⁸ (Mehta, 2007)

⁹⁹ (Varanda, 1994)

TASK SHARING IN CONSTRUCTION¹⁰⁰

| Who does what | Stone | Sundried earth bricks/earth | Reinforced concrete/cement | Tents |
|--|--|--|--|---|
| Men | Provision and transportation of construction materials. Participate in all the construction work, including hiring labourers to carry out the work, responsible for all financial expense /labour wages | Collecting and transporting the construction materials, mixing the earth to make earth bricks, and excavation assist in the construction work | Provision and transportation of construction materials, including hiring labourers to carry out the work, mainly responsible for all financial expense /labour wages | Provision of Materials, digging for frame structure |
| Masons and construction professionals | Skilled masons assisted by labour are responsible for building the stone foundations and walls, supervising and ensuring the building layout as agreed with the owner | Skilled labours construct the brick walls | Engineers provide the design and BoQs if needed, and skilled labour to carry out the work | Sometimes, labour to support the installation of the tent |
| Women and children | Responsible for providing the water, preparing the food and drinks for the participants in the construction site, participating in the collection of wooden poles for roofing as well as earth plastering inside the house | Collecting and transporting the construction materials, mixing the earth to make earth bricks, including providing water, cooking, and earth plastering, maintenance | Responsible for providing the water for the building, preparing the food and drinks for the participants in the construction sites | Provide water, cooking |
| Neighbours | Support the family during roofing by providing helping hands to place the wooden beams/poles and earth | | Sometimes during roofing, if needed | |

¹⁰⁰ Sa'adah shelter cluster sub-national hub collect of data

[3.8] SUMMARY OF LOCAL AFFORDABLE HOUSING TYPES¹⁰¹

| Construction type/parts | Stone | Sundried earth bricks/earth | Reinforced concrete/cement | Tents |
|-------------------------|---|---|--|---|
| Shape | Rectangular | Rectangular and circular | Rectangular and recent shapes | Rectangular |
| Foundation | Sustainable stone footing with earth or cement | Shallow from earth brick | Reinforce concrete footing | No, barriers |
| Walls/structure | Squird stones with 2 faces and then plaster internal walls with wattle and daub | Earth brick plastered with earth and <i>nurah</i> paint (hydrated lime) | Concrete blocks and bricks or marbles for the front face of building walls | Iron or wood frame and canvas wall |
| Floor | Earth, concrete and ceramic tiles | Earth | Concrete, ceramic tiles | Earth, <i>Kazaf</i> mat |
| Windows/doors | Wood or aluminium glass windows with iron mesh, including a half-moon shape above windows covered by engraved daub (unique for Yemen) iron and wooden doors | Small windows and ventilation of wood | Aluminium with iron mesh windows Iron, aluminium, and wood doors | Window/door cut in the tent itself |
| Roof | Plywood is placed on wooden beams and then covered either by earth or concrete | Wood poles and straw covered by earth | Concrete is carried by wooden beams and plywood, or reinforced slab | Iron or wood truss to hold the canvas sheet |



Stone house, Ibb – ©Alezz/ Shelter cluster



Earth brick house in Shabwa – ©YFCA



Cement block house Al Hudaidah – ©YFCA

¹⁰¹ sub-hub data collection

[3.9] PARTICULARITIES OF SANA'A, OLD CITY

The characteristic type of house is a tall, square, tower house with an entertaining room or rooms at the top. Many houses have more than 5 storeys, the largest commonly having 7, 8 or even 9 storeys. Most Sana'a houses are built of stone on the lower floors and with fired bricks wall for the upper storeys. Some have coursed random rubble stonework below and earth bricks for the upper storeys¹⁰².

There is a second type of house, rare in the old city, but widespread in the new quarters. There are lower and have their entertaining rooms on the ground, looking out across vine-shaded pools with fountains¹⁰².

A third type, also rare in the old city, is the called « Jewish » type with a courtyard. This type differs from the prototypical tower house in that way that at the uppermost level, the rooms are arranged in courts on the roofs with light wells (*shamsia*) for the circulation areas on the floors below. The last flight of stairs, serving the top courtrooms, is often off-centred to the main staircase's vertical axis. Almost all the houses of this quarter are built with earth bricks hidden under a thick coating of earth plaster. Occasionally, stone rubble forms the lower part, but it disappears under the uniform plaster. The sober facades have narrow windows with wooden shutters surmounted by square or rounded openings¹⁰².

Finally, there are cylindrical tower houses outside the city walls belonging to the farm building tradition¹⁰³.

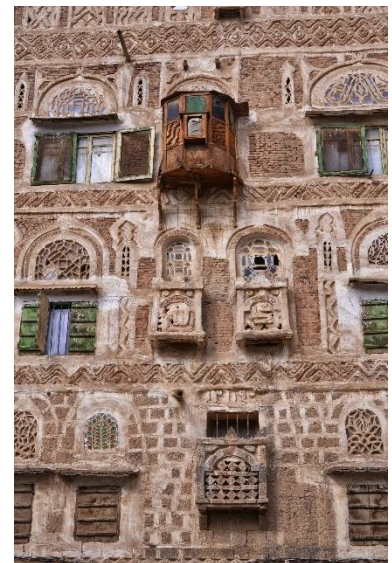
↘ In the city, it is not uncommon to find small gardens, even gardens adjoining the houses. These areas, better cultivated in the past than today, have large animal-drawn wells that discharge the water from the *dalw* (leather buckets) into gutters or a basin¹⁰².



Public garden in old Sana'a – CC Rod Waddington



Street of old Sana'a – CC Rod Waddington



House detail in Sana'a – CC Rod Waddington

↘ TO FIND OUT MORE

CITY-PROFILES OF SANA'A, UN-HABITAT

<https://yemenportal.unhabitat.org/urban-profiles/>

¹⁰² (Golvin, 2013)

¹⁰³ (Lewcock & Serjeant, 1983)

[3.10] PARTICULARITIES OF THE TIHAMA COASTAL STRIP

REED HOUSE¹⁰⁴

↳ The houses are up to 6 m in diameter and 6 m high. The structure is formed with regularly spaced vertical poles founded in the ground and cross-tied with flexible reeds. In the case of round buildings, they are tied together at the apex, forming conical roofs. In quadrangular houses, the pitched roof is based on a ring beam on the 4 walls and a ridge board running the length of the building.

The wall is covered with layers of vegetable fibres - palm leaves, straw or reeds - ranging from grass laid loosely over the frame to a woven fabric tied with ropes in careful geometric patterns. The exterior of the roofs is made of thatch only. Earth may be used for interior rendering of walls and ceilings and occasionally for solid walls. In the simplest houses, the structural frame may be exposed internally. In general, however, it is covered with either straw mats for walls and/or ceilings, or with mats on the ceiling and earth filling on the walls, or earth throughout. The separation between the roof and walls may be emphasised with rope motifs or ventilation strips. Compound walls are usually thatched but also made of earth or tied branches.

Decoration may have a functional aspect, like the ropes in geometric designs, or be purely aesthetic such as the reliefs on the exterior or interior of earth wall. Floors are usually of packed dirt mixed with dung, regularly made wet to maintain a cool climate. In some places, the floor is made of dried patterned earth.

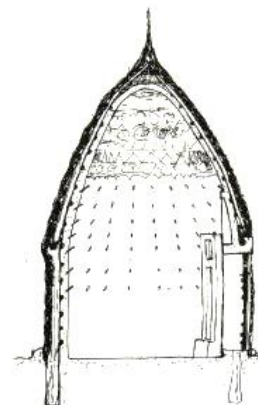
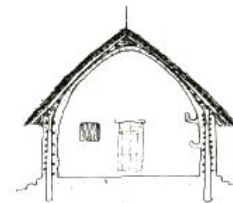
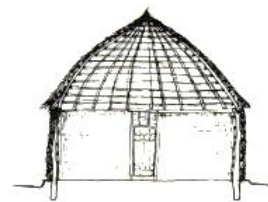
Sometimes they externally affect the shape of pointed cones, a kind of helmet that extends a rod erected like a lightning rod.



Reed houses – CC Motohakone



↳ TO FIND OUT MORE
FOR EXAMPLES OF SHELTER PROJECTS BASED ON REED CONSTRUCTION TECHNIQS, [SEE CHAPTER 5](#), p.64.



Examples of reed houses – ©Fernando Varanda

¹⁰⁴ (Varanda, 1982), (Varanda, 1994)

[3.11] PARTICULARITIES OF AL HUDAYDAH

HABITAT IN MOCHA, HODEIDA AND AL LUHAYYA

In Mocha, Hodeida and Al Luhayya, the Red Sea houses, known locally as "Turkish Houses", are 2 to 4 storeys structures with internal stairs. In these cities, the old central core consists of Red Sea architecture, and new concrete constructions supplant the old city centre. The ground floor is generally used for stores and shops, with sometimes their own entrance and thus not connected with the residential part. The first storey contains the main sitting room (*majlis*), and one or more sleeping/sitting rooms. A second storey contains private rooms and a semi-covered court (*kharja*). The uppermost floor characteristically has an isolated room preceded by a covered porch (*darwa*) and an opening to a roof terrace. Sleeping on this terrace is common. Additional areas of the terrace may be precariously roofed with thatched material or, more recently, corrugated metal sheeting. Kitchen, water rooms (where water for domestic consumption is stored) and bathrooms are located on the upper storeys. Ventilation is improved by the perforated high parapets of the terraces, latticed window and balcony shutters and perforations above the doors¹⁰⁵.

GENERAL DESCRIPTION OF HABITAT IN ZABID

The courtyard houses of Zabid are very different from the tower houses. A courtyard is dominated by the main room, the *murabba'*, a simple rectangular parallelepiped¹⁰⁶.

The house generally has only a ground storey, but quite frequently, a building is raised by one more storey. The houses of Zabid have thick walls intended to protect the interior from the overwhelming heat in summer that is still quite strong in winter. For reasons of ventilation, the ceilings are high, the rooms relatively vast, and the openings make the air circulate abundantly in the evening or in the morning before dawn. The main door, the only one that gives access from the outside to the inside, is usually double. The one that opens onto the street, the *bawwâba*, which precedes the inner courtyard, is rarely located in the axis of the facade¹⁰⁷.

The traditional building material is fired brick and plaster, but there is always a high percentage of organic materials, such as brushwood and earth, especially for less wealthy families. Today, the use of cement blocks and industrial bricks is predominant¹⁰⁸.



Zabid city – CC Tim Leiermann

¹⁰⁵ (Varanda, 1994)

¹⁰⁶ (Bonnenfant, 2000)

¹⁰⁷ (Golvin, 2013)

¹⁰⁸ Tom Leiermann



Zabid city – ©UNESCO



Zabid, interior of a merchant house – CC Tim Leiermann

TO FIND OUT MORE

CITY-PROFILES OF AL HODEIDAH,
UN-HABITAT
<https://yemenportal.unhabitat.org/urban-profiles/>

[3.12] PARTICULARITIES OF THE SA'DAH AND AL JAWF REGIONS

GENERAL DESCRIPTION OF HABITAT

In the Sa'dah and Jawf regions, traditionally, the high multi-storey houses are built with cob walls. Sun-dried earth brick technic is also present. The material is ochre-coloured earth mixed with chopped straw. Rows of fired bricks or earth bricks are often used to finish the top of the building in a simple frieze. Nowadays, stone has become the prestigious new material used, for example, in institutional buildings financed by foreign aid.



Sa'dah – CC Motohakone



Sa'dah, cob wall – CC Bernard Gagnon



Cob wall Al-Jawf Gov, Almttoon district, 2021 – ©YFCA



Earth bricks Al-Jawf Gov., Almttoon district, 2021 – ©YFCA



Cob wall, Al-Jawf Gov. - Almttoon district , 2021 – ©YFCA



Earth brick, damaged earth plaster, Al-Jawf Gov., Almttoon district, 2021 – ©YFCA

TO FIND OUT MORE

CITY-PROFILES OF SA'DAH, UN-HABITAT
<https://yemenportal.unhabitat.org/urban-profiles/>

[3.13] PARTICULARITIES OF AMRAN

GENERAL DESCRIPTION OF HABITAT

➤ Stone and earth-brick constructions are characteristic of the architecture in Amran. Despite several stone buildings, the region is characterised by a mixed architecture with stone ground storeys and projecting earth top storeys¹⁰⁹.

The scalloped crenelation along the rooftops and white plastered contouring around windows also distinguish the buildings of Amran. These buildings show careful consideration of both ventilation and lighting. Stylistic similarities between these elements have been pointed out between structures in Amran and Yarim. Many of the buildings of Amran also reveal a Turkish influence in their details, particularly in their wooden lattice additions¹¹⁰.

Traditional materials have persisted to some extent, but many of the more recent constructions have been executed with concrete frames and cement blocks.



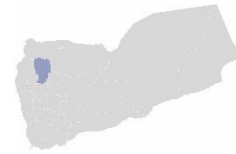
Mix of cob walls, earth bricks and stone masonry with earth plaster, Amran Gov. – ©CRAterre



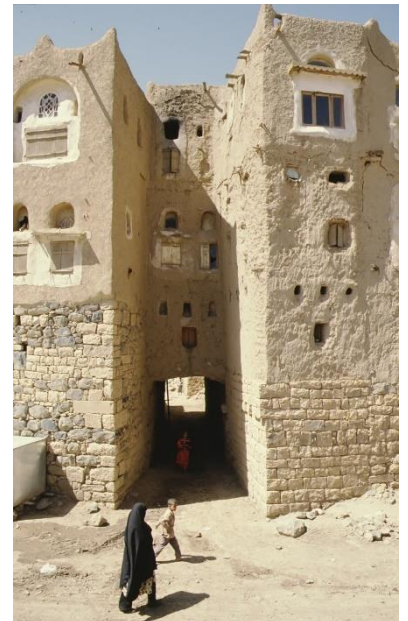
Window with lime protected plaster frame – ©CRAterre

¹⁰⁹ (Varanda, 1994)

¹¹⁰ (Matthews, 1985)



Window with solar protection – ©CRAterre



Mix techniques, earth bricks and stone masonry – ©CRAterre

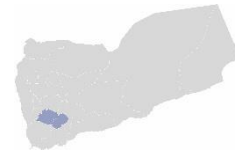


Terrace on earth bricks house, the roof top is often a woman space, Amran old city – ©CRAterre

[3.14] PARTICULARITIES OF IBB AND AL DHALE’E

GENERAL DESCRIPTION OF HABITAT

In the region of Ibb, the construction is a mixture of stone (the bottom floors) and earth (the top floors). The earth floor usually projects a little over the stone infrastructure. The style is unornamented. Traditionally, houses are made of stones, wood, limestone and *Al-Qdad* (a mixture of limestone and small stone balls). These materials were used as building, finishing and covering materials. Earth was also used as a filling material inside the walls¹¹¹.



Jibla, Ibb province – CC Rod Waddington



Rural area, stones load-bearing walls (internal and external stone masonry) and a wooden roof – Ibb – Hazam Al Udain district – ©Alezz/ Shelter cluster



Random settlements (unplanned or partially planned cities) – Ibb – Al Dhihar district – ©Alezz/ Shelter cluster



Rural villages (random building blocks without planning) – Ibb – Hazam Al Udain district – ©Alezz/ Shelter cluster



Earth walls settlements – Al Dhale’e – Qatabah, Tahani Mohammed – ©DEEM



Ibb province – ©Alezz/ Shelter cluster

¹¹¹ (Sub-national hubs, 2022), (Varanda, 1982)

[3.15] PARTICULARITIES OF HADRAMAWT AND SHABWAH

➤ In recognition of its unique architecture and environment, Wadi Hadhramat and the walled city of Shibam were declared a World Heritage site in 1982. In this region, the tower houses rise as much as 10 floors. The *wadi* developed its distinctive style of fortified earth brick tower houses for defensive purposes¹¹².

Shibam is considered as the “Manhattan of the desert” and is built with earth bricks, using a technique that has remained unchanged for centuries. They have a trapezoidal section to reduce the weight of the walls on the upper levels. The floors are built with wood and are bound by the outer walls; inside, wooden columns reduce the beams' light. As the facade is eroded by wind and rain, the walls are periodically covered with earth plaster¹¹³.

A fine tradition of carpentry still survives. Although no longer made of the local hardwood *ilb* (jujube or *Zizyphus Spina-Christi*'), highly decorated doors, windows and columns are carved from imported Malaysian hardwood and ornamented with metal nails and bow-tie-shaped fasteners. Lime know-how is also highly sophisticated and is used for waterproofing as well as decoration¹¹².

Tower houses are mostly square in plan, with a narrow stairwell, one to 3 rooms and a bathroom per floor. Setbacks form terraces on the upper floors. Surrounded by high parapets, these spaces are used for sleeping outdoors during the summer. A typical house is 40 feet by 40 feet. There tends to be a stricter division between the women's and men's quarters. The spaces are separated by terraced setbacks so that newer houses appear to be divided into 2 pavilions and are often U-shaped in plan. Typical Hadrami houses have windows that are rectangular and are set just above the finished floor surface. This is because minimal furniture is used - carpets, cushions and pillows replace the furniture - and every room can potentially serve more than one function¹¹².

The master mason generally designs a house. In the past, drawings were not used, but now floor plans are discussed with the owner. When orienting a house, the direction of sunlight and wind is studied. Ideally, the best rooms are often placed along the south facade, with the bathrooms along the north¹¹².



Village in Hadramawt – CC Aysegul Tastaban

¹¹² (Jerome, Chiari, & Borelli, 1999)

¹¹³ <http://hiddenarchitecture.net/shiba/>



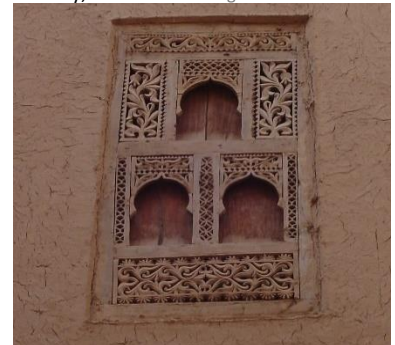
Earth-bricks, Hadramawt Gov., Rakhia district, 2022 – ©YFCA



Earth bricks with cement blocks extension, Shabwa, Almarkha Als. Dist., 2022 – ©YFCA



Old City, Shibam – CC Twiga Swala



Window detail, old city, Shibam – CC Mavilimon

➤ TO FIND OUT MORE

ARCHITECTURE OF EARTH IN THE HADRAMAWT, JEROME & CO, 1999
<https://www.researchgate.net/publication/269825587>

URBAN DEVELOPMENT PROJCT, SHIBAM, GTZ, 2007
<https://www.archnet.org/sites/52>

[4] Analysis of local building practices

[4.1] LIFESPAN AND MAINTENANCE

+ Positive points

Earth building

- Earth-building practices are alive in many regions of Yemen, mainly in rural areas. Skilled labours are available in many places, and inhabitants know how to maintain and repair their houses.
- If well-designed, built with know-how and maintained by the inhabitants, the lifespan can be very long: when talking about the age of the oldest house, local master masons' answers varied from eighty to 500 years. When a building is to be replaced and renewed, it is demolished, and the earth and timber are re-used in the new building. So, it is challenging to give exact dates for the construction of houses since probably most of them have been reconstructed, at least in part, during the past 100 years¹¹⁴.
- In Shibam, houses are reconstructed to the same layout and height, reusing any wood in good condition. Vertical-angled wood supports are placed against the base of buildings along with additional earth bricks in an attempt to buttress the foundations¹¹⁵.
- The maintenance can be done by the family with local resources and is affordable and environmentally friendly: maintenance of earth brick buildings consists of replastering the exterior walls, but only once the earth bricks begin to show. Depending on the rains, decades can pass before the need to replaster. Lime appears to be the best protection for roofs and parapets. Cracks are treated with whitewash. When earth plaster is only used, replastering may be performed after 10 years or after each rainy season to prevent tracking earth from the roofs (terraces) into the houses. Earth brick buildings in the Hadramawt region can last for centuries if maintained regularly. By contrast, local masons do not consider newer concrete buildings to be long-lasting¹¹⁴.

Reed houses

- In reed houses, termites are a potential problem, and spent oil can be applied to the wood before inserting it into the wall¹¹⁶.

Stone masonry

- The buildings are sustainable and durable. The material is available locally and is environmentally friendly. The structures are safe, secure and resistant to climate risks, floods, heavy rains, strong winds, fires, termites and erosion.
- Strong know-how exists, and skilled masons are available in urban and rural areas. Moreover, the technique is proven and people have confidence in its capacities.



The practices presented below are not exhaustive and represent only a sample of those existing. Some need to be better documented. They are constantly evolving and must be analysed on a localized scale.



Well maintained cob wall house with lime plaster to protect the walls capping – ©CRAterre



Stone masonry, Haraz mountain – CC Rod Waddington

¹¹⁴ (Jerome, Chiari, & Borelli, 1999) (Damluji, 1992)

¹¹⁵ (Damluji, 1992)

¹¹⁶ (Jerome, Chiari, & Borelli, 1999)

- The structure allows expansion, such as upgrading to multi-floors.
- Existing practices and technical details facilitate the maintenance. For example, in Sana'a, the use of wood ring beams allows sections of the stone wall below to be renewed with less danger of the wall above cracking¹¹⁷.

Concrete

- If well designed and built with know-how, a concrete structure may last long.
- Building, expansion and upgrading are possible but need skilled know-how, which is not easily available.
- Although typically more expensive, a concrete structure can be built in one season and provides wider interior square footage on the same parcel of land.
- The introduction of concrete has also meant innovation in terms of hybrid technology. For instance, reinforced concrete beams allow for greater spans within traditional earth brick construction. Galvanized plumbing pipes, roughly 2-1/2 inches in diameter, are used as joists and lintels instead of wood and steel lally columns have replaced decorative hardwood columns.

Tents

- The structure is easy and fast to install. No skilled work is required. The structure is mobile. This typology is very adapted to the nomadic culture and lifestyle.

- Negative points

Earth building

- Earth construction is getting synonymous with poverty. Around urban areas, people no longer maintain their houses and leave them abandoned.
- Earth brick houses need regular maintenance, even though they are affordable with local resources.
- Rainwater is by far the most serious problem, although light. Continuous rain has a less severe impact than heavy downpours of short duration. However, rain can cause deep fissures on the surface of earth brick walls by differential settling
- (-) Splashing at the ground level can result in basal erosion and structural collapse may occur due to ponding. In addition, once water penetrates, the base of the walls, which carries the greatest load, is vulnerable to loss of compressive strength.
- (-) Rising damp, which typically contains soluble salts that effloresce on or below the surface of the earth bricks, causes physical damage to the pore structure¹¹⁸.

Stone masonry

- (-) The high cost of stone masonry is a barrier. This technique requires hiring skilled labourers.

Fired bricks

- (-) Very low availability

Concrete



Lack of regular maintenance of earth building can lead to collapse, Amran Gov. – ©CRAterre



Unavailable skilled masons and high cost of cement and steel bars impact the quality of concrete housing, AlHudaidah Gov., AlKhokha Dist. 2020 – ©YFCA

¹¹⁷ (Matthews, 1985)

¹¹⁸ (Jerome, Chiari, & Borelli, 1999)

(-) Material and know-how are only available in urban areas. The high cost of the material and skilled labour is also a barrier.

[4.2] COMFORT, BIOCLIMATIC DESIGN AND ENVIRONMENTAL ISSUES

+ (Positive points)

- (+) The architecture in Yemen is of the highest standard, and housing has adapted distinctively to local climate conditions, locally available know-how and local building materials.
- (+) The thermal regulation of the walls is combined with the effect of climate on the compact form and proper orientation of the building and urban design providing shading. The cluster pattern of many cities and villages consists of narrow paths with building facades fronting each other, providing shadow¹¹⁹.
- (+) These buildings used low-technology and natural materials in their construction: stones, earth bricks for walls and wood for ceilings, which have no harmful effects on the environment and can be reused¹¹⁹.
- (+) Another influence of climate is in the design of windows. It is current and typical in Yemen to separate the 2 functions of a window, lighting and ventilation. The older windows were provided with translucent slabs of alabaster for light, with timber shutters below for ventilation control. Today, glass is used instead of alabaster. Further development is in the use of decorative infill panels comprising plain or coloured glass set in a rib-work of gypsum plaster, actually an almost indispensable element in window design in Yemen¹¹⁹.
- (+) In cluster patterns, houses often do not have windows, being lit and ventilated by holes in the roof.

In the coastal strip

- (+) In Tihama fishing and rural areas, where the climate is hot, people live in round or square-shaped reed houses built with earth. It provides the interior with cold and fresh air. In these houses, various features keep the interiors ventilated and cool. For example, the wall, if filled with earth, is often separated from the roof by an unsurfaced ventilation strip. Natural ventilators are opened in the earth or straw walls or latticed panels above the entrance doors.
- (+) Earth floors are regularly sprinkled with water to keep the interiors cool.
- (+) In rural areas, a wall-less covered area may be used as a sleeping area during the hottest nights.
- (+) In urban areas, such as Mocha, Hodeida, and Al Luhayya, glass is traditionally rarely used (in the Red Sea houses), as it interrupts the flow of the cooling breeze, which is needed in these humid regions for comfort. The wooden *mashrabiyyah* protect the openings from direct sunlight, provide natural light, and benefit from natural ventilation. The openings consist of upper and lower parts so that the air is moved using the pressure difference.



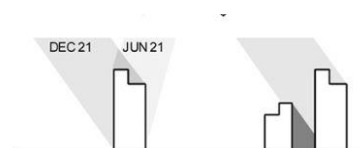
Narrow path increase the shade in Shibam
– CC Martin Sojka Flickr



Solar protection – ©CRATERre



Small windows, proper orientation and thick earth wall ensure a natural climate inside – ©CRATERre



The effect of the tower building shape on the thermal gain in winter and summer –
©(Abdallah, Hassan, & Al-Olofi, 2020)

¹¹⁹ (Abdallah, Hassan, & Al-Olofi, 2020)

- (+) In the hot climate, the window *mashrabiyyah* is also used to cool water with pottery and works as a natural refrigerator. The water stays cold even in hot times. Earth floors are regularly sprinkled with water to keep the interiors cool¹¹⁹.
- (+) The patio works as a thermostat that softens the atmosphere and creates balance in temperature¹¹⁹.

In the mountains

- (+) In Sana'a and its surrounding villages, where the climate is cooler, the long axis of shape tower building extends from east to west, which means that the long side of the building faces north and south, allowing placing most of the windows in the northern and southern walls. As a result, buildings can control solar thermal for heating and cooling in the summer and winter months¹²⁰.
- (+) The shape of tower buildings was designed to create large areas for walls to increase thermal gain in winter and reduce solar gain in summer due to the size of the ceiling relative to mass¹²⁰.
- (+) The backyard (*al-Bustan*) softens the atmosphere, creates a balanced temperature and purifies the air from dust. In Sana'a, every house contains a backyard that provides residents with vegetables, a water well and the solid waste used as fuel in fired brick ovens¹²⁰.
- (+) The houses use wood as breakers in the windows to prevent from cold air at night and reduce thermal gain in summer. The horizontal solar breakers, a strip of wood above the windows, are estimated to be 30cm from the wall and are installed on a wooden stand. It works to protect the windows from rain and provide shade from sunlight¹²⁰.
- (+) The external finishes are white, and light colours reflect the sunlight from the facades of the building, and sunrays are not absorbed. White plaster also covers the ceiling to reflect sunlight and prevent from heat gain¹²⁰.

In the highlands

- (+) The difference in height and regularity of the buildings helps to provide shadows between the buildings and reduce the external climate impacts. Irregular streets reduce the impact of the wind, and the courtyards ventilate and soften the atmosphere inside the building¹²⁰.
- (+) Stairs from the ground floor to the upper floors represent the backbone and wind catcher of the house. Most of these stairs are ventilated by windows and form with other openings, the continuous cross ventilation of the house¹²⁰.
- (+) Rural buildings are constructed with thick walls and roofs, a method having advantages from the climatic point of view. In the highlands zone, there is an extensive diurnal range of temperature (about 15° to 20°.) A heavy structure can thus store ("capacity insulation" and time-lag) the heat of the day, allowing restitution at night, providing a stable indoor temperature without any need for heating or air-conditioning. Studies on insulation were carried out in a house in Sana'a¹²¹, constructed of sun-dried earth brick walls 40 cm thick and with a traditional earth roof. The walls were rendered externally in earth plaster and



Backyard with trees softens the atmosphere, Radaa – ©CRAterre



House orientation with the small facade exposed to sunshine, and white surfaces around the window reflecting the sunshine, to reduce the absorption of warmth, Amran – ©CRAterre



A compact form with thick wall to keep the interior cool or warm depending on the season, Sa'dah – ©CRAterre



Differences in height and regularity of buildings helps to provide shade, old city, Shibam – CC Motohakone

¹²⁰ (Abdallah, Hassan, & Al-Olofi, 2020)

¹²¹ Al-Shibami, 2004

internally in gypsum. The external and internal room temperature was measured during the cold season (January and February). This showed the effect of a "time-lag", where the sun's heat took about 8 hours to pass through to the inside. The effect of the time-lag in the walls would be similar. This explains the even temperature inside the room, although the outside temperature fluctuated through a range of about 15°C. The results of this study show the importance of "capacity insulation", which can only be obtained through massive walls and roofs. "Resistive insulation" cannot achieve this effect, as it lacks the "night-storage" factor¹²².

- (+) The thermal regulation of the wall is combined with the effect of climate on the compact form and proper orientation of the building and urban design providing shading¹²².
- (+) In the highlands, the climate dictates orientation to ensure that living and sleeping rooms face south, with large windows to take advantage of the warming sun, whilst the summer sun, being overhead, has not the same effect. The preferred orientation is north for the circulation and service areas. For obvious climatic reasons, this is reversed in the subtropical southern and southwestern slopes and the Tihama¹²³.
- (+) In large houses, the use of the rooms may vary with the season, the warmest rooms being used for sleeping during the coldest season even though they are used differently during the rest of the year¹²⁴.
- (+) Despite their need for regular maintenance, traditional heavy roofs provide good thermal conditions. They reflect 60 to 80 % of solar radiation if plastered with lime¹²⁴.

- (Negative points)

Concrete houses :

- (-) One of the problems with concrete houses is still designing for the climate. Concrete buildings have cooling and heating requirements that were non-existent in traditional construction. This has proved problematic since the little available electricity comes from the overburdened public utilities or private generators, none of which is continuously operated¹²⁵.
- (-) The modern structures are hot in summer and during the day and cold in winter and during the night because of the thin walls and roofs. They also require expensive maintenance because their facades lack natural weathering materials.

[4.3] HAZARD-RESISTANT PRACTICES



Flash flood

- Areas prone to flash floods are commonly known, and construction is avoided in these areas: camouflaged earth brick cities and villages are perched along the

¹²² (Matthews, 1985), (Abdallah, Hassan, & Al-Olofi, 2020)

¹²³ (Matthews, 1985) (Ahmed, 2020)

¹²⁴ (Varanda, 1994)

¹²⁵ (Varanda, 1994), (Jerome, Chiari, & Borelli, 1999)

↳ TO FIND OUT MORE

TRADITIONAL YEMENI ARCHITECTURE AND ITS IMPACT ON ENERGY EFFICIENCY
http://www.irphouse.com/ijert20/ijertv13n8_25.pdf

THERMAL COMFORT AND ENERGY EFFICIENCY IN YEMENI HOUSES, AL-SHIBAMI, 2004
<https://theses.whiterose.ac.uk/12842/1/414636.pdf>



Conditioning air in cement building are unavailable in hot climate, Shabwa Gov., Almarkha alsofla Dist. 2022 – ©YFCA



A base in stone masonry protect the building against flash flood – ©CRATerre

escarpments, contrasting with the verdant swathes of date palm groves and cultivated fields that line the valley floor. This pattern allows for the maximum use of arable land and protects against occasional flash floods¹²⁵.

- In the *wadi*, the former practice of annually cleaning the water channel allowed removing overgrown vegetation. However, today concrete constructions in flood-prone areas act as barricades, so the floodwater and its rebounding effect push the flood toward more vulnerable buildings¹²⁷.
- A common practice in many places has been to pull down a whole building that has been damaged beyond repair and rebuild it in the same position and on the same principle of design. The positions of windows and ventilation openings are noted beforehand so they can be distributed in an identical pattern on the new building. Sometimes old doors and windows are refitted in their old positions in reconstructed buildings. The earth, stone and timber are re-used in the new building¹²⁶.
- In areas exposed to flood, wear mass of earth protects the base of the wall.
- In earth building, foundations, traditionally of stone, require 2 m below grade and about 1 m of exposed stonework above grade. Where the valley is narrower and the escarpments steeper, the above-grade height is over 1.50 m. Steep, narrow streets also act as spillways during flash floods, with dry stonework to retain the hillside and break the force of the cascading water. In Wadi Do'an, the traditional use of dry rubble stone is beneficial as it precludes rising damp, which happens through capillarity¹²⁷.
- Quality of earth: the topsoil is considered of poor-quality because it contains salts from agricultural fertilizers. In Wadi Do'an, master masons collect the earth from around the date palms after the floods¹²⁷.
- The masons know that the ratio of water-to-earth has to be well proportioned to obtain an earth mix stiff. The earth bricks will be thicker and more robust¹²⁷.
- Earth plaster is the first line of defence for protecting earth brick walls, which is the load-bearing structure. Earth plaster acts as a sacrificial coating: when the earth bricks begin to show, it is time to re-plaster¹²⁷.



Earthquake

- According to a UNESCO mission after the earthquake of 1982, "The purpose of earthquake-resistant design is not to prevent all damage by severe earthquakes, for such an objective would result in unreasonably expensive structures. The aim is first to ensure against loss of life or injury, and then to balance the cost of additional measures against the probable cost of repairing damage during the expected life of the structure". It should be added that where money is very scarce, the main object must be to prevent the collapse of buildings and consequent loss of life. One must expect buildings to crack and the need to repair them if there is a significant earthquake¹²⁸.

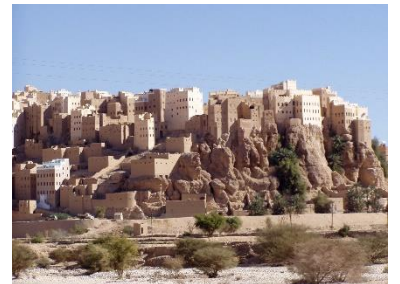
¹²⁶ (Damluji, 1992)

¹²⁷ (Jerome, 2010)

¹²⁸ (Matthews, 1984)



Protection of the base of the wall with wear mass of earth – ©Max Cortesi



Site selection is essential to protect earth building from flash flood, Al-Hajarayn – CC Dan



Earth plaster has to be regularly maintained to protect the façade, Shibam ©Shelter cluster Yemen



The quality of earth important, local masons generally know the best practices and location of earth extraction – CC Tom Leiermann

- To improve traditional buildings, diagnosing the types of destruction that occur during an earthquake is necessary. Field surveys show that the most typical type of failure is the breaking off of the 4 top corners of buildings. Cracking of the wall begins at roof level, where vibration is strongest. The wall then cracks, the whole corner shears off, and the roof falls in. The first severe shock usually does not last long enough to bring down the levels of the building below the top storey. A second shock may continue the process. The extent of cracking, shear and collapse depends on the strength of the materials and their bonding, which is in turn, affected by maintenance¹²⁹.



Stability of the walls thanks to the trapezoidal shape, Sa'dah – ©CRAterre

- Wood strips or bands (*basut*) embedded in the walls and running along the courses as a form of bracing for the masonry appear mainly in the southern half of the country, from Sana'a, through Dhamar to the Ibb province. These bands run around many of the houses, especially those with lower floors built in stone or fired brick. They appear to be carefully joined to form a continuous ring beam

¹²⁹ (Matthews, 1984)

holding the walls from bulging outwards. There are usually 2 of these bands above and below the lowest large windows, acting as sill and head, and sometimes another running through the stonework below. They are often whitewashed for weather protection and, therefore, not immediately recognizable as wood. Although other woods are used, apricot wood is favourite for this purpose, which becomes stronger when it is damp and resists decay. The system was still in practice in the mid-seventies, but the joists positioning seemed a matter of formality rather than an accurate understanding of their function. The 1983 earthquake sadly proved this to be the case. The older buildings seemed to have resisted this earthquake better than the newer ones, perhaps because there had been no earthquake for a long time and the memory of the threat receded, so the rational principles for using the *basut* were forgotten¹³⁰.

- After the earthquake of 1982, the differences in damage between the stone houses built on rocks and the adobe houses in the plains were studied. It seems that the stone houses were more damaged because the type of construction is heavier than the adobe. The position of the rock may have amplified the acceleration, while the softer adobe subsoil of the plain may have dampened the acceleration. The stone constructions have less internal bonding inside the structural walls, and the anchorage of wood construction to the walls is better in the earth brick constructions. A series of small vibrations will have a more cumulative effect on rock masonry than on adobe because adobe may compact and fill in the cracks. But as the main conclusion, the degree of damage was mainly explained by the bad state of maintenance and inadequate construction techniques¹³¹.
- Some plateau houses have stone construction basements with a lighter adobe upper structure. Regular maintenance of the adobe by filling in cracks may have contributed to their better resistance¹³¹.



Strong wind and cyclone

- Stone houses and earth houses with thick peripheral walls do resist well to cyclones.
- The stability of the walls comes with the trapezoidal shape, with thick walls at the base and thinner walls on the upper floors.



Fire

- Wood structures (joists or beams) are often covered with earth plasters, which ensure good resistance to fire.

[4.4] IMPROVABLE BUILDING PRACTICES AND RECOMMENDATIONS

Site planning indifference

- Indifference to construction rule of thumb in flash flood zones has taken its toll on the quality of new construction. There are known areas of the flood plain to be avoided, but despite this, construction occurred¹³².

¹³⁰ (Matthews, 1984), (Matthews, 1996), (Varanda, 1994), (Lewcock & Serjeant, 1983)

¹³¹ (Derek, 1984)

¹³² (Nienhuys, 1983)



No foundation in flash flood prone area can be disastrous, Shabwa Gov., Almarkha alsofla Dist. 2022 – ©YFCA



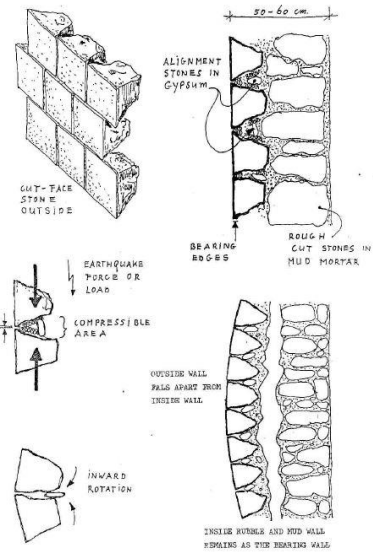
Destruction after the earthquake of Dhamar in 1982, no tie/through-stone in the wall – source Sjoerd Nienhuys 1984

Inadequate post-disaster responses

- The post-disaster responses tend to propose systems that emphasise strength and resistance but ignore climatic requirements and comfort conditions inside the houses¹³³.

Loss of know-how

- The question of techniques lost because of not being applied over a long period is illustrated by what seems to have happened with the waterworks found at Habur and elsewhere. The good quality of the waterworks implied durability and long-lasting structures, resulting after a couple of generations, when repairs and expansion were finally needed, in a loss of the technique by the craftsmen¹³⁴.
- Many damaged newer houses after the flash flood in 2008 had inadequate or no foundations¹³⁵.
- In stone masonry, the fine and square tailoring or cutting off only the exterior face of the stones, and the complete lack of tie-beam constructions, caused a general lack of bonding. The 20th century introduced the square cut-face stone technique with conically cutting away the rear side, which caused severe problems due to wind and water erosion, and foremost with earthquakes¹³⁶.
- Maintenance is essential in traditional roof covering materials like lime plaster and new roofs like asphalt, terrazzo tiles and cement plaster. All types of roof covering tend to leak due to the lack of a waterproof membrane, insufficient slopes, loss of know-how and poor maintenance¹³⁷.
- Experienced master masons indicate that earth mortar joints should be thinner than the earth bricks, but in newer Hadhrami constructions, the joints are frequently the same width as the earth bricks. In addition, the earth mortar mix should be of a certain quality, well mixed and reinforced with wild grass¹³⁸.
- Experienced earth masons say that earth bricks should be mixed with finely chopped straw and rest for 3 days before use. Now, earth plaster is mixed with less straw and applied after half an hour. In addition, the fresh earth plaster is trowelled on in a thick layer instead of 3 layers (scratch coat, brown coat and finish coat). As a result, it washes off with the first rain instead of lasting 10 years¹⁴³.
- The earth bricks are supposed to be stacked on a running bond, with headers or soldiers connecting the width of the wall and strengthening its construction. Now walls are built a single earth brick wide, and nothing is connecting the inboard and outboard elevations of the walls¹⁴³.
- The fact that new constructions are built without proper foundations, using lesser quality bricks, and with poorly braced walls can be rectified through better quality control and information dissemination to prospective homeowners¹⁴³.
- Earth brick construction in the Hadramawt region is only meant to be carried out during the winter months when the weather is cool enough not to cause



Study of stone wall weakness to earthquake, stone are squard – source Sjoerd Nienhuys 1984

TO FIND OUT MORE

DHAMAR AIDED SELF-HELP RECONSTRUCTION PROJECT SJOERD NIENHUYS, 1984

<https://www.researchgate.net/publication/232659229>



Some combination between traditional and industrial material can lead to severe structural disorder, Shabwa Gov., Rodhom dist. 2022 – ©YFCA



Good top roof drainage system made of wood, rain water is evacuated far from the façade – ©CRATERre

¹³³ (Matthews, 1984)

¹³⁴ (Varanda, 1994)

¹³⁵ (IFRC & UNDISDR, 2009)

¹³⁶ (Nienhuys, 1983)

¹³⁷ (Miles & Ahmet, 1984)

¹³⁸ (Jerome, 2010)

shrinkage cracks. Additionally, one story should be built annually, giving buildings the time to settle before being loaded with an additional floor¹⁴⁰.

Incompatibilities of different building materials

- When earth brick houses are reconstructed, cement plaster is applied to the bases to protect the basement. Unfortunately, the incompatibility of the 2 materials (cement tends to trap moisture) accelerates the structure's deterioration and collapse.
- Some combinations of traditional and new materials and techniques show a degree of adventurousness and apparent carelessness with a risk of not being successful¹³⁹.
- In Wadi Hadramawt, the hydraulic mortar *ramad*, a mixture of lime putty ash and sand, was used in the past before the introduction of cement. At least *ramad* did not introduce soluble salts into the earth's superstructure. By contrast, cement contains soluble salts deleterious to earth construction. Cement mortar, now commonly used in foundations or even concrete foundations, promotes the migration of soluble salts from the cement into the earth brick superstructure with disastrous results¹⁴⁰.
- Today, a plastic sheet is often placed on the beams under the 15 to 20 cm layer of earth plaster to improve roofs' resistance to water infiltration. This way of preventing water infiltration can have severe consequences on the wood joists and the roof's stability by preventing the moisture from escaping¹⁴¹.

Water management

- Unfortunately, sewage disposal systems capable of accommodating the increased demand have been slow to catch up, creating rising damp at foundations. Any leak in the plumbing systems results in disastrous consequences for the water-vulnerable construction material, and entire sides of buildings collapse. The main structural problem in Shibam, for example, is the modern sewage and drinking water infrastructure. The introduction of drinking water and sewage pipes to the city, in which wells and water pipes organised water access and drainage for centuries, created a permanent risk for humidity in the ground and caused leaning walls, cracks and the eventual destruction of buildings. While old Shibam is surrounded by palm yards, no plants are allowed inside, as plants require underground irrigation and would create a risk for foundations¹⁴².
- Unsightly, pipes are invariably placed vertically on the exterior of buildings, and supply and waste lines are laid on top of the streets, creating hazards for pedestrians¹⁴².

Consequences of a changing building sector

- In the past, construction teams were paid by the day. Today changes in payment methods for contracting, which are paid by the project, result in rushed and poor-quality construction¹⁴³.

¹³⁹ (Varanda, 2012)

¹⁴⁰ (Jerome, 2010)

¹⁴¹ (Sub-national hubs, 2022)

¹⁴² (Varanda, 2012)

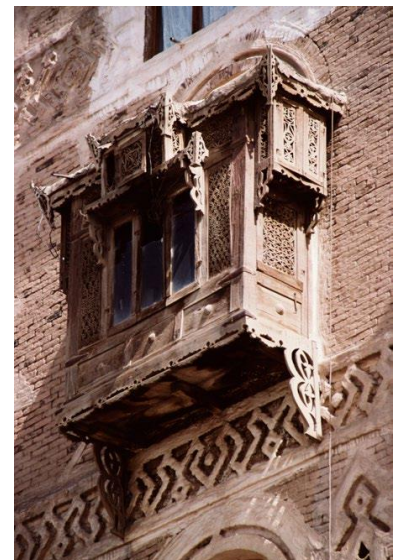
¹⁴³ (Jerome, 2010)



Waste drainage that may impact the foundation – ©CRATerre



Terrace, women space ©CRATerre



Mashrabiyya in Sana'a, watching without being seen – CC Hasso Homann

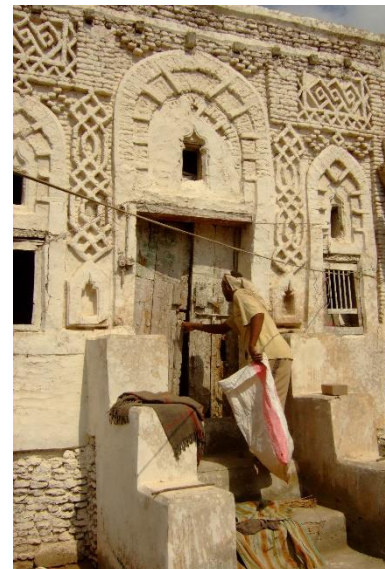
- The modern house's design does not only lack local characteristics but also fails to respect the Islamic values in the internal spatial organisation¹⁴⁴.
- The increased use of cement to protect vulnerable parts of earthen buildings is a physical risk of long-term damage. Some of these interventions are a severe risk for earthen structures. The neoclassical "Greek-style" motifs in gypsum or cement are very popular in the region and cover villas and new buildings. Each renovation of earthen facades requires the whole removal of the surfaces to a depth of 2 fingers. This is used for aesthetic "upscaling" that can easily lead to the rapid destruction of earthen façade features.



Sana'a decoration, strong identity – CC Rod Waddington

[4.5] GENDER ASPECTS

- In Yemen, social space is usually separated into men's exterior and women's interior space. However, the relation between these spaces cannot be accurately described by oppositions such as public-private and privileged-deprived. These opposites are based on Western thinking: a binary tree-like logic of hierarchical division, resulting in an understanding of space as an absolute entity that can be cleanly subdivided into parts. The Yemenite concept of space is inherently connected to the continuous balancing of honour. Thus, space is fluid and relational. Men's exterior and women's interior space are both relational spaces¹⁴⁵.
- The window *mashrabiyyah* provides privacy, as women are allowed to see the outside without the possibility of being seen¹⁴⁶.
- Women have a strong and diversified relationship with the house: for instance, in nomadic societies, it is their responsibility to set up and dismantle the tents; in the Tihama coastal plain, the decoration of reed houses is often their responsibility¹⁴⁷.



Decoration to create shade on the facade, Zabid – CC Will De Freitas

[4.6] HEALTH ISSUES RELATED TO HOUSING

+ (Positive points)

- (+) In tower houses, the kitchen is usually located at the top of the house or even on the terrace to protect the living quarters from smoke and odours, but this arrangement can vary, especially if several households (naturally closely related) live together in the building¹⁴⁸
- (+) In case the kitchen is located on lower floors, holes in the walls improve a little the ventilation of the kitchen. In some examples, a whole part of the wall is multiperforated with staggered stone or earth blocks¹⁴⁹.

- (Negative points)

- (-) Tents don't have a bathroom



House decoration is very important in the Yemeni culture, painted ceiling in Zabid – ©UNESCO

¹⁴⁴ (Matthews, 1996)

¹⁴⁵ (Kotnik, 2005)

¹⁴⁶ (Ahmed, 2020)

¹⁴⁷ (Varanda, 1994)

¹⁴⁸ (Golvin, 2013)

¹⁴⁹ (Varanda, 1994)

- (-) Kitchens are the least attractive part of the house, being smoke-blackened rooms, bereft of comfort, poorly lit, and ventilated. Women and girls are most affected by the poor quality of these spaces.

[4.7] USE AND AESTHETICS

+ (Positive points)

- (+) The decorations and elevation elements have very strong identities and unique styles.
- (+) House spatial organizations fulfil social and climate needs. The spatial organization is distributed according to social needs and orientation, providing cold rooms during summer and warm rooms during winter¹⁵⁰.
- (+) In Zabid, the facade decorations create shade on the facade and participate in the climate regulation inside.

- (Negative points)

- (-) Tents are not suitable for all lifestyles in Yemen and may provide low privacy.

[4.8] SOCIO-CULTURAL PRACTICES THAT PROMOTE RESILIENCE

- The Yemeni people have created a unique architecture based on their deep cultural roots. In small settlements, the principle of mutual aid is inherent to the community. All its members are bound to participate in any aspect of public welfare, ranging from constructing or repairing terraces to the erection of a school, mosque or other community facilities. At a more personal level, mutual aid is extended to the construction of individual houses or by offering assistance to those afflicted by disaster or misfortune. This partly explains why, in the past, even in the very low cash economy level of pre-revolutionary Yemen, deep poverty was virtually non-existent¹⁴⁹.
- The fact that the used methods of construction and concepts of design are part of the traditional discipline, and mastered by the local population, means that this population can run the process of design and construction self-sufficiently and without having to rely on material or technical aid from other sources¹⁵¹.
- Anonymous master builders and workers formed an integral part of the community. They used only locally available building materials to fuse form and function in their creations. An elementary but effective organisation for construction existed. There were many compelling merits of this construction industry model, which survived and remained unchanged over the centuries. Foremost was the application of technology utilising only available materials that could be transported easily to the site. Designs were to meet the needs of the environment, never to violate it¹⁵².



Unique architecture based on deep cultural roots, Sana'a Gov. – ©CRAterre

[4.9] TENDENCY AND ADAPTATION OF THE LOCAL BUILDING SECTOR

- The emerging trend of modernization and the urgent need for infrastructure and housing projects have caused an ongoing hasty shift from traditional to globalized

¹⁵⁰ (Ahmed, 2020)

¹⁵¹ (Damluji, 1992)

¹⁵² (Kulkarni, 1983)

and industrial/traditional buildings. The traditional Yemeni buildings are well adjusted to the hardships of the different climatic regions of the country, together with the efficient use of local resources. On the other hand, modern and modern/traditional buildings are over-designed and inefficiently implemented with imported construction technologies and materials. Cost reductions are achieved by lowering the quality, consequently creating a less attractive built environment and unsustainable buildings¹⁵³.

- Cost comparison does not always favour the use of local materials and techniques. In 1994, stone construction was already almost 6 times more expensive than cement block construction, and in some areas, a master mason was paid 3 times more if he worked on traditional rather than concrete constructions. Former low-cost materials such as earth bricks or fired bricks are disappearing from around the city, and the raw material is now found only at a distance with high transporting costs. However, houses built by farmers with local resources and with the help of their neighbours remain affordable¹⁵⁴.
- In the Hadramawt region, the earth brick industry is an apprenticed craft that continues to play a critical role in the Hadrami economy. In 2005, over 90 % of construction in the Hadramawt was earth-based. There is also a high availability of experienced labourers and craftsmen (builders and master masons). The cost of an earth house is lower than a concrete construction, which generally runs up to 30 % higher due to steel reinforcing¹⁵⁵.
- According to economic studies, with imported materials, a large proportion of the cost goes into the pockets of a few contractors, with only about 25% remaining in the district¹⁵⁶.
- In 2008, some of the difficulties associated with Yemen's construction industry were mainly unclear. There are no unified construction technologies, methods or regulations that control the construction process. This has created a tendency in the project's owners to minimize their construction costs by eliminating or minimizing the technical and engineering assistance in design and supervision. This tendency has led to over-designs, excessive use and site waste of construction materials. Quality concrete of the specified strength is not frequently produced due to the operation being improperly supervised¹⁵⁷.

Major cities

- In Sana'a and major cities of the country, the construction evolves towards less high buildings, of maximum 3 floors, while remaining very attached to the stone masonry considered as a noble material. New materials are used for entrance doors or store gates: wrought iron plated on thick metal sheets¹⁵⁸.
- In the western mountains of Yemen, earth bricks are associated with rusticity and underdevelopment. In less than a decade, concrete blocks for cheaper construction replaced sun-dried earth bricks, occasionally maintaining the forms



Stonewalls combined with concrete frame, Shabwa, Rodhom district, 2022 – ©YFCA



Model that represents not always affordable modernity, Hadramawt Gov., Rakhia district, 2022 – ©YFCA



Ta'izz, city of today – CC Hiro Otake

TO FIND OUT MORE

MODERN/TRADITIONAL BUILDINGS IN YEMEN AND SUSTAINABILITY, 2008

https://www.researchgate.net/figure/Traditional-Buildings-in-Sanaa-Shibam_fig1_256599703

EARTH ARCHITECTURE OF YEMEN, HOWARD MEADOWCROFT, 2018

<https://www.theglobaldispatches.com/articles/earth-brick-architecture-of-yemen>

¹⁵³ (Sultan, 2008)

¹⁵⁴ (Varanda, 1994)

¹⁵⁵ (Mehta, 2007)

¹⁵⁶ <https://al-bab.com/commentary-yemeni-traditional-architecture>

¹⁵⁷ (Sultan, 2008)

¹⁵⁸ (Golvin, 2013)

of the past. But, more generally, new forms, influenced by the revival of a traditional formulary, followed new materials¹⁵⁹.

- Cob walls were still common in the north and northeast by the mid-1980s, but their cost in Sa'dah City was higher than one of stone. But in rural areas around Sa'dah and Al Jawf, piled earth wall techniques are still widespread¹⁵⁹.
- Fired bricks have lost favour, apart from isolated cases betraying the classicist tastes of the house owners, some minarets and a few oddities attempting to adapt to a contemporary taste. The small quantities of the traditional fired brick which remain around Sana'a City may be sufficient for restoration work but not for large-scale construction¹⁵⁹.
- Stonewalls, mostly combined with concrete frames, are definitely assumed as the prestige material for both housing and commercial and institutional buildings¹⁵⁹.
- Corrugated Iron used in canopies for windows and the market stall is frequent. Its use in rural ancillary constructions, yard walls and substandard housing rapidly increases¹⁶⁰.

Hadramawt

- Contrary to what happened in the western mountains of Yemen, where earth construction, both in bricks and coursed clay, is almost abandoned, in the Hadramawt area of influence, earth brick construction is still widespread. Like in the rest of Yemen, there was a construction period with concrete frames and blocks introduced 40 to 50 years ago. It was thought to be quicker and cheaper to build but also considered "modern". However, after a long and continuing experiment with globalized construction, the Hadramis generally recognize the inherent qualities of their earth brick buildings, and although the latter is more labour intensive, there is also an inclination to return to the traditional¹⁵⁹.



Shibam, living earth-building know-how—
CC Wikimedia

↘ New approach

Some new challenges need new approaches, but essentially, the architects should adapt to the master builders, not the other way around—they are the base of any solid dealing with the local architecture, and any weakening of their functioning system would be disastrous.

¹⁵⁹ (Varanda, 2012)

¹⁶⁰ (Varanda, 1994)

[5] Examples of projects based on local building cultures

↳ TO FIND OUT MORE

YEMEN SHELTER TYPOLOGIES, NRC, 2020
<https://www.sheltercluster.org/yemen/documents/yemen-shelter-typologies-2020>

[5.1] ALUHAYIA DISTRICT – TRANSITIONAL SHELTER

Due to the fact that the sites of these families are located in hot areas with severe, harsh weather conditions, NRC designed suitable shelters for this climate using traditional construction methods and local materials. NRC implemented shelters in the Aluhayia district, Hodeida governorate.

It was not implemented 100% according to one design as it was a cash modality, and the beneficiaries have made different choices so that the BoQs (bill of quantities) differ in some details from one area to another depending on the availability of the material in each sub-district and space required per family. This approach requires more efforts to provide community mobilization and technical support.



Transitional shelter – ©NRC



Transitional shelter – ©NRC

[5.2] TIHAMA COAST – EMERGENCY (TESK) AND TRANSITIONAL SHELTER

Due to the hot weather on Tihama Coast and all coastal regions in Yemen, the IDPs could not live inside the ESK shelter made from plastic sheets installed on a wooden frame. UNHCR decided to upgrade this shelter adapting it to the local climate with local materials covering the ceiling and walls. The new shelter was designed with a strong ceiling to become later a Transitional Shelter Unit (TUS) for IDPs that they could upgrade themselves by adding earth walls along the external perimeter of the shelter or any additional local materials.

There is almost no difference between the TESK and the transitional shelter except for the earth wall, the wooden door and the metallic mesh on the wall.

The main challenge is the lack of availability of the local materials called *al-Khazaf*. This material is produced locally by host communities’ families in the Tihama area, and the production has to be anticipated to have a sufficient quantity. To address this challenge, UNHCR is trying to multiply sources.



Tahama emergency shelter using *khazaf* materials – ©John Wain, Shelter cluster



Transitional shelter pilot utilizing earth walls and *khazaf* – ©John Wain



Local shelter upgrade – ©John Wain



Transitional shelter, coastal region Abs District, UNHCR ©UNHCR

[6] Conclusions: Key points

NUCLEAR AND EXTENDED FAMILIES

- When relocating due to a crisis or disaster, it is necessary to consider the situation of families (nuclear or extended) so that residential units are not separated.
- In Yemen, nuclear family houses prevail in buildings of flats in urban areas. Nevertheless, in cities and the countryside, extended families still live in isolated houses as long as there is enough space for family members¹⁶¹.
- Yemeni houses are generally built for one nuclear family. In the case of several households, each one occupies a floor, thus constituting an autonomous cell¹⁶².
- Commonly, rooms are added to the father's house, and several families of the same patrilineal descent (extended family) are accommodated in the same building, each having a private area and sharing certain communal rooms. In the largest families, the parents live with the eldest son. The best rooms are reserved for the eldest and the youngest.
- Some spaces are culturally crucial: Al-diwan is the room used for the main events of the family's life, such as weddings, births and funerals. It is also the room where the owners of the house would sleep in case the house is crowded.

TASK SHARING IN CONSTRUCTION

- It is important to remind that in Yemen, working as a stonemason or bricklayer is regarded as an honourable pursuit, and only members of the highest social class are engaged in these skilled handicrafts. Long and proven practical experience is needed to obtain the highest title in the construction hierarchy. A young mason spends several years under the guidance and name of his master, who may be a parent or patron until he can work independently.
- Farmers are also builders, and they build their houses with the help of their families and neighbours. Outside help was called for technical details such as wood or plaster carving and, more recently, plumbing and electric wiring.
- Task sharing in construction is divided among men, masons and construction professionals, women, children and neighbours. It is essential to understand these dynamics when proposing housing or shelter programmes.
- It has to be raised that IDP beneficiary participation was important in the emergency and reconstruction shelter phases.

ACCESS TO SERVICES, WATER AND SANITATION

- The geographical dispersion of the Yemeni population is one of the main features of the country. This has implications on various levels, most notably on service provision and accessibility. The under-developed state of road infrastructure is one of the main factors causing the isolation of rural people, limiting their access to services and economic opportunities, and hampering the movement of people and goods¹⁶³.
- Access to safe water and sanitation remains a high priority which has the lowest global level of water availability per capita, coupled with increased water scarcity and WASH-related diseases that have reached critical levels.
- Water collection is a burden that falls on women and girls, and 39% of households report a travel time greater than 30 minutes¹⁶⁴.
- Sanitation remains a major public health risk, with open defecation practised by about 4 million people (13 % of the population)¹⁶⁴.
- Tackling these issues is crucial for every shelter or housing project.

¹⁶¹ (Sub-national hubs, 2022)

¹⁶² (Golvin, 2013)

¹⁶³ (Yemen National report, 2016)

¹⁶⁴ (OCHA, 2021)

SITE SELECTION

- The choice of a construction site is critical to safety whenever it is possible to choose it. One of the important aspects is to consider local knowledge, historical data and the opinion of local authorities and communities to know whether an area is subject to a specific risk. In addition, it is, of course, necessary to check the land tenure status. It is also crucial to build on relatively compact ground so that buildings do not move while considering the nature of the soil, which may be composed of expansive clays and require less important foundation solutions to avoid building cracking.
- In each area, there are recommendations, rites and customary rules for selecting the site to settle a house, for construction, etc. Therefore, it is essential to identify these aspects beforehand.

CONTEXTUALIZED HOUSING AND ARCHITECTURAL SOLUTIONS

- Yemen has a varied environment. In each area, human settlements and architecture are adapted to the climate and locally available resources. As a result, varied building solutions frequently occur in the same settlement or building.
- Yemeni houses can be classified into 4 types: nomadic tents, 1-storey reed houses, 1/2-storey brick houses with courtyard(s), 1/2-storey houses and multistorey tower houses.
- Regarding construction techniques, the main traditional construction types are the following: in the Tihama coastal region, the walls may be of reed or entirely of fired bricks; in the mountains and desert, the walls are commonly built with fired bricks, stones, earth bricks or piled earth (cob); in the coastal lowlands windows have no glass, being fitted with timber grilles and shutters - the *mashrabiyyah*, permitting a cooling breeze to enter the building in such humid conditions; in the uplands, high buildings have large, glazed windows that benefit from the winter sun.
- Choosing the most contextualized housing typologies and architectural solutions is essential for cultural appropriateness and bioclimatic design.

CHOICE OF MATERIALS AND BUILDING TECHNIQUES

- Materials used for contextualized construction are usually available in situ. Except for vegetal fibres used in the Tihama region, the traditional materials of Yemen are raw or fired earth and stone for the walls; wood and earth for floors and roof structures; earth, lime, and gypsum plaster for the rendering of exteriors and interiors; wood, alabaster, and coloured glass for wall openings, and iron or brass for fittings. Thus, earth construction is predominant in alluvial deposit areas and stone masonry on rocky slopes.
- Cement and reinforced steel are mostly imported, and the execution of reinforced concrete is often of poor quality for reasons such as lack of training, poor shuttering timber, inferior aggregates, polluted water, inadequate compaction and poorly maintained concrete mixers.
- After a disaster/conflict, shelter (re)construction responses increase the resource extraction rate for construction materials. Beware of resource over-exploitation and plan strategies for sustainable environmental management.
- Moreover, it is necessary to prefer technical solutions that promote the circular economy and allow most project funds to be injected into the local economy. If the budget spent remains within the local economy, there will be an impact on the improvement of the habitat of the families supported by the sector, but also for the whole population.

CONSIDERING LOCAL STRENGTHS FOR RESILIENT PROJECTS

- Finally, as discussed in chapter 4, “Analysis of local building practices”, local habitat strengths are an enormous potential on which to build shelter or housing projects. Therefore, analysing local housing and construction strengths is necessary to make project decisions that consider what is positive in a given place, strengthen it, and, most importantly, avoid worsening situations with inappropriate project decisions.

[7] Additional resources and bibliography

KEY CONCEPTS



Adaptive Capacity: The ability of systems, institutions, humans and other organisms to adjust to potential damage, take advantage of opportunities, or respond to consequences¹⁶⁵.

Disaster: Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic or environmental effects that require an emergency response(s) to satisfy critical human needs and possibly external support for recovery¹⁶⁵.

Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services, resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected¹⁶⁵.

Globalised habitat: Housing is influenced by “global trends” promoted in the media, but also by industrial companies and the formal education system. Cement, steel and CI Sheets are gradually replacing traditional materials, but such changes don’t always result in real improvements. Difficulties in affording respect for norms and standards lead to compromising space quality, thermal comfort and even structural safety.

Hazard: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources¹⁶⁵.

Local building cultures: A building culture is the intangible dimension of what is produced by humans to live, work, thrive, etc.. It includes assets related to each phase of the building life cycle: design, construction, use(s), maintenance, replacement, extension, adaptation, etc., that are linked to social, economic, environmental and cultural aspects. The genesis and evolution

of building cultures are closely linked to their environment and the specific history of each territory. This is why they are so diverse worldwide and why several building cultures can co-exist within a single territory.

Precarious habitat: This covers different realities depending on the factors that generate it: economic difficulties, climate change, disasters or armed conflicts. It characterises houses or shelters built by low-income families or those who, without a land property title, prefer to limit their investment by choosing light structures that are easy to dismantle or repair.

Resilience: The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation¹⁶⁵.

Risk: The potential for consequences where something of value is at stake and the outcome is uncertain. Risk is often used to refer to the potential for adverse consequences on lives, livelihoods, health, ecosystems and species, economic, social and cultural assets, services (including environmental services) and infrastructure.

Vernacular habitat: It is characterised by using local resources to respond to people's needs, way of life and local climate. It results from reproductions, improvements and ongoing adjustments or adaptations over time and often includes external inputs and imported solutions, though rather parsimoniously. Such constructions often rely on strong links between the inhabitants, their families and neighbours, and their persistence facilitates housing accessibility, pride and feelings of belonging within the community.

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt¹⁶⁵.

¹⁶⁵ (IPCC, 2014), AR5 Synthesis Report: Climate Change 2014

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