



# The relevance of earthen architecture in the Gaza strip

Rania Arar

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# **The Relevance of Earthen Architecture in the Gaza Strip**

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## **Abstract**

In Gaza Strip, housing construction projects have been exposed to various challenges due to the Israeli imposed siege and the shortage of construction materials. As the construction sector is one of the most important industries in the Gaza Strip and around the world, there has been an urgent need to think of alternative construction materials and new building techniques.

The purpose of this study is to improve and recover the housing construction sector in the Gaza Strip and find alternatives to deal with the housing crisis, through investigating the relevance and applicability of using earth as a construction material for housing projects in the Gaza Strip.

The different factors that have been affecting the use of earth materials were investigated through a feasibility study which included: detailed study of the local building culture, the construction sector and the availability of local materials, in addition to a questionnaire which targeted the citizens of Gaza and worked as a very effective method in investigating the feasibility, and finally stakeholders' analysis.

Development strategy for promoting earthen architecture was developed as a response to different factors that are affecting the widespread use of earth in housing projects. The strategy covered different approaches: the first approach was studying the contemporary architecture of Gaza. The second approach presented three earthen construction technologies that can be used in the contemporary scenario of the Gaza Strip. The third approach included three case studies of contemporary earthen architecture. Finally, different values of using earthen architecture have been elaborated.

The use of earth as a construction material is already initiated in Gaza, with a need for improving and developing in the construction techniques, as well as changing in the perception of people who perceive earth as a weak and fragile material. Thus, based on the result of the feasibility, the study concluded with proposing innovative earthen construction techniques, as well as recommendations.

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## List of abbreviations

| Acronym | Definition                             |
|---------|--|
| LBC     | Local Building Culture                 |
| GRM     | Gaza Reconstruction Mechanism          |
| NGOs    | Non-Governmental Organization          |
| UNRWA   | United Nations Relief and Works Agency |
| UNDP    | United Nations Development Program     |
| CEB     | Compressed Earth Block                 |
| ILO     | International Labour Organization      |
| RC      | Reinforced Concrete                    |

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# ***Chapter 1: Introduction***

## **1. Introduction**

This chapter introduces a background about the critical housing situation of Gaza Strip, and the innovative attempts of using alternative materials to respond to the crucial need for housing. The problem of the research is discussed in this chapter as well as the aim of the research, and highlights the research objectives, limitations and scope, followed by the significance of the research, and the research methodology that is used to achieve the aim and objectives of the research, and finally the primary and secondary research questions.

### **1.1 Background**

Earth is considered as the cheapest, and the most available and accessible material in the world, it has been used in different forms and techniques following the local culture, traditions, climate conditions, and the human needs. In addition, the advanced technologies of earth construction techniques are generally considered as a sustainable architectural solution for the 21st century as a construction material that achieves thermal comfort at a low cost in hot and cold climates. (Abboud, 2014)

Earth has been used in different countries around the world, it is one of the oldest building materials known to mankind for nearly ten thousand years, and it used through simple techniques to meet his need for shelter. The Tower of Babel which is the first skyscraper in history was built of mud in the seventh century BC; also building with earth in harmony with the environment was also spread in the civilizations of Mesopotamia and Egypt, and the Arab and Islamic civilization in India and Mexico and in various civilizations in Africa.

It is the way of building that people used to build their homes for at least 10,000 years in Jordan Valley including Jericho in Palestine, and in Gaza mostly in rural areas during the Ottoman era and continued until the early beginning of the 20<sup>th</sup> century. (Massad, 2013)

In Palestine, all buildings and structures are threatened with destruction, and Israeli companies export the vast majority of the construction materials to Palestinians, which is an expensive and unstable resource, as it depends on the political situation and restrictions imposed by the occupation authority. So building with earth material came as a tool to face critical housing situations.

Gaza Strip has a particular situation as a besieged area, the successive Israeli wars caused massive destruction of buildings; a lot of people are still homeless or living in caravans, in addition to the collapse of the economy; as the construction sector is considered one of the main sectors in Palestine, and contributes to the operation of 12.2 % of the labor forces in the Gaza Strip and West Bank. (Sawalhi & Abu Ajwa, 2014)

Accordingly, a new thinking of construction sector has started in order to find affordable alternative materials such as earth, and passive architectural designs, to overcome the financial problem and revive the social and cultural links.

Innovations in the building sector have been initiated, in response to the needed shelters. Earthen construction has been revived as a tool to face the political situation and the ultimate need for housing and public structures due to the impossibility of importing sufficient amount of construction materials such as cement and steel.

Several attempts have emerged out individually or by international organizations in the Gaza Strip to use earth as an alternative construction material, with recycled local materials to provide housing in emergency situations. But the prevalence of this kind of architecture is still limited to few buildings and individual attempts, and needs to be enhanced in Gaza community as it's still perceived as a poor architecture and people have doubts about its durability.



Figure 1 Governmental building using Mud-bricked in Gaza. Source: (Fayez, 2009)





Figure 2 (Left) Production of mud bricks in Gaza. Source: (BBC News, 2009)



Figure 3 (Right) House of sandbags in Khan Younis-Gaza. Source: (Aljazeera, 2011)

This research aims to study the relevance and potential of earthen architecture in the Gaza Strip, by developing a feasibility study to explore the barriers and the opportunities of using earth as a construction material to alleviate the suffering of people, and then to develop a strategy that corresponds with the output of the feasibility study which in turn will contribute to support the explored and existing opportunities in the Gaza Strip, and open up to innovative earth techniques and alternative solutions.

## 1.2 Problem Statement

The successive wars on the Gaza Strip have caused a huge building destruction. With the imposed siege that hinders the entering of construction materials, the construction and reconstruction process have become impossible, and the housing tragedy is becoming increasingly complicated.

After the war of 2014, 78 % of the citizens have been forced to build and live in poor quality houses, tents and caravans. Thus, the thinking of alternative construction resources and techniques has emerged. However, the use of alternative resources and techniques such as earth does not seem to be enough widespread to meet the urgent need of housing. From here, the research came to deal with the housing emergency in the Gaza Strip, in light of the limited lands and resources, and investigate the reasons of the limited usage of earthen construction as an alternative solution for housing.

### **1.3 The aim and objective s of the study**

- The aim of the research is to intensify the number of housing units, as a response to the crucial need of housing in the Gaza Strip which has very limited available lands and high population growth, and investigate the relevant and visibility of the earthen architecture in the Gaza Strip.
- Study the potential, relevance, and the feasibility of using earth as a material for construction purposes in the Gaza strip.
- State the problems and barriers toward adopting earthen houses in the Gaza Strip.
- Study various earth construction techniques that can be applicable and acceptable in the case of the Gaza Strip.
- Clarify the potential of earth material in contemporary architectural scenario.
- Identify the applicability of using earth for housing in the Gaza Strip, and its role in respecting the sustainability dimensions.
- Encourage the community and increase the awareness to think of alternative and innovative construction techniques for housing.

### **1.4 Research limitations and scope**

1. The main focus of the study will be on housing projects in the Gaza Strip; as a priority for helping people and enhancing the economic sector, and particularly in Gaza Strip because it has currently the most serious situation in Palestine.
2. The collected data mainly depends on previous studies and online questionnaires, as it is quite difficult to have an access to Gaza for direct interviews due to the political situation, in addition to the difficulty that faced me in posting the online questionnaire via Face Book pages.
3. This research targeted both; the citizens of Gaza who were asked to answer the online questionnaire, and construction professionals and different stakeholders who will benefit from the outcome of this research for future earthen projects in the Gaza Strip.

The scope of the research is to develop a comprehensive strategy that can be a helpful tool for innovative housing projects in the Gaza Strip.

## **1.5 Significance of the study**

Housing is an urgent need in Gaza Strip, and its provision is a main tool towards helping people who are still living in misery situations, as well as revive the construction sector which is considered the main sector that contributes to the economy of the Strip.

This study can be used as a theoretical basis for concrete practices using earth and future housing projects, as it depends on understanding the perception of people of Gaza, answering their doubts associated with earth materials, and works on encouraging and promoting the use of earthen architecture. Thus, increasing the awareness of people and professionals in the Gaza Strip towards new unique alternative ways of construction can be considered the first step to contribute to the widespread use of contemporary earthen architecture in the Gaza Strip.

## **1.6 Research Methodology**

In order to answer the research questions and achieve the research objectives, the study depends on primary and secondary data.

The primary data has been identified as "data originated for the first time by the researcher through direct efforts and experience, specifically for the purpose of addressing his research problem". (keydifferences, 2016). Concerning that an online questionnaire has been conducted with the people in the Gaza Strip, through social networking pages dedicated to the people of Gaza, and that will be detailed in the questionnaire analysis part in chapter 3. The primary data has been developed in order to understand the relevance and potential of applying earthen architecture in the Gaza Strip.

The secondary data has been defined as "second-hand information which is already collected and recorded by any person other than the user for a purpose, not relating to the current research problem". (keydifferences, 2016). This kind of data depended on various resources in order to reach an accurate and various information about the situation of the Gaza Strip from different aspects. The resources included: journals, articles, books, censuses, governmental documents, organizations' publications, and websites.

## 1.7 Primary and secondary research questions

| Primary research question   | The source of data         |
|---|----------------------------|
| How to use earth as an alternative and complementary material to intensify the number of housing units in a very limited available land and resources, taking into consideration the high population density? | Secondary data             |
| <b>Secondary research questions</b>   |                            |
| How to encourage the people in Gaza to adopt earth as a material for housing construction?  | Primary and secondary data |
| What are the added values of adapting earthen architecture in the Gaza Strip?   | Secondary data             |

Table 1 Primary and secondary research questions. Source: Author, 2017

## **1.8 Description of the thesis's chapters**

The thesis is represented in six chapters:

The first chapter "introduction" gives an overview about the topic of the research. This includes: general background about earthen architecture and its relevance in the Gaza Strip, problem statement, aim and objectives of the study, scope and limitations of the research, the significance of the study, research methodology, followed by the research questions, and finally the description of the thesis's chapters.

The second chapter "literature review" describes the living conditions and challenges in the Gaza Strip, through studying the population growth and density, the size of buildings' damages, the housing emergency, and the existed buffer zone and its effect on the land use of the Gaza Strip.

The third chapter "feasibility study" investigates the potential of using earth materials for construction purposes. The feasibility study included five aspects: the local building culture of Gaza Strip, the construction sector and the available local building materials in Gaza Strip, constructing a questionnaire, and stakeholders' analysis.

In chapter four, development strategy concerning promoting earthen architecture in the Gaza Strip has been developed based on the results of chapter three. The strategy followed four approaches: studying the contemporary architecture of Gaza, introducing three earthen construction techniques which are: adobe, compressed earth block (CEB), and rammed earth, in addition to presenting three case studies of earthen contemporary architecture, and finally clarifying the earthen architecture values.

The chapter five "design and technical proposals" includes design concepts and technical construction proposals, which are: in-fill walling technique, envelope technique, floors extension, and new housing units.

Chapter six "conclusions and recommendations" is the final part of the research and it is dedicated to discuss the results of the research as well as providing recommendations for future housing projects and research concerning earthen architecture in the Gaza Strip.

## **Chapter 2:** *Literature review*

## 2. Introduction

This chapter analyzes the current situation of the Gaza Strip through studying the context of the research, its population census and population density, and the size of building's destruction and the crucial need for housing, followed by the challenges that are facing the Gaza Strip resulting from the imposed Israel's buffer zone.

### 2.1 The context

Gaza Strip is located in the south-eastern of the Mediterranean Sea, and the south-western part of Palestine, with an area of about 360 sq. km, and about 1.79 millions of people living there; which make it one of the most densely populated areas in the world. Gaza Strip is an isolated area, surrounded by five borders: four with Israel and one with Egypt. Gaza has five major cities and eight refugee camps. It is one of the most populated cities in the world, with about 5,000 people/sq. km, and increasing natural population 3.41% per year, which increases the need for housing. (Muhaisen, Development of the House Architectural, 2016)



Figure 4 Location of the Gaza Strip.  
Source: (Muhaisen, 2016)

### 2.2 Population

Population growth is increasing and expected to grow to 2.13 million by 2020, the population density of the Gaza Strip is considered the highest in the world; 4,505 people live on one square kilometer, and with increasing the growth in such a limited area it is expected to reach rise to 5,835 people per square kilometer by 2020. (BBC, 2014)

The following map shows the population density respectively from the highest to the lowest population density in five major cities in the Gaza Strip; Gaza City, North Gaza, Dier al Balah, Rafah, and Khan Younis.

Gaza City and North Gaza respectively are the densest parts of the Gaza Strip. To give more sense of the high population density, the map shows a comparison between the size of London and the size of the Gaza Strip which almost have the same population density while having a big difference in sizes; where London is three to four times the size of the Gaza Strip.

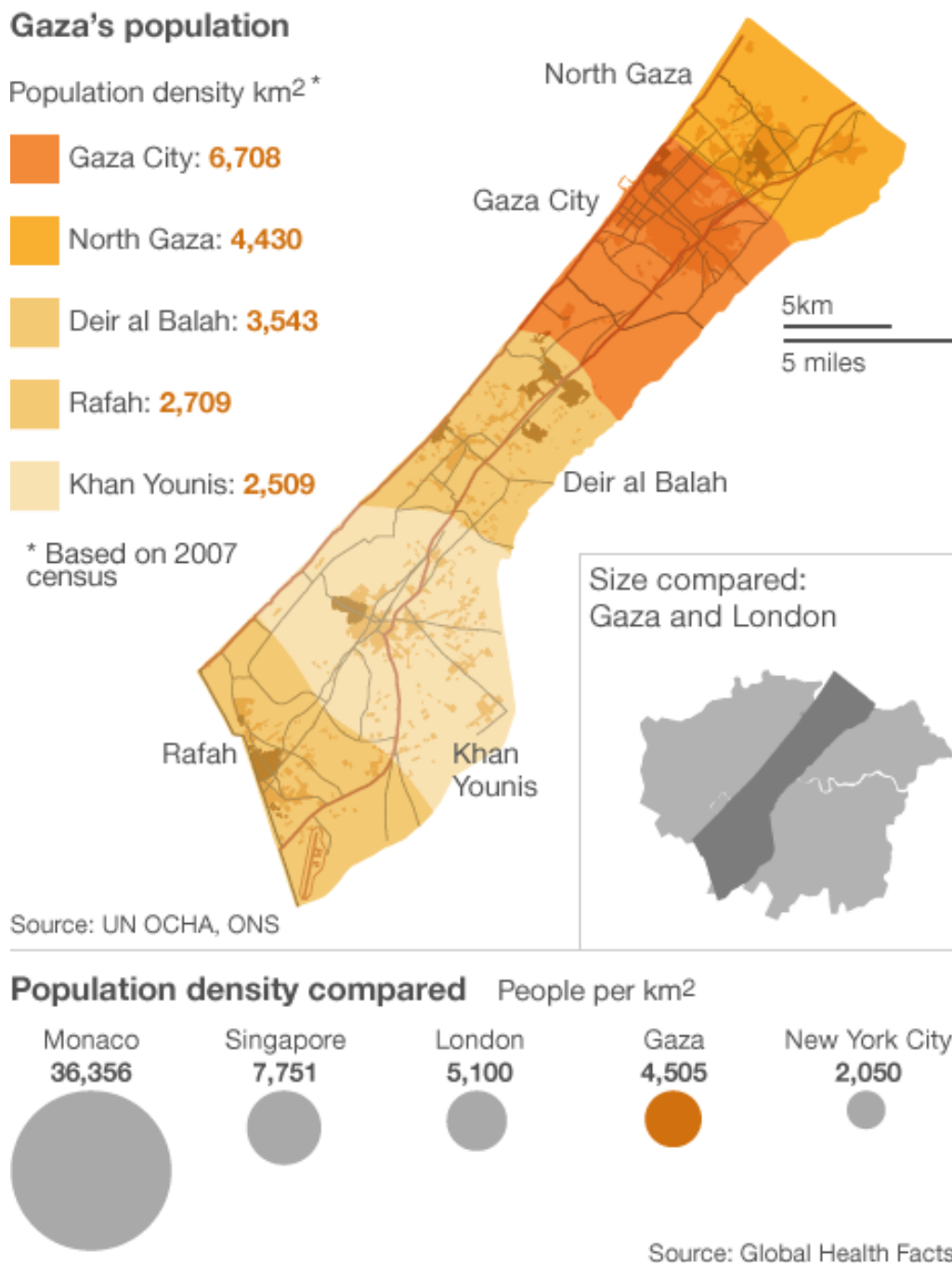


Figure 5 Gaza's population. Source: (BBC News, 2014)



## 2.3 Housing emergency in the Gaza strip

Gaza is considered one of the most emergent zones in term of housing. During the 50 day of war from 8 July until 26 August 2014, 2,251 Palestinians were killed, with a huge scale of destruction; 10,000 housing units were completely damaged, 10,000 housing units with severe damages, and about 40,000 housing units were partially damaged. (Germanà & Alatawneh, 2016). 500,000 persons were displaced and 75,000 persons remain displaced to this day living in rubble, caravans and tents, and not able to build their own houses. (UNRWA, 2017)

The map shows in detail the size of destruction in the five main cities of the Gaza Strip during the war of 2014, where the most affected areas are located in the north and the south of the Strip.

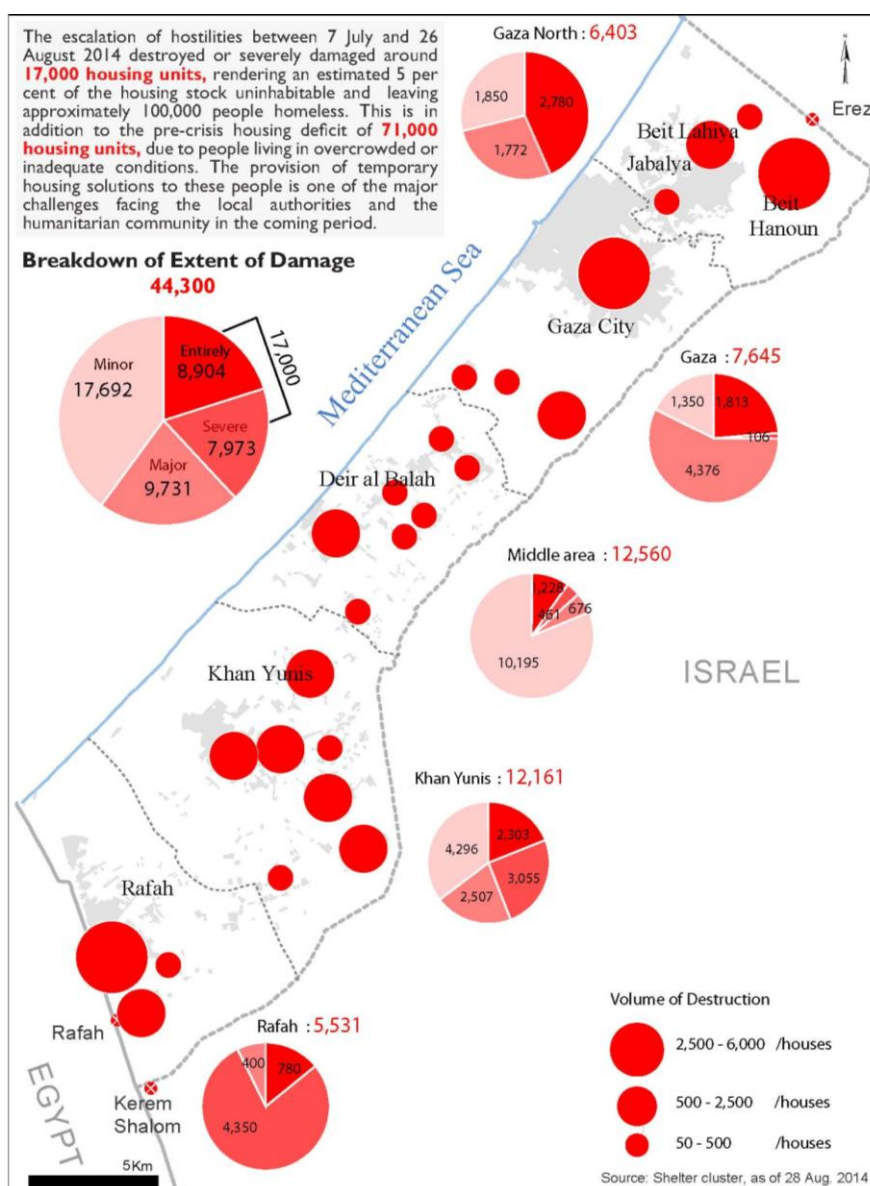


Figure 6 The housing emergency in the Gaza Strip. Source: (OCHA, 2014)

| Severe Damage  | Partial Damage  | Total Damage  |
|--|---|---|
| “Housing units where the skeleton incurred heavy damages to such an extent that it has become unsuitable for living.” (UNDP, 2014) | “Housing units that incurred damages while the house is still adequate for living. In case the damages are less than USD 5,000 it can be categorized as a house with minor damages”. (UNDP, 2014) | “Housing units that are totally in rubble or where at least 50% of the structure of the house has incurred severe damage”. (UNDP, 2014) |

Table 2 The classification of damage. Source: (UNDP, 2014)



Figure 7 (left) Severe Damaged apartment, source: (Harriet, 2015)

Figure 8 (Middle) Partially damaged house, source: (Arnesen, 2009)

Figure 9 (Right) Totally damage buildings, source: (Schilling, 2014)

With the lack of construction materials and the increasing of the population growth, it is expected by 2020 that additional 71,000 houses are needed due to the inadequate and overcrowded level of living conditions. (OCHA, 2016)

The imposed restriction on entering the construction materials hinders the completion of housing projects. From the thousands of tons (approximately 577,000 tons) the needed cement, only 4% of the needed cement is available. 39% of the affected buildings have been rehabilitated, and only 16% of the totally destroyed houses have been completed.



Figure 10 Progress in construction of 17,800 homes destroyed or severely damaged during 2014 conflict: Source (OCHA, 2016)

## 2.4 The buffer zone and land use

According to the UN, 2009, "The area inside the Buffer Zone along the northern and eastern borders with Israel contains nearly a third (29%) of the Gaza Strip's arable land, and is inaccessible to farmers." This in turn means that 100% of the Israel's buffer zone is arable lands. According to the UN, the buffer zone is extended to 3 Km by 2014, in the northern and eastern part of the Gaza Strip, with a total area more than 40% of the strip. (IMEMC Agencies, 2015)

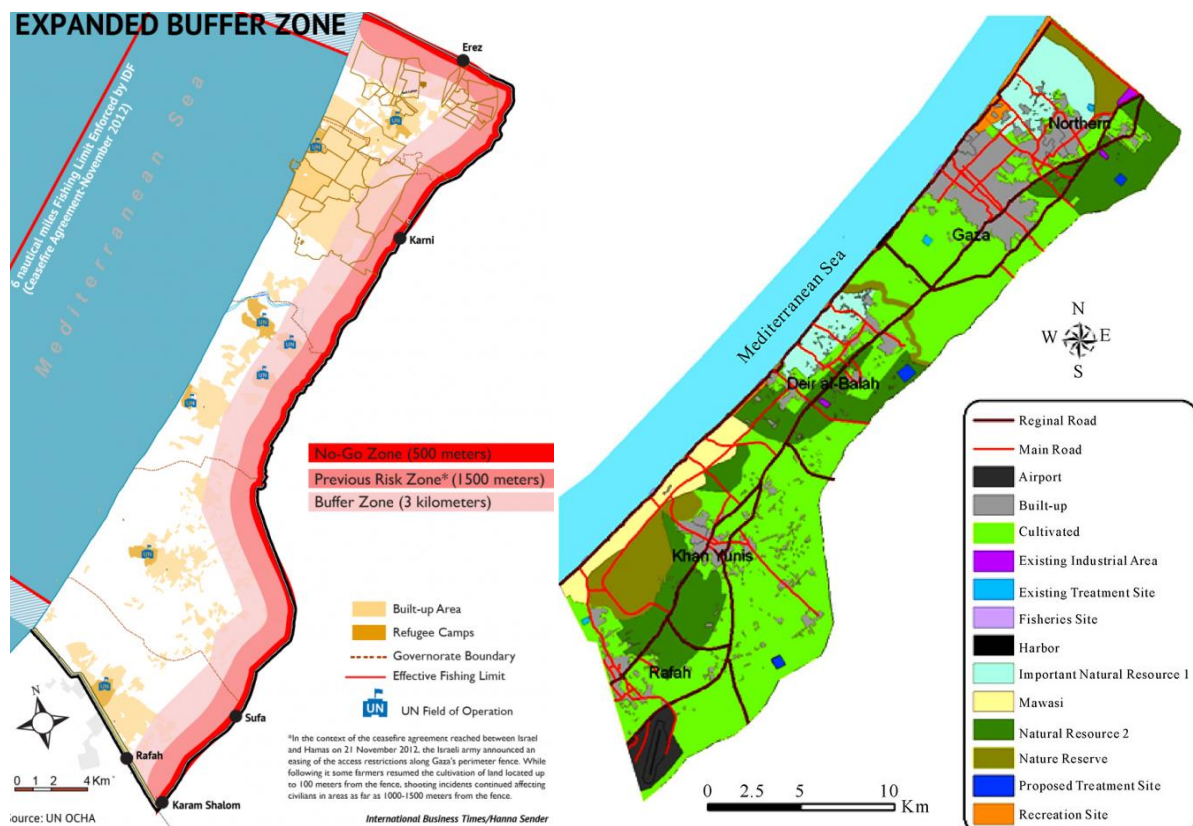


Figure 11 (left) The buffer zone map in the Gaza Strip. Source: (Sennder, 2014)

Figure 12 (Right) Land use in the Gaza Strip. Source: (Shomar, Abu Fakher, & Yahya, 2009)

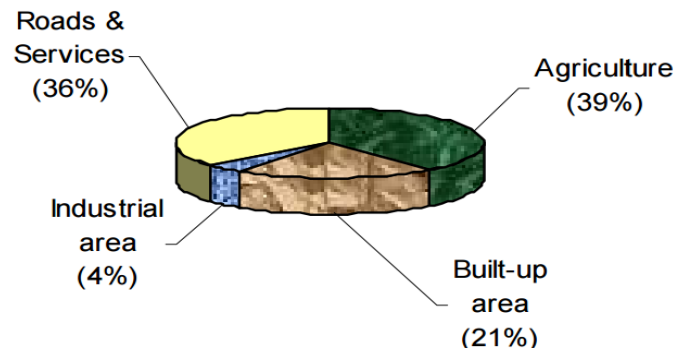


Figure 13 Major land use sectors in the Gaza Strip. Source: (Shomar, Abu Fakher, & Yahya, 2009)

The graph clarifies that 39% of the Gaza strip lands is agricultural areas, most of which located in its eastern part, where around 30% of which is located in the Israel's buffer zone. (IMEMC Agencies, 2015)

Many residential agglomerations are located on the edges of the buffer zone, which justifies the large destruction in these areas during the wars particularly in the northern part of the Strip.

## 2.5 Conclusion

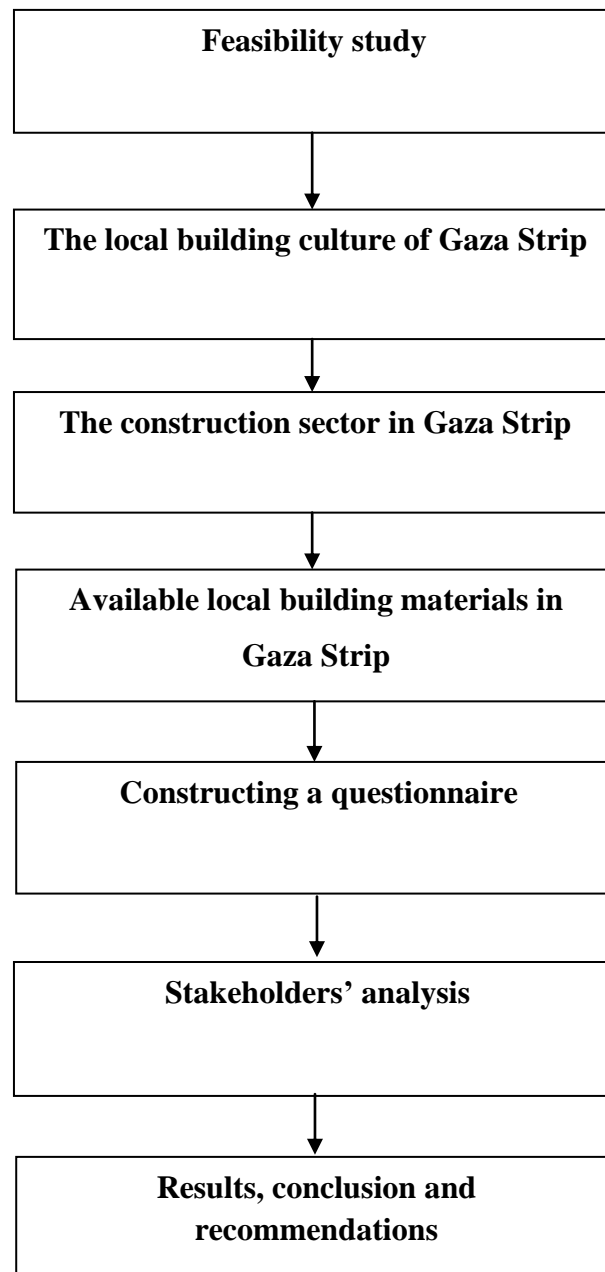
Gaza Strip suffers from high population density and population growth, and the buffer zone controls the land use distribution of Gaza, as people are not able to build or work in the agriculture field in high risk zones. Thus, meeting the housing needs is becoming increasingly complex.

The current situation forces to deal with these challenges and achieve the best use of the available lands through deep understanding of the context and its available resources that could be the key to mitigate the suffering and risks resulting from the lack of adequate housing.

## **Chapter 3: Feasibility study**

### **3. Using earth as a construction material in the Gaza Strip**

In order to investigate the opportunities and challenges of using earth for constructions in the Gaza Strip, detailed study has been carried out depending on four main factors which are: the local building culture, the construction sector, available local building materials, stakeholder analysis, and the conducted questionnaire.



### **3.1 The local building culture (LBC) of Gaza Strip**

The LBC is the result of "adapting a community to the environmental conditions of territory in which it is established" to produce "a situated architecture and building systems respectful of their local environment". These building practices are "the result of people's customs, beliefs and capacities", and "a consequence of available resources, local climate, social practices and cultural models", which result in various building cultures around the world. (Markovic, 2016, p. 28)

According to (Caimi et al, 2017, p. 5) "A local building culture results from the adaptation of a community to the environmental conditions of the territory in which it is established - physical, climatic, social, economic and cultural".

Several construction techniques have been used over the years, depending mainly on earth materials such as clay, stone, mud, sand and others. The Palestinian buildings including Gaza's houses are classified as traditional and contemporary houses; traditional houses that used natural earthen materials and mainly characterized by thick slabs and walls that have low thermal transmittance thus high thermal comfort, whereas the contemporary houses depend on new materials with thin slabs and walls and high thermal transmittance.

In order to investigate the relevance of earthen architecture in the Gaza Strip, the first step will be through studying the local building culture in the Gaza Strip.

Mud and sand are considered the main local materials that have been traditionally used in houses construction in Gaza Strip. Three types of houses have been classified according to construction materials which are: sandstone houses, mud houses, and concrete houses.

#### **3.1.1 Sandstone houses**

Sandstone was used as a building material for thousands of years in the Gaza Strip by rich people, it is also used as a material of historical monumental and all buildings made of stone in Gaza. (Muhaisen, 2016)

It exists along the coast, easy to quarry and dress, with using plaster for the exterior walls, as it behaves badly with weather fluctuations. (Hadid, 2002)

The majority of these houses were built in the Ottoman era, and continued in the Gaza Strip in the period 1517-1914. (Muhaisen, Development of the House Architectural, 2016)

Sandstone was considered the basic building material for the rich; it represents a distinctive architecture and elements in the old city of Gaza. The sand was extracted from ancient quarries located in the east and north of the old city of Gaza, these quarries are not almost available as it was covered with the expansion of the built up area, especially with the stop of using such material during the 20<sup>th</sup> century.

The houses were built of sandstone, one or two floors maximum, with uncovered stair case leading to the upper floor, walls were thick, and roofs were vaulted made of intersecting sandstone arches, and it looks flat from the top.

- **Design elements and characteristics**

The courtyard was the main feature of the traditional houses in the old city of Gaza; surrounded by small habitable rooms. The courtyard is considered the heart of the house, as all the daily and social activities were happening in it, in addition to its environmental advantages in providing comfortable thermal zone, especially with planting it with some vegetation and trees. The courtyard was an important factor in letting in natural light, internal shade areas in summer, and warm sunshine during winter. (Muhaisen, Development of the House Architectural, 2016)

Using decoration elements such as columns and arches were used for aesthetic value, as well as representing the socioeconomic level of the occupants. The visual privacy was a very important issue; that was represented by broken entrance, and small few openings, in addition to the function of these factors in keeping the internal space clean of dust.



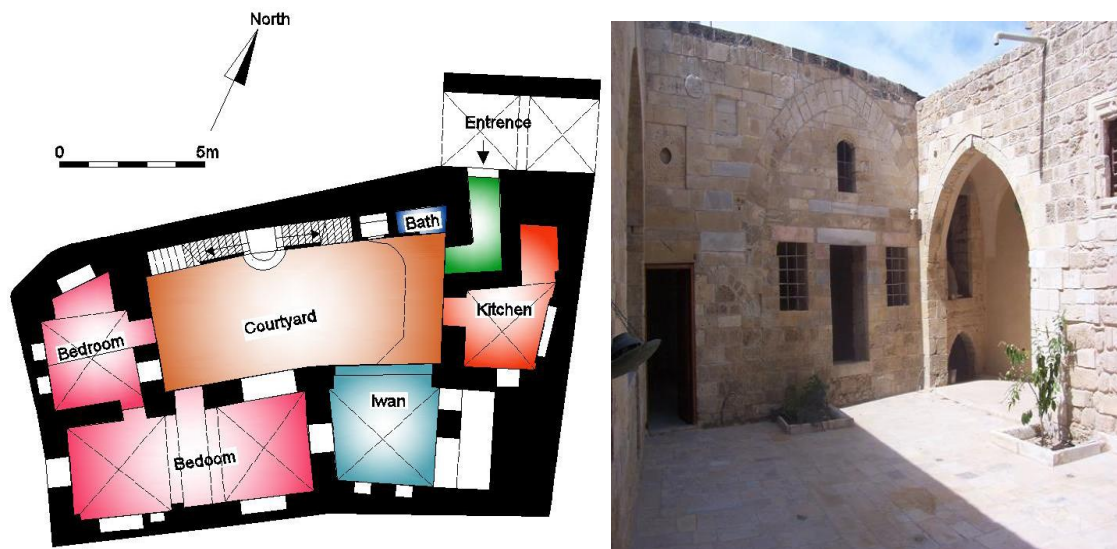


Figure 14 (Left) Plan of a Courtyard Sandstone House in Gaza (Alamy House). Source: (Muhaisen, 2016)

Figure 15 (Right) Courtyard Spaces in Sandstone Houses in Gaza. Source: (Muhaisen, 2016)

### 3.1.2 Mudstone (sun dried bricks)

Mud was extensively used by poor, low-income people and farmers, because of its low cost in comparison with sandstone. Mudstone houses were almost located in periphery areas outside the city and rural areas. (Muhaisen, Development of the House Architectural, 2016)

Clay is considered the basic material to erect the walls and roofs, supported by branches of local trees such as palm, sycamore and eucalyptus trees.

- **Design elements and characteristics**

The mudstone houses were made up of small rooms, and big rooms for crops and animals, around a small courtyard, where there was a part of it dedicated for a mud oven. For the large rooms, the roof took the form of intersecting vaults, made of stone arches supported by stone pillars placed in the mud walls, for the small rooms, the roof was flat made of trunks and trees branches and covered with mud from the top. (Muhaisen, Development of the House Architectural, 2016)

Unlike sandstone houses, domed and vaulted roofs did not usually exist, because of the modest techniques skills of the owner and his neighbors, and the need for well trained workforces.

The mud construction was usually made collectively; the owner was building his house with a cooperation with his friends and neighbors which reflects a unique social cohesion.

Openings were high and small in order to maintain privacy and natural ventilation. The mud has various advantages that contributed to be widely spread over a long period of time such as: it's the availability as simple and cheap material that is easy to build and form with without high skilled workforce, in addition to the thermal isolation characteristics of mud walls and roofs.

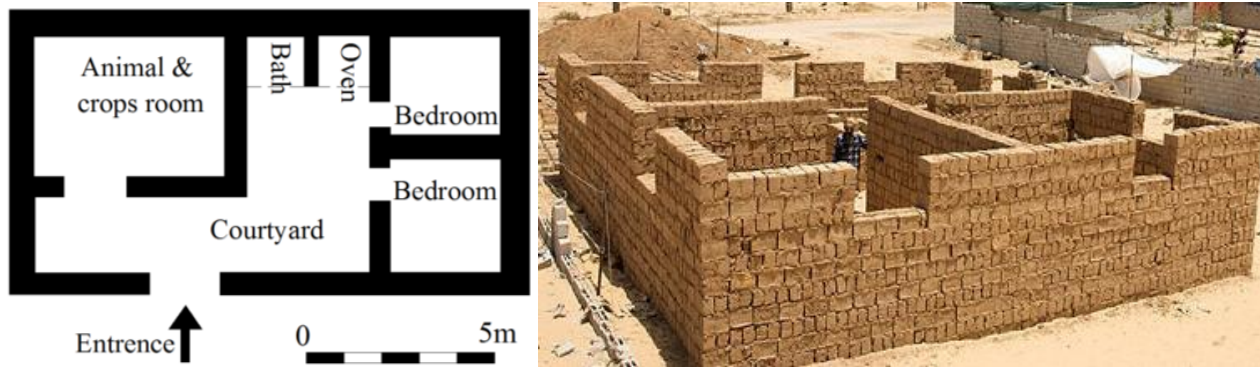


Figure 16 (Left) Plan of Traditional Mud House in Gaza. Source: (Muhaisen, 2016)

Figure 17 (Right) Recent Mud House in Gaza in the Construction Process. Source: (Muhaisen, 2016)

In spite of these advantages, some disadvantages like the low resistance to moisture and rain water, in addition to the limited vertical and horizontal expansion hindered the continuity and development of this kind of architecture.

The majority of these buildings are no longer available; they disappeared, because of the lack of maintenance and continuous destruction of them to build new cement houses. Only 130 houses based on these techniques (sandstone and mudstone) are still existed in the old city of Gaza.

Currently, due to the shortage of the cement material, some governmental, international and private initiatives have called for reviving the construction with mud as a temporary solution. Thus, few public and individual initiatives have appeared and achieved kind of success, but due to some disadvantages of mud construction in term of water resistance, durability, maintenance and the limited availability of mud in the Gaza Strip, and the destructive impact on the agricultural area in case of its overuse, the mud construction expansion has been undesirable. (Muhaisen and Ahlbäck, 2012)

### **3.1.3 Concrete houses**

With the entry of cement material in the first half of the 20th century, concrete houses widely spread to become the most common way of construction. Concrete structure provided a high degree of construction flexibility, which allows speed building process, and vertical and horizontal expansion. Thus the using of sandstone and mud discontinued and stopped in the second half of the 20th century. (Muhaisen, Development of the House Architectural, 2016)

The construction sector in Gaza Strip has extremely developed after introducing the cement; it allowed for free exterior and interior design with a variety of finishing materials, and multi-story buildings in very limited areas to respond to the high need for housing. This in turn led to increase the population density.

Besides these positive characteristics, this transformation brought some negative impacts on losing the local culture and unique architectural elements, in addition to the loss of the local architectural identity of Gaza Strip, where concrete buildings are a global style and existed everywhere around the world. From other side, the high thermal conductivity and low thermal resistance of concrete in compare with sandstone or mud led to the reliance on technology to provide comfortable thermal condition.

- **Design elements and characteristics**

Multi storey concrete buildings are widely spread in Gaza strip; the flats in each floor usually consist of three main zones: sleeping, living, and service zones, with exterior balconies. (Muhaisen, 2016)

Privacy principles are also applied in the design and zones arrangement of the house. For example, the guest room, kitchen and WC have to be near the entrance.

The buildings structures are made of reinforced concrete, the walls are erected by concrete hollow blocks. Windows have medium size, with aluminum frame and single glazed.

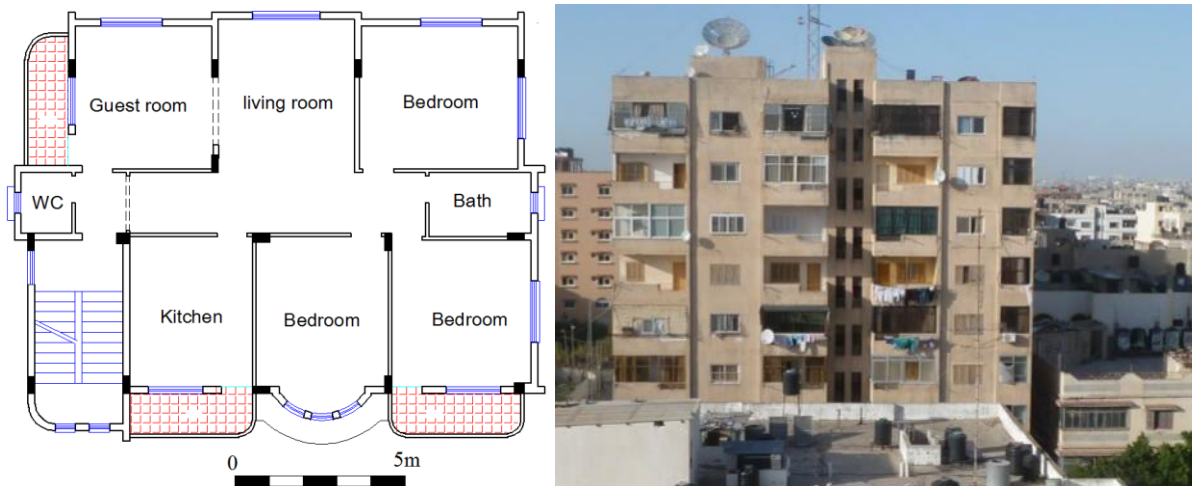


Figure 18 (Left) A plan of a single flat of Multi-stories concrete building in Gaza. Source: (Muhaisen, 2016)

Figure 19 (Right) Multi-stories concrete house buildings in Gaza. Source: (Muhaisen, 2016)

### 3.1.4 Contemporary residential buildings in the Gaza Strip

The contemporary style of the Gaza Strip started to be appeared since 1995s, influenced from the post-modern designs. (Badawy, 2012)

The types of residential buildings:

1. Separate house: the single house style is usually popular for extended families, it usually has two floors; the building materials are either concrete or hollow blocks, plastered and painted exterior walls, and lack thermal isolation so they are hot in the summer and very cold in winter. The separate houses have good ventilation from four sides.  
This type of houses exists in all cities and villages of Gaza.
2. Villas: villas exist in modern architectural style in cities and villages in Gaza, they usually built for young families, with hollow blocks as a building material and in some cases they built with concrete, and they are plastered with stone.
3. Apartments:
  - Low and medium rise buildings: in highly populated urban areas, buildings blocks are distinguished for housing accommodations. The demand for these apartments was increasing as a result of population growth. The number of floor reaches 7 above the ground level, with 1, 2, or three apartments in each floor. The building materials are also concrete and hollow blocks.

- High rise (tower) buildings: this type of buildings exists since 1995, it can reach 15 floors, it has been used for residential and office functions. The facades usually built concrete material and painted with light colors.



Figure 20 (Left) Common style of separate house in Gaza. Source: (Aqarfelesteen, 2015)

Figure 21 (Middle) Type of villas in Gaza. Source: (Sogarab, 2014)

Figure 22 (Right) Multi-stories building in Gaza Strip. Source: (Aqarfelesteen, 2016)

Hollow concrete is used in Gaza cities, villages and refugee camps as a cheaper material in compare with stone, which is 45% less than the total cost of stone building.

A survey done by the Ministry of Public Works and Housing in 2011 after the first war in Gaza found that the foundations of 1000 house of one story out of 3,500 demolished units were designed to be vertically extended up to 3 to 5 floors.

### **3.2 The construction sector in the Gaza Strip**

Studying the current condition of the construction sector contributes to determine the strength and weakness points as well as opportunities associated with developing the housing sector in Gaza.

According to local and international organizations, there is a significant shortage in the needed housing units to meet the population growth. The rapid population growth in combination with the imposed blockage and the destruction housing process before and during the Gaza war, are the main causes of the inadequate housing conditions. (Muhaisen and Ahlbäck, 2012)

Various organizations had efforts to provide houses and overcome this problem, but insignificant outcomes have been carried out up to now; only 12% of the houses have been reconstructed. 78 % of

the citizens are living now in caravans and tents due to the lack of construction materials and infrastructure services. (The Independent Online, 2014)

Increasing the demand for buildings construction will in turn increase the demand for resources to unsustainable levels. (Muhaisen and Ahlbäck, 2012)

The degradation in the construction sector also contributed to a high unemployment rate up to 58%. (Worldbank, 2017). In 2005, the construction sector provides 22,220 employments, and dropped to 4800 by the end of 2009 due to the blockage that hinders the access of construction materials. In the late of 2010, the number of workers in the construction sector slightly increased to reach 7900, due to limited easing in the entering of construction materials.

Some construction projects are done by international organization using the allowed quantity of construction materials in addition to smuggling materials through the tunnel under the border with Egypt. (Muhaisen and Ahlbäck, 2012)

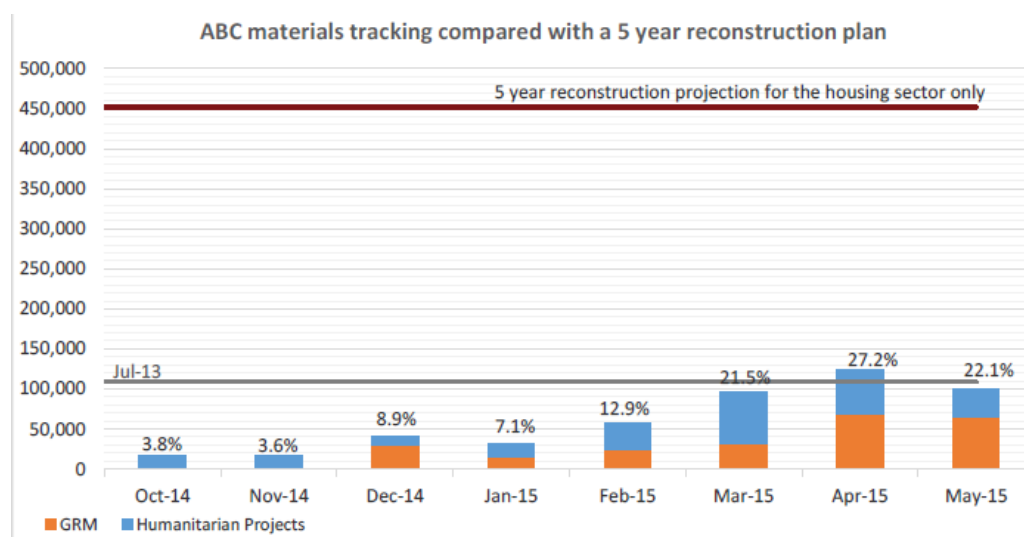


Figure 23 Quantities of construction materials entering Gaza (ton) Oct 2014- May 2015. Source: (Palestine Shelter Cluster, 2015)

The humanitarian projects in the graph included only the construction materials that are used to construct public buildings and not housing, while the materials that enter by GRM (The Gaza Reconstruction Mechanism) a portion of which is used for housing construction and the other is used for public buildings. (Palestine Shelter Cluster, 2015)

The 5-year projection line represents the needed ABC materials for housing construction for the next 5 years. It includes the wars before 2014 and the war of 2014, as well as an expectation of the amount of houses needed as result of the natural population growth of Gaza.



The restrictions imposed by the Israeli authority on external trade have highly affected the economic potential of Gaza. The smuggling through tunnels have been developed in order to provide the basic building materials, it is estimated that in 2012 1.7 million tons of aggregate, cement and steel bars were imported through the tunnels, and one million tones of the same materials entered the Gaza Strip from Kerem Shalom in the south of the Strip only for authorized projects.

Most of the newly constructed buildings in Gaza strip have been constructed by exporting the construction material from outside and especially from Israel, since the siege and especially after the Cast Lead Operation in 2008, the amount of exported construction materials became very limited.

### **3.2.1 Construction training centers in the Gaza Strip**

Several training centers are existed in the Gaza Strip; belonging to NGOs, and international, private and governmental organizations. They provide technical and professional training to the workers in the construction domain, such as: plastering, tiling, carpentry, electrical installations, air conditioning, building construction, metal work, bumping, and others for around 150-200 students each year. (Muhaisen and Ahlbäck, 2012)

The government has four training centers and they provide different training courses, the United Nations Relief and Works Agency (UNRWA) have two training centers to train refugee students.

Traditionally, workers inherit the construction profession from one generation to another; they acquire skills and trainings from the worksites, in a preference of ensuring regular income rather than long period of training in training centers.

Beside training centers, there are community colleges and universities that have different specializations related to building construction activities. About 70-100 students graduate annually from the colleges with a diploma certificate, in addition to 300-350 architects and engineers graduate from local universities.

These centers are considered a big opportunity for construction practices, although they still in need for improvements to deal with the current requirements, in addition to updating the trainer with the latest construction practices. Labs are below the needed standards, which affect negatively the proficiency of the acquired skills, with a better level in the universities of Gaza, but still improvement is needed.

### **3.3 Available local building materials**

#### **3.3.1 Recycled construction material**

Local and international organizations have given attention to reusing and recycling rubble that resulted from extensive destruction of buildings during the wars, in an attempt to find alternative materials and improve the construction sector. (Muhaisen and Ahlbäck, 2012)

For example, the war in 2008 generated about 600,000 tons of concrete rubble; the recycling process focuses on producing aggregate to be later used for concrete mixes, blocks manufacturing, and roads constructions.

In late 2010, the aggregate produced from recycling processes was approximately 38,000 tons. There are 30 to 50 small rubble crushers in Gaza, privately owned; they employ 180-300 workers directly involved in the rubble recycling, and other workers indirectly work in collecting the rubble and crushing blocks from destructed sites in Gaza. Two big rubble crushers belong to the United Nations Development Program (UNDP) also produce aggregates for concrete mixes and road construction purposes.

Tests results indicate that the concrete made using crushed construction and demolition wastes gives almost as much as strength as normal concrete.

Block factories are also distributed along the Gaza strip; they manufacture blocks from their producing of small aggregates. The using of recycled materials as well as smuggled materials through tunnels has contributed to revive the construction sector. The availability of these materials is declining and it has become a depleted source, thus the employment in these activities is also declining. (Muhaisen and Ahlbäck, 2012)

#### **3.3.2 Alternatives and natural resources**

Other traditional and local building materials can be used as alternative resources; such as steel sheets, wood, plastic bottles, however, the availability of these materials is limited, in addition to their doubtful quality that don't allow large scale use in the construction sector. (Paccoud, 2015)

Earth materials are considered an available and sustainable resource for construction purposes. The using of earth materials depends on the available type of soils, and the construction technique that will be used later.



The following map clarifies the six types of soil in the Gaza Strip, which are; dark brown/silty clay, loess soil, loessal sandy, sandy loess soil over loess, sandy loess soil, and sand regosols. Each type of soil has different percentages of sand, clay, and silt, and depends on these percentage the earth construction technique will be determined.



Figure 24 Soil map of Gaza Strip. Source: (Hamad, Eshtawi, M. Abushaban, & Habboub, 2012)

| Soil classification                | Sand% | Clay% | Silt% |
|------------------------------------|-------|-------|-------|
| <b>Sandy</b>                       | 87    | 9     | 4     |
| <b>Loess soil</b>                  | 58    | 6     | 34    |
| <b>Loess sandy soil</b>            | 66    | 14    | 20    |
| <b>Sandy loess soil</b>            | 56    | 23    | 27    |
| <b>Sandy loess soil over loess</b> | 66    | 18    | 16    |
| <b>Dark brown/reddish brown</b>    | 62    | 25    | 13    |

Table 3 Soil parameters for Gaza Strip. Source: (Hamad, Eshtawi, M. Abushaban, & Habboub, 2012). Edited by author.

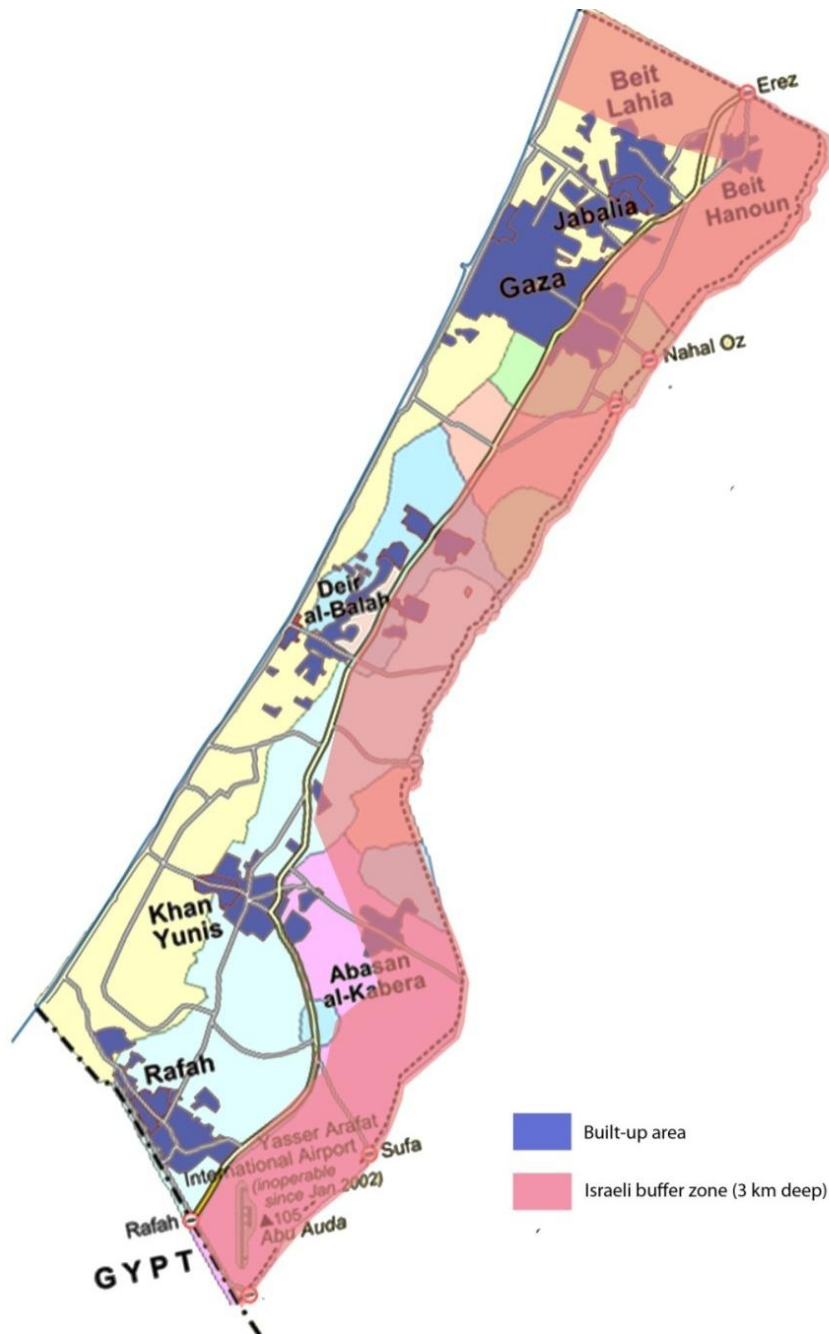


Figure 25 The Israeli buffer zone, built-up area, and soil types in Gaza Strip. Source: (Author, 2017)

(Figure 25) clarifies the limited availability of lands for building and agriculture activities, due to the large proportion of lands took by the Israeli buffer zone, in addition to the high population density.

The Israeli buffer zone has expanded several times since 2005 up to August 2014, and keeps preventing the Palestinians from accessing their own lands; as the buffer zone is high risk zone and civilians are prone to direct targeting and indiscriminate attacks by Israeli attacks that may result in injury or death. (IMEMC, 2015). As mentioned before; 95% of this restricted area is arable land, which constitutes 35% of the agricultural areas of the Gaza strip.

- **Analysis of the map**

The remaining area of the *dark brown* soil has to be left for agricultural purposes as it has the highest proportion of clay (25%), or the amount of the fertile soil can be carefully transferred to other site for agriculture uses, then the site can be used for construction activities.

The remaining land of the *loess soil* can be used for urban expansion, as the amount of clay is low (6%).

The remaining lands of the *loessal sandy* soil can be used for both urban expansion using earth techniques and agriculture purposes as it has 14% of clay. In case it will be used for construction, it is recommended to use the extracted amount of soil to build with or transfer it for agricultural use.

The remaining lands of the *sandy loessal soil over loess* can also be used for both; constructions using earth techniques and agriculture purposes as it has 18% of clay. In case it will be used for construction, it is also recommended to build in the same site using the extracted amount of soil to build, and transfer the fertile soil for agricultural use.

The remaining lands of the *sandy loessal* soil has a high quantity of clay (23%), so in this case it is recommended to be exploited for agricultural purposes.

The coastal area which is completely out of the buffer zone has a *sandy regosols soil*, which has only 9% of clay, so it can be used for sand bags construction techniques that will be explained in the case studies part. From other side, this type of soil is not suitable for agriculture purposes unless another type of soil with high amount of clay transfers to these sites.

According to the study of Paccoud (2015) a soil test done by the labs of the Islamic university found that a proper soil for earth construction purposes is available in Erez extraction area, which is located in the north of the Gaza Strip near Beit Lahia, under the sandy regosols soil after digging about 2m in the ground.

In order to clarify the feasibility of using earth for constructions in the Gaza Strip, the main critical points of the first three parts of this chapter are summarized in the following **SWOT** Analysis:

| <b>Strengths</b>   | <b>Weaknesses</b>   |
|--|---|
| <ul style="list-style-type: none"> <li>• The use of earth materials for construction purposes in collaborative way years ago.</li> <li>• Smuggled conventional construction materials.</li> <li>• Importing construction materials from Israel.</li> <li>• Several training centers exist along the Gaza Strip.</li> <li>• Block factories and rubble crushers to reusing and recycling rubble also exist.</li> <li>• Available different types of soils.</li> </ul> | <ul style="list-style-type: none"> <li>• The imposed blockage that hinders the access of construction materials.</li> <li>• Expensive prices of imported materials from Israel.</li> <li>• The continuous destruction of housing.</li> <li>• Significant shortage in the needed housing units.</li> <li>• High unemployment rate.</li> <li>• Limited availability of lands for building and agriculture activities.</li> <li>• Limited availability of clay.</li> <li>• Limited availability of recycled construction material.</li> </ul>  |
| <b>Opportunities</b>   | <b>Threats</b>  |
| <ul style="list-style-type: none"> <li>• Several training centers exist along the Gaza Strip, some of them can be used as training centers for earthen construction practices.</li> <li>• Community colleges and universities are specialized in building construction, so earthen techniques could be inserted and developed.</li> </ul>  | <ul style="list-style-type: none"> <li>• Rapid population growth that will increase the need for more housing units.</li> <li>• Smuggling the construction materials through tunnels cannot be considered stable source as it follows international policies.</li> <li>• Importing construction materials from Israel is also unstable resource as it depends on the political situation, in addition to the instability in the prices of imported building materials.</li> <li>• The Israeli buffer zone, as its borders shifted with the outbreak of war, as well as the risks of construction and agriculture in that region.</li> </ul> |

Table 4 SWOT analysis. Source: Author, 2017

### 3.4 Questionnaire Analysis

After discussing with professionals who had earthen projects in Gaza and analyzing several documents, and finding out that they almost have in mind that people in Gaza mostly have a negative image towards earthen architecture, so an online questionnaire has been developed to ensure the feasibility of this research.

The questionnaire has been conducted in order to realize the people's perception and acceptance toward using earthen architecture for housing construction in the Gaza Strip, getting an idea about their knowledge of earthen architecture, and being more closed to the situation of people in Gaza, their needs and desires.

The questionnaire targeted the citizens of the Gaza Strip, and it has been distributed through social networks (FaceBook) to people who are living in the Gaza Strip, through pages dedicated to the people of Gaza, and few number of friends. The number of the respondents was 47. (See appendix-A)

The questionnaire has been distributed in Arabic. The questionnaire was available online from the 5<sup>th</sup> of May until the 18<sup>th</sup> of May/2017. The short period of time (from 5th-18th of May) is due to the lack of acceptance by these pages to publish the questionnaire.

#### Results analysis of the questionnaire:

The questionnaire started with basic questions that give a general idea about the respondents group. All of the percentages are out of 100% which represents the 47 respondents.

##### 1. The age

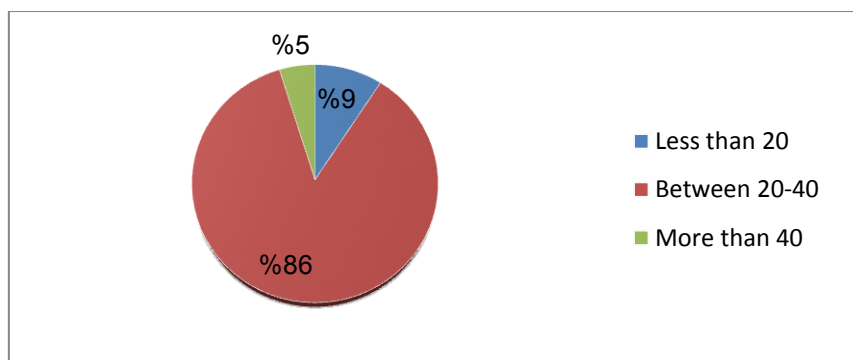


Figure 26 Graph of the age groups of the respondents in the questionnaire. Source: Author,2017

The high majority of the respondents have an age less than 40, which means that the results will reflect the point of view of earthen architecture from youth and new generation, this category is considered the most influential trends in society.

## 2. Professional background

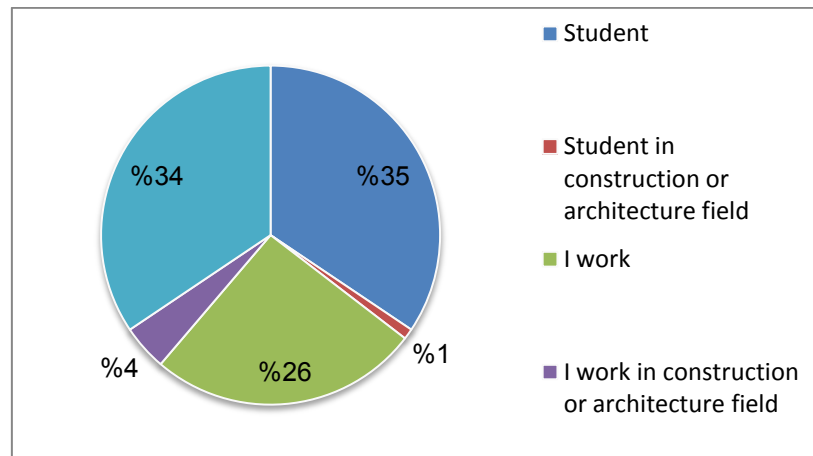


Figure 27 Graph of the professional background of the respondents in the questionnaire. Source: Author,2017

The majority of the respondents are educated, with 5% working and studying in architecture and construction field, that reflects the importance of adopting the results. Taking into consideration that 92% of the population of Gaza has the basic education, and 67% are high educated. (UNDP, 2014)

34% of the sample are unemployed, which is considered high percentage when 95.7% aged less than 40. As previously mentioned, 58% of the total population in the Gaza Strip are unemployed. In this regard introducing new construction techniques using earth can have a potential to create new job opportunities.

## 3. Place of living

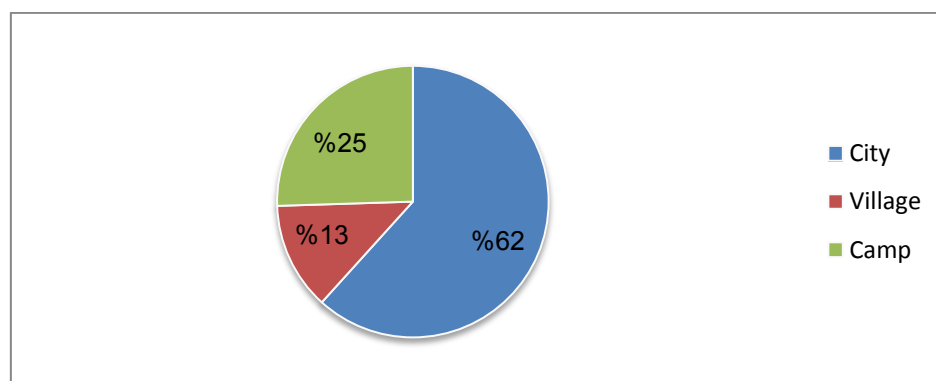


Figure 28 Graph of the living area of the respondents in the questionnaire. Source: Author,2017

This question has been proposed to study the effect of the place of living on the feasibility of using earth in Gaza. In the case of Gaza, the majority of the respondents live in cities that may have an effect on the final results, as we usually assume that people from cities have less interest in earthen houses.

That comes in line with the fact that the percentage of urban population is 73.9%, while the percentages of population in rural and camps areas are 16.6% and 9.5% respectively. (PCBS, 2016)

#### 4. What is the construction material of your house?

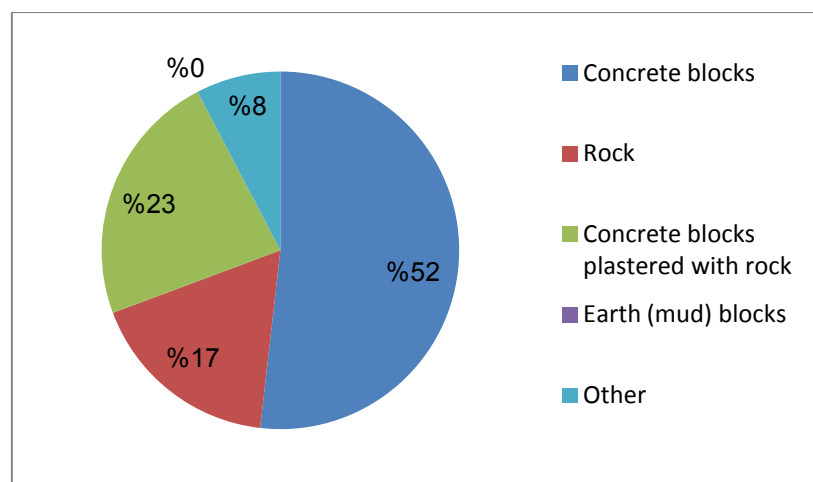


Figure 29 Graph of the construction materials of the respondents' houses in the questionnaire. Source: Author, 2017

The percentage of mud houses is 0, so the respondents have not experimented earth materials. Also almost all the houses in Gaza are built with concrete blocks and rocks.

#### 5. Type of housing

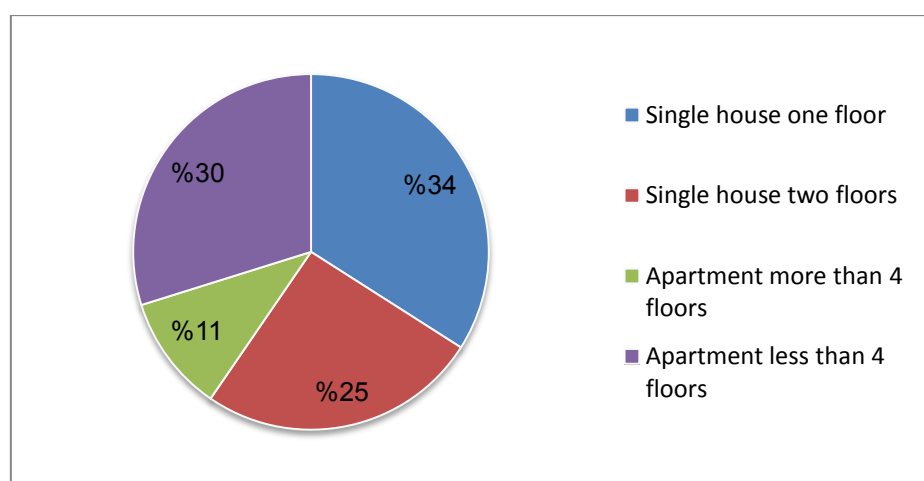


Figure 30 Graph of the type of respondents' houses in the questionnaire. Source: Author, 2017

This question gives an indicator about the possibility of applying the proposed vertical extension technique that will be mentioned in detail in chapter (5).

## **6. what is your top priority when you build your house?**

The answers were as in the following graph,

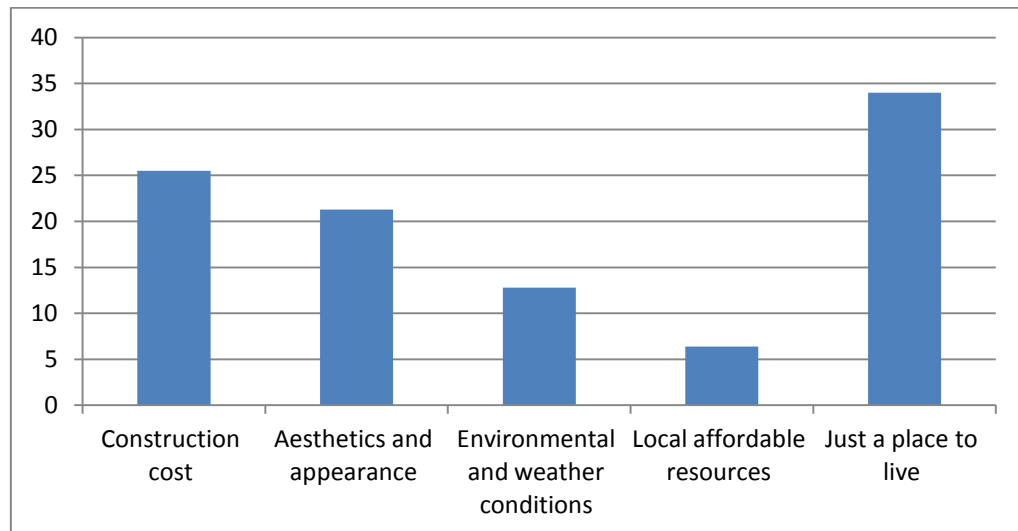


Figure 31 Graph of the building priorities of the respondents in the questionnaire. Source: Author,2017

The result of this question reflects the different interests of people, with a lowest attention for local resources and weather conditions, and highest for "just place to live". Which gives an opportunity to address earthen architecture from different aspects and perspectives in line with each interest, and prove its ability to meet different interests.

## **7. The following two questions aim to realize how much knowledge and experience people have in earthen architecture.**

Through showing an image of building called Casa Candelaria made of rammed earth in Mexico.

Different options have been proposed besides the correct answers such as rocks, mud bricks, and cement.





Figure 32 Casa Candelaria made of rammed earth in Mexico. Source: (Dezeen, 2016)

The percentage of the correct answer was 10.6%. The majority of answers 40% was "I don't know".

From here we can say that people don't have a strong knowledge in earthen techniques, at the same time, they may have no belief in the ability of using earth to produce unique houses. The response of this research will be through introducing different innovative contemporary case studies using earth materials.

#### 8. The following question focused directly on the people's perception towards using earth and local resources for housing construction.

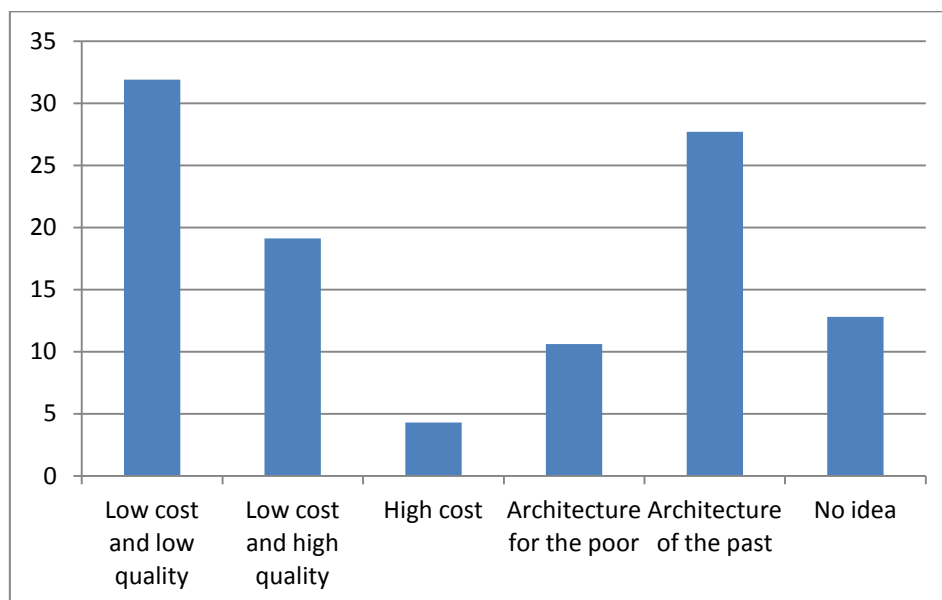


Figure 33 Graph of the people's perception of earthen architecture in the questionnaire. Source: Author, 2017

The majority of the answers (31.9%) perceive earthen buildings as low cost and low quality buildings, while 19.1% had the opposite point of view, the reasons of their perception have been clearly explained in the written part of the questionnaire.

27.7% of the respondents see it as architecture of the past and 10.6% as architecture for the poor as mentioned before. Different case studies will show the ability of using earth materials in the contemporary scenario.

### 9. Have seen earthen houses in the Strip?

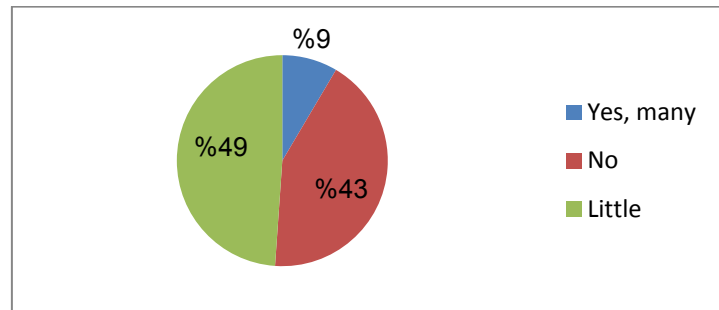


Figure 34 Graph indicates the widespread of earthen architecture in the Gaza Strip based on the questionnaire. Source: Author,2017

This question has been asked in order to understand the widespread of earthen buildings in the Gaza strip. Almost the half of the respondents have seen few earthen buildings in the Gaza Strip, while 43% have not seen any building made of earth. This indicates that earthen architecture started to take a place in the Gaza Strip but still it is limited in prevalence.

### 10. Do you know the advantages of using earth and local materials?

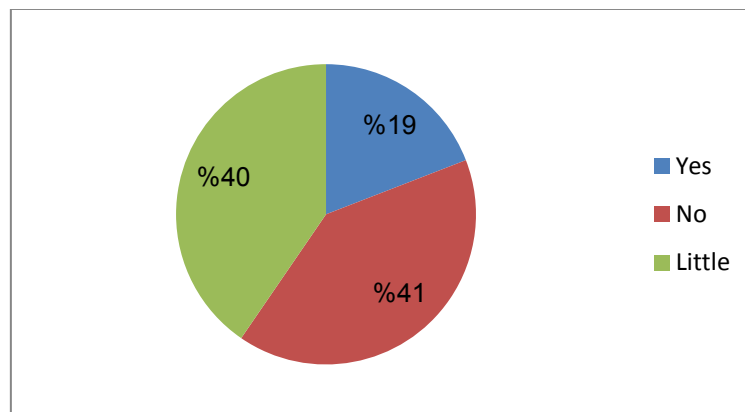


Figure 35 Graph indicates the knowledge of the advantages of earthen architecture in the Gaza Strip, based on the questionnaire. Source: Author,2017

This question evaluates the output of the questionnaire. The result indicates the limited knowledge about this kind of architecture, thus, a strategy to increase the realization of people of earth materials is needed.

**11.** In order to investigate more concretely the feasibility of using earth in Gaza context, three different questions have been asked:

**11.1 Would you like to experiment the building with earth and other available materials?**

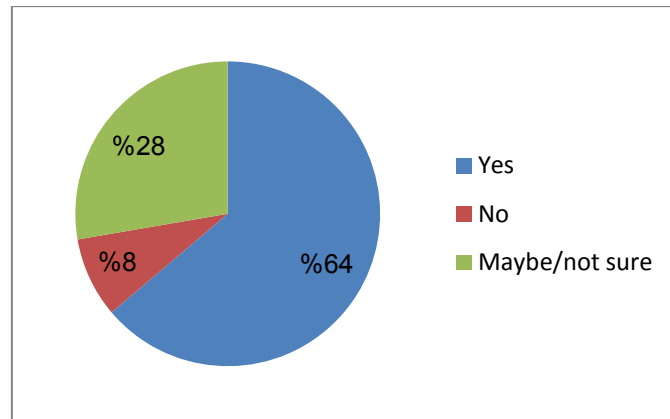


Figure 36 Graph indicates the level of acceptance towards experimenting earthen architecture in the Gaza Strip, based on the questionnaire. Source: Author,2017

**11.2 Do you promote the spread of the contemporary earth buildings in the Gaza Strip?**

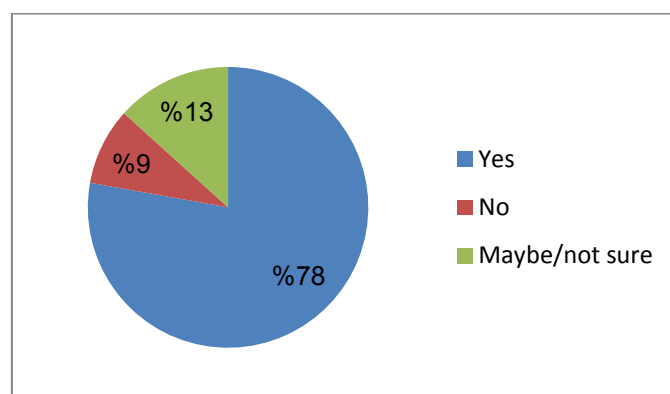


Figure 37 Graph indicates the level of promoting the prevalence of earthen architecture in the Gaza Strip, based on the questionnaire. Source: Author,2017

### 11.3 Would you accept to have your house constructed with local and earth material which takes into consideration the construction strength and aesthetics?

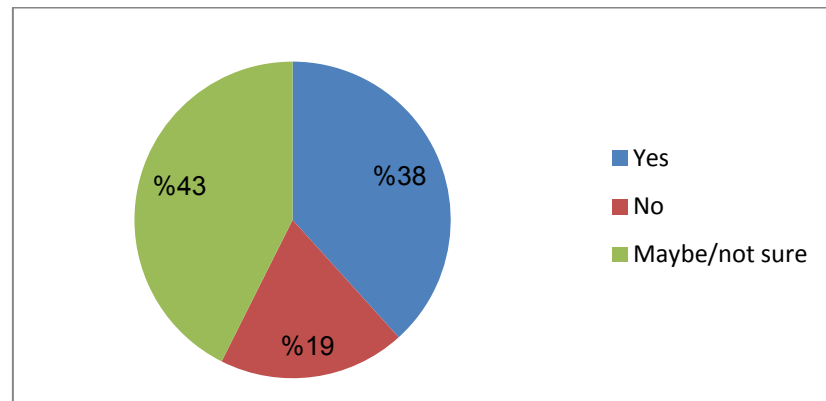


Figure 38 Graph indicates the level of acceptance towards owning earthen house, based on the questionnaire. Source: Author,2017

The three questions generally show the high acceptance for experimenting, promoting, and owning earthen houses. Referring to the studied part of the local building culture of Gaza, we found that building with mud and sand stone was common, and that might inspired the answer to revive the past as we will notice in the following written part of the questionnaire.

The answer with not sure/maybe can be considered as having doubts towards this type of architecture but not categorically rejected, so there is a need to enhance their knowledge about earthen architecture, its designs, techniques, and advantages.

**12.** Other three optional text questions have been asked in order to understand more deeply the different points of views, and present the later proposed strategy on the critical issues that they pointed them out.

The most relevant answers have been summarized in the following tables:

| Question  | NO. Of comments | People's Responses   |
|---|-----------------|--|
| <b>12.1 What hinders the use of natural and local materials to solve the housing problem in Gaza?</b> | 5               | - Low durability and resistant to climate conditions (humid climate)                     |
|   | 3               | - The scarcity of natural building materials due to building expansion                   |
|   | 3               | - Lack of available lands for construction   |
|   | 2               | - Lack of efficient manpower   |
|   | 2               | - Risk   |
|   | 2               | - It has become an old-fashioned material, only for poor                                 |
|   | 2               | - Lack of possibilities to extract and exploit them properly                             |
|   | 1               | - Lack of financial resources  |
|   | 1               | - lack of community confidence in the available natural resources                        |
|   | 1               | - People prefer modern appearances and aesthetics  |
|   | 1               | - People are dependent on imported external sources                                      |
|   | 1               | - Low resistant to aggressive bombing  |
|   | 1               | - Women in this age and in this society do not accept simple house of natural materials. |
|   | 1               | - Soil quality   |

Table 5: Summery of people's responses in the online questionnaire about the use of natural and local materials to solve the housing problem in Gaza. Source: Author, 2017

In this table, the answers are ordered according to the number of comments that have been obtained through the questionnaire. This classification helps to understand what the most significant issues that people tend to focus on, and reflect the reasons of why people are not using earth as an alternative material, which are mainly because of its low resistant to climate conditions and the unavailability of natural resources and lands.

| Question   | NO. Of comments                      | People's Responses   |
|--|--------------------------------------|--|
| <b>12.2 What are the negative points that dis-encourage you to build with earth and local materials?</b> | 9<br>7<br>2<br>2<br>1<br>1<br>1<br>1 | <ul style="list-style-type: none"> <li>- Poor , weak, and fragile</li> <li>- Non-resistance to atmospheric fluctuations</li> <li>- Not resistant to bombing</li> <li>- The need for horizontal space so there is no ability to build multi-story buildings; thus it is unable to resolve population congestion in Gaza.</li> <li>- Lack of experience in earth construction</li> <li>- Modest architecture</li> <li>- Consumption of environment materials without control might cause environmental imbalance</li> <li>- With skilled worker people will dispense a lot of other resources</li> </ul> |

Table 6: Summery of people's responses in the online questionnaire about the negative points that dis-encourage you to build with earth and local materials. Source: Author, 2017

From here we can realize that people perceive the earthen architecture mainly as a week structure and do not have the ability to withstand the different weather conditions as well as bombing.

| Question   | NO. Of comments                                      | People's Responses   |
|--|--|--|
| <b>12.3 What are the positive points that encourage you to use earth and local materials for construction?</b> | 12<br>7<br>2<br>2<br>2<br>2<br>1<br>1<br>1<br>1<br>1 | <ul style="list-style-type: none"> <li>- Cheap construction</li> <li>- Simplicity and beauty</li> <li>- Less time and effort</li> <li>- Preserve the originality of the past and future as Palestinians</li> <li>- More environmentally friendly than current pollutants at the present time</li> <li>- Provide comfortable heat</li> <li>- More natural aesthetics and can be placed as archaeological sites.</li> <li>- New experience</li> <li>- Protect the environment</li> <li>- Alleviating the suffering of the lack of building materials.</li> </ul> |

Table 7 : Summery of people's responses in the online questionnaire about the positive points that encourage you to use earth and local materials for construction. Source: Author, 2017

The majority of the answers see earth as a cheap material, and for them it is positive point, which is reasonable according to the well known situation of the Gaza Strip. Another point is the simplicity and beauty which might be inspired from their past, this is can be understandable through referring this to the local building culture that clarifies the beautiful architecture and simple way of living that they have had.

Some people are aware to the role of earthen materials in providing balanced temperature inside the building environment, and its environmental advantages as well.

Other study done by Abu Ajwa (2011) based on qualitative data hold with 48 contractors working with UNRWA and other clients, revealed the top factors that are affecting mud building in the Gaza strip: the result summarized in; high need for maintenance, vertical expansion is not possible, need labor intensive, poor resistance to weather conditions and earthquakes, lack of skills, type of clay, unwilling of people to build with mud, no encourage by Non-Governmental agencies to build with mud, and generally, the idea of building with earth was not accepted by most of the contractor due to cultural aspects.

### 3.5 Stakeholder analysis

This section will identify the people, organizations or groups that could affect or be affected by the earthen construction projects in the Gaza Strip. This analysis based on understanding the needs, requirements, and expectations of the stakeholders.

Promoting appropriate stakeholders is a significant factor to achieve best engagement in decisions and activities in different stages of the earthen project.

- **Types of stakeholders:**

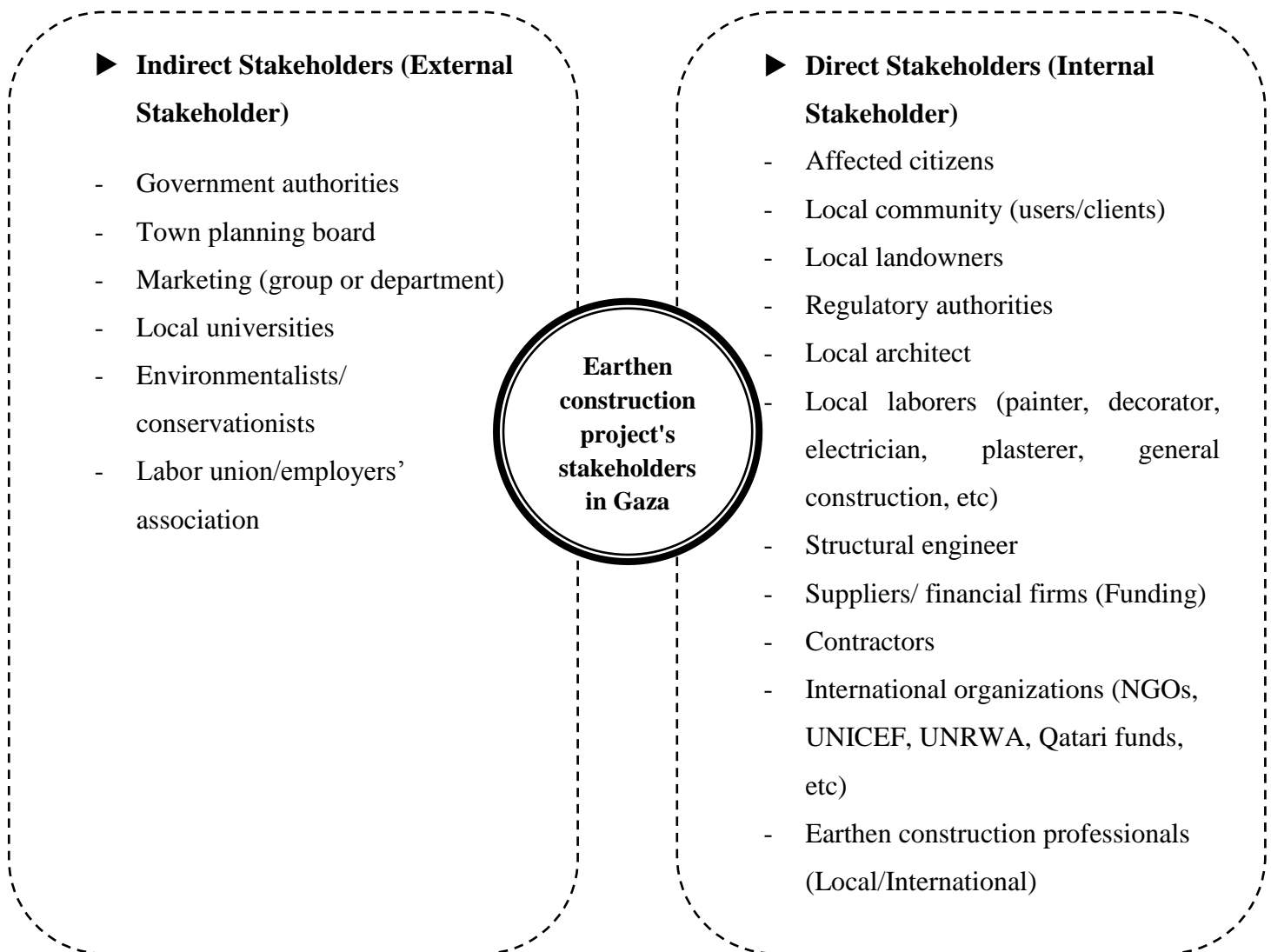


Figure 39 Earthen construction project's stakeholders in Gaza. Source: Author, 2017



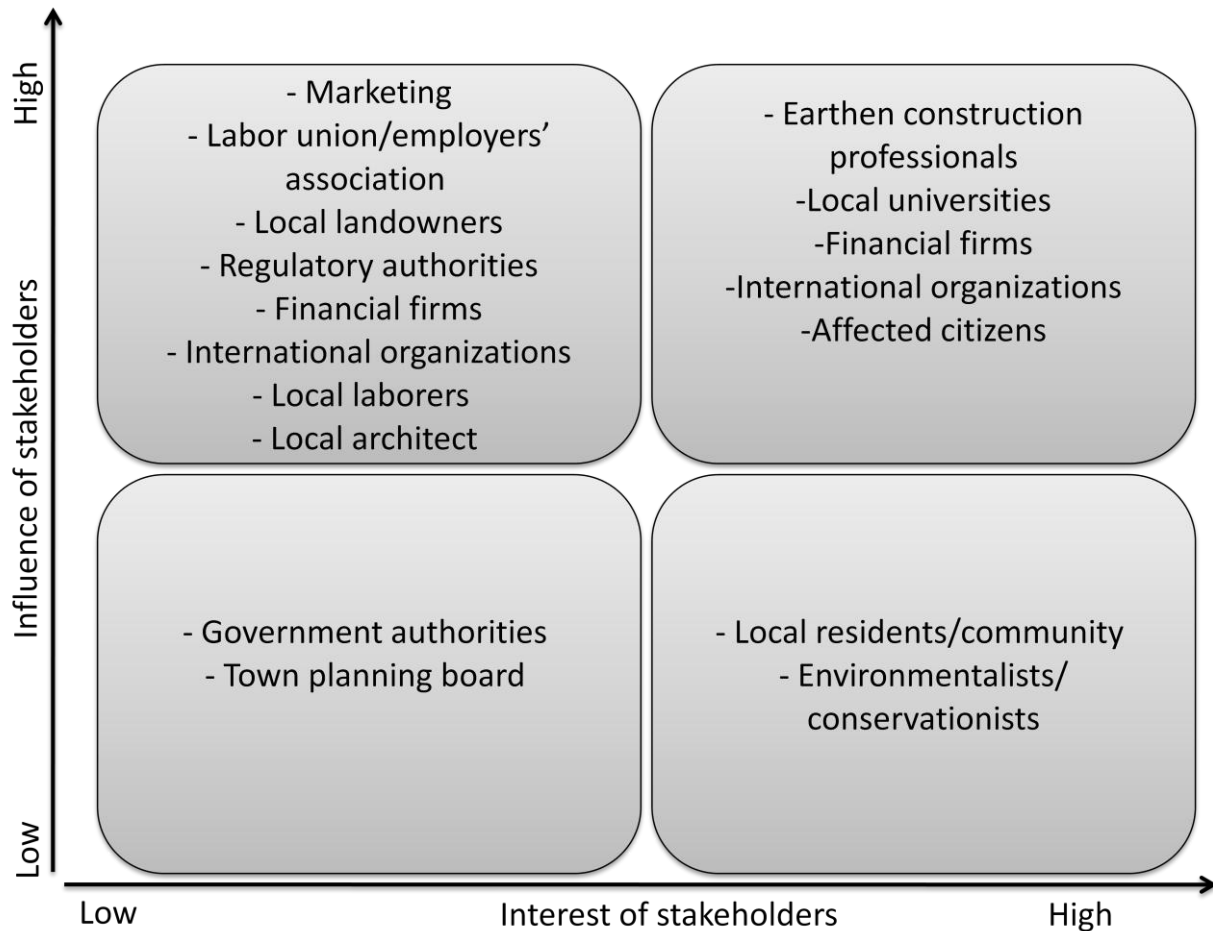


Figure 40 The influence and interest of stakeholders in earthen projects in the Gaza Strip. Source: Author, 2017

Introducing earthen constructions in the Gaza Strip can include and benefit different stakeholders, and that varies according to the level of interest. Studying the level of influence and interest was based on the questionnaire analysis as well as previous studies in the same field. But it still requires more detailed study to ensure the feasibility, and that can be done in future research.

### 3.6 Results and Conclusion

The use of earthen materials in the Gaza Strip has been started since hundreds of years, where sandstone and mud bricks were the basic building materials. People had distinguished life style and houses designs that pay attention to environmental aspects. While the lack of maintenance as well as skilled workers, and the availability of cement materials led to the disappearance of this type of architecture, and the appearance of global architectural style.

After the successive Israeli wars on the Gaza Strip, people lost their houses and jobs. Different studies show the limited amount of imported construction materials, and the high unemployment rate. The lack of basic life requirements has inspired some people to search for the materials that they have been using in the past to avoid living in misery situations.

After studying the available building materials which are mainly: recycled rubbles, limited quantity of wood, steel, cement and earth materials, it is found that these materials give a chance to applying different earth techniques using a combination of them, taking into account that many factories and training centers are available along the Gaza strip even if they are not currently specialized in manufacturing with earth materials, it still can be an opportunity to present new earthen construction methods and train previous construction workers and provide more job opportunities.

All of the previous analysis has been supported by the questionnaire's results which could be considered encouraging results. Creating the questionnaire was quite an important factor in developing a strategy based on the people's perception, needs, and problems associated with earthen architecture that have been identified mainly through the questionnaire.

Overall, we can suppose that earthen architecture is feasible and relevant in the Gaza Strip, but without ignoring the doubts of people toward earthen materials. So that, several problems associated with the construction with earth will be addressed, to be responded through documents analysis, and case studies with the aim to clarify that there are some precautions and innovations that can overcome what people consider problems and limitations.

From here we can conclude that there is a need to enhance the concept of earthen architecture and increase the awareness about its applicability in different contexts. According to the questionnaire of this study and other study, the main points that are going to be discussed are classified in design and technical challenges. The main design challenges are: people like modern appearance and aesthetics and earthen architecture is simple and from the past, earthen houses need horizontal space which is not available in Gaza and the vertical expansion is not possible, shortage of available natural materials, and the nature destruction because of using natural resources. As for the technical challenges, people have doubts toward the durability of earth in bad weather conditions and the risk of bombing.

The answer for these ideas and doubts have been summarized in the following diagram, some of them are already discussed and analyzed in previous sections and others will be discussed in the following chapters.

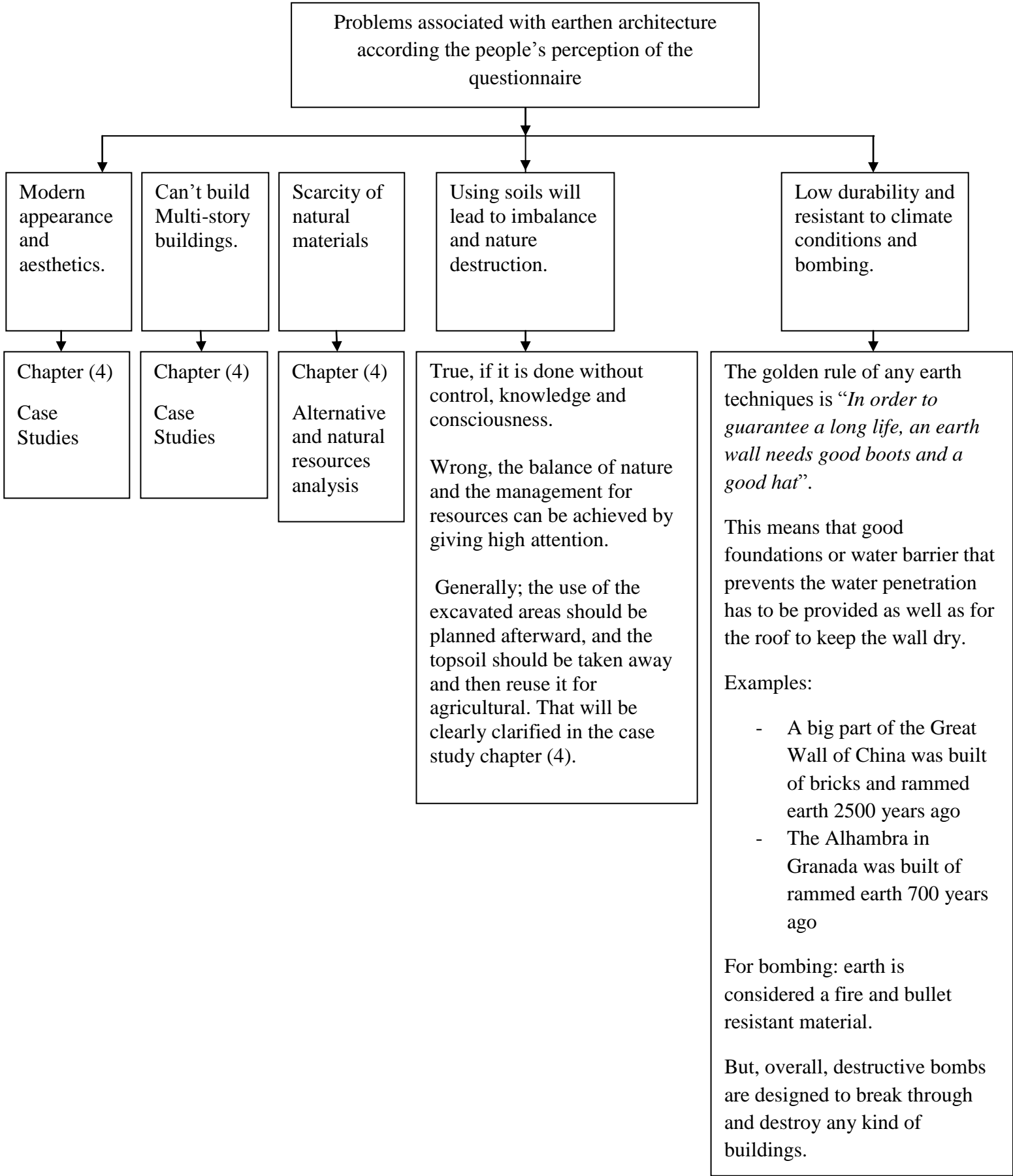


Figure 41 Challenges-proposals diagram of the feasibility study. Source: Author, 2017

## **Chapter 4:** *Development strategy*

#### 4. Development strategy for earthen architecture in Gaza Strip

This chapter will focus on four main dimensions that have been addressed in order to gather various types and methods in presenting earth architecture that will contribute to increasing the awareness level of people about earthen architecture, and play a role in convincing professional, builders, beneficiaries, and different stakeholders to launch earthen projects.

The developed strategy includes; studying the contemporary architecture in Gaza, contemporary earthen construction techniques, case studies of contemporary earthen architecture, and addressing the earthen construction values.

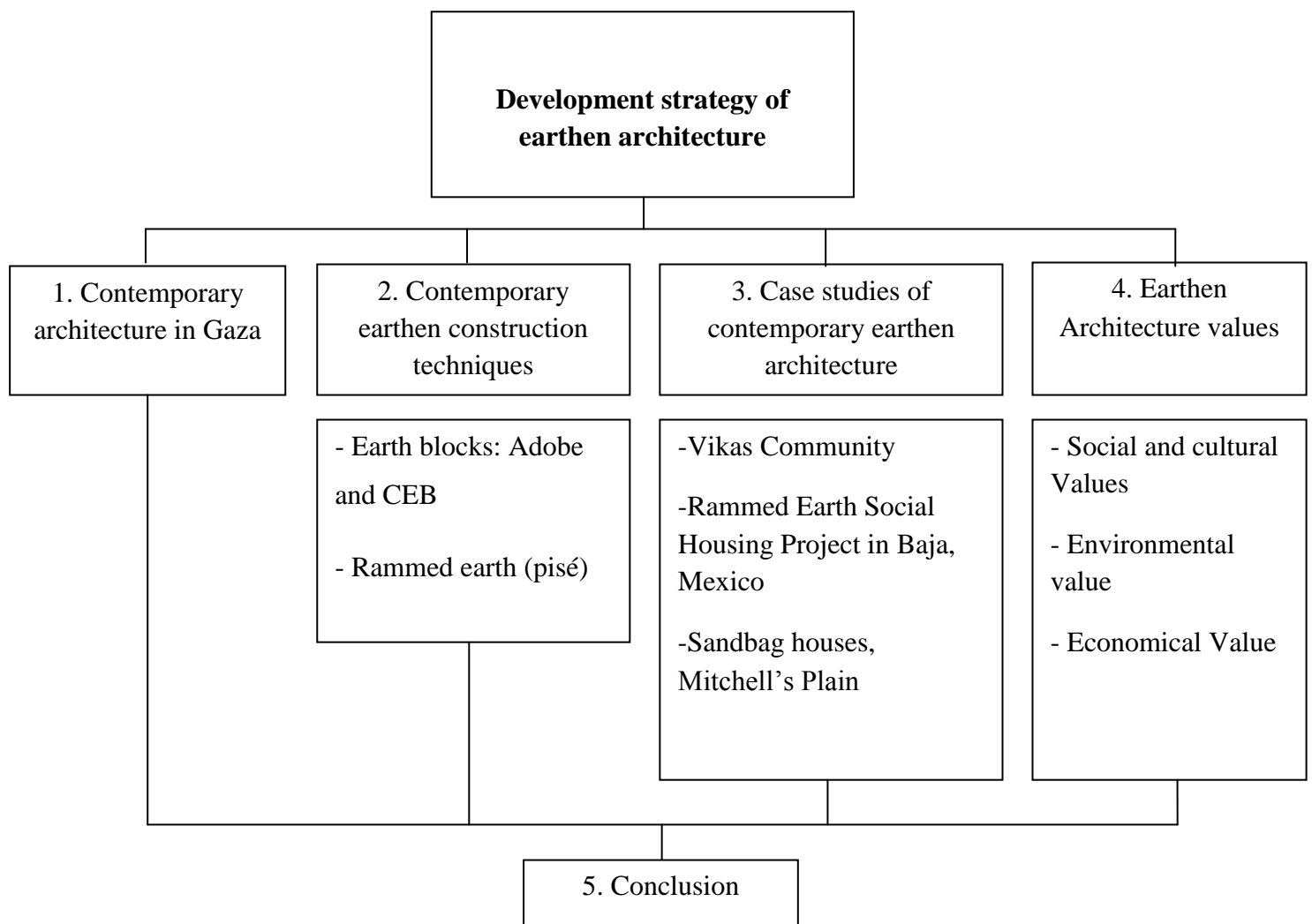


Figure 42 The developed strategy of earthen architecture. Source: Author, 2017

#### **4.1 The contemporary architecture in Gaza Strip**

Studying what is the contemporary architecture in Gaza, its characteristics, and the changes between past and present help in taking advantages of the entire building's scenario and choosing the following steps of the strategy based on that.

Based on the description of the local building culture, there are many changes in the building prototype and construction between past and present; these changes have highly effected the house development, and social and economic factors. Each type of house has different pros and cons. A study done by Muhaisen (2016) aimed to compare the three prototypes based on 20 several standards and criteria ended up with a highly desirable evaluation for concrete houses, followed by significant for sandstone houses, and low desirable for mudstone houses.

The Palestinian architectural style generally and particularly in Gaza shows a big difference between the past and present, the traditional architecture no longer has the same characteristics of contemporary architecture. The excessive use of cement and natural stone in addition to a random mass construction without paying attention to urban fabric, context, environment, and even to the economic level of people led to scattered buildings and poor quality in some cases, thus the loss of the architectural identity, and less attention to social cohesion, environmental issues, and economic aspect; where people spent too much time of their life to build a house!. (Germanà & Alatawneh, 2016)

The gap between traditional and contemporary architecture exists in many countries around the world, but in the case of Palestine, the architectural style is quite linked with the political situation that affected the social, environmental and economic aspects and therefore the housing situation in the Palestinian cities and villages.

Palestinian cities and villages had a homogenous urban fabric on social and physical levels; people were a part of the construction process in their houses and neighbor's house, strong social relations and cohesion in extended families.

The most influential factors that affected the past urban fabric were: the climate, construction materials, topography, people's need, and cultural and social aspects. Unique houses were evolving through generations started from using local primitive methods without designers.

The house was an integrated system; it was not limited to have a physical space to shelter, the functional design was combining the social activities by designing courtyard as a collective space, taking into consideration the cultural aspects as a conservative community, and awareness towards the environmental needs.

In the contemporary case of Palestine, the contemporary buildings are not at all connected with the traditional style; there is no longer an interest in social, climate condition and environmental aspects, as well as indentifying the architectural identity. The use of earth has disappeared, and in the case of Gaza, a huge trend went towards using cement. The result was constructing buildings that hinder the natural light and ventilation, and setbacks in the isolation system due to changes in the buildings materials and designs.

Many studies of the Gaza Strip have found that concrete houses is the most preferred while sandstone and mudstone houses are less preferred respectively, each type has distinguished features that cannot be ignored. So this study will be searching in taking full advantages of the traditional building features and characteristics including sandstone and mudstone in accordance with the concrete characteristics, using modern building techniques that aim to make a step towards creating local architectural identity for Gaza strip, that combines between traditional and contemporary architecture and deals with the challenges of materials availability, and consistent with the prevailing social and economic situation of Gaza Strip.

Under the notion of “Build Back Better” and the global interest of researchers, architects and professional in the sustainability aspects, in combine with urgent humanitarian need in Gaza Strip, a comprehensive building design should be followed.

## 4.2 Earth as a building material

*“Build your architecture from what is beneath your feet”. - Hassan Fathy*

Soil has been used for thousands of years as an economic and effective way in building construction all over the world. About 30% of the world’s population lives in earth constructions, around 50% of which are in developing countries. (Blondet, Garcia M, & Brzev, 2003)

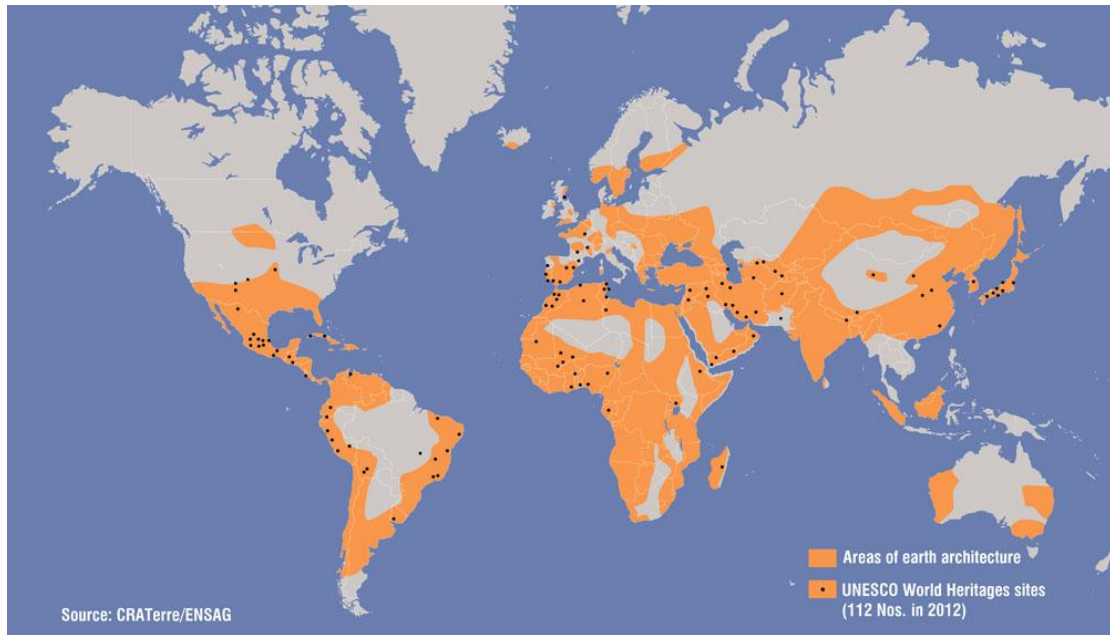


Figure 43 Earth construction areas of the world. Source: (Auroville Earth Institute , Undated)

The earth material has approved its durability and aesthetic characteristics throughout the ages as shown in the following examples:



Figure 44 (Left) The Gate of Yemen surrounds the old city of Sana'a from the 11th century. Source: (Pinterest, Undated)

Figure 45 (Right) Rammed earth walls of Château de la Bastie d'Urfé in France from the 15th century. Source: (Paccoud, 2015)



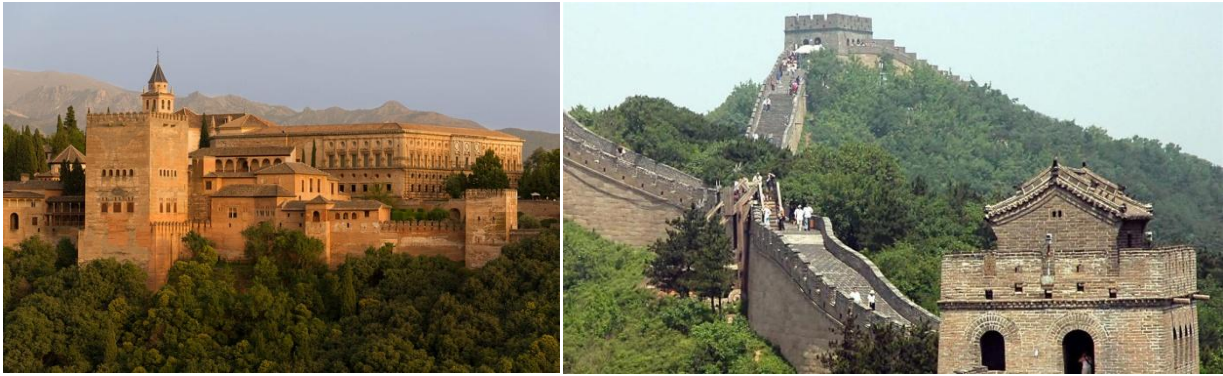


Figure 46 (Left) The Alhambra in Granada was built of rammed earth 700 years ago. Source: (Jebulon, 2012)

Figure 47 (Right) A big part of the Great Wall of China was built of rammed earth 2500 years ago. Source: (The Great Wall of China, Undated)

The different ancient buildings show different earthen construction techniques that have been developed based on climate conditions, environment, and local culture.

The earth used for building purposes consists of four main elements: gravel, sand, silt and clay. The soil has different behaviors and properties based on the qualities and quantities of the pre-mentioned elements. The soil accordingly consists of; gravely earth, sandy earth, silty earth, and clayey earth. A lot of soil can be used as a building material, and sometimes it needs improvements.

In the modern practices, they increase the stabilization and mechanical properties of soil by using additives, such as cement and lime.

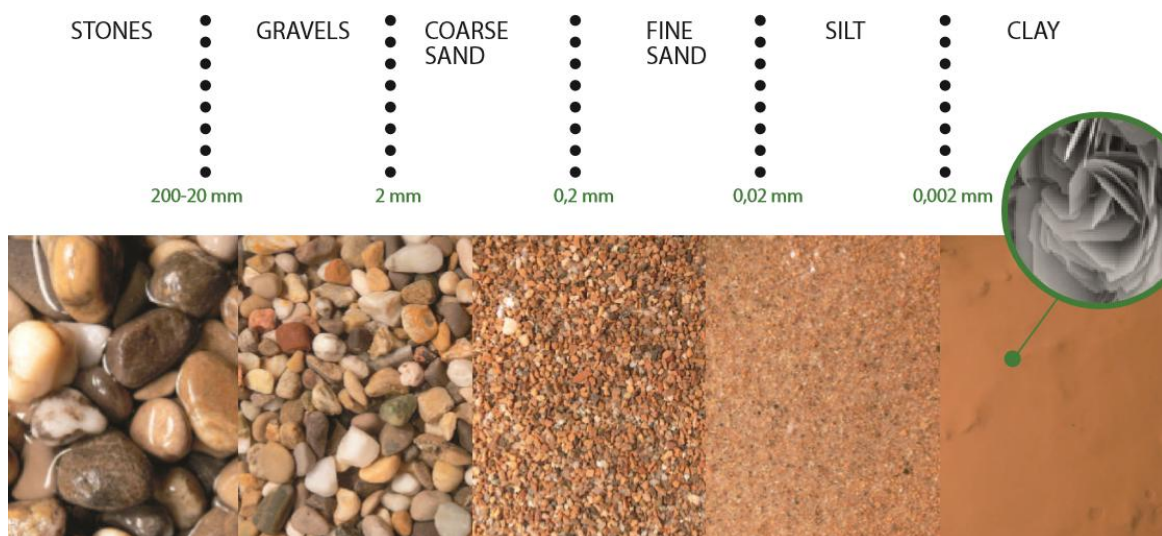


Figure 48 Earthen material components. Source: (Samin, 2016)

Using earth construction is influenced by three main factors, which are: first, the availability of local materials, as the chosen earth technique is based on its constituent materials. Second, the building layout, where the buildings shape is usually related to cultural and historical building style. The third factor is the building size, where the size of buildings depends on the urban fabric and population density, as usually multi-story buildings are often existed in densely urban areas, while in rural areas single-story houses are most common. (Abu Ajwa, 2011)

The study focuses on three main earth constructions techniques; which are adobe, CEB (compressed earth blocks), and rammed earth. These have been chosen for Gaza context according to the availability of materials, some initiatives that have emerged to build with these technologies may reflect receptivity, knowledge and experience, and the fact that they combined the advantages of traditional construction in a contemporary way which is considered quite important according to the contemporary building style in Gaza.

#### **4.2.1 Earth blocks: Adobe and CEB**

The two techniques are blocks in various sizes, made of soil and other additional materials such as gravels or sand, and vegetal fibers in adobe to improve the raw material properties. Other additions such as lime and cement are used to improve mechanical strength, erosion resistance and production time. (Paccoud, 2015)

These techniques are used to build simple straight walls and complex vaulted and domed roofs. These construction methods and this kind of roofs are chosen as they are quite linked with the traditions of Gaza, and a few years ago some initiatives built their own houses in adobe and CEB. The appearance and final result of applying these methods depend on the quality of the produced blocks.

##### **4.2.1.1 Adobe (dried clay brick)**

One of the oldest building techniques, it has been first identified and produced in Syria 9000 BC, and has been used all around the world, in Jericho, Jordan valley, and Mesopotamia around 8000 BC, and in many Egyptian sculptures. (Vador, 2012)

Adobe is traditionally used in very hazard prone regions as a low cost and available construction material. Adobe is a self made construction because of its easy process of manufacturing without additional energy consumption, it is also called “non-engineered” construction as it is manufactured by the local community and does not require architects or engineer. (Blondet, Garcia M, & Brzev, 2003)

- **Materials and process:**

Adobes are blocks made of soil and sometimes with vegetal fibers; it should include optimal proportions of clays, sands, gravels to get good compression strength. The density of the mix depends on the additional materials such as straw and fibers that makes the block lighter and responds to shear forces which is unbalanced vertical force. (Paccoud, 2015)

The mixture pours into moulds in different sizes, and then they will be removed and left to dry outside; sometimes depends on the weather conditions, blocks should be stored in covered areas and protected from the rain.

The mix must be kept at a constant level of composition and moisture, to avoid the variation in the height and strength of the block.

It is considered a very productive method, where one person is able to produce 300 blocks per day, and automatic process could manufacture from 1500 to 4000 block if materials are sufficiently and locally available. (Vador, 2012)



Figure 49 Adobe bricks production process. Source: (Sasabe Adobe, Undated)

- **Main Characteristics:**

- The percentage of water should be between 15 and 30% of the mix. (Paccoud, 2015), or about a quarter of the dry earth volume. (Abu Ajwa, 2011)
- Straw from 5 to 10% of the mixture. (Abu Ajwa, 2011)
- The size of the adobe block in Gaza is around 10x30x50cm. (Paccoud, 2015)
- Compressive strength 2 to 5 Mpa.
- The blocks manufacture manually or by mechanical equipment whether on-site or in factory
- Acoustic +, thermal mass +. Thermal mass is defined as “the capacity of a material to generally absorb and store up heat and subsequently release this heat when it is necessary”. (Obafemi & Kurtb, 2015)
- Insulation - . It can be defined as the act of preventing the transmission of heat, moisture, or sound from escaping or entering. (FAO, Undated). With more straw we get better insulation but leads to less compression strength. (Paccoud, 2015)
- Cost (in France): Simple wall costs around 170€/m2, Double block wall cost around 350€/m2

- **Buildings’ appearance:**

- Retraction in adobe blocks usually uncontrollable.
- The wall can be left in its natural appearance or plastered.
- Moulds are existed in different shapes and sizes, which gives a flexibility of the designs.
- Adobe can be used for decoration purposes through using creative moulds and mixes.



Figure 50 (Left) Modern adobe house. Source: (Idea Bedroom Design , 2015)



Figure 51 (Right) Adobe house in Greece. Source: (Adobe House Greece, 2012)

#### 4.2.1.2 Compressed earth blocks (CEB)

Another technique of using earth material is the compressed earth blocks (CEB). This technique is fabricated in simple technology, and overcome most of the mud construction drawbacks, as it is more durable, does not require continues maintenance, and requires a small amount of clay and much of sand. CEB is manufactured and constructed with minimum energy, and it is thermally efficient. (Muhaisen and Ahlbäck, 2012)

- **Materials and process:**

CEB is fabricated from; sand, clay in small quantity, gravels to reach a good compressive strength, and combining additives. The soil mixed with a proportion 8- 12% water of the compacted material, to produce humid mixture, then to be placed in manual or hydraulic, motorized, electrical compressor, after molding the blocks, they maintained for 7 days under humid conditions, then further 21 days to cure in the air. (Zami & Lee, undated)

The top soil has to be removed then the excavated soil should be free of organic materials, as they affect the strength of the produced blocks that are used in building walls, this method also allows building arches, vaults, domes. (Paccoud, 2015)

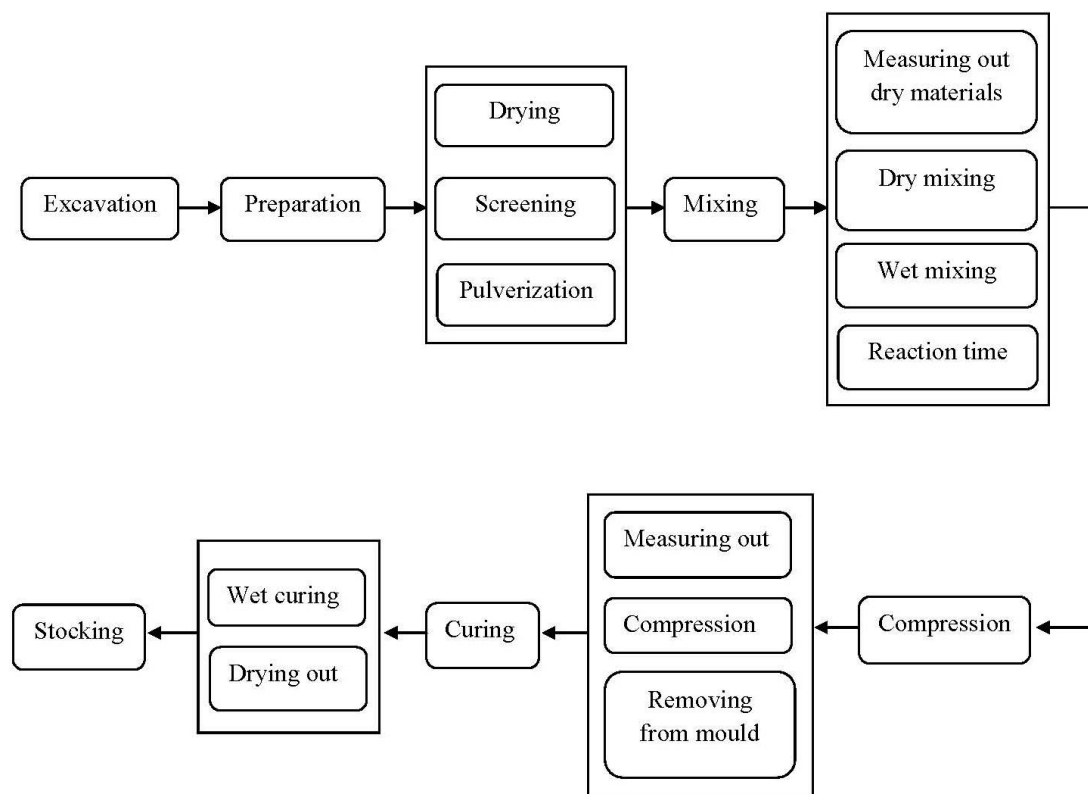


Figure 52 Production process of compressed earth block. Source: (Rigassi, 1985). Edited by Author.



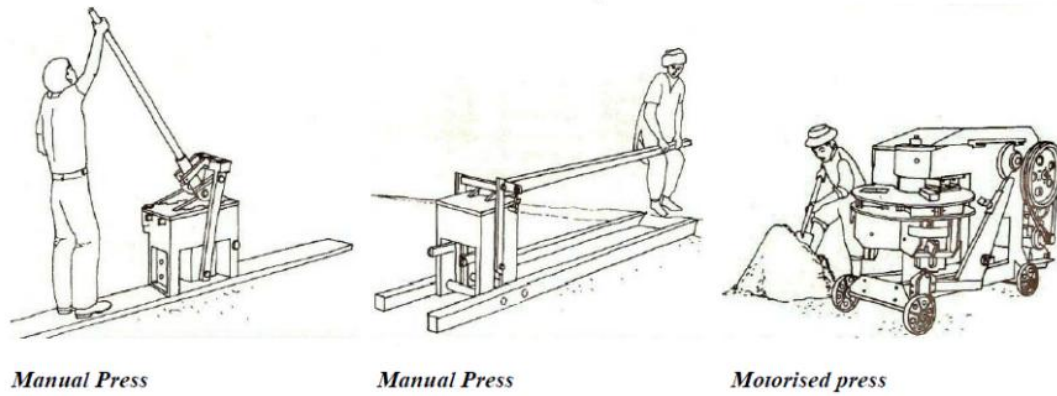


Figure 53 The compaction techniques. Source: (Zami & Lee, undated)

- **Main characteristics:**

- The humid mix should have small size grains less than 1 cm
- The mixture stabilized with hydraulic binders as lime or cement in proportions between 3% and 15%.
- CEB is manufactured manually or mechanically using hydraulic Press.
- Compressive strength is around 3 Mpa
- Acoustic +, thermal mass + (depends on thickness), insulation –
- Cost (in France) 450€/m<sup>2</sup> for a double wall (thickness = 2 blocks).

- **Appearance:**

- It has uniform faces, and its roughness depends on the aggregates' size
- The blocks color depends on the color of used soil and stabilizations
- Moulds exists in different sizes and shapes

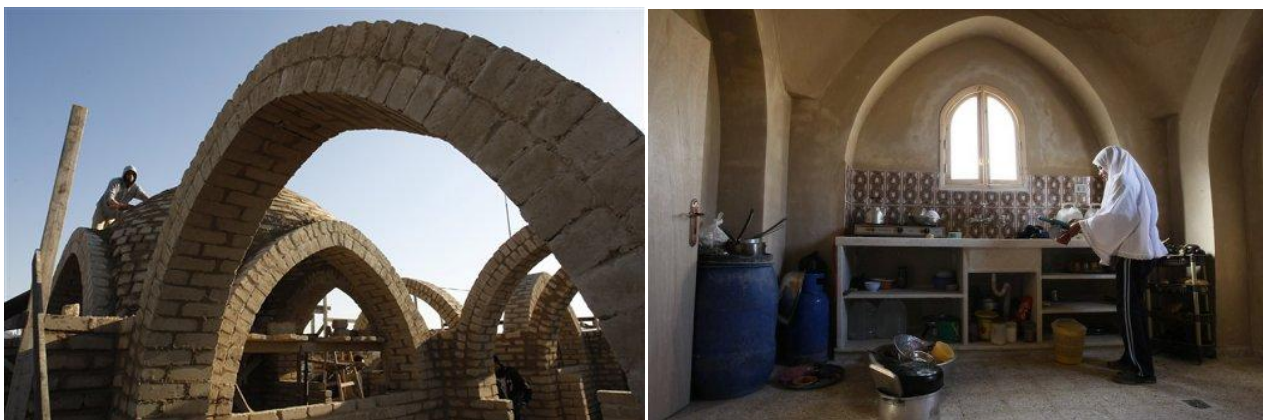


Figure 54 (Left& right) compressed mud bricks houses in Gaza. Source: (Earth architecture, 2009)

- **The advantages of using Adobe/ CEB**

- Raw materials usually exist in abundance. (Zami & Lee, undated)
- The production of CEB can be closed to the construction site to avoid time consuming and transportation cost.
- Low energy for production is required.
- The production cost is affordable.
- Low labors skills is required which allows the community participation in the production process.
- Environmentally friendly technology in term of; pollution, deforestation, and thermal mass and acoustics.
- Fire resistant which enables the use in fire and earthquake prone areas.

#### **4.2.2 Rammed earth (pisé)**

Rammed earth is a technique of building thick massive walls by compacting humid soil.

- **Materials and process:**

Materials included: optimal proportion of clays, sands, gravels until having a good compressive strength. The rammed earth walls have usually a thickness from 40 to 60 cm, by compacting layer layers of moist sub-soil in temporary framework, each layer has from 100 mm -150 mm deep, and compacting using manual rammers or other sophisticated technology, and then the mould will be taken away, when the compacted wall is finished. (Paccoud, 2015)

The best soil for rammed earth is sandy or gravely rather than clayey. When the local soil is more clayey or silty they use other technologies like adobe, cob and wattle and daub. Moist earth; 30% clay/silt and 70% sand/gravel, water from 8-16% of the mix. (Vador, 2012)

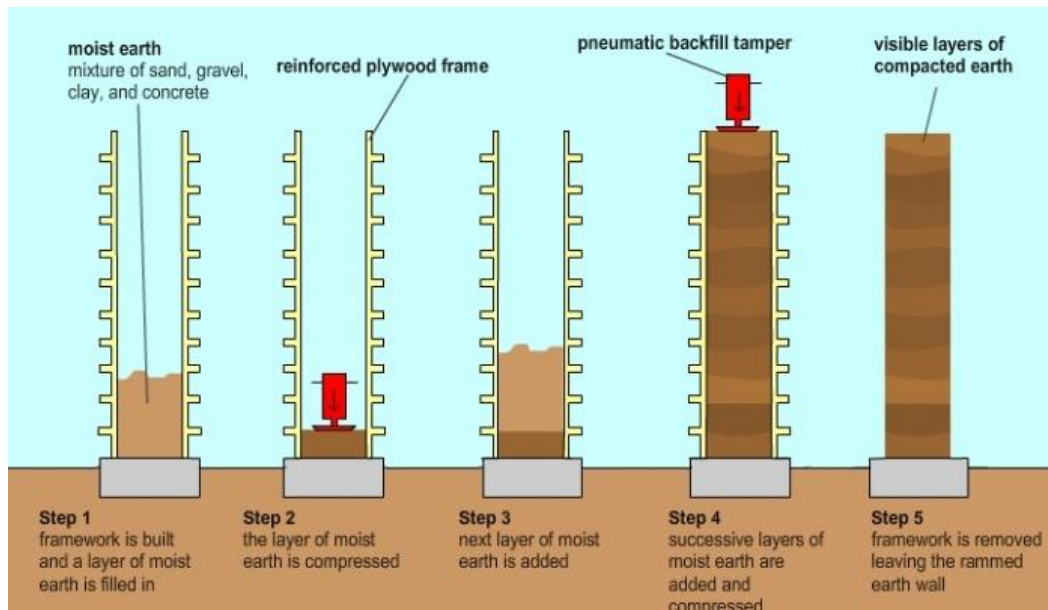


Figure 55 Rammed earth compaction process. Source; (Green Architecture & Building Products, 2017)

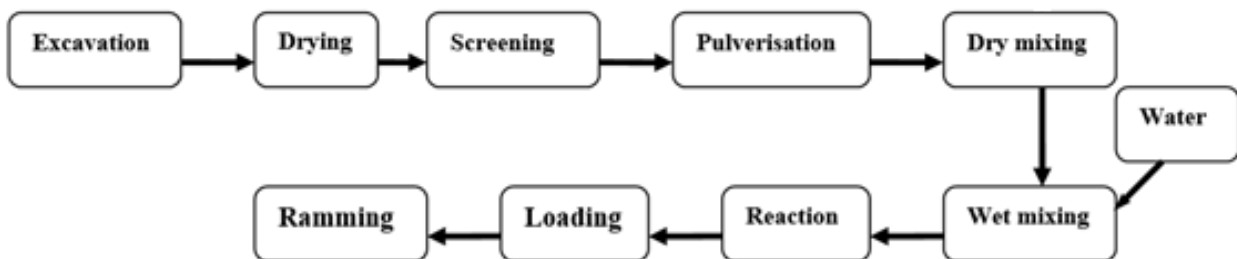


Figure 56 Production process of rammed earth, Source (Zami & Lee, undated):

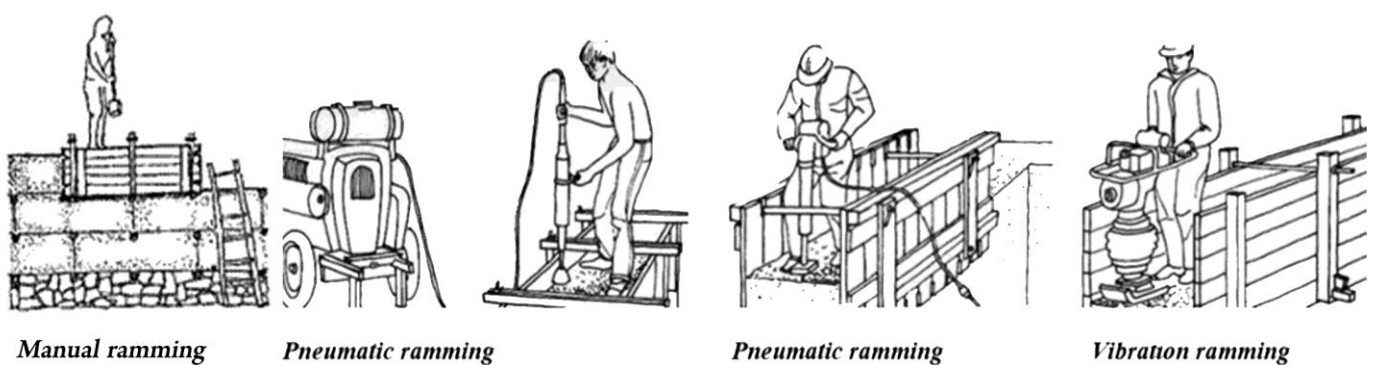


Figure 57 Ramming techniques. Source: (Zami & Lee, undated). Edited by Author





Figure 58 (Left, middle, & right) Rammed earth test walls in Gaza Strip. Source: (Paccoud, 2015)

- **Main characteristics:**

- The mixture needs to be sandy between 50%-75%. Using too much of clay cause shrink and crack.
- The percentage of water in the mixture between 8 and 12%.
- Optional stabilizers such as lime or cement can be added with a percent 4-12%. (Vador, 2012).
- It sustains for vertical loads (compression), with strength between 1 and 2 MPa.
- Compressive strength 1 to 3 Mpa.
- Built on site or pre-fabricated
- The soil is mixed using a horizontal mixer; concrete mixers should be tested to avoid segregation in the mixture.
- Thick walls (acoustic ++, thermal mass ++, thermal insulation -)
- Cost (in France), between 600€ and 900€/m<sup>2</sup>.

- **Appearance:**

- The color of these layers depends on the color of the used soil, which gives the opportunity for nice appearance by playing with the soils' colors.
- The quality of produced walls depends on the quality of the used soil.
- The framework has different styles and shapes, and can be made of wood, steel, logs, aluminum, and fiber glass sheets.



Figure 59 (Left) College Paiamboué facades made of rammed earth. Source: (CTB, 2016)

Figure 60 (Right) Rammed earth building-wall. Source: (SIREWALL, Undated)

- **The advantages of using rammed earth:**

- Rammed earth is considered an economic construction technique, its cost 40% less than the construction of a standard stud wall.
- Provides very comfortable environment and energy-efficient buildings.
- Architectural aesthetics as usually the natural colors of soils are adopted.
- Using less wood in construction process saves the trees, and less chemical generally prevents polluting the environment.

All the pre-mentioned techniques and other earthen techniques have a shared advantage which is the reuse and reclamation by nature after being reached its life cycle as shown in the following graph, unlike other conventional materials that require Co2 Energy in recycling process such as producing aggregates from concrete.

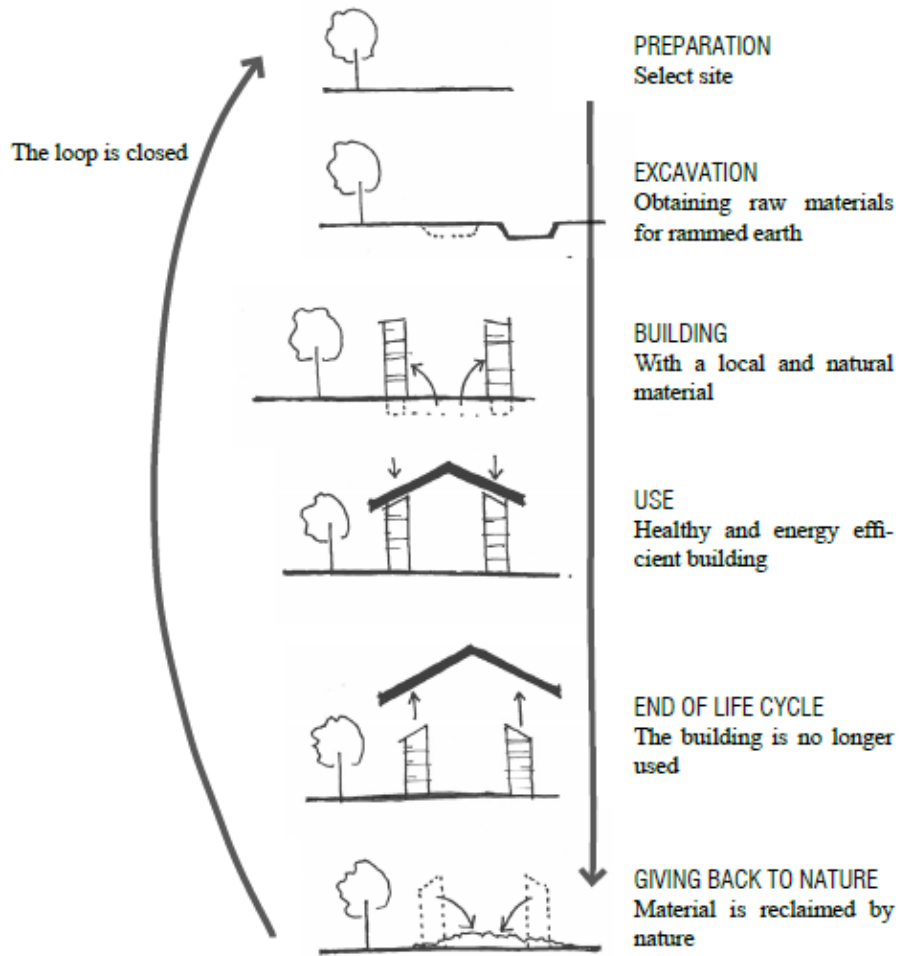


Figure 61 The life cycle of earth. Source: (ESCOBAR, 2013)

#### 4.2.3 Conclusion

All of the earth construction technologies are unique and applicable in our context; also earth as a material is fire resistant and considered bulletproof which encourage its use in the Gaza Strip. According to the maps analysis of available materials in the Gaza Strip, it has been found that;

**Adobe:** clay which forms the high percentage of the mixture is not quite available in the Gaza Strip, and preferable to be mostly used for agricultural purposes.

However, some of the available amount of clay can be used to manufacture adobe as in-fill blocks in reinforced concrete structure (this technique will be clarified in chapter 5), as the using of a combination of available local and earth materials can allow the production of more housing units, while avoid consuming too much clay as the management of using amounts of clay is quite necessary.

Adobe houses have already emerged in the Gaza Strip, thus the knowledge and experience of adobe technique exist.

More attention can be given for advanced designs and architectural appearance while buildings houses, that can be achieved through training, and engineering and architects contribution.

**CEB** requires a small amount of clay and much of sand; sand is available in abundance in the Gaza Strip, unlike clay. According to the International Labour Organization (ILO) project in Gaza in 2010, CEB shelters were more accepted by residents in compare with mud building and other temporary shelters.

There are few interlock factories in Gaza that have started to produce CEB mechanically, they employ around 10-15 worker, but they have almost the same quality as the CEB that are manually produced, so they can be improved to produce fine designs.

**Rammed Earth:** through a study done by (Paccoud, 2015), he found through interviews and online surveys that the most accepted technique is the rammed earth, due to its architectural impact and technical visibility.

This technique depends mainly on sandy soil which is available in Gaza, and building thick walls using rammed earth technique is a good option in a hot climate such as in Gaza, because good thermal regulation is an important factor in reducing the use of air conditioning.

At the same time, the thickness of rammed earth wall which is from 40-60 cm consume more space than other earthen techniques, in this case; rammed earth can be preferable for public buildings more than for houses, as the optimal exploitation of spaces is an important factor in the housing planning process in the Gaza Strip.

### 4.3 Contemporary earthen case studies

Presenting case studies that used earthen materials in contemporary way is considered a significant and motivated method in promoting the concept of earthen architecture in Gaza Strip, as it comes with different innovative earthen techniques, responds to wonders and problems associated with earthen materials, in addition to the fact that the visual interaction is a best approval and support for theoretical information.

Three innovative and contemporary earthen projects have been chosen to be introduced in this research, which are; The Vikas community project in India, Social Housing Project in Baja- Mexico, and Sandbag houses in Cape Town. These case studies have been chosen referring to their applicability and convergence of our context of Gaza Strip. Each case study has unique features and open up different building possibilities and opportunities in terms of building materials, techniques, and designs.

#### 4.3.1 Auroville experience with earthen architecture

Auroville is located in the south of India. The Auroville Earth Institute has been created in 1989; the construction of the visitors' centre of 1200 m<sup>2</sup> that has been built in 1992 was the start of the earthen architecture era in Auroville. The centre was built with compressed stabilized earth blocks (CSEB). (Auroville Earth Institute, 2005)

Since then, Auroville has presented a variety of earthen projects such as public buildings, schools, apartments, and individual houses, and that approves the potential of stabilized earth to act as a construction building material, in addition to its economic value, quality and comfort.



Figure 62 (Left) Visitors Centre and Kailash Youth Centre- CSEB. Source: (Auroville Earth Institute, 2005)

Figure 63 (Right) Kailash Youth centre – CSEB. Source: (Auroville Earth Institute, 2005)



One of Auroville's housing projects is the Vikas Community; this example has been chosen as a case study to be analyzed in order to take advantage of certain points which can be applicable in similar housing projects in the Gaza Strip.

#### 4.3.1.1 Vikas Community

The Vikas community is a housing project, materialised and built in Auroville, by the Auroville Earth Institute and has been done in several steps from 1992 to 1998, with the aim of responding to the shortage of housing. The creation of the community is based on particular spirit, life style, and sustainable approach. The project is 1448 m<sup>2</sup> floor area – with 23 apartments, and collective kitchen for 50 people

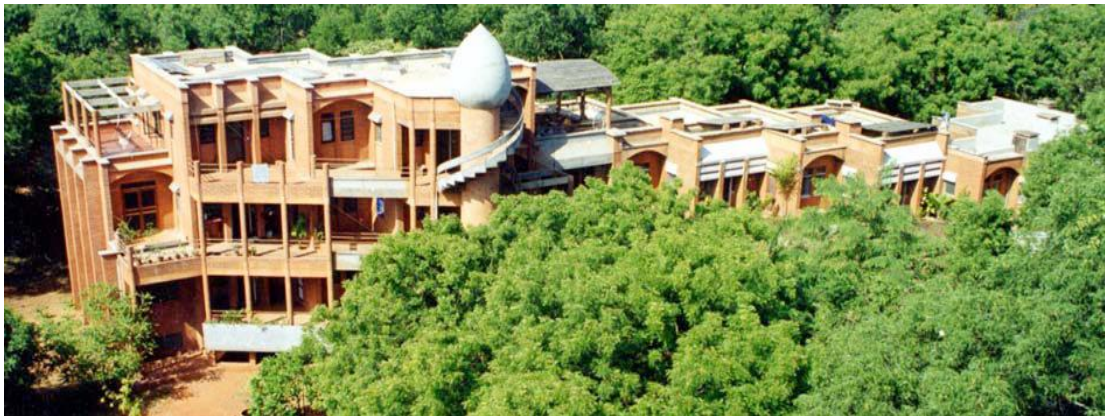


Figure 64 Vikas apartments. Source: (Auroville Earth Institute, 2005)

- **Main concepts and architectural design**

- |  |
|--|
| <ul style="list-style-type: none"><li>- The project was based on cooperation between the architect and people to come out with appropriate architectural design.</li></ul>   |
| <ul style="list-style-type: none"><li>- Adopting the basement floor concept: the concept was that the soil should be self-sufficient to complete the project, thus the soil was excavated from the basement floor by digging 1.20m under the ground level. A particular landscape has been design to protect the building from rainwater overflow.</li></ul> |

- The excavated soil was used to produce stabilized earth blocks.
- The needed soil exceeded the excavated quantity, so some soil had to be transferred from elsewhere.



Figure 65 ( Left & Right) Excavation of the basement floor – 1.2 m below ground level. Source: (Auroville Earth Institute , Undated)

- The project included individual apartments, a few individual houses, and common facilities.
- The design of the project took into consideration the eco-friendly and sustainable development principles through; using earth as a raw material, using sunshade and proper orientation to provide natural light and ventilation for the buildings, and landscape integration for the excavated areas.
- The plan of the project represents a unique design in exploiting the available area; the apartments have been designed on raw houses style. The buildings have different heights, and include apartments in different sizes as shown in the section.

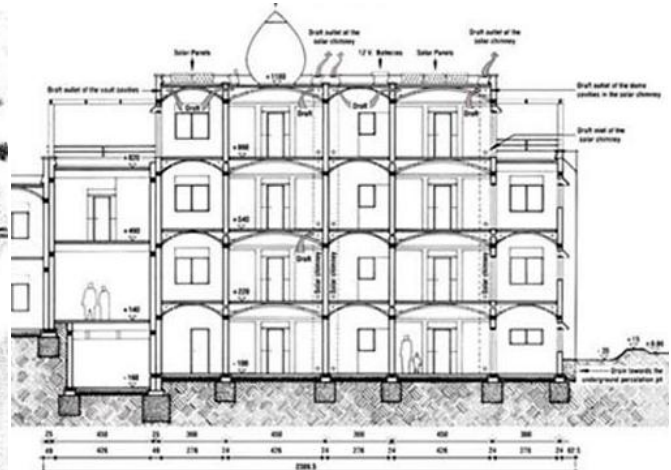
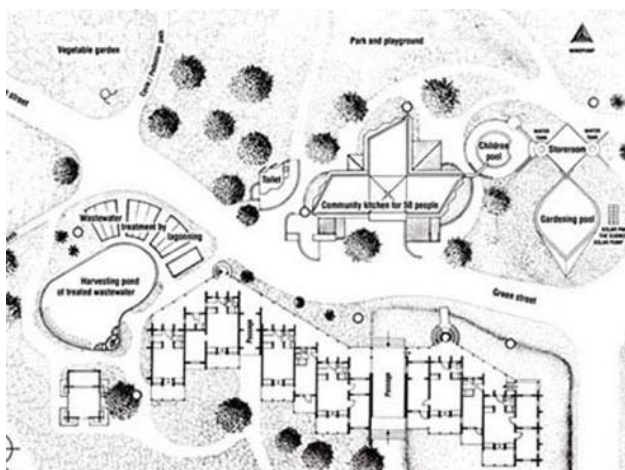


Figure 66 (Left) Vikas community plan, source: (Auroville Earth Institute , Undated)

Figure 67 (Right) Section of the third building, source: (Auroville Earth Institute , Undated)

- **Building technologies**

- The project built with stabilized earth (CSEB) (with 5 % cement by weight), from foundations to roof.
- The foundation was built using stabilised rammed earth.



Figure 68 (Left 1) Soil sieved from the digging trench. Source: (Auroville Earth Institute , Undated)

Figure 69 (Left 2) Adding sand, cement, and water on the pile of soil. Source: (Auroville Earth Institute , Undated)

Figure 70 (Left 3) Pouring the stabilised earth mixes in the trench. Source: (Auroville Earth Institute , Undated)

Figure 71 (Right) Checking the top level of the foundation from the reference level. Source: (Auroville Earth Institute , Undated)

- The walls made of Stabilized Compressed Earth Blocks CSEB with 24cm thickness. And maximum height of 13.4 m for four floors.
- Vaults and domes made of CSEB for roofs and floors; domes were made only for living rooms, and very flat floors and roofs were made of CSEB, using free-spanning technique.



Figure 72 (Left) Vault in bedroom of an apartment. Source: (Auroville Earth Institute , Undated)

Figure 73 (Middle) A cloister domes in living room of an apartment. Source: (Auroville Earth Institute , Undated)

Figure 74 (Right) A cloister domes in living room. Source: (Auroville Earth Institute , Undated)



- 25mm Ferro-cement channels were used for flooring and housing.
- Auroville buildings use Hourdi Roofing to create flat floors and roofs.

Hourdi roofing means placing hourdi blocks; which are hollow blocks made of CESB, on reinforced concrete T beams or Ferro-cement channels.

This technique has great advantage in hot climates as it provides very comfortable environment, and the block has extremely high resistance.

#### - Hourdi blocks on concrete T beams



Figure 75 (Left) Adjusting Hourdi blocks on T beams. Source: (Auroville Earth Institute , Undated)

Figure 76 (Middle) Concreting the roof with a cement concrete. Source: (Auroville Earth Institute , Undated)

Figure 77 (Right) Roof with hourdi blocks and T beams. Source: (Auroville Earth Institute , Undated)

#### - Hourdi blocks on ferrocement channels



Figure 78 (Right) Floor with Hourdi blocks and ferrocement channels. Source: (Auroville Earth Institute , Undated)

Figure 79 (Middle) Adjusting Hourdi blocks in between ferrocement channels. Source: (Auroville Earth Institute , Undated)

Figure 80 (Left) Casting an earth concrete: 1 cement: 2 soil: 3 sand: 4 gravel. Source: (Auroville Earth Institute , Undated)

- **Unique features**

- The building process of the project was done gradually; the first step was the community kitchen, to enhance the public interest, after that a block of 4 apartments, then the second block of 5 apartments, and later on the third block has four floors with 13 apartment; the first floor of the four floors was a basement floor.
- The management of resources was always a priority; the needed soil was extracted from the building site, and the soil quarries were planned first to allow perfect integration between the building and landscape, some of the quarries were integrated as gardens, water harvesting and wastewater treatment areas.

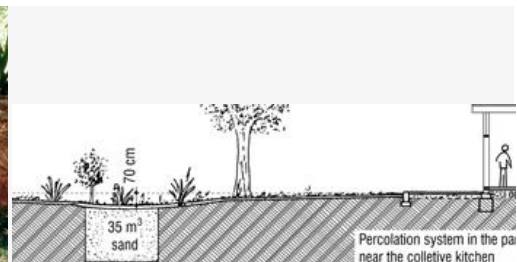


Figure 81 (Left) Pond for Wastewater treatment integrated with the buildings and nature. Source: (Auroville Earth Institute , Undated)

Figure 82 (Middle) Deep percolation pit, (70 m3) at vikas community. Source: (Auroville Earth Institute , Undated)

Figure 83 (Right) Principle of the percolation pit. Source: (Auroville Earth Institute , Undated)

- In a response to the housing shortage in Auroville, the concept of movable houses has been introduced. The city of Auroville was still under construction and there was no master plan, so they did not want to allow random buildings anywhere as that will hinder their major future developments.
- The movable houses innovated to be built in short time, and stay until achieving the development, then the materials will be reused to rebuild elsewhere, therefore, two cost effective prototypes have been built.



Figure 84 (Left) Legaum prototype with wooden shingles and interlocking CSEB. Source: (Auroville Earth Institute , Undated)

Figure 85 (Middle) Legaum prototype modified with coconut leaves. Source: (Auroville Earth Institute , Undated)

Figure 86 (Right) Legaum with foundations – Cloister dome type. Source: (Auroville Earth Institute , Undated)

- The concept fulfilled the aim of the project, while the social acceptability remained a problem, as people usually see the house as a rooted investment and property, so un-rooted houses were not succeeded in fulfilling their physiological needs.
- So rooted houses were built by self-builders based on community participation, after three weeks of training course, people followed provided plans to build the houses, and they were responsible of managing and developing their houses.



Figure 87 (Left & middle & right) Community participation: Block making and soil sieving. Source: (Auroville Earth Institute , Undated)

### 4.3.2 Social Housing Project in Baja, Mexico

A major hurricane hit a small touristic state; Baja California Peninsula in Northwestern of Mexico, in September 2014, huge devastation happened, and people lost everything: their homes and belongings. People who were living in unprivileged communities took long time to recover, and many organisations started to send help to the area. (BLOG LA76, 2016)

One of them was Cabo Hurricane Fund, this organisation created housing project with the aim of building more than 100 housing units for the most affected families. The organisation had a communication with a local organisation called CAPA, which has the interest in generation sustainable urban strategies in Baja, and they developed a proposal of sustainable social housing of rammed earth called “Casa O”. To response to the need of efficient houses with best architectural solution for affected people who have low economic level.

- **Main concepts and architectural design**

- The aim of the project was to develop social life around a green core “the patio”, which is the main architectural element inherited from Arab cultures through the Spanish colonization.
- The patio is the centre of the house and considered social and meeting space as well as very economical and sustainable as a tool to cool the living spaces and regulate the temperature inside the house.

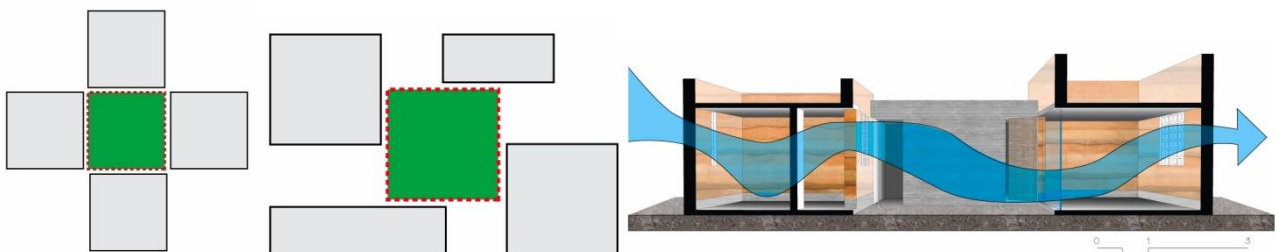


Figure 88 (Left) Concept plans. Source: (Plataforma Arquitectura, 2015)

Figure 89 (Right) Ventilation diagram . Source: (Plataforma Arquitectura, 2015)

- The concept of the project has been inspired from the Andalusian patio which is a common space of the entire architecture of the Mediterranean basin, generated over centuries from the architectural fusion of Roman and Muslim worlds as functional and aesthetic element of houses in hot and dry climates.





Figure 90 (Left) The patio of “Casa O” project. Source: (BLOG LA76, 2016)

Figure 91 (Right) Andalusian patio. Source: (IMAGES7.COM, Undated)

- The plan is functional, well organised, and applied the aim of developing enough spaces for social purposes and kids playing. The plan presents each function separately in four sides of a courtyard meant to be green. People benefit from the surrounding areas of the house for other activities such as agriculture and livestock breeding.
- The plan gives flexibility in the design; for adding blocks or floors as shown in the following plan, or even removing parts. The area for one floor house between 50-60 m2.



Figure 92 Progress and flexibility of the houses' plan. Source: (Domus, 2015)

- We notice the multiple construction materials used; rammed earth walls, concrete slabs for floors, foundation, and roofs, concrete blocks in some parts of the house, and hollow concrete blocks to make the pattern that has been used for windows and partition walls to allow more passage of natural light and ventilation.
- Using rammed earth add a sense of warmth and welcoming for the house.

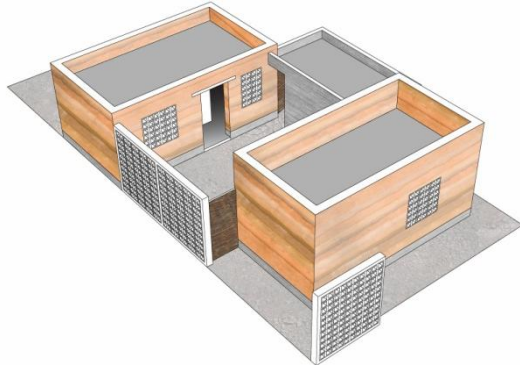


Figure 93 (Left) 3D model of one of housing prototype. Source: (Plataforma Arquitectura, 2015)

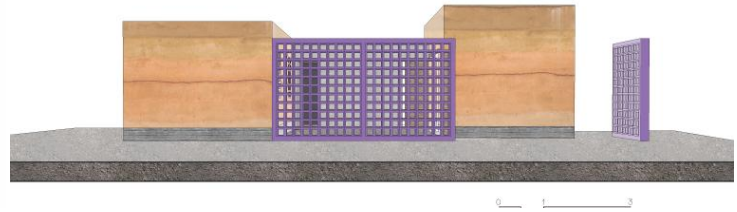


Figure 94 (Right) Lateral elevation. Source: (Plataforma Arquitectura, 2015)

### • Building technologies

- Rammed earth is the best technique for hot and arid climates, because it provides high thermal performance. It has been decided to be used particularly in this case based on the economic situation of the people and the fact that they won't have artificial air conditioning system.
- The process of self-construction is the main and popular method in Mexico, using rammed earth triggered social cohesion and kept the house at a cost less than \$10,000 US dollars.

### • Unique features

- The sense of community has been quite developed and focused on through various strategies on the project:
- The idea was not to give a free house for the beneficiaries but to involve them in the construction process, through this simple way deeper social links are achieved, by neighbours helping each other to construct their houses, this method ensures developing knowledge, appreciation, and sincere in working for each other.
- Involving the beneficiaries to build with rammed earth system eventually contributes to the widespread of this technique and counter balance the use of concrete blocks in the construction of the city.
- The housing prototype was flexible and open for free interpretation and adapted by the inhabitants, according to their specific needs as uses, environment, climate, and territory.
- The designing of the housing prototype took into account many social aspects; like income level and social activities, and different families' situations, such as disabled member, single mothers, nuclear or extended families, the existed low level of security, and torn social fabric.

### 4.3.3 Sandbag houses\_Mitchell's Plain

In Freedom park of Mitchell's Plain township in Cape Town, informal settlements have been replaced by a project of sand bag construction system to provide ten affordable houses, built on the outskirts of Cape Town with a budget around 8600€, in 2008. (DeZeen, 2008)



Figure 95 (Left & right) Mitchell's Plain\_ sandbag housing project. Source: (Smithsonian, 2011)

- **Main concepts and architectural design**

|   |
|---|
| - The design is a part of the 10×10 Sandbag House project, inspired from the indigenous use of mud-and-wattle construction method. (DeZeen, 2008)   |
| - The project initiated by Design Indaba that challenged ten teams of architects to provide innovative, dynamic, affordable and low cost design method.   |
| - The design aimed to improve the urban quality of life and the quality of low cost houses, by exploring sustainable and appropriate design methods.  |
| - The project has a design of two-story homes made of timber frames and sandbag in-fill construction.   |
| - With the given small plot sizes (112m <sup>2</sup> ) by the government, and allocate 40m <sup>2</sup> house for each household in limited budget, the design came in line with these requests and ensures the ability to accommodate density as shown in the following plan, by designing a detached and semi-detached houses of two stories in raw form. |
| - The design provides residential options of detached and semi detached houses. (Smithsonian, 2011)   |



Figure 96 (Left & right) The plan and 3D perspective of the Mitchell's Plain sandbag housing project. Source: (DeZeen, 2008)

- The evolved design achieved architecturally pleasing aesthetics. To achieve their aim of improving the quality of the urban environment; street edge layout for houses has been built to allow more space for garden and play areas for the family at the back of the houses, thus, the ground floor included living, kitchen/dining and wet areas for better connection with the external areas, and the sleeping quarters in the upper floor, to allow some separation and privacy.
- Design flexibility, which allows future expansion whenever the family is able to afford that, by using the external upper balcony and exterior backyard.

#### • Building technologies

- The Cap Town company has developed a system called Eco-beam and sand bag, this method has three elements; Eco-Beam framework (wood and metal beams), geo-fabric bags filled with sand, and finally cladding system (wire mesh, plaster, timber or plasterboard). (Stemmett, Undated)
- The framework of timber and metal provides tensile strength, while the sandbags provide excellent thermal mass which will keep the occupants in comfortable thermal zone, in addition to the sound absorbing properties that help in maintaining privacy, as well as both wind-resistant and moisture-resistant.
- The building method is also energy efficient, as it requires little or no electricity and little transport cost, since the Eco-Beams are also manufactured onsite.
- This technique is cost effective as it used sand which is extremely cheap material and sand dunes are available a few hundred meters away from the construction site.
-





Figure 97 (Left) The structural framework (Eco-Beam). Source: (Duarte, 2008)

Figure 98 (Right) Eco-Beam, sandbag system, and wood cladding. Source: (Duarte, 2008)

- Applying the sand bags in-fill with the previous existed structure.



Figure 99 (Left&right) Sandbag in-fill method in the Mitchell's Plain project. Source: (designindaba, 2009)

- **Unique features**

- Local community members participated in the housing building process, with little skilled labour was needed, which shows the applicability of the technique in other regions.



Figure 100 (Left) The community involvement in the building process. Source: (Smithsonian, 2011)

Figure 101 (Right) The community involvement in the building process. Source: (designindaba, 2009)

- The technique fits with mass production and provides a lot of job opportunities and develops skills for the local community, it is unique, simple and easy method to construct and favors low and unskilled labors, making it a good opportunity for women in the community.



Figure 102 (Left&right) The community participation and targeted working groups. Source: (Duarte, 2008)

The design overcomes the challenges of:

- Facing the fact that the accepted and dominant materials for building construction are bricks and mortar.
- The limited plot sizes and budget, so they maximized the usability of the available space as much as possible.
- Cost management in term of cost saving besides energy is the site-clearing work as a major cost on any construction site, so in the case of sandbag houses, there will be no bricks lie around the site during, before or after the construction process, thus no waste or loss of building materials.

#### 4.3.4 Conclusion and summary

Each of the three case studies has different characteristics that can be considered ideal opportunities to be taken into consideration and applied. The main points have been summarized as follows:

|                     |   |
|---------------------|---|
| <b>Case Study 1</b> | <ul style="list-style-type: none"><li>- The basement floor concept.</li><li>- Mixed type of housing.</li><li>- Following the sustainable development principles.</li><li>- Following the basic design principles of housing (ventilation, lighting, etc).</li><li>- Planning to use the available space efficiently.</li><li>- Learning different construction techniques (Ferrocement channels, Hourdi Roofing).</li><li>- Reviving architectural element of the Gaza Strip (Vaults, domes).</li><li>- Build the project gradually.</li><li>- Resources management.</li><li>- Movable/ rooted houses.</li><li>- Capacity building through community participation.</li></ul> |
| <b>Case Study 2</b> | <ul style="list-style-type: none"><li>- Cooperative work with local organisations.</li><li>- Reviving the courtyard as a unique architectural, social, environmental element, that linked with the LBC of Gaza.</li><li>- Combining different materials for construction according to their availability.</li><li>- Develop the sense of community through building capacities and participation, which was the followed building process in Gaza referring to the LBC.</li></ul>   |
| <b>Case Study 3</b> | <ul style="list-style-type: none"><li>- Reviving the indigenous earth construction technique.</li><li>- Using sand as an available resource for low cost houses.</li><li>- Dealing with the limited areas and budget.</li><li>- Using the existed structures with the sand bags technique.</li><li>- This type of construction is suitable in isolated areas, and ideal in sites with lots of sandy soil such as on the coastal area of Gaza Strip.</li></ul>   |

#### 4.4 The values of earthen architecture

Using earthen materials for construction purposes is an important factor in achieving the global aim of sustainability, which includes three main aspects; social, environmental, and economical aspect.

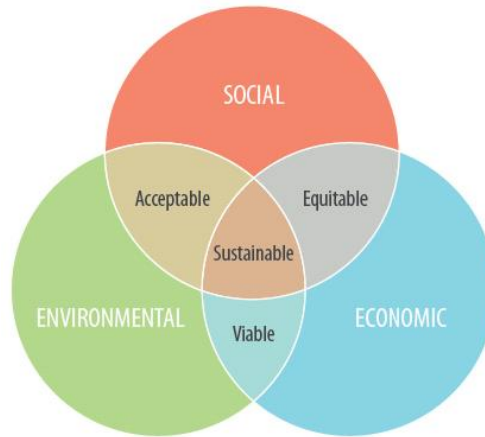




Figure 103 Dimensions of Sustainability. Source: (Martin, 2012)

|   |  |
|---|--|
|  <b>Social &amp; cultural values</b> | <ul style="list-style-type: none"> <li>- Using earth enables us to integrate the land that we live on into our houses, increase our comfort and happiness of our homes as it provides efficient thermal and acoustic isolation that helps you to create your own world which is considered an added attraction for many people. (anywaysolutions, Undated)</li> <li>- Preserve the LBC, and rehabilitate the social link through reviving the originality of unique architectural elements such as the courtyard in the ancient buildings of Gaza.</li> <li>- Aesthetically pleasing environment; the using of earth as a building material gives an opportunity for creative architectural designs, in addition to the beauty of colors and textures; the natural colors of the earth that give a sense of warmth in the living environment; the exterior facades are typically provided by a weather-resistant layer which can be colored or left natural, while the interiors can be plastered with various decorative elements and mixtures or left natural.</li> <li>- Design flexibility; domes, vaults, arches are options can be constructed using different earth construction techniques, which gives the ability to revive unique architectural elements have been used during the past.</li> </ul> |
|---|--|

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|--|--|
|  | <ul style="list-style-type: none"> <li>- Human security; earth walls are non combustible, thus the fire risk factor of earthen buildings is extremely low, also they resist bullets as they settle inside the clay wall.</li> <li>- Human health: the earth is a natural material free from toxic substances and made through non-toxic process, also the earth walls are breathable and have the ability to absorb smells and toxins from the indoor air.</li> <li>- Participatory process; building with earth usually requires low labor skills in many stages of the construction process, which in turn allows enhancing the social links, cooperative work, building people's capacities, and increase our adaptation to the local environment that we live in.</li> <li>- It gives a sense of local autonomy as long as all raw materials are on site.</li> </ul>   |
|  <b>Environmental value</b> | <ul style="list-style-type: none"> <li>- Earth is an environmentally friendly and non-toxic material and its manufacturing process is also non-toxic, so accordingly the building themselves are clean in compare with the modern construction practices that are filled with toxic gases and chemicals. (anywaysolutions, Undated)</li> <li>- Improve the air quality and protect the ecosystem.</li> <li>- Earth is also environmentally friendly in term of exploiting natural resources in comparison with conventional construction materials.</li> <li>- Using earth in construction practices increases the interest in conserving and restoring natural resources. (Design Build, 2011)</li> <li>- Energy saving; in both of the process of manufacturing the building materials and transporting them to the construction site, which in turn reducing the environmental impact.</li> <li>- Zero waste; the earth is whether used for construction or landscape, and it is also reusable material, and fully recyclable if it is unsterilized earth.</li> <li>- Temperature and climatic control.</li> <li>- Moisture control; Earth stabilizes the humidity rate and provides a healthy environment inside rooms through its ability to absorb and release the moisture from the indoor air</li> <li>- Conserve water; as it requires less amount of water in compare with the conventional materials.</li> <li>- Many earth construction techniques require no or low amount of wood, thus it contributes to the preservation of nature against deforestation.</li> </ul> |



## Economical value

- Less energy is needed for earth material production, transportation and production, thus extremely low cost. (Muhaisen & Ahlbäck, Towards sustainable construction and green jobs in the Gaza Strip, 2012)

- Using sustainable local material is an important factor in creating new job opportunities, as using recycled and local materials for construction purposes requires labor intensive; including architects, engineers, and workers, who work in producing and constructing the alternative materials, in addition to collecting and recycling materials. The core occupations in sustainable materials use in buildings are shown as follows:

Planning and  
designing

Architects and civil/structural/environmental  
engineers  
Architectural technicians and technical  
drawing specialists.

Manufacturing,  
Construction,  
Installation,  
Maintenance

Manufacturing of local construction  
materials; manufactures, and distributors in  
case of producing earth blocks  
Recycling; collectors, recycling specialists,  
materials transport.  
Construction; building site supervisors and  
site engineers/architects specialized  
knowledge in local and recycled construction  
materials, bricklayers, masons, other  
construction workers.

Controlling

Building inspectors and quality controllers.

Enabling

Educators and training providers.

- Using local materials such as earth contributes to overcome the challenge of importing construction materials, resulting in substantial financial savings and gains.
- Earthen houses are considered affordable constructions.
- Efficient production; the cost of an earthen wall in case of using earth blocks is about 40% cheaper than other conventional techniques; because earth blocks manufacturing requires little energy and usually made on



|  |  |
|--|--|
|  | <p>site thus little fuel consumption and transportation cost.<br/>(anywaysolutions, Undated)</p> <ul style="list-style-type: none"> <li>- Long term efficiency in cost and energy; earthen house provides incredible savings in energy thus the cost for the owner throughout the house's life. The owner savings can be up to 14% on cooling and heating costs. This is at the individual level; so much effect will be on community level and bigger scales.</li> <li>- Life cycle cost; earth buildings require simple periodic maintenance.</li> </ul> |
|--|--|

## 4.5 Conclusion

Reviving the use of local materials has become a necessity in the Gaza Strip in light of the serious siege and scarcity of building materials, and the urgent need for shelter for displaced people.

The contemporary earthen architecture and its building methods are a good opportunity to rebuild Gaza and utilize from architectural elements and authentic values of the society, as well as meet the physical and physiological needs of the population.

Using local building materials is considered a friendly solution as it ensures the sustainability in different ways; socially and culturally, environmentally, and economically as it promotes the local autonomy.

Building with earth aim to build durable economic houses, build better, decrease the dependency on imported materials, and overcome the challenges with innovative alternative materials.

# ***Chapter 5: Design and technical proposals***



## 5. Basic design and construction proposals for housing in the Gaza Strip

This chapter provides some technical solutions for housing that respond to the high population density and growth, and the future need for housing, followed by design recommendations.

### 5.1 Design concept

After analyzing the general condition of Gaza and the availability of the local materials, it found out that using earth as a building material does not mean to build all with earth, because to build durable housing and rapid the building process; other materials and equipments are needed; such as stabilizations for foundations, structure, or roofs.

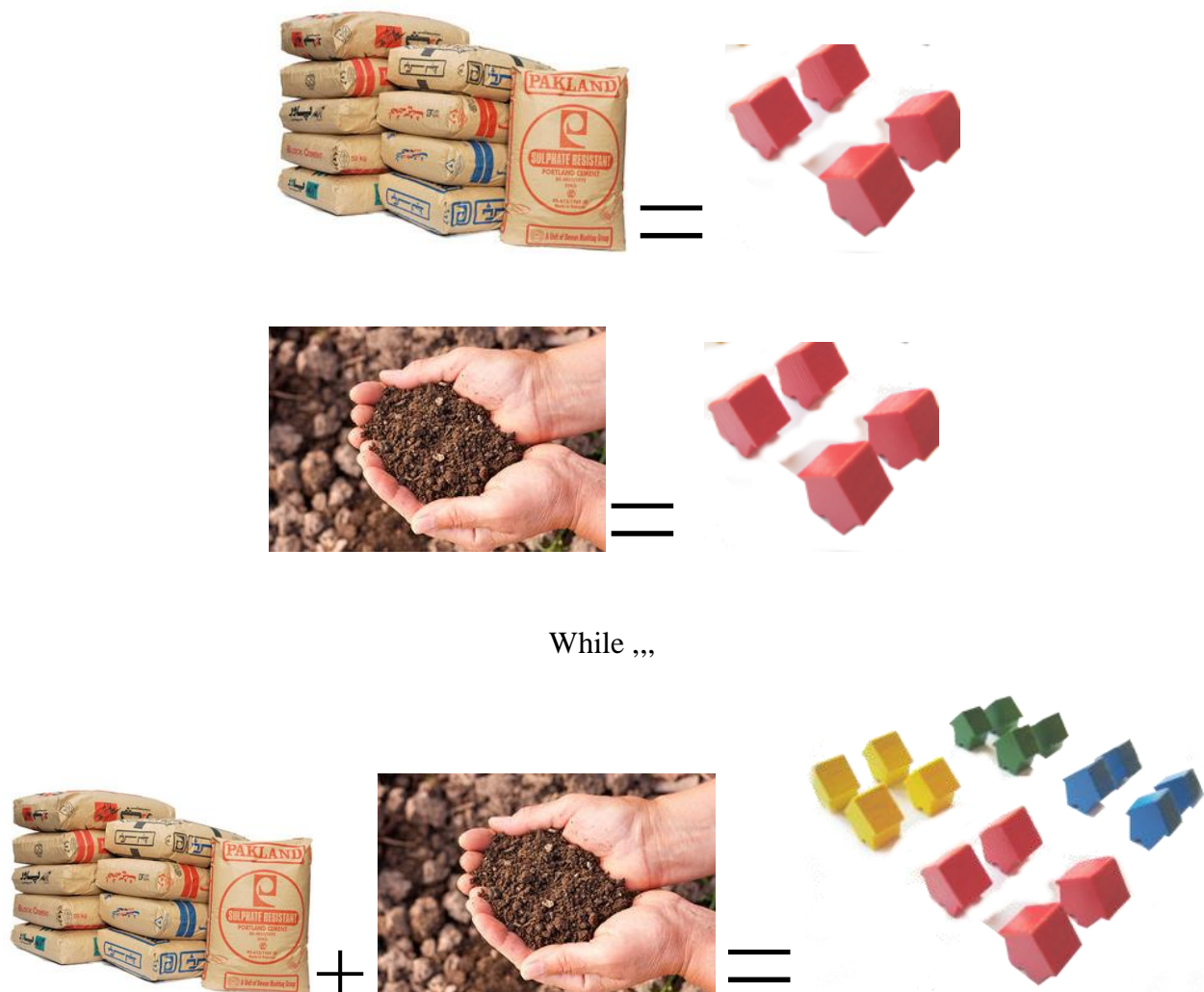
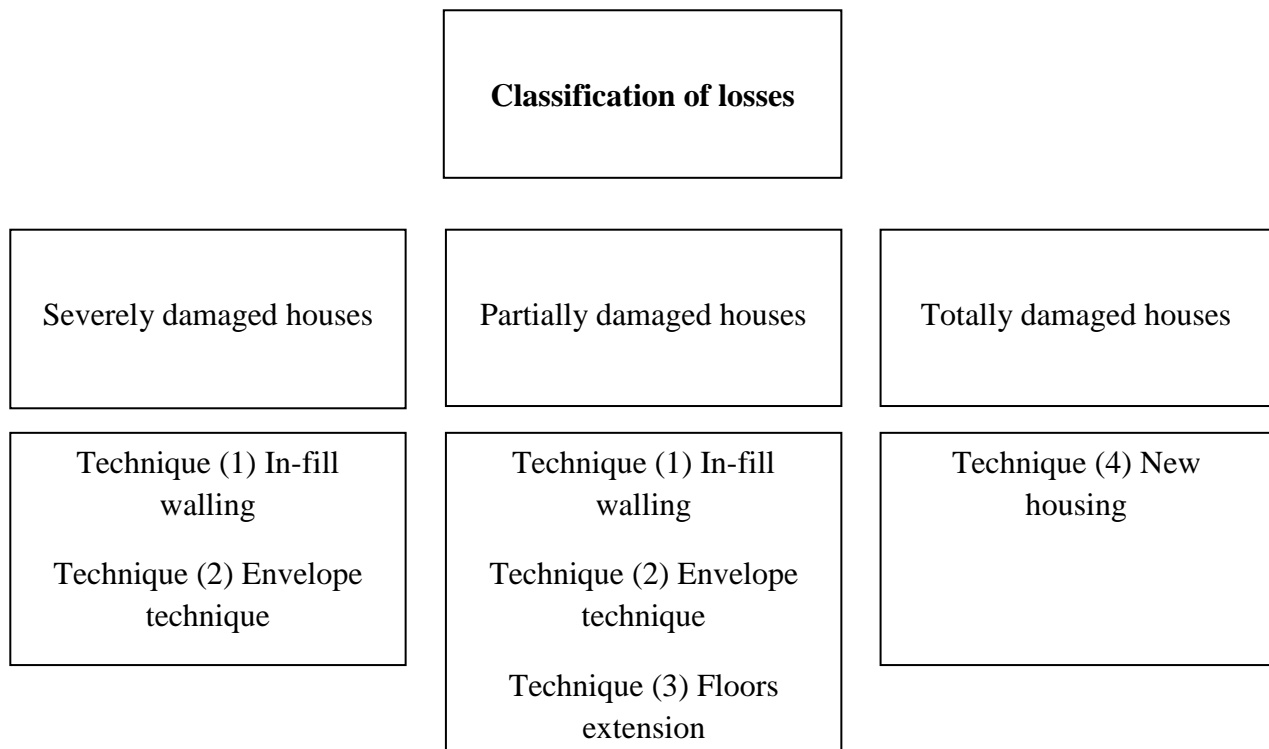


Figure 104 Design concept. Source: Author, 2017

## 5.2 Proposed construction techniques

Different construction systems are proposed dealing with the housing problem, and the high population density and growth of the Gaza Strip. The proposals are based on the destruction size of building as shown in the following scheme:



Scheme 4. Classification of losses and proposed techniques. Source: Author, 2017

### 5.2.1 Technique (1): In-fill walling

In-fill walling can be used for severely and partially damaged houses that can be repaired, according to the following points. (Samin, 2016):

- The demolished parts have to be removed, and keep the safe parts of the buildings.
- The strength of the building has to be carefully checked.
- If the structure has the required capacity, we apply the infill walling, where infill walling is "the generic name given to a panel that is built in between the floors of the primary structural frame of a building and provides support for the cladding system. Infill walls are considered to be non-load bearing". (steelconstruction, Undated)

- Reinforced concrete frame will be filled with earth blocks (adobe, CEB), or could be using rammed earth, then it will be plastered with earth or left natural.
- This technique is a way of taking advantage of the existed concrete frame; after being checked to ensure its capacity and strength, then to be in-filled with one of the earth techniques.
- The earth construction techniques that could be used in in-fill system are;
- For exterior walls: rammed earth, CEB, adobe bricks, or sand bags.

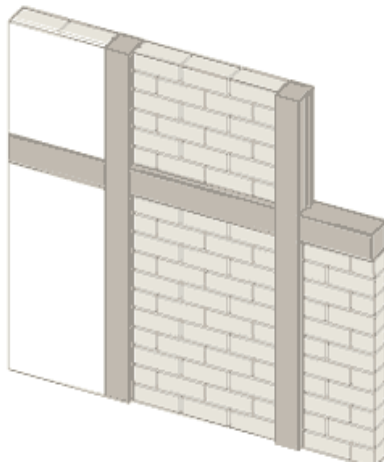


Figure 105 (Left) Infill CEB/ Adobe bricks. Source: (earthbuilding, Undated)

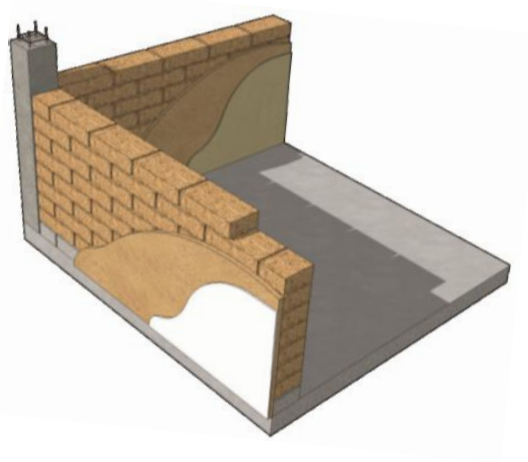


Figure 106 (Right) Infill CEB/ Adobe bricks with cladding. Source: (CRAterre, 2016)

- For roofs; Hourdi blocks on reinforced concrete T beams or Ferro-cement channels. Hourdi blocks are used for roofs and floors. (Aroville Earth Institute, 2005)



Figure 107 (Left) Hourdi blocks on reinforced concrete T beams. Source: (ballutblocks, Undated)



Figure 108 (Right) Hourdi blocks on Ferro-cement channels. Source: (Auroville earth institute)

Other light techniques to produce light blocks for roofs and floors can be used but depend on the availability of straw, according to (Paccoud, 2017) people in Gaza are using straw for cattle. Other source of vegetal fiber that needs to be checked is the sea plants or any other fiber material, in order to be able to produce light adobe bricks.



Figure 109 (Left) Sea plant/fibers, Source: (CRATERRE, 2016)

Figure 110 (Middle) Straw, Source: (RUF, Undated)

Figure 111 (Right) Light earth blocks, PNEED-TYPHA project in Senegal. Source: (CRATERRE, 2016)

The following pictures clarify the possibility of using light earth blocks in the roofing system while having concrete structure. The earth blocks should be covered with a layer of cement in order to increase its capacity to climate conditions.

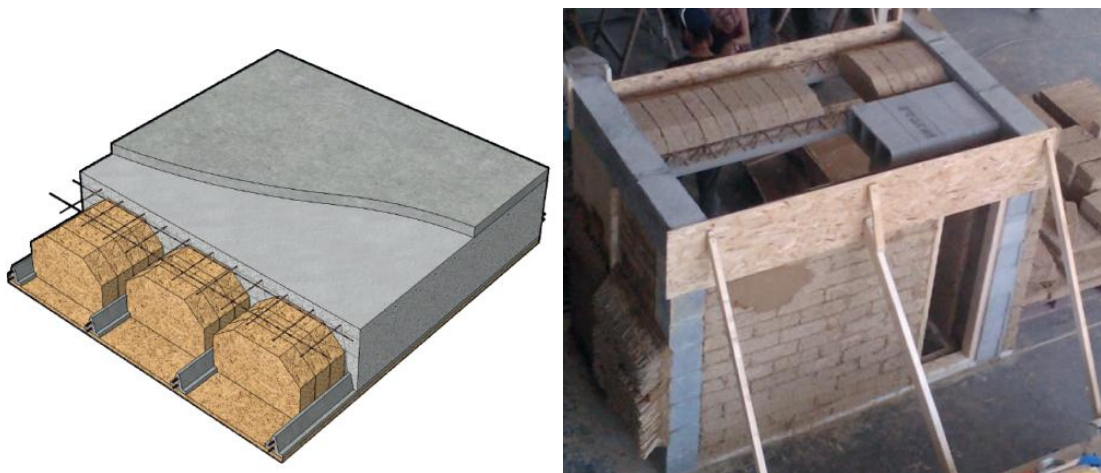


Figure 112 (Left) Light earth blocks and concrete slab for roofing. Source: (CRATERRE, 2016)

Figure 113 (Right) 3D model of light earth blocks used for walls and roofing, and reinforced concrete structure. Source: (CRATERRE, 2016)

### 5.2.2 Technique (2): Envelope technique

- The envelope technique means adding an extra layer of earthen materials, while taking advantage of the existing structure.
- This method can be used for the reparation of partially demolished buildings, and can also be done as an additional layer for the in-filled parts.
- The structure strength has to be checked with engineers before applying this method.
- Envelop technique has a great economic and environmental advantages when it uses as an additional layer for partially demolished buildings and even buildings in good condition, as it provides high thermal efficiency.
- After the structure being checked, demolished and sharp edges have to be carefully removed, then to have the demolished part ready for in-fill material then the envelop.

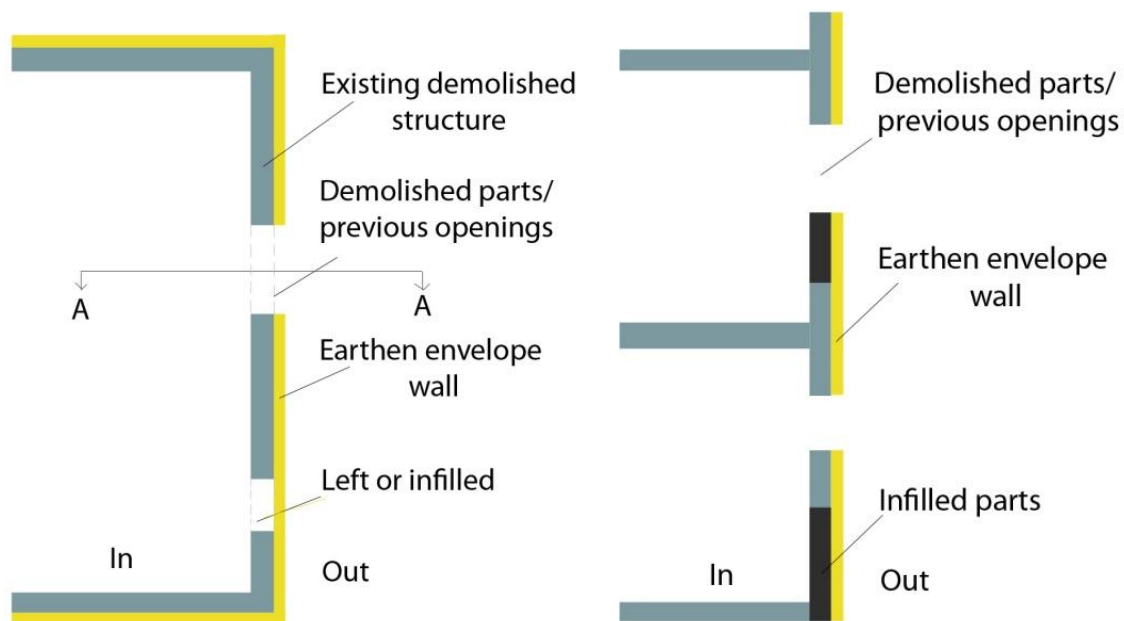


Figure 114 (Left) Abstract plan of the proposed envelop technique. Source: Author, 2017

Figure 115 (Right) Abstract section (A-A) of the proposed envelop technique. Source: Author, 2017

- Different techniques can be used depending on the size of the damage; envelope layer can be done using CEB, sand bags, adobe bricks, or light adobe bricks as shown in (figure 114). The envelope technique used as an interior or exterior layer for partially demolished buildings or masonry in good conditions, to increase the thermal efficiency.



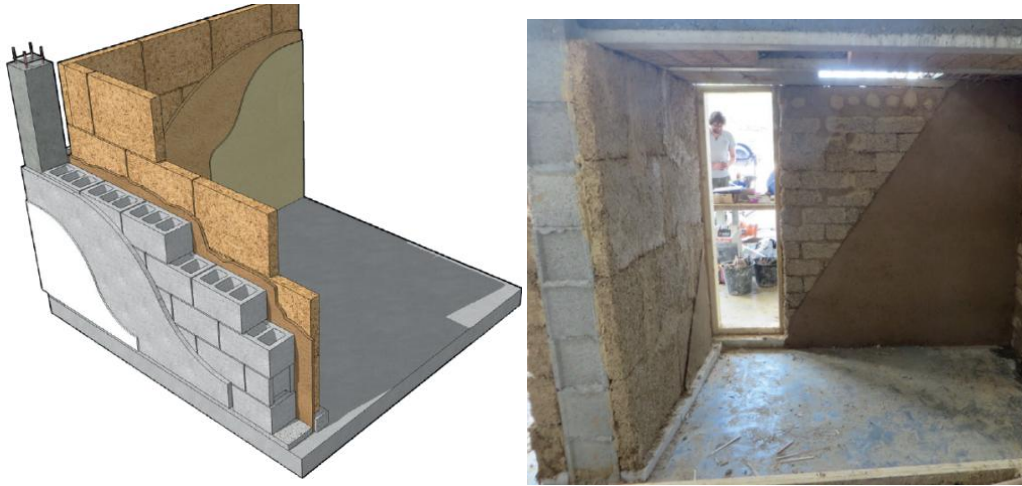


Figure 116 (Left & right) Envelope technique using light earth blocks for existing masonry structure. Source: (CRAterre, 2016)

- One of the applications of the envelope technique is “Mashrabiya”, which is a unique architectural element has been used traditionally in the Palestinian community.
- This element appears a lot in the architecture of the architect Hassan Fathy, and modern architecture.

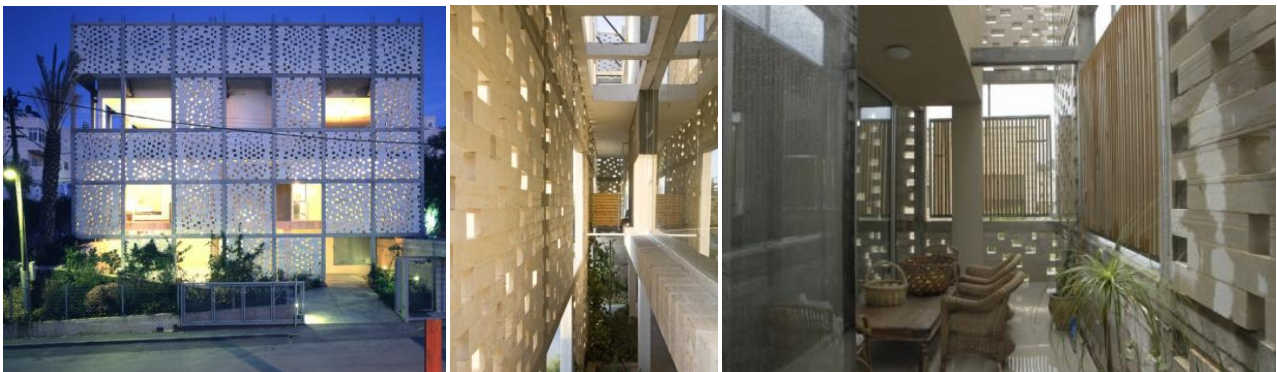


Figure 117 (Left, middle, &right) Mashrabiya House in Jerusalem, Palestine. Source: (AW, 2012)

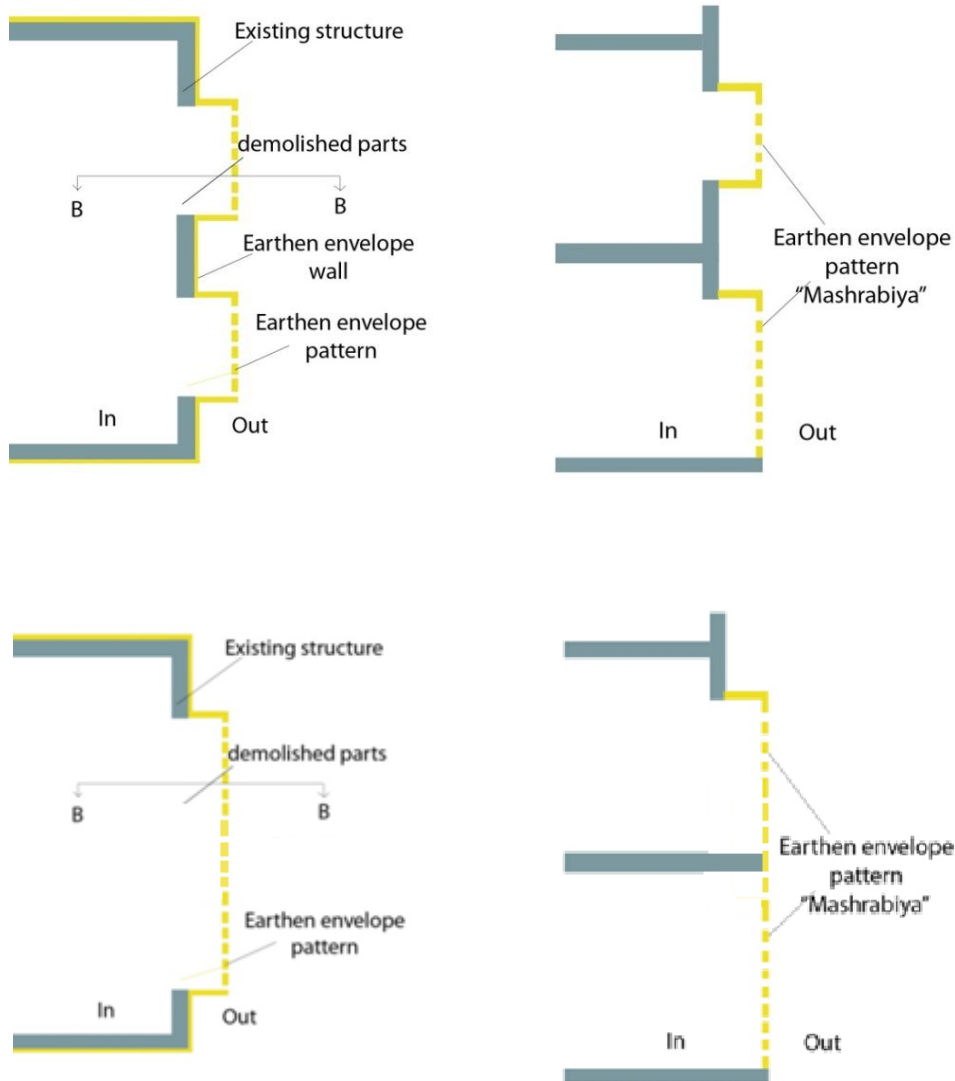


Figure 118 (Left) Abstract plans of proposed envelop technique (Mashrabiya). Source: Author, 2017

Figure 119 (Right) Abstract sections (B-B) of proposed envelop technique (Mashrabiya). Source: Author, 2017

### 5.2.3 Technique (3): Floors extension

Due to the huge demand for housing and the limited land; another proposition is to increase the number of floors for both the partially demolished and buildings in good conditions, using the pre-mentioned techniques.

As mentioned, a lot of houses have been designed to be vertically extended up to 3 to 5 floors, which allows us to think of such a proposal to densify the number of housing units and serve as much families as possible.

- The structure of the partially demolished house has to be checked first to decide the possibility of increasing the number of floors. Choosing the best construction technique as well as the number of floors depends on the bearing strength of the structure.
- It is recommended to use light weight techniques to build the extra floors such as adobe, and CEB.
- According to Paccoud (2017), strong concrete structure can bear one extra floor using light adobe or CEB without concrete bearing wall, while for more floor concrete bearing structure is needed. Overall, the building must be evaluated to apply the extension method.

#### **5.2.4 Techniques (4): New housing**

All the previously mentioned techniques can be used to build single houses or housing project. Adobe and CEB can be used in any type of housing, while it's recommended to use rammed earth for single houses or community buildings not for housing projects, as rammed earth walls have a thickness 40cm-60cm, so it takes more space than the other techniques, which is not in line with the fact that Gaza struggles with the lack of space.

- Excavate the area where the building is demolished and use the underground soil, to avoid transportation cost, at the same time, build the house on the excavated area. The volume of produced soil might be enough to produce earth blocks and various work.
- The house could have RC structure and in-filled with earthen blocks.
- The building should start from underground level, to get a basement floor (half underground floor).
- The concept of building housing in Gaza should be inspired by the heritage of Gaza; where their architecture had unique social relations and activities based on the their old houses designs, as well as respecting environmental issues, and community participation.
- Integrating design elements from heritage of Gaza, where they used to design roofs of very flat vaults, and domes for living rooms. Courtyard is a unique element that can be done in contemporary way.



The following pictures show various styles of courtyards that can be revived in the Gaza Strip and preserved as a distinctive architectural element.



Figure 120 (Left) An ancient house belonging to the Ottoman era in Gaza. Source: (felesteen, 2016)

Figure 121 (Middle) An ancient house in Gaza. Source: (paltoday, 2016)

Figure 122 (Right) Modern and contemporary courtyard. Source: (homedesignlover, Undated)

To build a housing project some points have to be taken into consideration, these points are based on analyzing the current situation of Gaza, as well as understanding the different construction techniques. (Author, 2017):

- Take advantages from the debris on the site through recycling processes.
- Follow housing mix strategy, which means having different sizes and types of flats to avoid consuming more lands.
- Build gradually, to ensure the sufficiency and availability of construction materials.
- The chosen area for the earthen housing project should be in highly affected or demolished neighborhood to build in this area, to avoid consuming more lands.
- Identify the proper earth technique according to the available materials.
- Soil in the chosen area should also be examined to ensure the possibility of using the extracted materials for the project or if there is a need to transfer the soil.
- Build with reinforced concrete frame and in-fill using earthen blocks, to get the opportunity of having high rise buildings.
- The project site should be away from the buffer zone, as it is quite dangerous to have large groups of population over there.

### **5.3 Conclusion**

The dealing with the existing houses that are damaged or partially damaged is a complex objective, but it achieves a wider benefit. In this regard using partially damaged houses that still keep their strong concrete structure will be the first vision towards using;

1. Severely and partially demolished houses with weak structure should be demolished; materials can be recycled and reused.
2. Severely demolished houses with good structure that cannot have more loads will be in-filled and enveloped if required.
3. Partially demolished houses with strong structure; apply the in-fill and envelope techniques for the existing structure, and extend the number of floors using light techniques such as adobe or CEB to intensify the number of residential units in Gaza.
4. Totally demolished buildings: saving space is the priority, in this case, recycle the debris and build the house on the same area.

### **5.4 Design and construction guidelines:**

- Build gradually, to insure the sufficiency of the required materials.
- Training people to build their capacities and increase their participation by providing short training courses and houses plans in order to help them build their houses by themselves.
- Movable houses: In the mean time of constructing project, movable houses can be created for the affected families and that can be a process of learning earthen construction technologies, and the used materials can be reused.
- Collaboration with universities that could increase the awareness about earthen architecture through research projects, lectures, abroad training courses, etc.
- The recycled aggregates comes from bombed site, so further information needed to investigate the quality of the aggregate according to its inclusion of harmful materials, otherwise using standard aggregates.
- The reconstruction projects should start by repairing partial damages, finding alternatives to reconstruction in the siege, and developing plans to be rebuilt after the siege.
- “Build Back Better”; the materials and building techniques which provide protection against heat and humidity during the summer, and cold during the winter such as earth in different forms are preferred and considered a rational choice.

- Absorb different foreign cultures while designing a building but without losing the local identity. This can be through encouraging architects to respect the local building style to achieve a certain degree of consensus.

*“Treat the Earth well. It was not given to you by your parents. It was loaned to you by your children”. Kenyan Proverb*

Proper management strategy of earth resources is needed. The management of resources and earth raw materials should follow the following steps:

1. Top soil should be scraped away to be used for agriculture purposes.
2. Sieve the soil in the quarry, the waste soil can be used for landscape.
3. The use of quarries as water harvesting pond /waste water treatment ponds/ landscape design, work or play areas, or gardens.
4. Produce integration between the excavated area with the buildings and landscape.
5. Increase the planting density of low planting areas to avoid the consumption of other areas for agriculture.

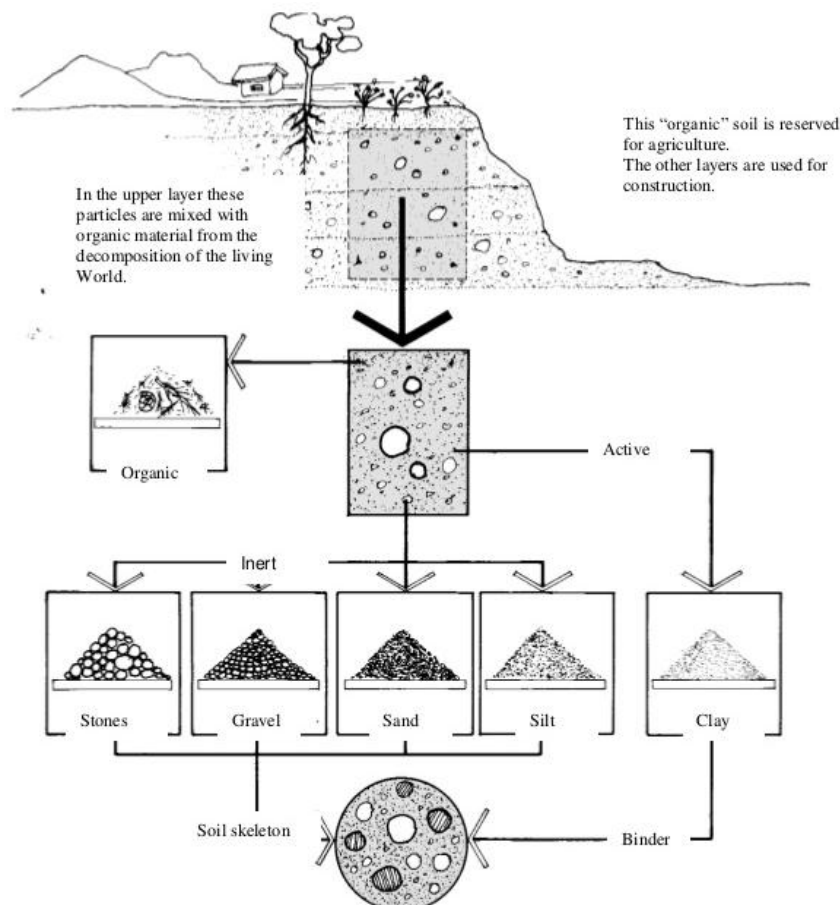


Figure 123 The soil layers and its management. Source: (Samin, 2016)

# ***Chapter 6:*** *Conclusion and* *Recommendations*

## 6.1 Conclusion

The aim of the research was to study the feasibility of using earthen architecture in the Gaza Strip, the aim and the objectives have been achieved through followed steps that considered the main steps to approach earthen architecture in the Gaza Strip. The first step of the research focused on studying the local situation and challenges in the Gaza Strip in order to clarify the necessity of developing earthen architecture in the Gaza strip, this part came out with an urgent need for new housing units as a result of the large devastation during the wars. Many challenges had to be taken into consideration while planning for future reconstructions, such as population explosion, scarcity of building materials, economic deteriorations, energy depletion, and the existed Israeli buffer zone and its effect particularly on the agriculture sector.

The second part of the study came to ensure the feasibility and the relevance of using earth as a construction material, as well as introducing the contemporary earthen architecture in the Gaza Strip. The feasibility study shows the potential and the relevance of the earthen construction as an alternative solution to meet the urgent need of housing after the successive wars on the Gaza Strip. This has been found through studying and analyzing five different approaches of the feasibility study which are: studying the LBC, the construction sector in Gaza, the available local materials, conducting a questionnaire, and stakeholders' analysis.

Studying the LBC shows the different construction materials that have been used between the past and present. Mud houses were one of the followed construction systems in the Gaza strip, and that indicates the possibility of introducing the earthen architecture and combining together old and modern building practices.

The economic situation is highly affected by the deterioration of the construction sector, so inserting earthen construction methods will bring an improvement on the economic level of the Gaza Strip, as long as there are many training centres for construction purposes that can be used for practicing and developing earthen construction techniques.

The study shows the available amount of recycled materials as well as natural materials. The availability of local building materials plays a major rule in the potential of innovating new construction methods that will consider earth as one of the main construction materials.

The result of the questionnaire shows high acceptability from people to experience building with earth and other local materials, despite the lack of knowledge in the field of earthen structures, its construction methods and advantages that still needs to be developed.

The feasibility study also included different stakeholders who can benefit from introducing new construction methods, and have interest and influence on earthen constructions.

A strategy to promote earthen architecture has been developed as a response to the gap between the lack of knowledge and experience in earthen architecture especially for the new generation and the potential of developing it in the Gaza Strip. The strategy includes different earthen construction techniques, case studies, and emphasizing the values of using earthen architecture.

The research ended up with proposed construction techniques that depend on available local materials including earth as a main component in combine with other local materials and existed concrete structures, in addition to other various techniques, as well as recommendations for future housing projects.

Accordingly, earthen architecture is relevant and feasible in the Gaza Strip, and can help and bring a lot of advantages to the community if it is properly adopted. Still some effort needs to be added to reach specific standards to ensure the success of adopting the earthen architecture in the Gaza Strip. Therefore, some recommendations and design guidelines have been already mentioned previously, and others will be mentioned in the following parts.

## **6.2 Recommendations**

It is recommended to have qualified contractors with good technical experience in earthen buildings, as well as, qualified group of engineers and architects in earthen architecture in order to achieve the functional and aesthetic benefits.

Designers and architects are recommended to add notable improvements on the designs and architecture of earthen houses, as well as on the structural techniques to overcome cracks and water penetration problems.

Clients can participate in different processes during the construction, but it is recommended to have experience while erecting earthen buildings in order to avoid time consuming, low quality buildings, and maintain the aesthetics.

People are recommended to supervise the construction process and have training on earth construction techniques in order to build their capacities in constructing safe, simple, and healthy earthen houses in urgent situations.

People are recommended to learn earthen techniques as a tool to generate job opportunities for unskilled labors, and threatened labors who were depending on the construction industry for their livelihoods.

The government and local cultural institutions in Gaza should promote the use of earthen architecture through establishing public buildings using earth such as restaurants, guest houses, and touristic centers; this in turn will lead to change the perception of people towards earthen architecture.

### **Recommendations for future research**

The study dealt with revealing the relevance of earthen architecture in the Gaza Strip in a comprehensive way, through making a balance between the social and cultural acceptability of earthen architecture on one hand and the structural and technical aspects on the other hand.

Still, more efforts can be done in future research regarding the social and cultural acceptability as well as technical aspects through organizing field work, practical activities, and on-site interviews if possible. Since the information and results that were obtained during this study were mostly based on on-line resources and on-line questionnaire, due to the difficulty of reaching the Gaza Strip, and this was one of the challenges and limitations that prevented getting close results.

As many of the people's comments were focusing on the weakness and fragile of earthen architecture against weather conditions and bullet resistance, it is recommended to conduct a specialized study that shows some details of how to improve the behavior of earth to be used for construction purposes.

Further deep study is needed regarding the stakeholders and their level of influence, support and interest.

The earth material in the Gaza Strip and its characterizations, in addition to the soil quality have to be examined in cooperation with local laboratories as well as the exact percentage of soil components to build with earth.

This study addressed and verified the potential and applicability of using earthen architecture in the Gaza Strip in many aspects, thus, the study can be used as a base for future studies or concrete earthen construction projects in the Gaza Strip.



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## Appendix A:

Short introduction about the questionnaire: Thank you for agreeing on participating in this questionnaire concerning the relevance of earthen architecture in the Gaza Strip. All answers you provide will be used for educational purposes. This questionnaire should only take 5-10 minutes to complete.

مقدمة موجزة عن الاستبيان: أشكركم على موافقتكم على المشاركة في هذا الاستبيان بشأن أهمية العمارة الطينية في قطاع غزة. سيتم استخدام جميع الإجابات التي تقدمها لأغراض تعليمية. هذا الاستبيان يستغرق فقط من 5-10 دقائق.

| The form of the questionnaire in English   | The form of the questionnaire in Arabic  |
|--|--|
| 1. Age<br>- Less than 20<br>- 20-40<br>- More than 40  | 1. العمر<br>- أقل من 20<br>- 20-40<br>- أكثر من 40   |
| 2. Your job?<br>- Student<br>- Student in construction or architecture field<br>- I work<br>- I work in construction or architecture field<br>- I don't have a job | 2. ما هو عملك؟<br>- طالب<br>- طالب في مجال الانشاءات والعمارة<br>- أعمل<br>- أعمل في مجال الانشاءات والعمارة<br>- لا اعمل                    |
| 3. Where do you live?<br>- city<br>- village<br>- camp   | 3. أين تسكن؟<br>- المدينة<br>- القرية<br>- المخيم  |
| 4. Type of housing?<br>- separate house one floor<br>- separate house two floors<br>- apartment more than 4 floors<br>- apartment less than 4 floors               | 4. طبيعة سكنك؟<br>- منزل منفصل طابق واحد<br>- منزل منفصل طابقين<br>- شقة سكنية - عمارة أكثر من 4 طوابق<br>- شقة سكنية - عمارة أقل من 4 طوابق |
| 5. What is the construction material of your house?<br>- Concrete blocks<br>- Rock<br>- Concrete blocks plastered with rock  | 5. ما هي المادة الانشائية لمنزلك؟<br>- الطوب الاسمنتي<br>- الحجر<br>- الطوب الاسمنتي الملبس بحجر   |

|  |   |
|--|---|
| <ul style="list-style-type: none"> <li>- Mud block</li> <li>- Other</li> </ul>   | <ul style="list-style-type: none"> <li>- الطوب الطيني</li> <li>- مواد اخرى</li> </ul>   |
| <p>6. What is your top priority when you build your house?</p> <ul style="list-style-type: none"> <li>- Construction cost</li> <li>- Aesthetics and appearance</li> <li>- Environmental and weather conditions</li> <li>- Local affordable resources</li> <li>- Just a place to live</li> </ul>  | <p>6. ما هي أكثر أولوياتك عند انشاء منزلك؟</p> <ul style="list-style-type: none"> <li>- التكلفة الانشائية</li> <li>- المظاهر والجماليات</li> <li>- العوامل المناخية والبيئية</li> <li>- المواد الانشائية المتوفرة</li> <li>- مكان للسكن فقط</li> </ul>  |
| <p>7. What is the used construction material in this building?</p>  <ul style="list-style-type: none"> <li>- Concrete blocks</li> <li>- Rocks</li> <li>- Clayey sandy earth</li> <li>- I don't know</li> </ul>  | <p>7. ما هي المادة الانشائية المستخدمة في هذا المبنى؟</p>  <ul style="list-style-type: none"> <li>- الطوب الاسمنتي</li> <li>- الحجر</li> <li>- التربة الطينية الرملية</li> <li>- لا اعرف</li> </ul>   |
| <p>8. What is your perception towards using earth and local resources for housing construction?</p> <ul style="list-style-type: none"> <li>- Low cost and low quality</li> <li>- Low cost and strong architecture</li> <li>- Architecture for the poor</li> <li>- High construction cost</li> <li>- Architecture of the past</li> <li>- No idea</li> </ul> | <p>8. ما هو مفهومك عن استخدام المواد الطبيعية المتوفرة لأغراض البناء؟</p> <ul style="list-style-type: none"> <li>- تكلفة انشائية منخفضة ونوعية الانشاء ضعيفة</li> <li>- تكلفة انشائية منخفضة و عمارة قوية</li> <li>- عمارة للفقراء</li> <li>- تكلفة انشائية عالية</li> <li>- عمارة الماضي</li> <li>- ليس لدي معلومات</li> </ul> |
| <p>9. Do you know the advantages of using earth and local materials?</p> <ul style="list-style-type: none"> <li>- Yes</li> <li>- No</li> <li>- Little</li> </ul>   | <p>9. هل تعرف إيجابيات البناء الطيني او المواد المحلية؟</p> <ul style="list-style-type: none"> <li>- نعم</li> <li>- لا</li> <li>- اعرف قليلا</li> </ul>   |
| <p>10. Have you ever seen a building with earth materials in Gaza?</p> <ul style="list-style-type: none"> <li>- Yes, many</li> <li>- Yes, few</li> <li>- No</li> </ul>   | <p>10. هل سبق ان رأيت في قطاع غزة مباني طينية؟</p> <ul style="list-style-type: none"> <li>- نعم كثيرا</li> <li>- نعم قليلا</li> <li>- لا</li> </ul>   |
| <p>11. Would you like to experiment the building with earth and available local materials?</p> <ul style="list-style-type: none"> <li>- Yes</li> <li>- No</li> <li>- Maybe</li> </ul>  | <p>11. هل ترغب بالتعرف على تجربة البناء بالمواد المحلية؟</p> <ul style="list-style-type: none"> <li>- نعم</li> <li>- لا</li> <li>- ربما</li> </ul>  |

|   |  |
|---|--|
| <p>12. Would you accept to have your house constructed with local and earth material which takes into consideration the construction strength and aesthetics?</p> <ul style="list-style-type: none"> <li>- Yes</li> <li>- No</li> <li>- Not sure</li> </ul> | <p>12. هل تقبل ان تملك منزل من المواد الطبيعية (التربة الطينية والرملية ) مع المواد المتوفرة كالاسمنت التي تراعي القوة الانشائية والجماليات؟</p> <ul style="list-style-type: none"> <li>- نعم</li> <li>- لا</li> <li>- ربما</li> </ul> |
| <p>13. Do you promote the spread of this kind of buildings in the Gaza Strip?</p> <ul style="list-style-type: none"> <li>- Yes</li> <li>- No</li> <li>- Not sure</li> </ul>   | <p>13. هل انت مؤيد لانتشار العمارة التي تمزج بين المواد الطبيعية و الاسمنت في قطاع غزة؟</p> <ul style="list-style-type: none"> <li>- نعم</li> <li>- لا</li> <li>- ربما</li> </ul>  |
| <p><i>(Optional questions)</i></p>  | <p><i>(اسئلة اختيارية)</i></p>   |
| <p>14. In your opinion, what hinders the use of natural and local materials to solve the housing problem in Gaza? What are your proposals?</p>  | <p>14. برأيك ما الذي يمنع استخدام الموارد الطبيعية والمحلية لحل مشاكل السكن في غزة؟ وما هي اقتراحاتك؟</p>  |
| <p>15. What are the negative points that discourage you to build with earth and local materials?</p>  | <p>15. باعتقادك ما هي سلبيات العمارة بالموارد المحلية والطبيعية؟</p>   |
| <p>16. What are the positive points that encourage you to use earth and local materials for construction?</p>   | <p>16. باعتقادك ما هي ايجابيات العمارة بالموارد المحلية والطبيعية؟</p>   |