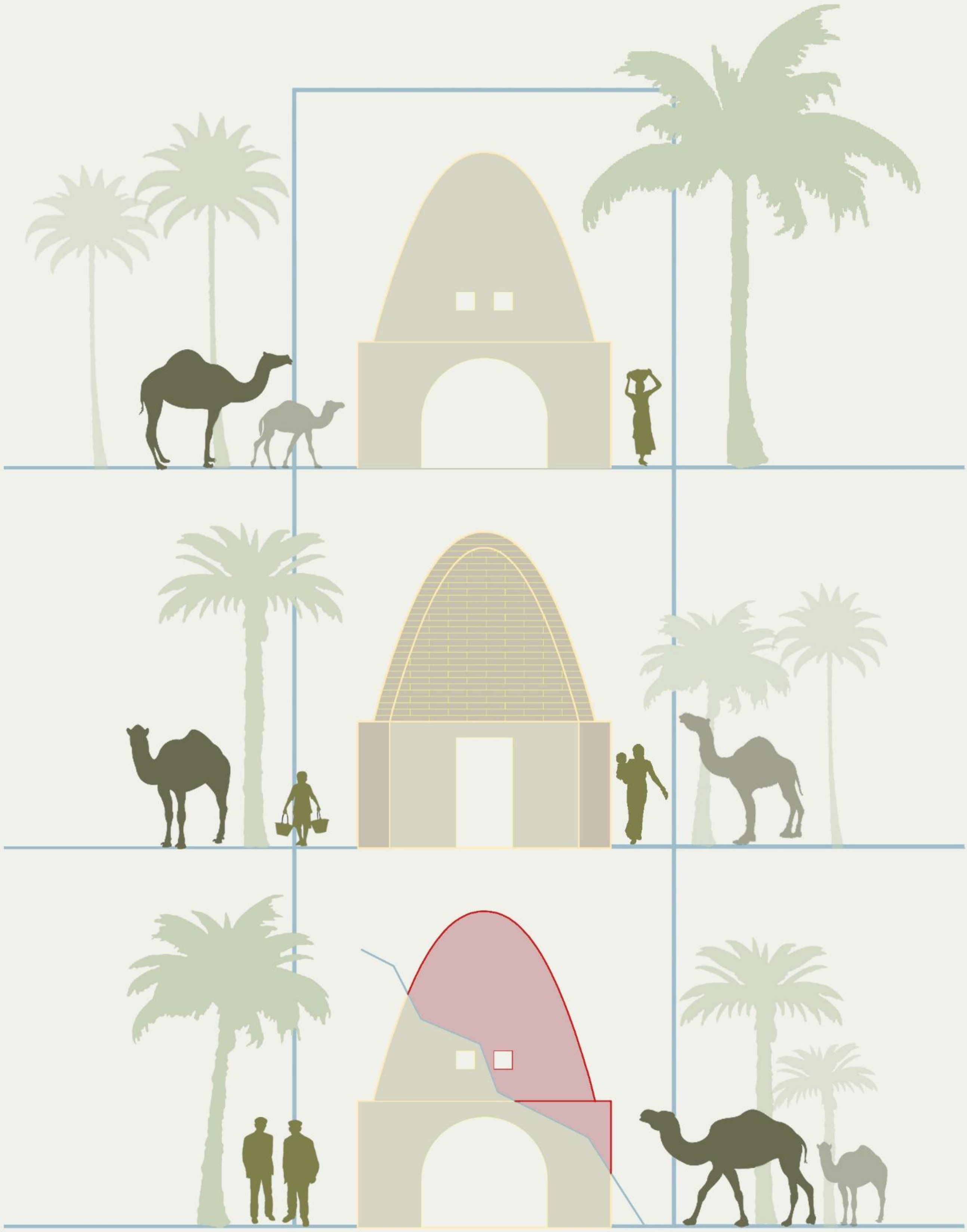

CONSTRUCTIONAL FEATURES OF HARRAN DOMED HOUSES.
ON-SITE ASSESSMENT OF EARTHQUAKE-INDUCED DAMAGE.

POLITECNICO DI TORINO

MASTER'S DEGREE IN ARCHITECTURE FOR HERITAGE

CONSTRUCTIONAL FEATURES OF HARRAN DOMED HOUSES.
ON-SITE ASSESSMENT OF EARTHQUAKE-INDUCED DAMAGE.

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I would like to express my deepest love and appreciation to my parents and my sister, who have never withheld their support and affection throughout my journey of coming to Italy for my master's degree, and who have been by my side in overcoming every challenge I faced, always trusting in me.

Before coming to Torino and throughout my time here, I deeply thank my first landlord, dear Edoardo Russo, for his help, kindness, and attention in every matter.

ABSTRACT

Domed houses built using the corbelled technique, found in many countries around the world, represent a significant part of vernacular architectural heritage with their rich historical background. Harran domed houses, located in the Harran District of Şanlıurfa Province in Turkey, stand as a particularly notable example.

Harran domed houses were built using the corbelling technique, where each layer of bricks slightly overhangs the one below. Their main building materials are stone and brick, collected from the surrounding area.

The earthquakes that occurred in Turkey on February 6th, 2023, affected eleven provinces, one of which was Şanlıurfa. Harran domed houses were among the architectural heritage that suffered significant collapse as a result of the disaster.

The aim of this thesis is to study the constructional features and to identify the types of collapse sustained by Harran domed houses, whose numbers have been steadily declining and whose existence is currently under threat due to the earthquake. The methodology includes a literature review and on-site assessment.

The analysis of several collapsed or damaged domed houses allowed recognising the typical seismic response of this peculiar building type, highlighting the main factors that affect its earthquake resistance and that can be traced back to the very dome or its supporting walls.

Keywords : Vernacular Architecture, Beehive Houses, Domed Houses, Corbelled Dome Technique, Earthquake Damage.

All Turkish texts were translated into English by the author of the thesis. Additionally, all photos, drawings, models and tables without a cited source were taken, drawn or created by the author of the thesis.

CONTENTS

Introduction

Scope and Purpose of the Study

Vernacular architecture represents a building culture that emerges from the needs of its geography, constructed by individuals without formal architectural training using locally available materials in response to the climate. Beyond being merely a physical creation, it reflects the local identity and cultural accumulation of the region. Therefore, it is a highly significant architectural heritage.

In this context, beehive-shaped domed houses, which originated at the last period of the Neolithic Age (5900–5300 BC) in Mesopotamia within the Halaf Culture, are unique and remarkable examples of vernacular architecture with a deep-rooted historical past.

The domed house structure type -whose most important examples include the *trulli* in Italy, *bombo and pont* in Spain, *al-mantarah* in Palestine, and the domed houses in Syria- has spread in many countries in Europe, especially in the Mediterranean, and in some Asian and African countries. Although they have certain structural and morphological differences depending on the geographical conditions of the countries where they are found, they have all been built for the same purpose: to meet the need for shelters to raise animals in developing rural areas.

This thesis essentially investigates Harran domed houses, which are vernacular structures located in the Harran district of Şanlıurfa province in Turkey, focusing on two main aspects :

- Architectural and constructural characteristics by explaining their plan types, spatial layout, openings such as windows and doors, corbelled dome technique, building materials and structural elements making up a house.
- Seismic behaviour during the February 6, 2023 earthquake that determined several but not generalized collapses.

This earthquake has been referred to as the disaster of the century due to both its wide impact area and the extensive loss of life and property it caused, affecting eleven provinces in southeastern Turkey, including Şanlıurfa.

After the earthquake, local residents in Harran built concrete apartment buildings to address the challenges of inadequate living conditions. Moreover, it has been observed that no conservation or restoration initiatives have been undertaken in the region. These two main factors significantly threaten the existence of Harran domed houses.

Thus, the main motivations for selecting Harran domed houses as a thesis topic are both their vernacular values and the fact that earthquakes remain a highly current issue, together with the absence of any studies in the literature addressing the impact of earthquakes on these houses. The lack of any conservation efforts for the houses has led to a gradual decrease in their numbers. Therefore, this study aims to analyze and categorize the types of collapse and to explain the collapse mechanisms of these structures in order to better understand their vulnerabilities.

Methodology and Structure of the Thesis

Throughout the thesis, the characteristics of domed houses both in Harran and in various other countries have been researched, supported by a comprehensive literature review. Furthermore, on-site assessment was also conducted for the Harran domed houses, which is the core focus of the thesis (Table 1).

During the site visit, the interiors of two typical Harran domed houses were examined, photos and measurements were taken for the general layout of the house and its building materials. These two houses are still in good condition and are still used for touristic purposes. Following the site visit, these measurements were utilized and reflected in architectural 2D and 3D drawings that illustrate structural details of Harran domed houses. All these contributed to the chapter about the architectural and structural characteristics of Harran domed houses in the thesis (Table 1).

Additionally, during the site visit, for the chapter on the earthquake, seven houses that collapsed due to the earthquake were identified and examined. Photos of these houses were taken from different angles to show the collapsed portions, and their locations were marked on the map obtained from the Harran Municipality. Then, the collapsed parts were indicated on the plans and elevations for each house and classification was done by interpreting these drawings. Finally, some outcomes were derived based on these classifications and the collapse types were illustrated with 3D models and photographs to understand the collapse mechanism in a better way (Table 1).

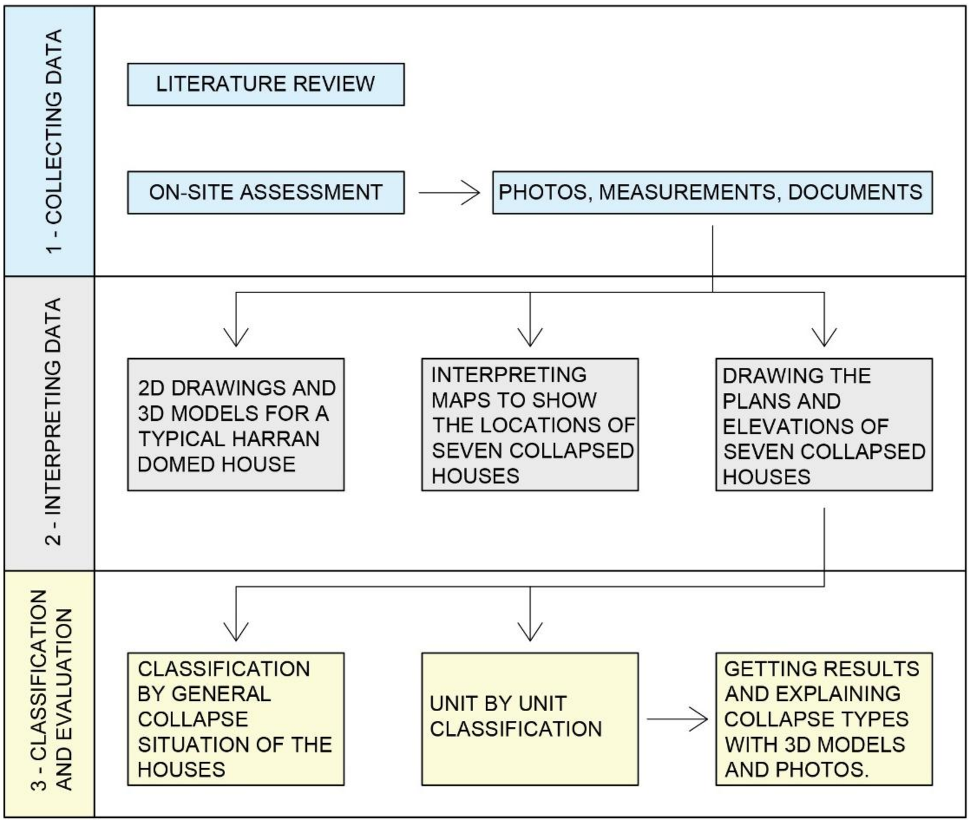


Table 1 : Structure of the Thesis (2025).

Chapter 1 : Vernacular Architecture and Domed Houses

1.1 Concept of Vernacular Architecture

The term 'vernacular' in architectural works refers to the local context of building activity (Akbaş, 2023). ‘The word ‘vernacular’ derives from the Latin *vernaculus*, meaning ‘native’, so the definition ‘native science of building’ is really quite appropriate.’ (Oliver, 2006, p. 4)

In today’s world, in the field of architecture, many terms have the same meaning as ‘vernacular architecture’. For example, ‘rural architecture’, ‘indigenous or indigene architecture’, ‘spontaneous architecture’, ‘folk architecture’, ‘primitive architecture’, ‘architecture without architects’, etc. All these terms can provide an architectural image both individually and together; however, small differences among them and variations in their meanings prevent the exact definition of the concept of ‘vernacular architecture’. The term ‘rural’ generally refers to all areas outside urban ones. It cannot be said that vernacular architecture is found only in rural areas. The concept of ‘spontaneity’ contrasts with the art of building, as no structure can come into being on its own. The term ‘primitive’ has often been used with a derogatory intent, disregarding its original meaning. Besides, concepts such as ‘indigene architecture’ restrict and narrow the topic. As a result, it is obvious that all these terms are unable to clearly explain ‘vernacular architecture’ and often lead to misunderstandings (Sezgin, 1984).

Vernacular architecture is widely accepted as a tradition primarily developed by architects without formal education. This architectural form emerges from years of trial and error, the use of local building materials, and the collective responses of a community to its cultural values and religious beliefs (Hamza, 2019).

As explained by Sezgin (1984), the person constructing the building is knowledgeable about traditional rules and materials. Also, the owner of the building usually participates in the construction process. The work starts with the general outlines and the most basic schema. Then, details are considered. The idea in the creation of the building is based on doing the work in the simplest, most natural, and most direct way. Other features of vernacular architecture are as follows:

- In vernacular architecture, there is no specific method of design and expression. The structure and construction material implemented determine the form of the building.
- The construction material is always natural and locally sourced.
- The building is simple, precise and easy to understand.
- Vernacular buildings generally have the ability to expand in an additive and attached manner.
- In vernacular buildings, it is seen adaptation to climate and nature and integration with them.
- By tradition, it is natural to respect the rights of others and other objects in the construction of vernacular buildings.
- Aesthetic quality is not separately created for each building. This is a traditional practice passed down from generation to generation.

Briefly, the building stock of this architectural type has the potential to represent the distinctive features of the region where they are constructed (Akbaş, 2023). It is important to view vernacular architecture specifically as a cultural process as opposed to just a tangible end product (Asquith & Vellinga, 2006).

Another remarkable definition about vernacular architecture was done by ICOMOS (International Council on Monuments and Sites) CIAV (International Committee of Vernacular Architecture) : ''The built vernacular heritage has been accepted as a characteristic and attractive product of society. It appears informal, but nevertheless orderly. It is utilitarian and at the same time possesses interest and beauty. It is a focus of contemporary life and at the same time a record of the history of society. Although it is the work of man it is also the creation of time.''

The built vernacular heritage plays a vital role in expressing a community's culture and its connection to the land, while simultaneously showcasing the rich cultural diversity found across the globe.

The way communities house themselves is through vernacular building, a practice rooted in tradition and nature. It involves an uninterrupted process of essential alterations and ongoing adaptation shaped by social and environmental influences.

Vernacular examples may be identified by :

- A construction technique collectively practiced by the community.
- A noticeable local or regional identity that adapts to the environmental context.
- Consistency in visual character, or the use of conventional building types.
- Traditional construction and design knowledge that is passed down informally.
- A successful adaptation to functional, social, and environmental limitations.
- The successful implementation of traditional construction techniques and artisanal skills

(ICOMOS, Charter On The Built Vernacular Heritage, 1999).

1.2 Historical Overview and Global Distribution of Domed Houses

It is expressed that the first dome form in architecture is dated back to the last period of the Neolithic Age (5900–5300 BC.) in Mesopotamia, attributed to the Halaf Culture. In this period (6th millennium BC.), circular planned (tholos) ovens and storages were seen in Tel Sabi Abyad in Syria (Figure 1). It is claimed that circular houses with conical domes (tholos) were the earliest examples of tholos structures in Mesopotamia, built at the beginning of the Halaf period in Arpachiyah, near Mosul in Iraq (Figure 2), (Önal, 2022).

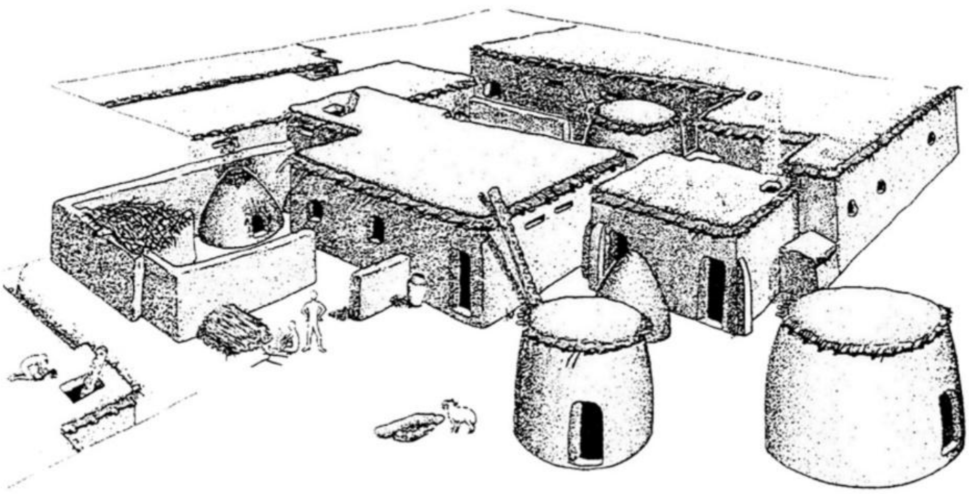


Figure 1 : Reconstruction of flat-roofed, circular Halafian structures at Tell Sabi Abyad, Syria (Verhoeven & Kranendonk, 1996).

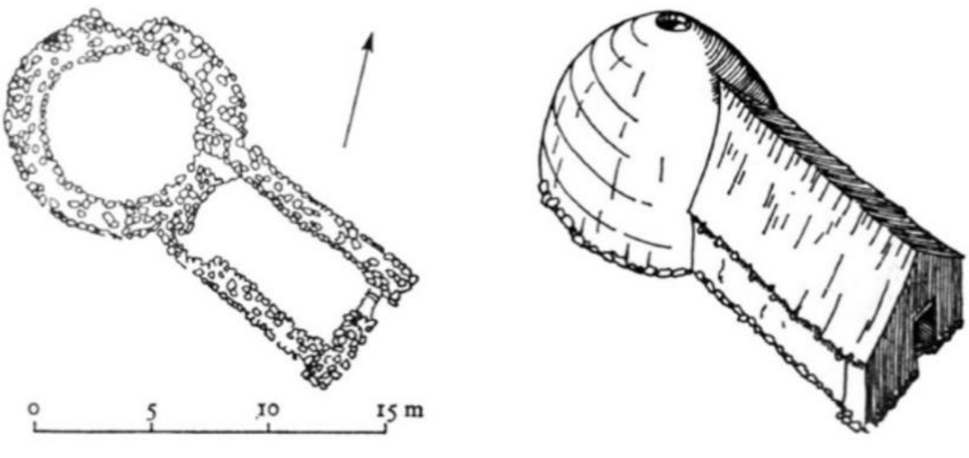


Figure 2 : Reconstruction of a circular Halafian structure featuring a corbelled dome at Arpachiyah, Iraq (Mallowan & Rose, 1935).

Subsurface tombs from the third millennium BC. were built in Ur, in southern Mesopotamia, utilizing barrel vaults and corbelled domes. As a result of avoiding the usage of wood, which is scarce in that area, for the roof structure, this building technique was used quite frequently in ancient Mesopotamian architecture (Tunca & Rutten, 2009).

Dating back to the end of the third millennium BC, the Aegean region is home to stone-built, domed circular structures, most of which served funerary purposes. These buildings create a clear separation between the living and the dead, with the circle exclusively symbolizing death, marking the distinction between the two realms (Palyvou, 2009).

The dome's usage as a roofing technique in at least some regions of the ancient Near East can be almost certainly confirmed. One instance of iconographic evidence can actually be mentioned in this regard. The Neo-Assyrian relief that was found at Nineveh shows a scene of wood transport and dates back to the Assyrian king Sennacherib's reign (704-681 BC.). There are multiple domed buildings in the background (Figure 3), all of which have shapes that are strikingly similar to today's recognized ones (Tunca & Rutten, 2009).

Figure 3 : This relief, found in Sennacherib's palace at Nineveh, depicts houses with domes (Patterson, 1915).

Excavations in Mesopotamia reveal that dome-shaped structures with a square front court or room were in use as early as the 7th century BC. These domes typically had diameters ranging from 5 to 10 meters (Figure 4), (Özdeniz et al., 1998).

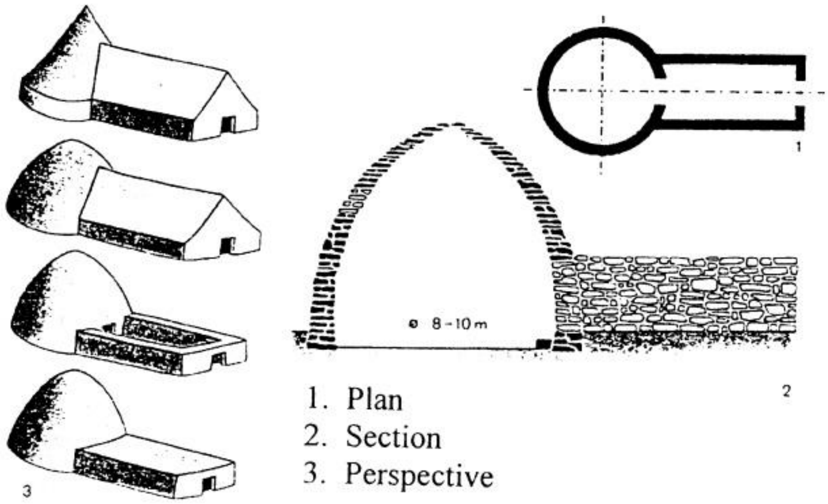


Figure 4 : Discovered at Mesopotamian excavations, domed building forms date to the 7th century BC. (Müller & Vogel, 1974).

Domed houses are in the form of beehives and are a structural type built using local materials (Gülmüş, 2023). They are widespread especially in Europe and some countries of Asia and Africa (Figure 5). As stated by Rovero and Tonietti (2014), main reasons of the need of these buildings in many countries are the development of rural life and the requirement of shelters for sheep-breeding activities. Some structures in the Mediterranean region, such as the *Trulli* of Puglia, the monumental *Nuraghes* of Sardinia, and the massive megalithic temples of Malta, may be regarded as nearly monumental due to their striking architectural and visual impact, as well as their distinctive construction techniques. As indicated by Juvanec (2009), usually, stone shelters are situated individually, each in its own pasture area. However, a few of them are set in groups, such as small *siska*, as they are called in Slovenia, which might be built by a hardworking herder constructing as many as five on his own pasture.

Figure 5 : Distribution of domed houses around the world (2025).

In this chapter, a few important examples of domed houses of some countries will be mentioned in detail. Here is the domed structures in Mediterranean area as follows :

In **Spain**, *El Bombo* near Tomelloso in La Mancha is a stone-built shelter for people and livestock. The structure resembles a stone mound, standing apart from frame (Figure 6). These shelters typically have one to four celled building. The living area features an open hearth with a low chimney and small niches on either side (Figure 7). The livestock section includes a manger running along the rear wall. The floors are made of compacted clay, while the walls are lime-washed in the living space and coated with brown clay in the livestock area, up to a height of 2.20–2.40 meters. Entrances are usually positioned on the southern side, and there are no windows (Juvanec, 2004).

Menorca's shepherd shelters exist in two forms of *ponts* : ancient and more recent. The oldest, found in the island's interior, were constructed with impressive precision as half-cubic structures on a circular plan, typically with two or three staggered heights and made of grey stone with a capstone (Figure 8). In contrast, the newer and larger shelters in the northern plains, where horses and bulls are raised, are constructed from uniform yellowish stone. To meet growing needs, modern *ponts* are built larger, fitting up to ten horses, with stepped exteriors and pebble-filled terraces for stability (Figure 9). Their flat-fronted walls feature mangers on either side of the entrance, framed by triangular lintels. Enclosed within marked boundaries, they stand as distinctive landmarks in Menorca's landscape (Vegas et al., 2009).

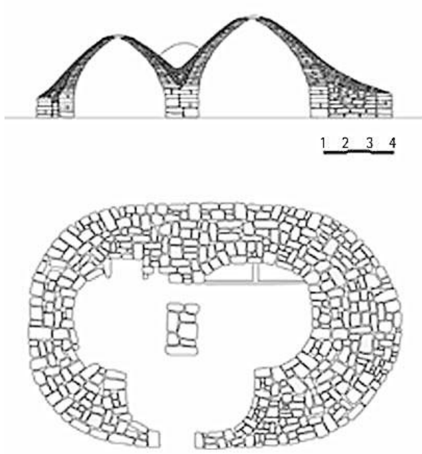


Figure 6 : *El bombo* located in Tomelloso, La Mancha, Spain in 2002. (https://www.stoneshelter.org/stone/objects/bombo/6.htm)

Figure 7 : Plan and section of the triple *bombo* corbelled dome structure in Castilla la Mancha, Spain (Vegas et al., 2009).

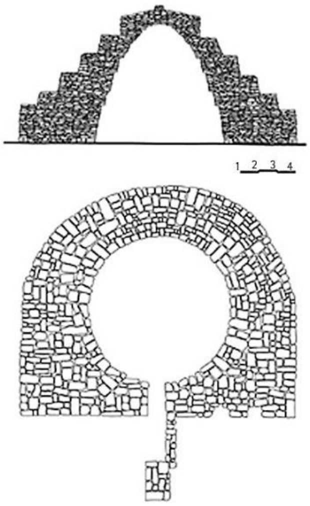
 

Figure 8 : *Pont* in Torretrencada, Menorca, Spain in 1995.
(https://www.stoneshelter.org/stone/objects/pont/6.htm)

Figure 9 : Plan and section of a *pont* corbelled dome structure in Islas Baleares, Spain (Vegas et al., 2009).

In **Portugal**, you can find *cardenhas* of various sizes and layouts within the settlement. They are a form of vernacular architecture found in the village of Vale de Poldros and commonly seen throughout northern Portugal. During the hottest season, people and their animals, who relocated from the valley to the mountains, resided in these buildings (Figure 10). They may be built with one or two levels. For two-story structures, the lower floor was used for animals, and the upper floor was for human occupants. Each floor comprised a single room with an external entrance. *Cardenha* construction relies on three key components: the foundation, dry stone masonry for the walls, and a corbelled dome. The smallest *cardenha* has a square base with sides measuring 3.8 m, while the largest spans up to 5.9 m. The structure is built entirely from stones, mostly granite or schist, meticulously arranged. Stone sizes vary greatly, ranging from 0.05 m to 2.50 m in length (Figure 11), (Martynenko, 2017).

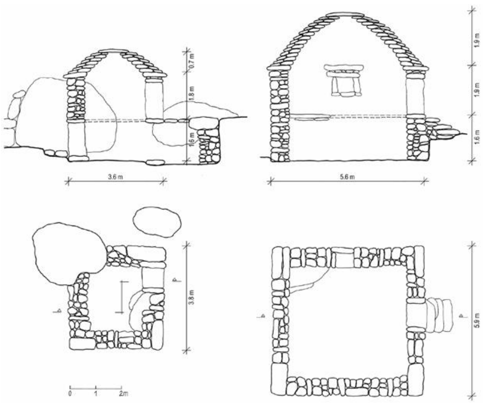
 

Figure 10 : *Cardenha* in Santo Antonio Val de Poldros, Portugal (Davis, 2006).

Figure 11 : The smallest and largest *cardenha* with their sizes (Davis, 2006).

Mitata structures located in the eastern part of the island of Crete, **Greece**, are rectangular and terraced. They are small and modest, built on mountain slopes at lower altitudes along pathways and winter grazing areas. The term *mitato* refers to a grouped structure composed of 2-3 corbelled domes (Figure 12). It has some specific areas : a coumos which is people's main living space, a space for cheese producing, a *tyrokelli* or *kleidospito* serving for the preservation of dairy products. Spacious courtyard featuring a dry-stone enclosure (mandra) for the daily task of milking ewes, as well as an outdoor dining area (Figure 13). The narrow entrance is the only opening; occasionally, there is a central opening for air circulation at the top of the dome. A platform made of stone for seating, a cheese-making fireplace, and a smaller one for cooking are all located inside. A mitato complex was typically inhabited from May to November by a clan of shepherds, who could be brothers or cousins. Shepherds' lives underwent a significant transformation in the 1980s when roads for cars were built up to the mountains and this change caused to ending usage of mitata (Arakadaki, 2009).

Figure 12 : A *mitata* structure including 2 domes in the island of Crete, Greece. (http://www.wondergreece.gr/v1/en/Articles/Architecture/8721-Mitata_in_Crete)

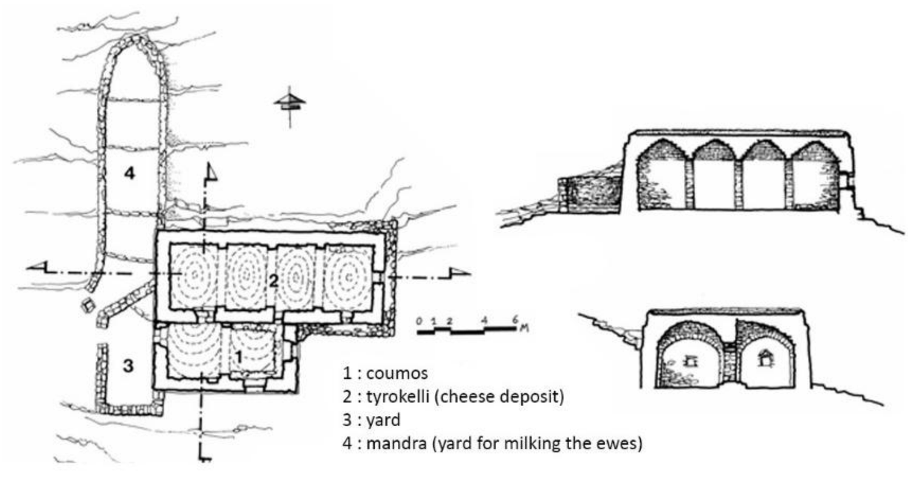


Figure 13 : Plan and sections of rectangular corbelling domed *mitato* in White Mountains, West Crete (Arakadaki, 2009).

Another significant example of domed house culture in the Mediterranean region is found in **Southern Italy**, particularly in its *trulli* houses in Apulia Region;

Trulli of Alberobello, situated in the heart of Apulia's Valle d'Itria, stand out as remarkable examples of rural architecture. These stone masonry structures hold significant value, serving not only as storage spaces for agricultural tools and shelters for animals but also as a vital form of housing, both historically and in modern times (Todisco & Sanitate, 2016). Alberobello is a town in the Bari province, located near the Murgia hills and the Itria Valley. The town's historic center, home to around 2,000 trulli, was recognized as a UNESCO World Heritage Site in 1996 (Figure 14), (Corbi et al., 2023).

Figure 14 : *Trulli* structures in Alberobello, Italy.
(https://whc.unesco.org/en/list/787/)

Initially, *trulli* were constructed by people without experience, and a new profession known as *maestro trullaio*, meaning an expert in building *trulli*, emerged as a result of the evolution of this type of structure (Sanitate et al., 2014). *Trulli* are constructed with a straightforward method that reduces labor on the material and removes the need for temporary scaffolding during dome building. The outcome is a structure made of thick double-leaf walls, that bear the load of a corbelled dome (Todisco et al., 2017). As illustrated in figure 15, *trulli* consist of two primary structural components: the basement and the dome. Composed of large calcareous stone layers, the base is either circular or quadrangular in shape. The thickness, typically reaching up to 1 meter, is determined by the internal volume. The walls function both to resist the horizontal thrusts from the dome and to define the interior space. A material named *bolus*, made up of small clay and stone fragments, usually fills the interior of the masonry. The *trullo's* dome, or *candela* is built using the tholos method with corbelled stones arranged in concentric rings. Starting at the base, the stones project inward, forming rigid rings with the help of *scarde* stones wedged between them. Each successive ring has a smaller diameter until the opening is sealed with a final stone, the *serraglia*. Occasionally, the interior of the *candela* is smoothed to expose the edges of the rings, creating a polished surface resembling classical masonry domes. The *trullo* is completed with a roof covered in *chiancarelle*, a thin limestone layer (3-7 cm thick) placed on the dome with a slight outward slope for water drainage, along with plastered exterior walls and a *pinnacle* (Figure 16), (Sanitate et al., 2014).

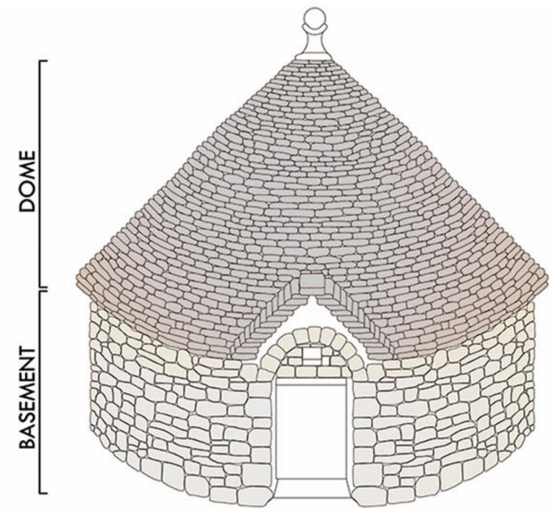


Figure 15 : Main parts of *trulli* (Todisco & Sanitate, 2016).

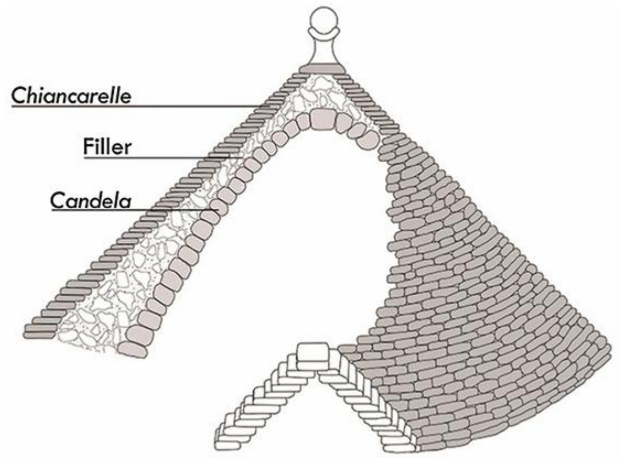


Figure 16 : Main layers of the dome (Todisco & Sanitate, 2016).

Other elements that define a trullo's structure are foundation, floor, water tank etc. as shown in figure 17. Excavated 50–60 cm into the same rock as the trullo stones, the foundations are then covered with a mixture of local pozzolana and cement-lime. Beneath the building, a large water tank is placed within a square or rectangular cavity, designed to collect water directed by the curved roof stones. The trullo's floor rests on a 40 cm high stone foundation, with its central part supported by the barrel-vaulted roof of the water tank below (Corbi et al., 2023).

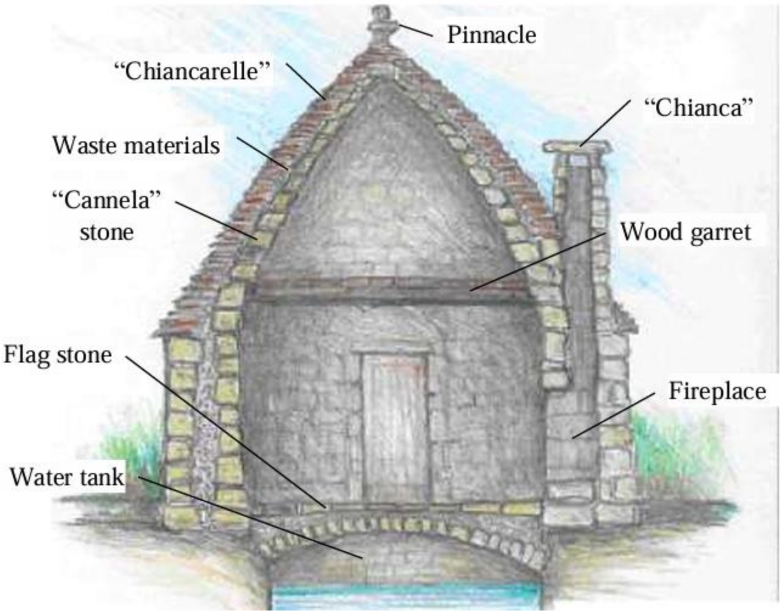


Figure 17 : Structure of a *trullo* (Corbi et al., 2023).

Inside the trullo, a large central area with an open entrance is the focal point around which the smaller areas, divided domes, or an alcove set apart by an arch are arranged (Figure 18). In order to improve heat distribution, the kitchen and fireplace area has openings on several sides, and a bed is frequently positioned in one corner (Dipasquale & Silva, 2009).

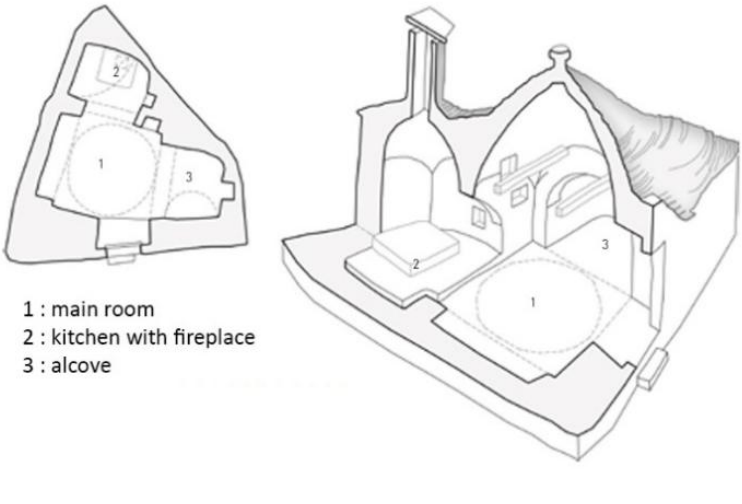


Figure 18 : Spatial organization of a *trullo* (Dipasquale & Silva, 2009).

In areas where the soil's geological properties ensure an abundant supply of raw materials, trulli have become widespread. Likewise, the physical and mechanical characteristics of the materials used are closely tied to the different forms of trulli (Corbi et al., 2023). Consequently, different *trulli* types were created, as shown in figure 19.

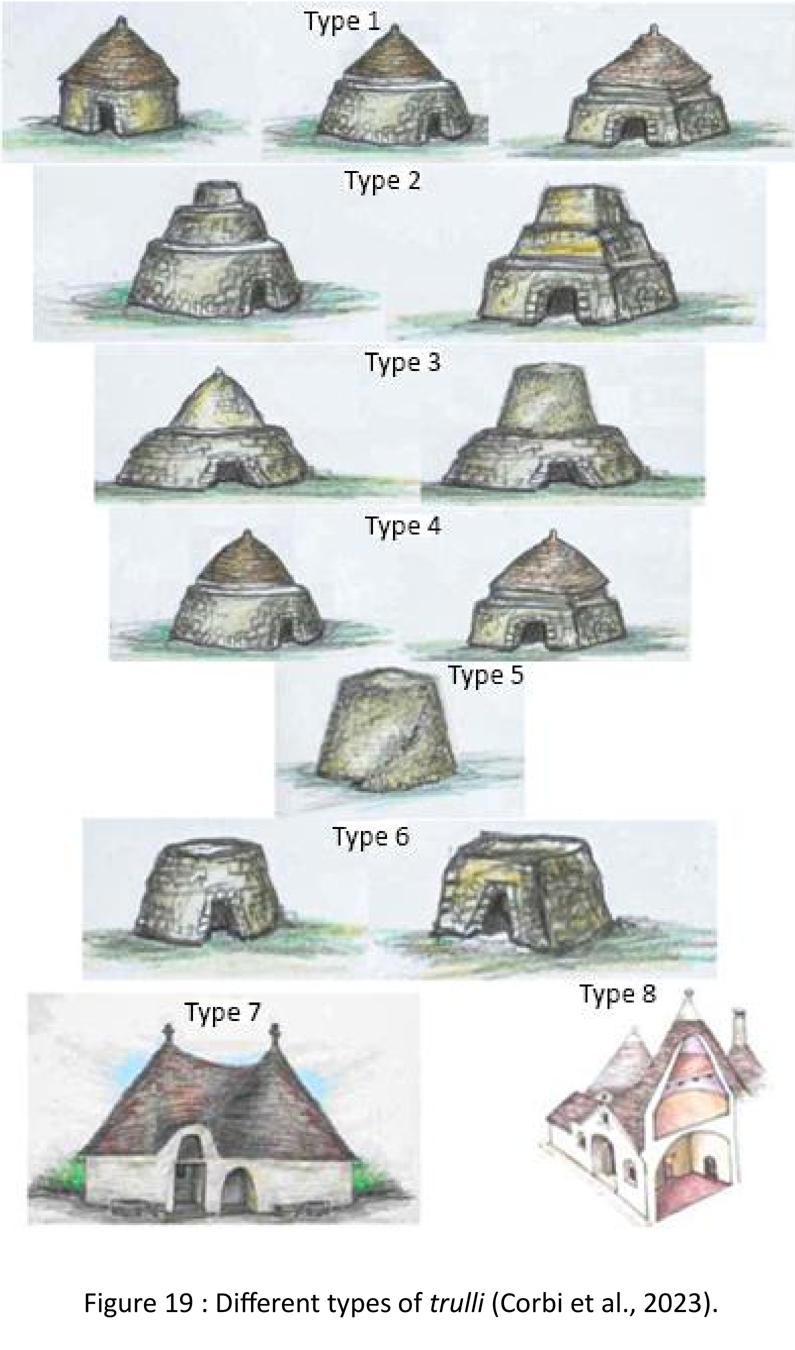
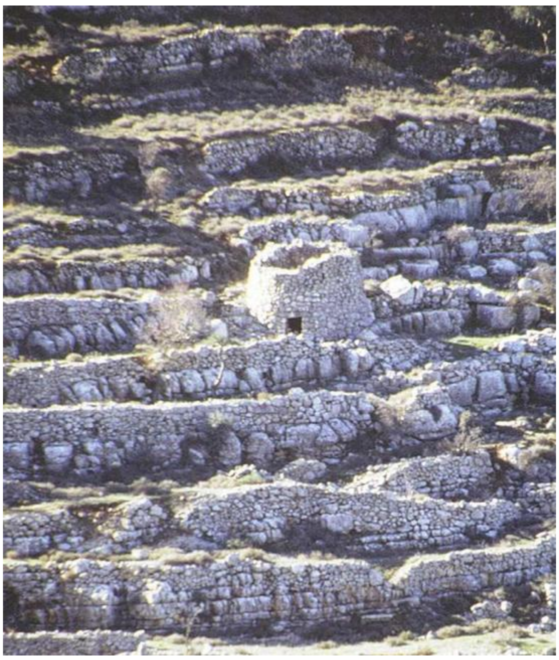


Figure 19 : Different types of *trulli* (Corbi et al., 2023).

Visibly, every single types of trulli are characterized by different architectural features. In the research conducted by Corbi et al. (2023), type 1 *trulli* have a circular or square basement and when combined, they form the iconic *trulli* of Alberobello. The structure of type 2 rises in four or five truncated cone or pyramid-shaped steps, resembling a "multi-tiered cake." Type 3 has a circular base, with either a circular dome or a truncated cone on top. While resembling type 1, the type 4 *trullo* is distinguished by a steeper dome, which is shaped by a gentle curve in the interior. Unlike typical dry-stone structures, Type 5 *trulli* have a masonry stone basement with weak soil-and-water mortar. With buttresses serving as external walls, the dome extends outward. Type 6 *trulli* are known as *Pagghiari*, *Furneddhi* or *Caseddhe* have buttresses for horizontal support, a truncated cone or pyramid shape. Type 7 features a solid body of large stones known as *chianche* that connects the two domes. Its façade features two arched doorways, but it lacks windows. Type 8, the King Trullo in Alberobello, is a two-story structure and it features twelve cones and a 14-meter central dome, standing as a notable architectural monument.

Outside Europe, corbelled dome structures may still be seen especially in Asian continent;

The **Palestinian** *al-mantarah* is a traditional dry-stone hut, adapted for farmers through the years (Figure 20). Found across Palestine, it reflects Mediterranean architecture shaped by historical displacement and cultural exchange. It was built using the corbelling method, without any materials used to hold the stones together. There are three types of these huts as shown in figure 21. Type A was the most basic version, built using spheroidal dolerite or rough sandstone blocks, arranged in offset courses that slanted inward, leaving a small opening at the top, typically closed by a large stone slab or several stacked slabs. Type B was developed to provide more interior space. By employing an enhanced building method, the builders raised its height to 150 cm and diameter to 200 cm. In Type C, the hut's axis was lengthened to create an oval shape, expanding the interior space even more (Shadi, 2012).



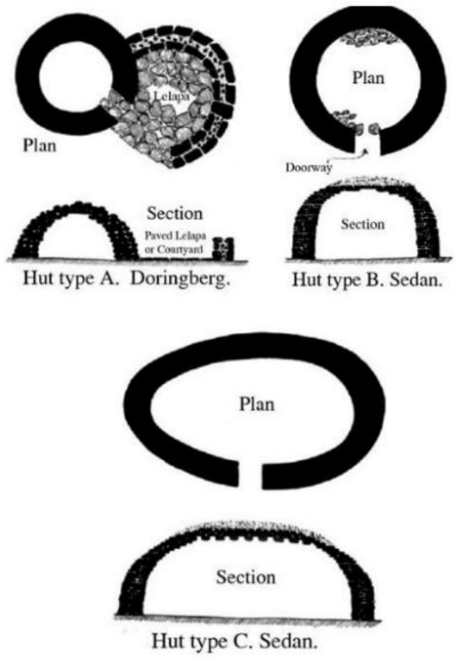


Figure 20 : *Al-mantarah* found in Silwad village near Ramallah, Palestine, seeming entirely natural and blending seamlessly with the surrounding landscape (Shadi, 2012).

Figure 21 : Different types of huts in Palestine (Walton, 1951).

In 440 BC, **Iranians** mastered storing ice in the desert during summer. Ice was transported from nearby mountains in winter and kept in Earth refrigerators (Figure 22), underground structures with thick, heat-insulating walls made from *sarooj*—a unique mortar blend of sand, clay, egg whites, lime, goat hair, and ash, precisely mixed for water resistance. These chambers, often linked to Qanats, used wind catchers to cool the interior to freezing temperatures. In some areas, the dome of the Earth refrigerator is very tall, often being the highest structure in the city or village (Figure 23). This height helps keep the lower levels cool during summer, as the upper levels absorb more heat from the central sunlight (Niroumand et al., 2012).

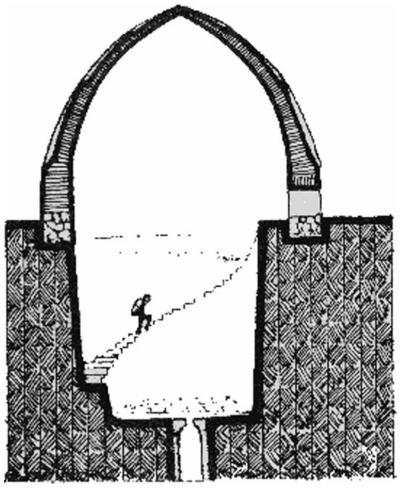


Figure 22 : Earth refrigerator (ice house) in Meybod, Iran. (https://eartharchitecture.org/?p=570)

Figure 23 : Section of an earth refrigerator in Iran desert (Niroumand et al., 2012).

One of the domed house types geographically close to the domed houses in Harran, which is the subject of this thesis, is located in **Syria.** As reported by Dello and Mecca (2009), In northern Syria, there are three main methods applied in the construction of earthen domes : adobe (earthen bricks), cob and mud-stone. The history of earthen architecture techniques in Syria reveals that these local methods have existed for thousands of years.

In terms of plan organization, Syrian domed houses have some different types. Houses can be formed either by one room or by two, three, or four rooms placed side by side, or by rows of houses that are not connected to each other, or by two circular plans with connected domes placed next to each other (Figure 24).

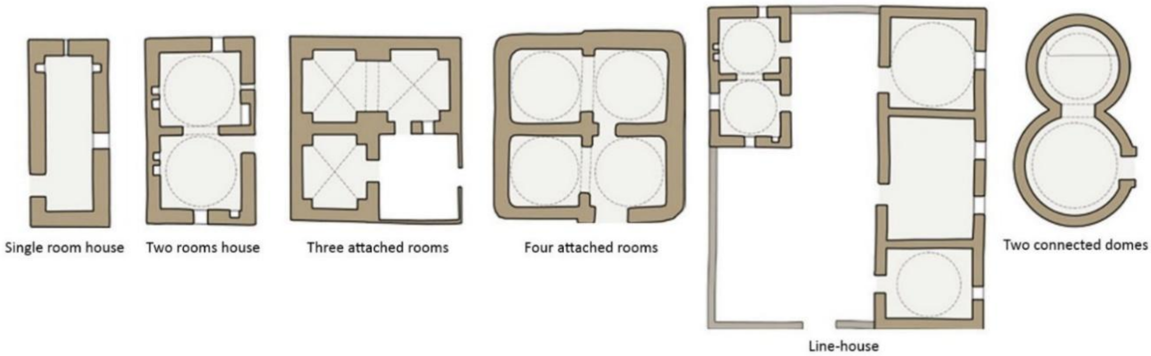


Figure 24 : Various layouts of Syrian domed houses (Dello & Mecca, 2009).

With respect to the dome shapes, there are two main types as expressed by Dello and Mecca (2009) :

1. Circular domed rooms which the dome originates directly from the ground level (Figure 25).
2. Quadrate domed rooms, known as 'normal dome' and 'Sultan dome' (*Qubba Sultanya*), are distinguished by the varying heights at which their domes rest on walls (normal dome: 10-90 cm; Sultan dome: 1-2.5 meters). Due to their more complex construction, Sultan domes were typically built by wealthier individuals (Figure 26).

Figure 25 : Circular domes in Idlib, Syria (Dello & Mecca, 2009).

Figure 26 : Sultan domes in South Aleppo, Syria (Dello & Mecca, 2009).

In **Turkey**, the domed houses that are geographically closest to Harran are the beehive houses of Suruç, located in the same city, Şanlıurfa (Figure 27). Key difference between Harran and Suruç domed houses is construction material. While stones and bricks recovered from ancient building remains were used in Harran domed houses. As indicated by Şahinalp (2012), main construction material of Suruç domed houses is adobe. Moreover, two types of domes in Suruç domed houses can be seen: conical and flat-topped. While conical domes reach a height of 1.5-2 meters, flat-topped domes are lower due to the end of adobe layers after 1-1.5 meters and the covering of the upper gap with wooden planks, followed by layers of straw or cotton stalks and mud (Figure 28).

Figure 27 : Suruç domed houses in Turkey.
(https://www.yenimesaj.com.tr/suruc-kumbet-evleri-ilgi-odagi-oldu-H1489964.htm)

Figure 28 : Dome types of Suruç houses: conical dome (on the left) and flat-topped or truncated dome with wooden material used (on the right), (Şahinalp, 2012).

Suruç domed houses are characteristically single-story and lack courtyards, ranging from a single row of two rooms around an *iwan* to five rows. They consist of three main sections: living spaces, barns and grain storage areas, and enclosed livestock pens and stables. The rooms are arranged from south to north: the living area in the south, the livestock pen for small animals and the stable for larger animals are in the middle, and barns and grain storage in the last row. The livestock pen and stable are on either side of the same iwan. Although this arrangement reduces living comfort, it was designed to protect the animals from theft (Figure 29). These houses, as a part of rural life, include several additions: Kitchens are separate from the dwelling, with tandoors locally known as *tendur* for baking and cooking typically built adjacent to the house in the southeast corner. Barns, called *kadin*, are feed storage areas in stables and pens with one or two rooms as needed. Hot summers have made summer pens, called *gom*, necessary. Usually located at the front of the dwelling, these open-roofed pens are built with simple dry stone walls and an opening for entry. *Ca'ls* are external storage pits, about 1-1.5 meters deep, used for grains and located at the front of the dwelling. Similarly, *lods* are used in rural areas to store hay for sale or animal feed, kept outside the main storage area. A *seki* is a 30-40 cm high, stone-filled step covered with mud, typically 3-4 meters wide, built in front of dwellings for sitting or sleeping in the evenings during hot summers, offering some protection against pests (Şahinalp, 2012).

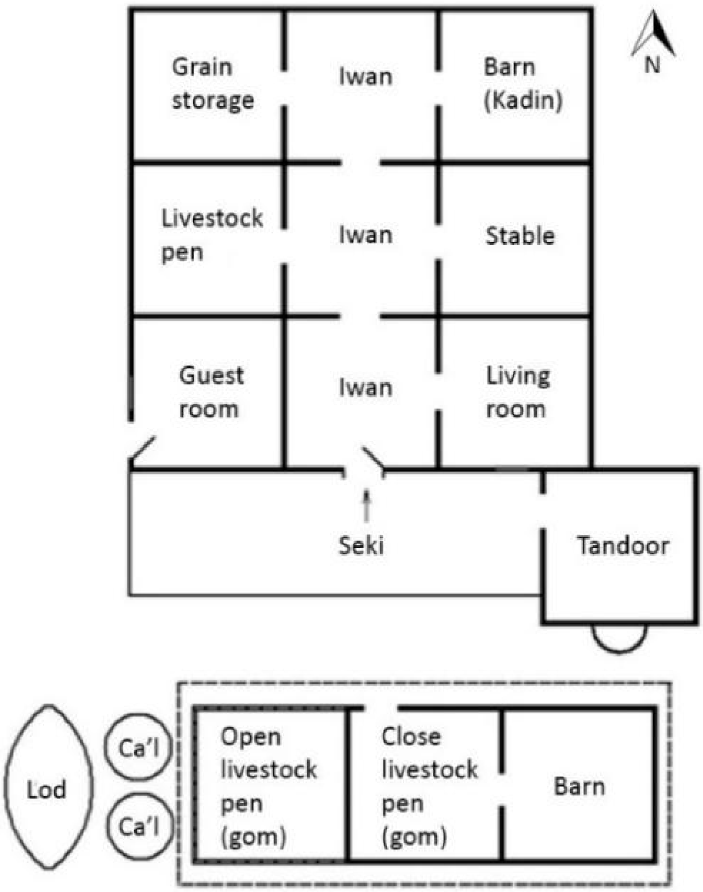


Figure 29 : Plan of a typical Suruç domed house (Şahinalp, 2012).

Chapter 2 : Architecture of Domed Houses in Harran/Turkey

2.1 Region of Şanlıurfa - Harran

2.1.1 Geographical Location, Topography and Climate

Harran is a district of Şanlıurfa province. It is located in southern Turkey, near the Syrian border, and is 44 kilometers away from Şanlıurfa (Figure 30), (https://tr.wikipedia.org/wiki/Harran). It is an important ancient city in the southeastern Anatolia region, located between the Fırat and Dicle rivers (Yıldırım, 2015).

Harran, situated 375 meters above sea level, is located in the lowest plain of the surrounding area. This settlement, where a continental climate prevails, has typical continental climate characteristics with temperatures reaching 46 degrees in the summer and falling below 0 degrees in the winter. Due to the scarcity of rainfall, green vegetation is not commonly seen. These natural environmental conditions have created a very different settlement pattern in Harran. The corbelling dome houses, with a history of approximately 150-200 years, possess a distinctive architecture within this pattern (Mamir, 2016).

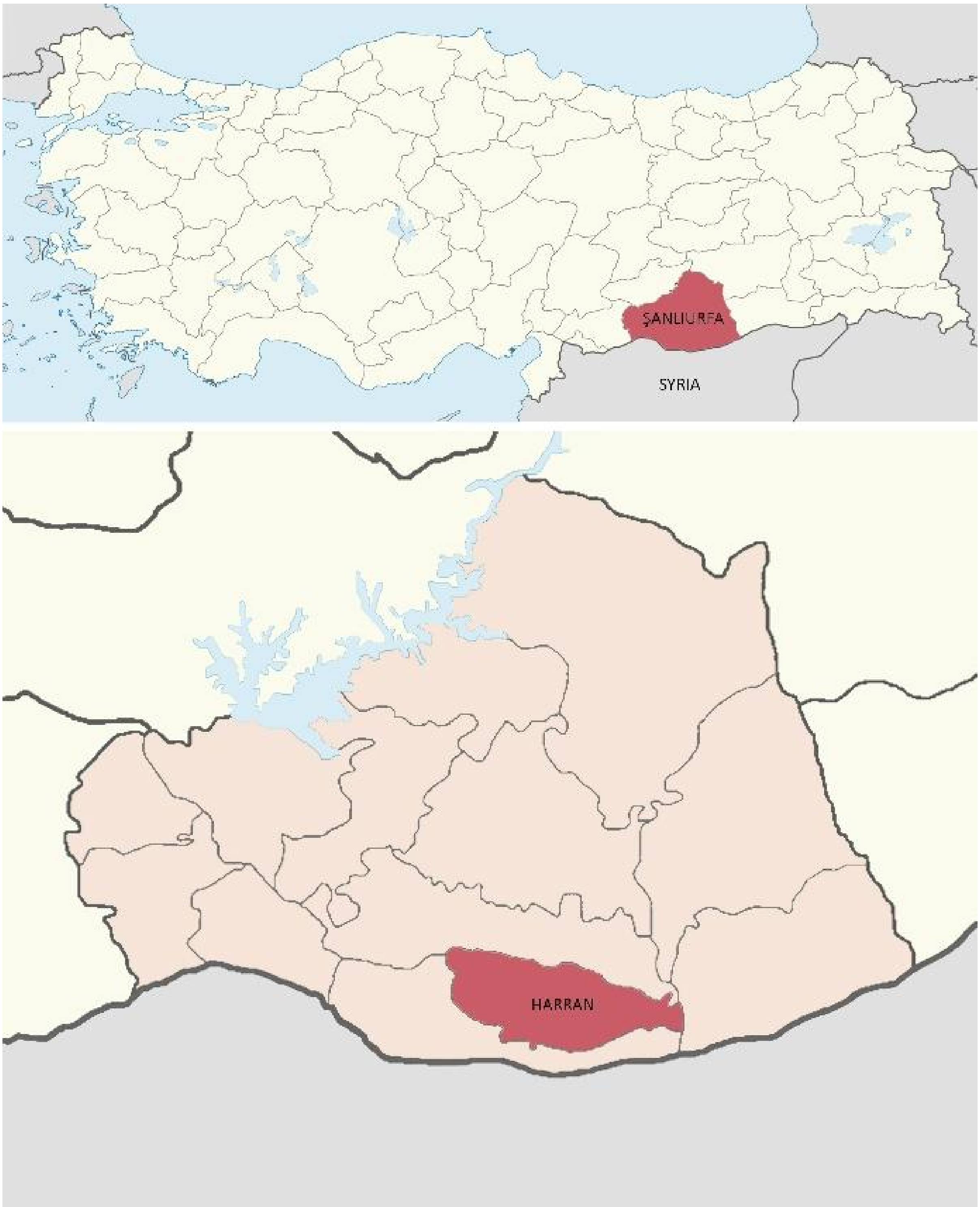


Figure 30 : Location of Şanlıurfa province and Harran District in Turkey.
(https://tr.wikipedia.org/wiki/Hilvan#/media/Dosya:%C5%9Eanl%C4%B1urfa_in_Turkey.svg)
(https://tr.wikipedia.org/wiki/Harran#/media/Dosya:%C5%9Eanl%C4%B1urfa_location_Harran.PNG)

2.1.2 Socioeconomic and Cultural Structure

Harran functioned as the cultural and religious hub of established societies for a significant portion of its history. Over the past 500 years, nomadic societies have temporarily settled there. The majority of people living in Harran Plain today speak Turkish. Furthermore, 10% of them are native speakers of Kurdish, and 19% of them speak Arabic (Özdeniz et al., 1998).

The move to irrigated agriculture over the past 50 years has altered tribal life and the patriarchal family structure of the past. Currently, settled habitation and seasonal nomadism are more common (Özdeniz et al., 1998). Families with insufficient financial resources migrate to some villages in Harran to work in cotton harvesting from May each year. They return to Harran in mid-October or November. Sometimes, it is observed that an entire family participates in the migration. After 1989, particularly with the establishment of the Atatürk Dam and the improvement in the population's standard of living, the residents of Harran began to abandon their traditional domed houses and move into concrete buildings, as the domed structures no longer met their contemporary living needs. Consequently, the function of these domed houses, which represent an important architectural culture over time, has changed. However, the social and cultural life of the community still reflects the characteristics of the region, which can be observed in the clothing, customs, and traditions of both men and women (Yıldırım, 2015).

2.1.3 Historical Overview

Since Harran is located at the intersection of Mesopotamian and Anatolian cultures, it has been influenced by these cultures. Throughout history, Harran has been under the rule of many states, making it a city where cultures have merged and been adorned with rich architectural works. Harran's history dates back to approximately 2500 B.C. Due to its proximity to the fertile lands of Mesopotamia and its location on trade routes, many civilizations developed here (Yıldırım, 2015).

Situated atop a tumulus, the town of Harran is encircled by historic city walls. Despite being designated as a historical site by the Department of Culture, history is in danger of disappearing because there haven't been enough appropriate conservation efforts or scientific excavations conducted in the area (Özdeniz et al., 1998).

It is reasonable to estimate that the current domed houses are no older than 70–150 years. These homes may have been destroyed, forgotten, and rebuilt numerous times throughout history. Over time, there had also been modifications to their form. Conical domes were constructed on the ground like tents, as depicted in a 19th-century image of Harran (Figure 31), but in the 20th century, all conical domes were constructed on square, pre-planned cubical bases (Figure 32), (Özdeniz et al., 1998).

Figure 31 : An image of Harran from the 19th century (Kürkçüoğlu, 1995).

Figure 32 : Domed houses in Harran, in 1911.
(https://gertrudebell.ncl.ac.uk/p/gb-3-1-21-1-12)

It can be said that today, domed houses with circular plans that begin with a dome at ground level are not preferred for housing, as their interiors are not functional or comfortable in terms of user practices and are restrictive in relation to human scale. Observations have shown that these types of structures are mostly used for secondary purposes, such as warehouses and barns. The type of structure that rises on a square base, with walls almost as tall as a person and domes resting on these walls, is more suitable for the integration of multiple units. It can respond to different and changing needs with the flexibility it provides in spatial organization. It is the most common type of structure nowadays (Figure 33), (Gülmüş, 2023).

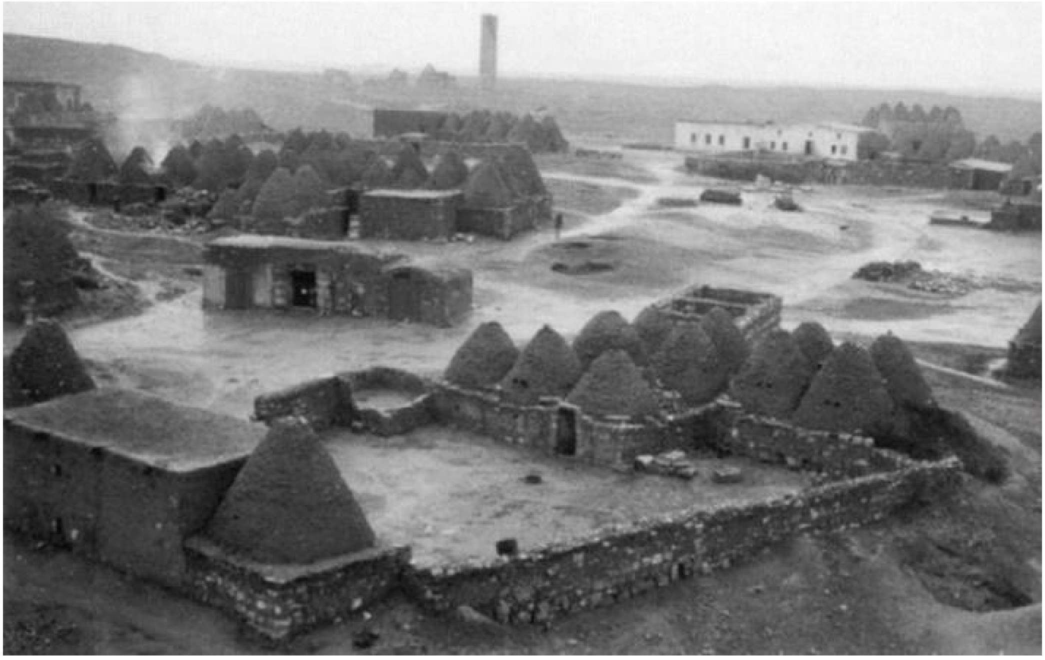


Figure 33 : In the mid-1960s, Harran (Mehmet Özdoğan's archive).

2.2 Formal Features

2.2.1 Urban Settlement, Plan Geometry and Spatial Organization

The *ashiret* culture or *ashiret* organization is rooted in the unique architecture and urban texture created by Harran's dome houses. *Ashiret* is the term for the type of tribal organization found in the area and in Şanlıurfa. The lifestyle and values of the *ashiret* and nomadic cultures are reflected in Harran's dome houses (Dikçınar Sel et al., 2015). The layout in these houses were shaped according to social structure and it created an organic urban fabric. As families belonging to the same *ashiret* preferred to live together, the buildings were constructed adjacent to or close to each other. Consequently, the street layouts are natural and have emerged spontaneously (Önal, 2022).

In this type of structure, where each domed space is considered a 'unit' (Önal, 2022), square-planned small volumes (Figure 34) are placed side by side to form a house. As time passes, new domed units can be added to expand the house based on an increase in the number of family members or other needs.

The dimensions of square-planned units can vary, sometimes being 3x3 meters and sometimes 2.5x2.5 meters from inner wall to inner wall. The wall thickness is at least 50 cm. The height of the walls, on which the dome will rest, also shows slight variations, ranging from a minimum of 150 cm to a maximum of 200 cm (Figure 35).

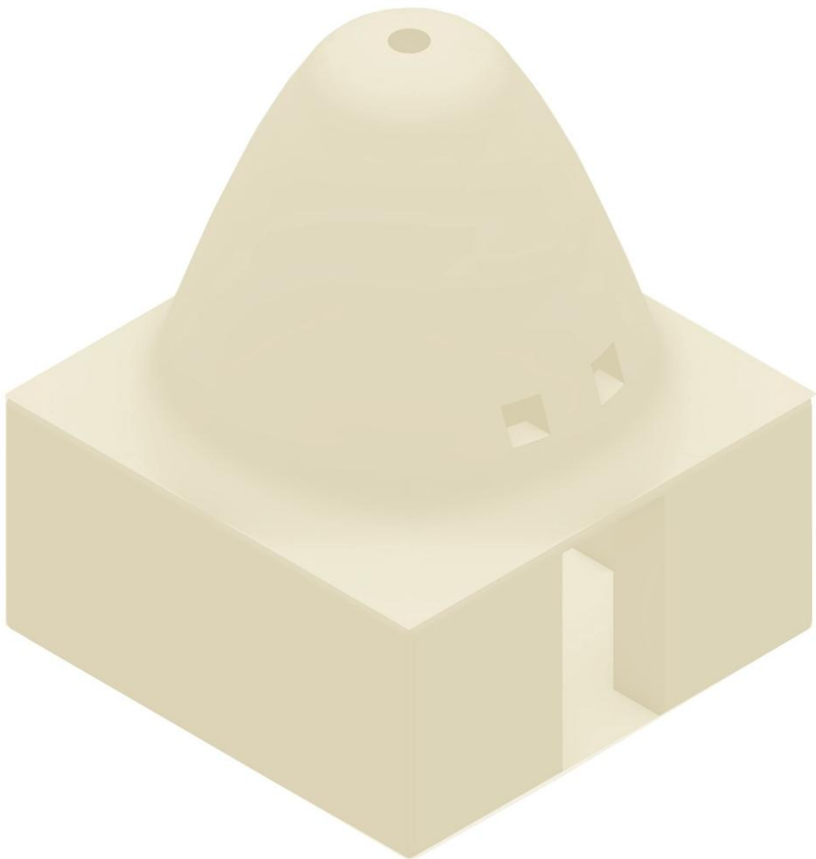


Figure 34 : Basic isometric model of a standard 3x3 meter 'unit' (2025).

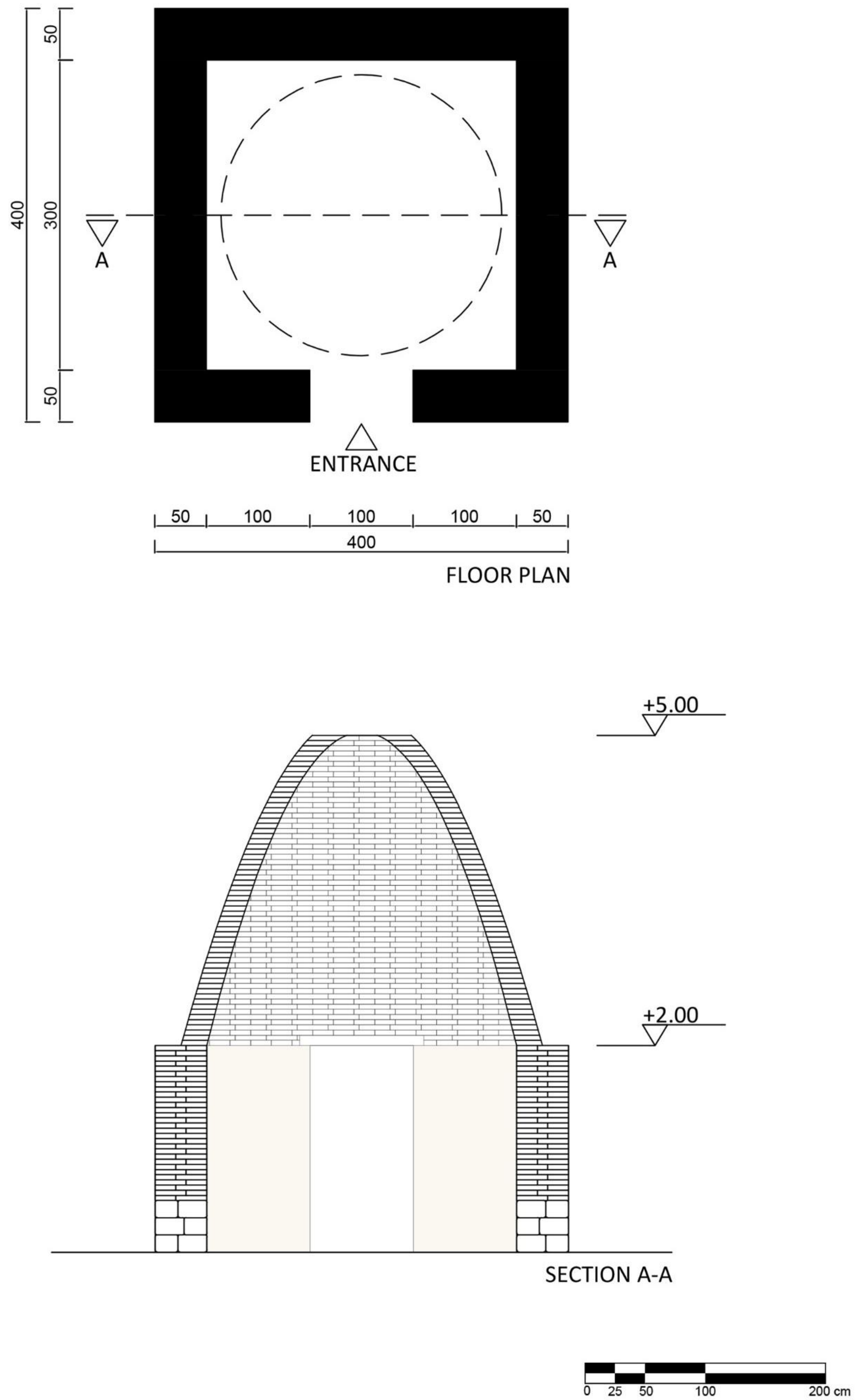


Figure 35 : Plan and section of a standard 3x3 meter 'unit' (2025).

The plan of the houses in the region can be categorized into two types: either domed units arranged around a courtyard, enclosed by walls with access to the courtyard from the outside (Figure 36), or open to the exterior and not enclosed (Figure 37). Units that are enclosed are generally arranged in an L or U shape around a courtyard, with access to the exterior provided through the courtyard gate. The boundaries of these organized units are perceived more clearly. The spatial organizations are better designed for living, sleeping, dining, sheltering, etc. In such arranged domed houses, the concept of privacy is at a higher level (Yıldırım, 2015).

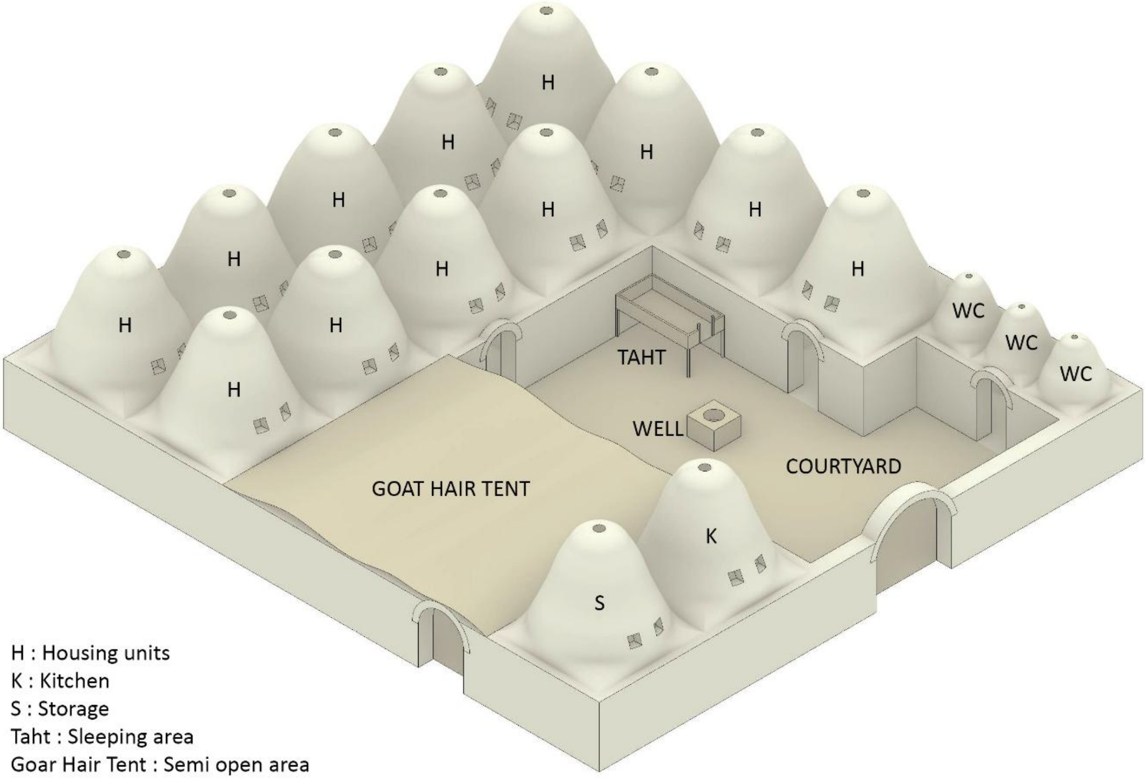


Figure 36 : 3D model of spatial organization of a domed house with courtyard and its photo (2025).

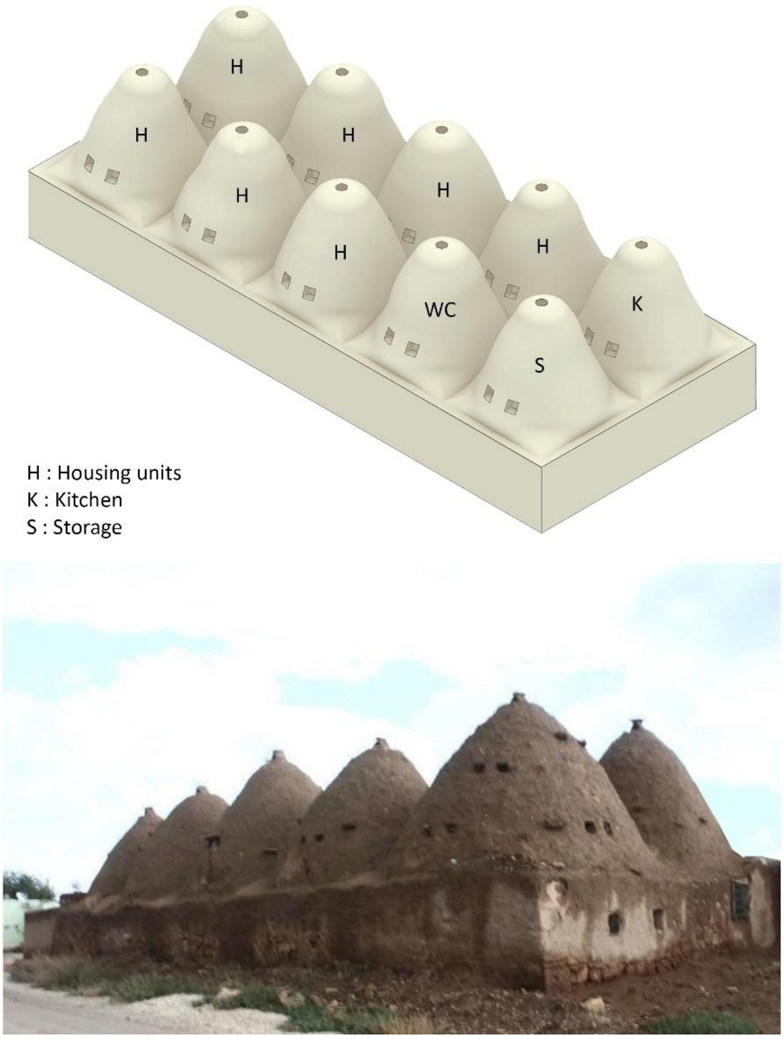


Figure 37 : 3D model and photo of a domed house with direct access to exterior (2025).
(Source of photo: Gülmüş, 2023).

The tent made of goat hair, located within the courtyard, serves as a shaded area for animals and a space for making dairy products, while also functioning as a semi-open space where family members gather, sit and rest. Additionally, wooden platforms called *taht*, raised from the ground, are equipped with mattresses, allowing for sleeping outdoors on hot summer days. In the center of the courtyard, there is a well that meets the water needs (Figure 36), (Yıldırım, 2015).

Domed units serve as living room, bedroom, kitchen, storage and barn (Figure 38). Furthermore, rooms can serve multiple functions. For example, a unit used as a living room during the day can turn into a sleeping area at night by laying mattresses on the floor. Similarly, the kitchen can also function as a sitting area during the winter. In the interior spaces, household items are hung, placed on shelves or put in niches on the walls (Figure 39). Additionally, a gap was created at the bottom of the wall for the stove, where food is cooked in the kitchen (Figure 40).

Figure 38 : Interios spaces of a domed house, from left to right : living room, bedroom, kitchen (Harran, 2024).

Figure 39 : The use of objects on walls (Harran, 2024).

Figure 40 : Stove in the kitchen (Harran, 2024).

2.2.2 Openings

Openings in a domed house serve three functions: ventilation, lighting, and circulation. A minimal approach is dominant in terms of the number and size of the openings.

The circulation inside a domed house is facilitated by openings with arches or flat lintels in the walls, providing access from one room to another. The height of these openings, in other words, serving as doors, is approximately the height of an average person, around 170-175 centimeters. They usually require one to bend down to pass through. Their widths can vary significantly: sometimes they are 90-100 centimeters wide, like the standard doors of modern houses, while other times they can reach 200-220 centimeters, covering a large portion of the wall in which they are located. In terms of position within the interior space, door openings may be located either in the corner or the middle of the walls (Table 2).

In addition to these, in domed houses with courtyards, there are doors that open to the courtyard from the dome units, which serve as the main living area. These doors, which are generally arched, may rarely have a flat lintel. The dimensions of the arched ones are larger than the doors providing internal circulation, and especially their width can almost match the room width of the dome unit they are located in. For example, the width can be nearly 250 centimeters in a standard 3x3 meter domed unit (Table 2).

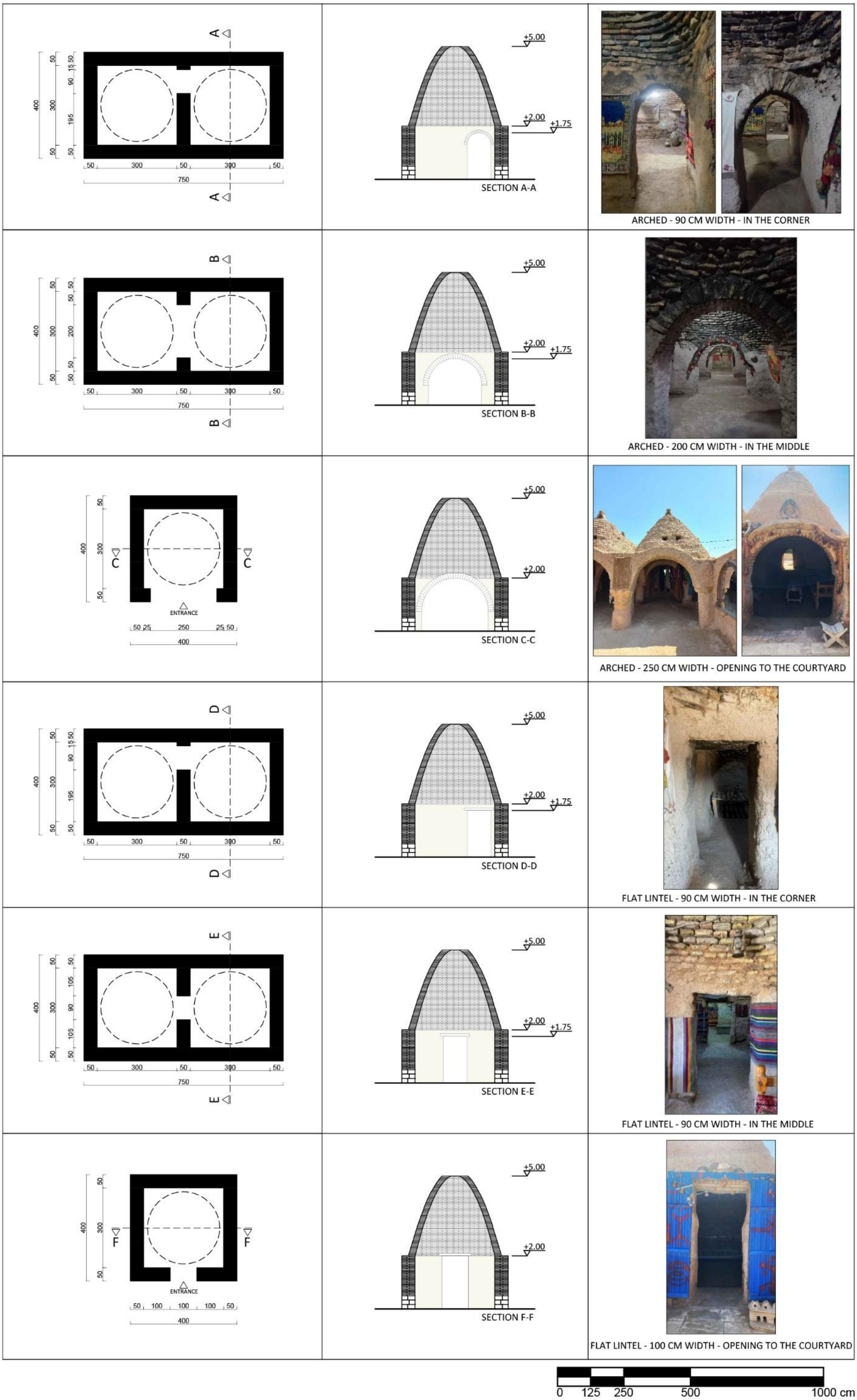


Table 2 : Types of door openings in Harran domed houses (2025).

There are several openings and holes both on the walls and dome serving to the ventilation and lighting purposes.

The openings on the walls of cubical base may be considered as windows and visual contact between courtyard or street and interior space is achieved through the small window openings (Figure 41). Their shapes are almost a square and sizes are 30x30 centimeters (Figure 42). Window openings can be closed especially in winter to prevent the cold air go inside (Figure 43).

Figure 41 : A Harran domed house which have windows facing the courtyard (Harran, 2024).

Figure 42 : A small square window on the wall (Harran, 2024).

Figure 43 : Closed windows of a Harran domed house (Harran, 2024).

The holes on the domes are positioned on opposite surfaces, facing each other. The number of holes on a single surface can sometimes be two or sometimes three (Figure 44). The hole at the top of the dome, approximately 30 centimeters in diameter, is of crucial importance for ventilation, allowing airflow from doors and windows to circulate naturally within the space (Figure 45). As noted by Mamir (2016), in order to prevent rain leaks, some top holes are covered with 3 small stones as a roof (Figure 46).

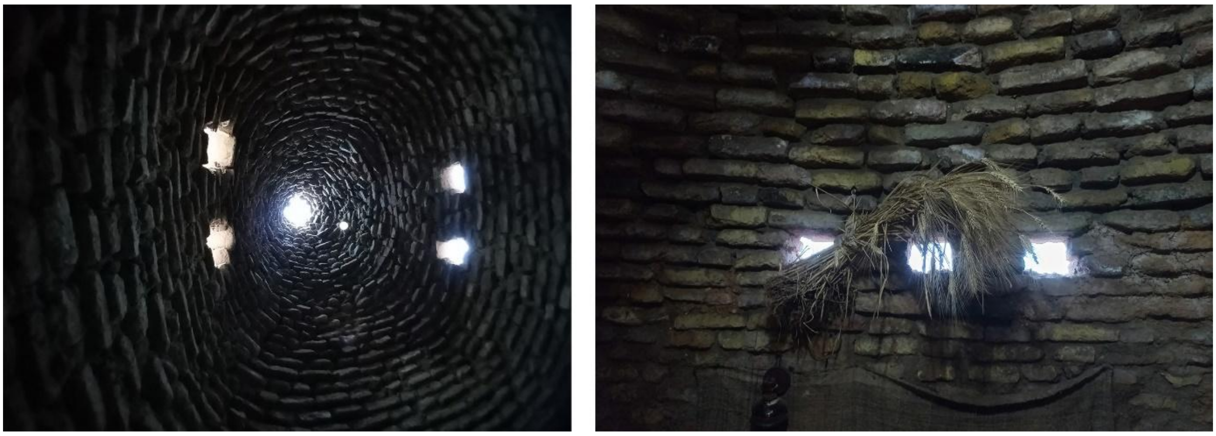


Figure 44 : Holes of domes in Harran houses (Harran, 2024).

Figure 45 : Hole at the top of the dome in Harran houses (Harran, 2024).

Figure 46 : Domes with top holes covered with small stones (Harran, 2024).

2.3 Construction Techniques and Structural Features

2.3.1 Structure of Dome

The domes in Harran houses were designed and constructed with a parabolic shape. This shape is the result of the overlapping dome technique, where the dome rises in a circular pattern from the center, transferring a significant portion of the load to the supporting walls as a pressure load. This explains why the dome's longitudinal section developed into a parabolic or conical shape rather than a semicircle (Karaçar & Güner, 2023).

In this structural system, also referred to in the literature as a "corbelled dome" or "pseudo-dome," the dome can be built using adobe, stone, or brick. In the Harran domed houses, brick was used as a primary material. Each brick course is slightly projected inward compared to the one below, gradually reducing the span of the space and forming the dome. By stacking the bricks layer by layer in this manner, a parabolic-shaped dome with a thickness of 20–30 centimeters is achieved, leaving an opening at the top until the space is fully covered (Figure 47), (Gülmüş, 2023). The domes were built by stacking 30-40 rows of bricks on top of each other, using 700-1200 bricks in total (Önal, 2022).

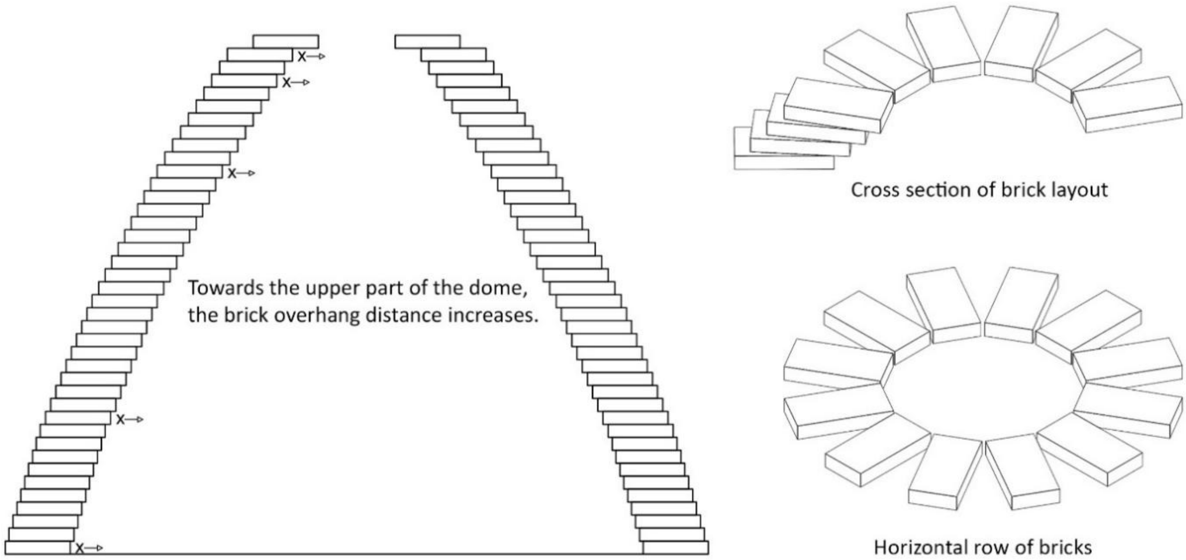


Figure 47 : Construction method of domes in Harran houses (2025).

2.3.2 Building Materials and Construction Techniques

In this chapter, the material details of the structural components, from the base to the dome, of a typical Harran house will be examined. Besides, exceptions regarding the different uses and solutions of materials and structural components will also be reviewed.

Large, flat, and rigid limestone blocks were used in the base of the structure (Figure 48), and these large stone blocks were brought from the Bazda Caves, historical quarries located very close to the area where the Harran domed houses were built (Figure 49).

There are some different scenarios in the use of materials for the base: sometimes limestone and brick were used together and in such cases, the base may sometimes start with layers of bricks instead of limestone, with limestone placed on top. (Figure 50).

Figure 48 : Limestones used in the base of Harran domed houses (2024).

Figure 49 : Bazda Caves in Harran region (2024).

Figure 50 : Examples of combined use of different materials in the base. The red arrows indicate that the base begins with rows of bricks (2024).

After the base is built to a height of approximately 50 cm, the load-bearing walls are constructed on top, reaching a total height of about 1.5–2 meters. Alternatively, there are a few exceptions where the transition from the base directly to the dome occurs, resulting in a wall length of approximately 50-60 cm in total (Figure 51). Bricks brought from nearby ancient building remnants and ruins, like limestones, have been used as the primary material for the walls. These bricks were made of clay and were processed by either sun drying or burning. Although their dimensions are not standardized, they are approximately 20×30×5 cm in size (Figure 52). The wall thickness is about 50 cm. Just like the bases, there are cases where different materials were used in the walls as well: while limestone and brick were used together, there are also a few exceptions where the wall was made entirely of stone (Figure 53). Additionally, in some cases, a cross arrangement of bricks has been observed in the walls (Figure 54).

Figure 51 : From left to right: first three photos are the examples of the wall with nearly 1.50-2 meters height and the last one is an exception where the wall height is 50-60 cm (2024).

Figure 52 : Examples of the walls made of bricks (2024).

Figure 53 : From right to left, limestone and brick were used together in the first two photos. In the last photo, stone is the only material of the wall (2024).

Figure 54 : An example of herring bone arrangement of bricks in the wall (2024).

Before starting the construction of the dome, a transition element is required after completing the wall construction. For this reason, stone blocks placed diagonally at a 45° angle in the wall corners serve as pendentives. Their dimensions are approximately 60x30x20 cm (Figures 55, 60 and 61). Although in most Harran houses the pendentive is a structural element that is only visible from the inside, there are a few houses, as shown in the figure 56, where it is also visible from the outside. The dome, which is about 5 meters above the ground, is also made of bricks, just as most of the walls (Figures 57, 60 and 61). At the junction between the wall and the dome, the wall extend outward, forming a protrusion (Figure 58). To securely bind the bricks in both the walls and the dome, the soil found in the Harran Plain, which is suitable for adobe production, is used to prepare adobe mud as mortar (Figure 58), (Gülmüş, 2023).

The entire exterior of a completed domed house (both the walls and the outer surface of the dome) is covered with plaster. On the interior, only the walls are plastered, while the bricks of the dome are left exposed (Figures 58, 59 and 61). As stated by Yıldırım (2015), the plaster material consists of clay-based soil mixed with straw or plant residues (Figure 58).

The plaster of domed houses needs to be renewed every two years. Otherwise, the dome may collapse due to neglect. When it rains, the soil on top of the plaster falls off, and as the rainwater seeps between the bricks, it erodes the mortar, which can cause the dome to collapse. For this reason, it is important to regularly renew the plaster.

Figure 55 : Pendentives in Harran domed houses (2024).

Figure 56 : Examples of Harran domed houses where the pendentive is visible from the outside.
(From left to right: Tuncay, 2014 – Photograph by the author, 2024)

Figure 57 : The domes made of bricks of Harran houses, from left to right : bottom view of the dome, sectional view of corbelled dome of a collapsed house (2024).

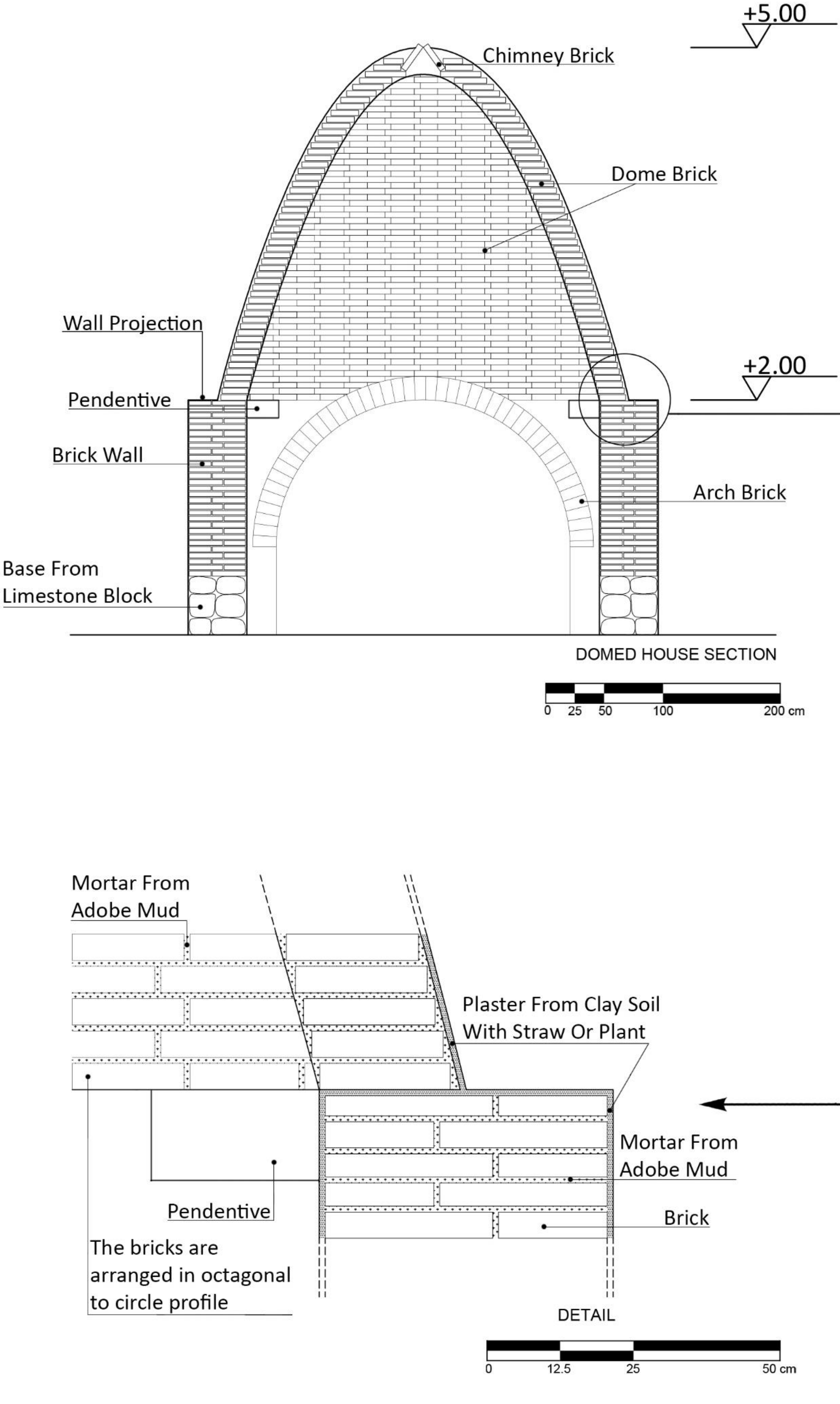


Figure 58 : Section of a typical Harran domed house showing the structural elements and detail showing the mortar between the bricks and plaster of the exterior structure (2025).

Figure 59 : From left to right : Completely plastered exterior surface, plastered interior walls and a partially exposed interior dome (2024).

The bricks used in the construction of the dome are laid starting from the lowest part, based on an octagonal line naturally formed by the pendentives. With each layer, the rows of bricks are arranged slightly inward, while the octogonal profile of the bricks gradually transition to a circular shape.

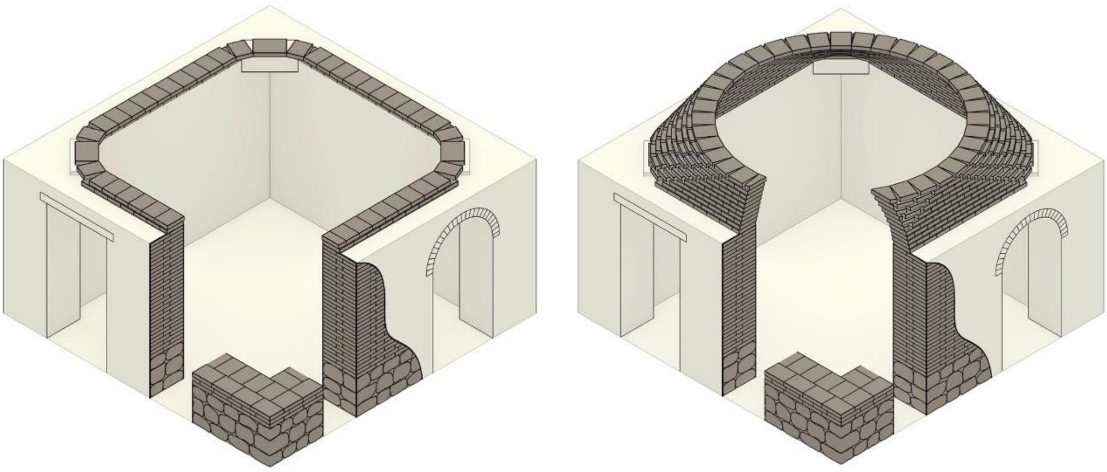


Figure 60 : 3D diagram explaining how the bricks are laid in the lower courses (2025).

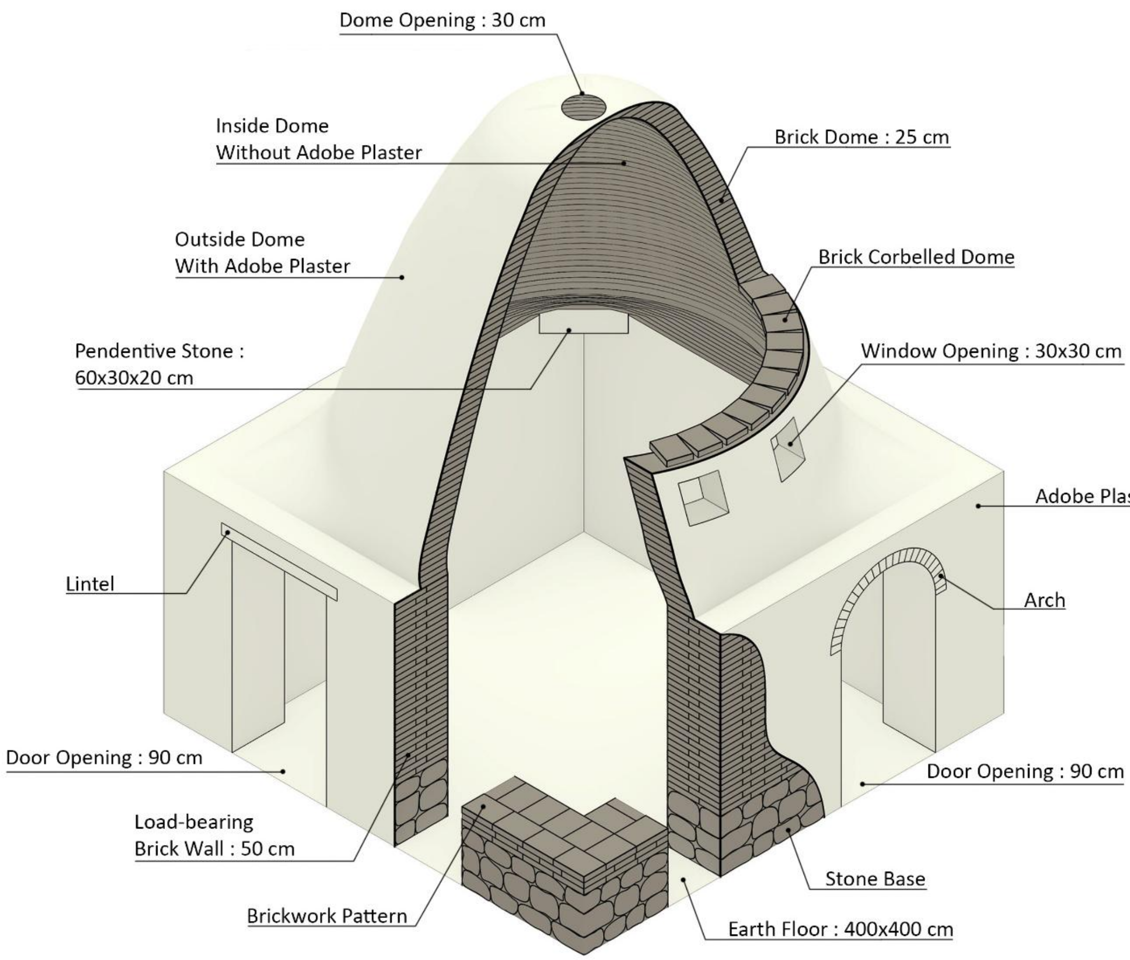


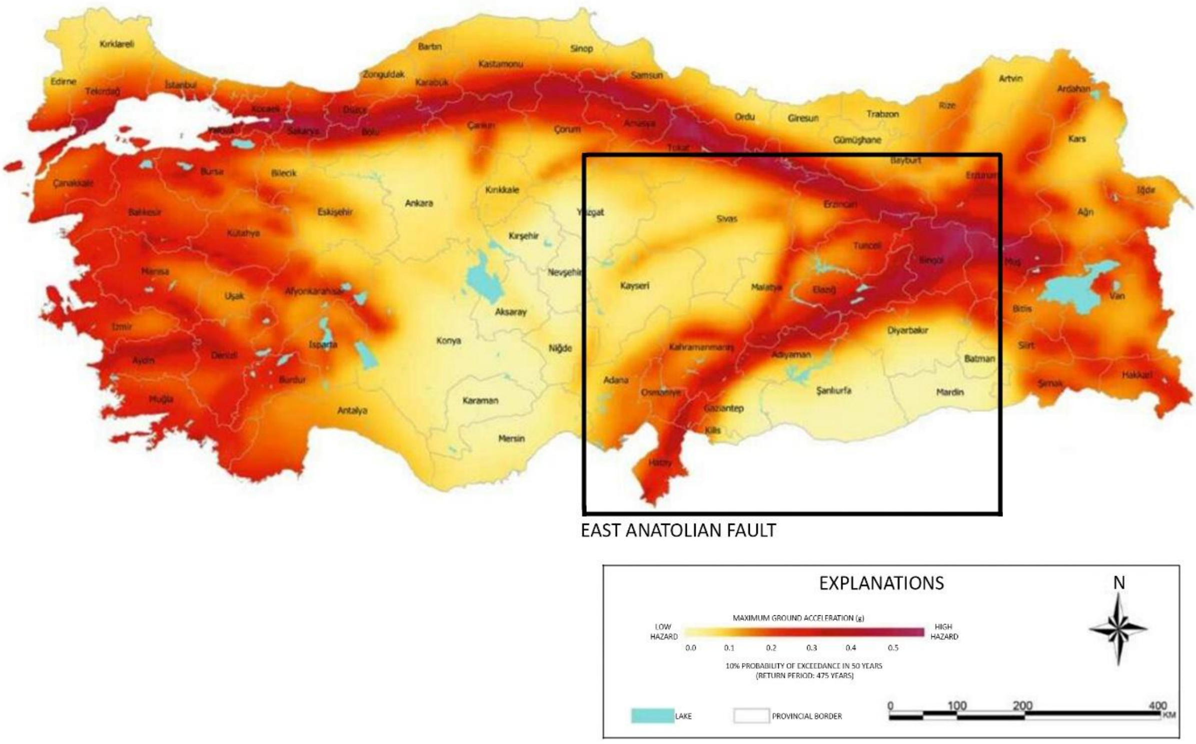
Figure 61 : 3D Axonometric section showing the structural elements of a typical Harran domed house (2025).

As a conclusion of this part, Harran domed houses are primarily constructed with locally produced or supplied building materials. There are even some that were recovered from the remains of old structures. The local term for these building materials is '*devsirme*' ,which translates to 'the collected' (Özdeniz et al., 1998).

Chapter 3 : February 6th, 2023 Earthquake and Collapsed Harran Houses

3.1 Effects of Earthquake on Turkey, Şanlıurfa and Harran

Two earthquakes with magnitudes Mw 7.7 and Mw 7.6, with epicenters in Pazarcık (Kahramanmaraş) and Elbistan (Kahramanmaraş), respectively, occured on February 6, 2023, at 04:17 and 13:24 Turkey time (Figure 62). While the 7.6 magnitude earthquake happened at a depth of 7 km, the 7.7 magnitude earthquake happened at a depth of 8.6 km. Earthquakes were intensely felt in Kahramanmaraş, Hatay, Adıyaman, Gaziantep, Malatya, Kilis, Diyarbakır, Adana, Osmaniye, Şanlıurfa and Elazığ, they caused loss of life and severe damage (AFAD, 2023a). The East Anatolian Fault (EAF) is located in the region covering the provinces where the earthquake occurred (Figure 62).



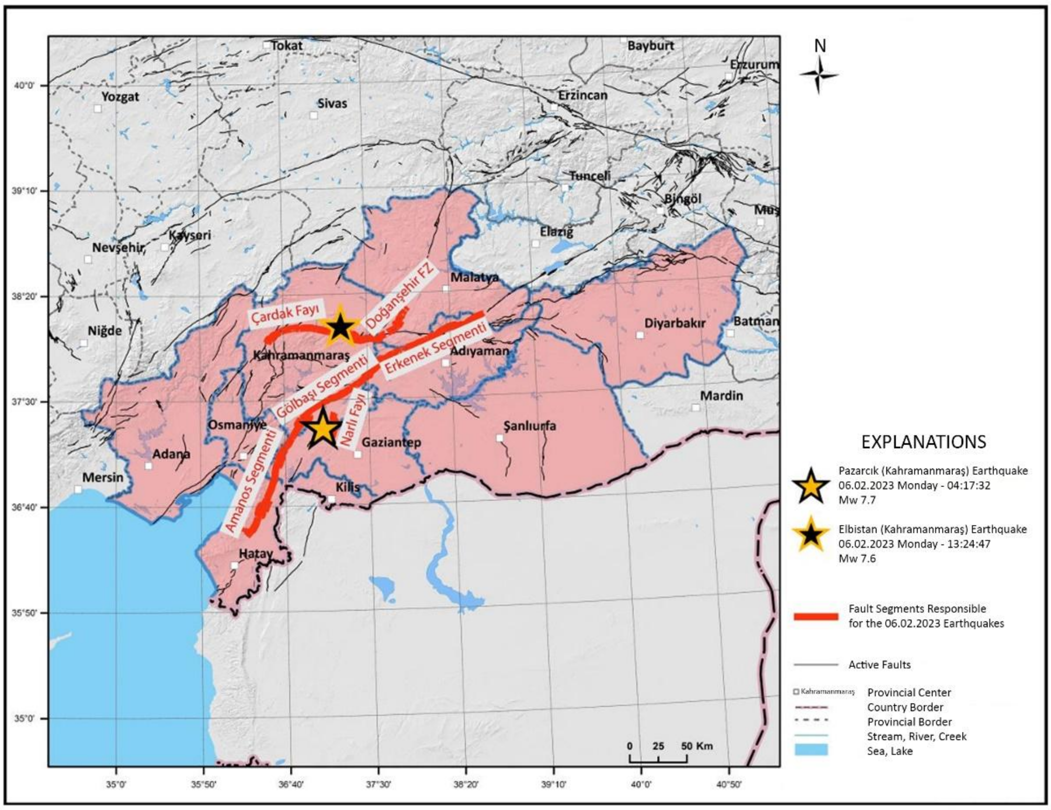


Figure 62 : From top to bottom: Turkey's earthquake hazard map - A map showing the fault segments of the East Anatolian Fault Line (AFAD, 2023a).

The earthquake affected an area of 108,812 km², covering 11 provinces in the Eastern and Southeastern Anatolia Regions (Figure 63). According to records of strong seismic activity, field observations, and information obtained from local residents, these two main shocks—recorded as the most destructive earthquake storm in the country's history—suggest that the first earthquake had a more significant impact in Kahramanmaraş and Hatay, while the second earthquake was particularly more severe in Malatya (AFAD, 2023b).

Figure 63 : Provinces affected by the February 6, 2023 earthquakes in Turkey (AFAD, 2023b).

The tremor was very close to the surface, and the affected area was very large. This disaster has been described as the disaster of the century because the earthquake resulted from the merging and breaking of faults, the affected area was extensive, and its destructive impact was great (Sabırsız & Şöhret, 2024). The destruction caused by the earthquakes and aftershocks, the trauma they induced, and the inadequacy of facilities led to numerous kinds of grievances experienced simultaneously. While those trapped under the rubble were struggling to stay alive, those outside had to contend with inadequate resources and harsh climate conditions (Öztürk & Kırca, 2023, p. 1).

As of March 6, 2023, damage assessment studies have been conducted on 1,712,182 buildings in the 11 provinces affected by the earthquake. According to the findings, 35,355 buildings have collapsed, 17,491 buildings require urgent demolition, 179,786 buildings have suffered severe damage, 40,228 buildings have moderate damage, and 431,421 buildings have minor damage. In addition to residential buildings, the collapsed or heavily damaged structures include historical and cultural buildings, schools, administrative buildings, hospitals, and hotels (Table 3), (Türkiye Cumhuriyeti Cumhurbaşkanlığı Strateji Ve Bütçe Başkanlığı, 2023).

	Number of buildings	Independent Unit
Undamaged	860.006	2.387.163
Slightly Damaged	431.421	1.615.817
Moderately Damaged	40.228	166.132
Severely Damaged	179.786	494.588
Collapsed	35.355	96.100
Requires urgent demolition	17.491	60.728
Not assessed	147.895	296.508
Total	1.712.182	5.117.036

Table 3 : Number of buildings with damage assessment in the 11 provinces affected by the earthquake (March 6, 2023), (ÇŞİDB, 2023).

After the February 6, 2023 Kahramanmaraş earthquakes, a total of 298,501 residential buildings were inspected in Şanlıurfa. Among these, 6,163 were classified as severely damaged, 6,041 as moderately damaged, 199,401 as slightly damaged, and 86,896 as undamaged (Table 4), (Akgül & Bayraktar, 2024).

Provinces	Total Inspected	Severely Damaged	Moderately Damaged	Slightly Damaged	Undamaged
Adana	199.682	2.952	11.768	71.072	113.890
Adıyaman	187.797	56.256	18.715	72.729	40.097
Diyarbakır	359.987	8.602	11.209	113.223	226.953
Elazığ	52.332	10.156	1.522	31.151	9.503
Gaziantep	595.292	29.155	20.251	236.497	309.389
Kahramanmaraş	307.538	99.326	17.887	161.137	29.188
Malatya	254.017	71.519	12.801	107.765	61.932
Hatay	442.757	215.255	25.957	189.317	12.228
Kilis	63.680	2.514	1.303	27.969	31.894
Osmaniye	141.108	16.111	4.122	69.466	51.409
Şanlıurfa	298.501	6.163	6.041	199.401	86.896

Table 4 : Housing damage assessment for Şanlıurfa and other provinces affected by the earthquake (Türkiye Cumhuriyeti Cumhurbaşkanlığı Strateji Ve Bütçe Başkanlığı, 2023).

Among the structures that demonstrate Şanlıurfa's rich architectural history and were affected by the recent major earthquakes are religious architectural examples such as mosques and churches, as well as significant examples of residential architecture and domed houses (Table 5), (Ölçer et al., 2024).

Number of Registered Buildings (2023): (1st and 2nd Group, Monumental and Civil Architecture Structures)			
	Collapsed	Severely Damaged	Slightly - Moderately Damaged
Mosque		5	23
House	43	40	224
Domed House	28	22	34
Church		1	2
Total	71	68	283

Table 5 : Şanlıurfa earthquake damage assessment studies (Ölçer et al., 2024).

One of the most important cultural heritage sites affected by the earthquake in Şanlıurfa is Harran domed houses, which is the subject of the thesis.

In Harran, which was registered as an archaeological and urban site in 1979 and where the domed houses were placed under protection, 960 domed houses were counted at that time (https://www.turkiyenintarihieserleri.com/?oku=2689). This number has decreased to nearly 110 before February 6, 2023 earthquakes due to the lack of maintenance over the years.

As seen in Table 5, a total of 84 domed houses were adversely affected by the earthquake, including 28 that collapsed, 22 that were severely damaged, and 34 that sustained minor damage. Considering that there are two types of domed houses in Şanlıurfa, located in Harran and Suruç (see: 1.2 Historical Overview and Global Distribution of Domed Houses), even though it is unknown how many of these 84 damaged or collapsed houses were in Harran and how many were in Suruç, it can be estimated that their total number has further decreased from 110 due to the earthquake disaster.

It was learned during the site visit that no conservation or restoration efforts have been made for the Harran domed houses that were damaged or collapsed after the earthquake. In addition, the houses that were collapsed before the earthquake were not only due to neglect but also because the local residents demolished them for the sake of building 2-3 story concrete houses. After the earthquake, some of the collapsed houses were rebuilt by the locals, while a minority of them were preserved by the Ministry of Culture, and concrete houses were constructed by the locals in place of others.

Most of the houses purchased and nationalized by the Ministry of Culture were also demolished by the locals. A significant portion of the Harran population has faced legal action for demolishing the domed houses in the protected area and constructing new buildings in their place, resulting in prison sentences or fines.

Consequently, while it is understandable that people, feeling helpless after the earthquake, resorted to building their own reinforced concrete houses, the lack of preventive measures and efforts by official institutions, along with public unawareness, has put the Harran domed houses at risk of disappearance.

3.2 Damage Issues in Harran Domed Houses

3.2.1 Damaged Harran Domed Houses

In this chapter, some of the houses detected during the site visit that were damaged by the earthquake will be examined. In figure 64 and figure 65, the map and the Autocad drawing from before the February 6th, 2023 earthquake shows a total of nine houses seen during the site visit, seven of which were ruined and two of which are well preserved. The architectural and constructional analysis of a typical Harran domed house has already been conducted in previous chapters based on the two houses that remain in good condition.

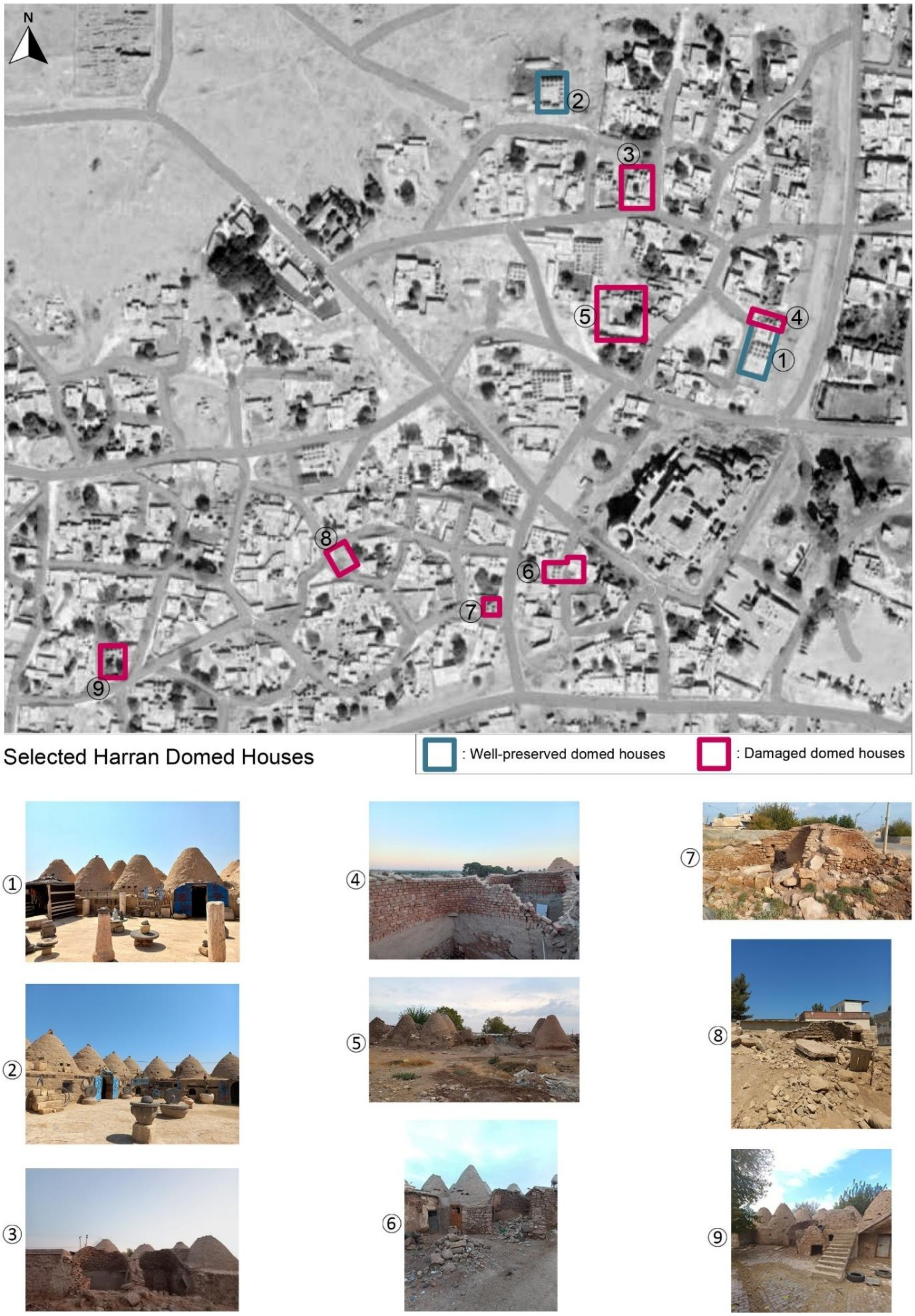


Figure 64 : Map and photos showing the selected seven damaged and two well-preserved domed houses (2025).

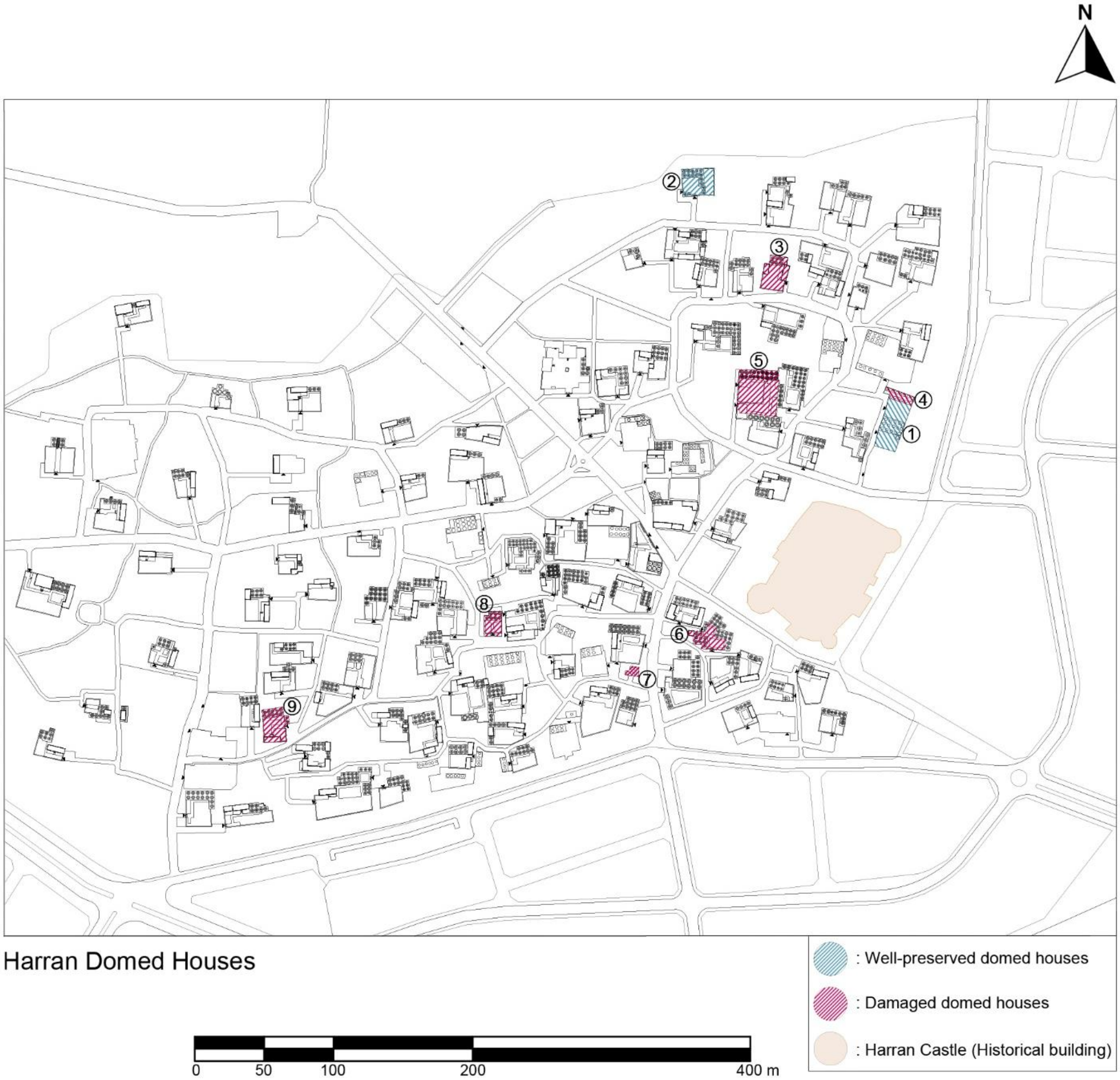


Figure 65 : Drawing showing the selected seven damaged and two well-preserved domed houses (2025).

In the following pages; plans, elevations and photos of selected damaged domed houses observed during the site visit will be presented to illustrate their damage.
Context plans of all seven houses are shown at the beginning, depicting surrounding elements such as courtyards and showing the pre-earthquake situation.
For each of the seven houses, the surviving portions are indicated with blue lines in both plans and elevations, while the collapsed portions are shown with grey dashed lines in the elevations.
Wall damage is represented using different shades of yellow according to the remaining wall height:

- Partially collapsed walls with a remaining height between 90–200 cm are shown in the darkest yellow,
- Those between 0–90 cm in medium yellow,
- And completely collapsed walls in the lightest yellow.

In addition, the angles from which the photographs were taken are shown in the plans.

HOUSE 3

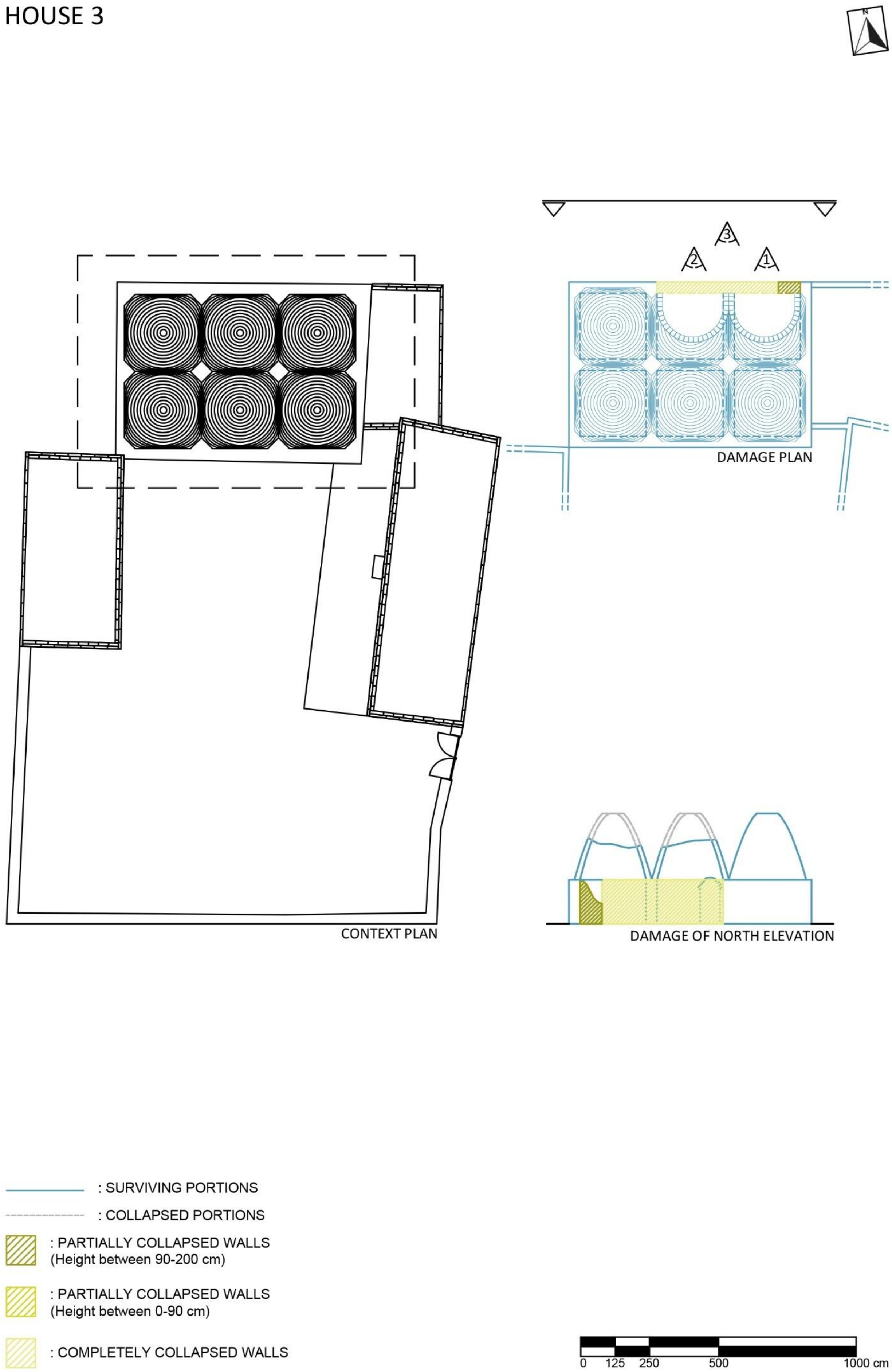


Figure 66 : Damage Drawings of House 3 (2025).

HOUSE 3

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③

Figure 67 : Damage Photos of House 3 (2025).

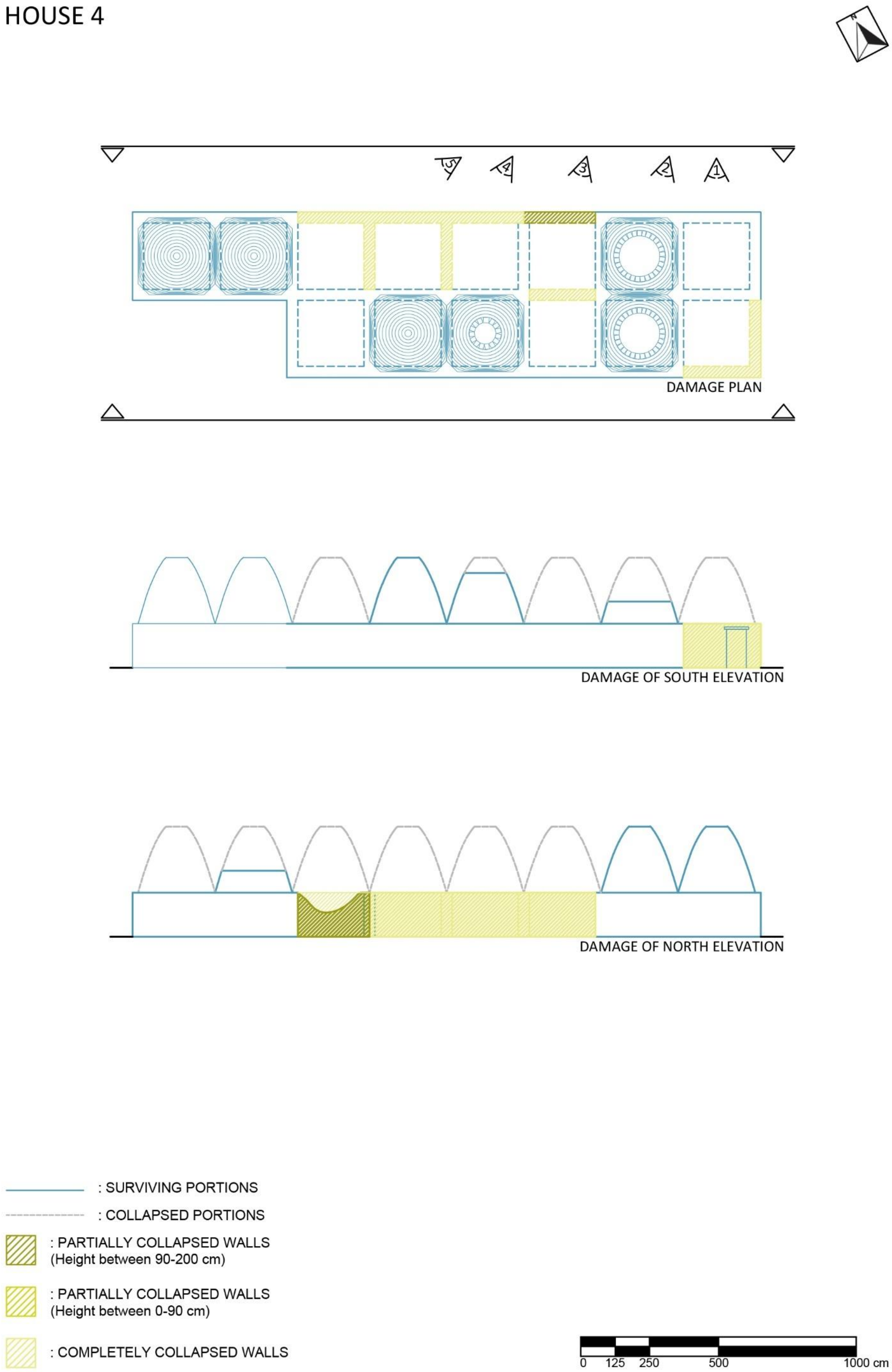

Figure 68 : Damage Drawings of House 4 (2025).

HOUSE 4

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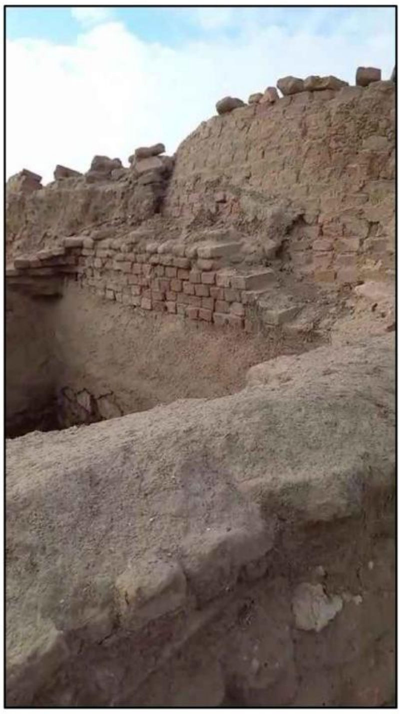
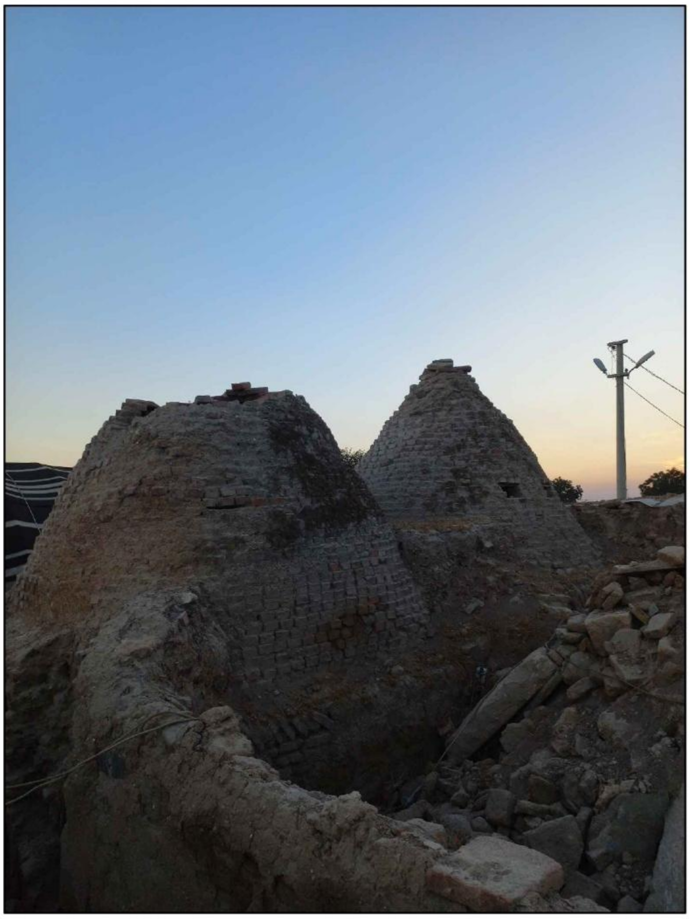
②



③

④



⑤

Figure 69 : Damage Photos of House 4 (2025).

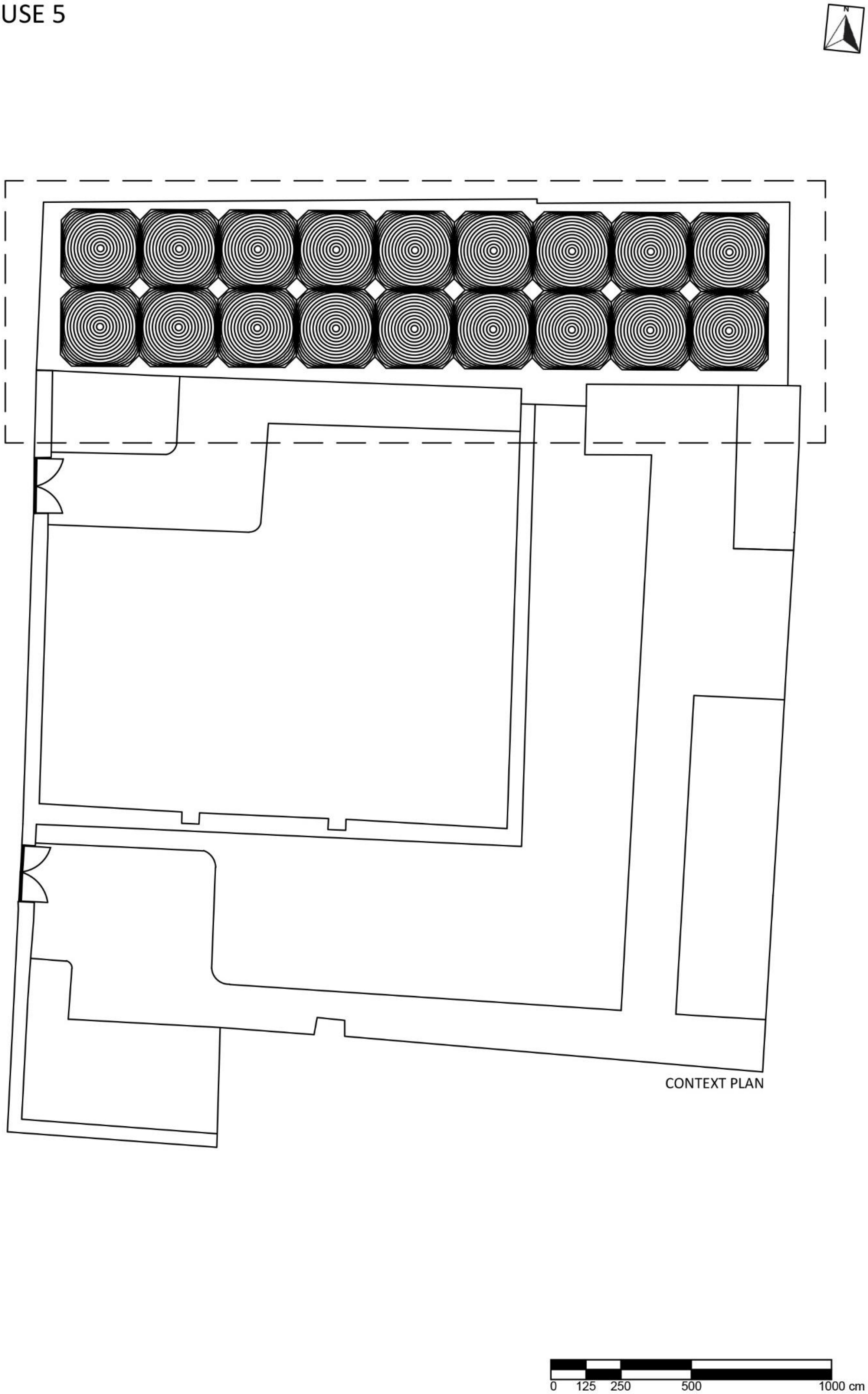


Figure 70 : Context Plan of House 5 (2025).

HOUSE 5

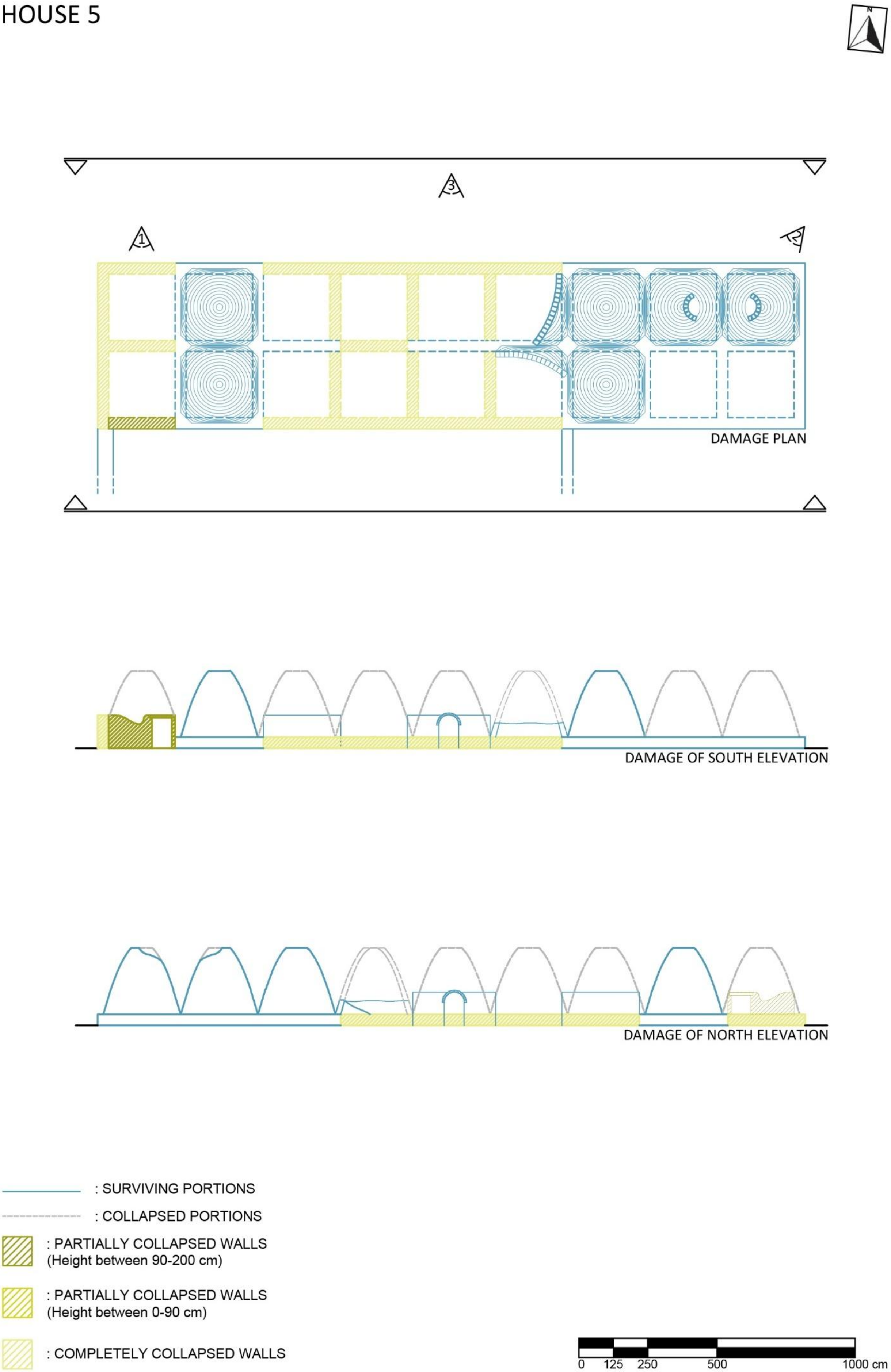


Figure 71 : Damage Drawings of House 5 (2025).

HOUSE 5

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Figure 72 : Damage Photos of House 5 (2025).

HOUSE 6

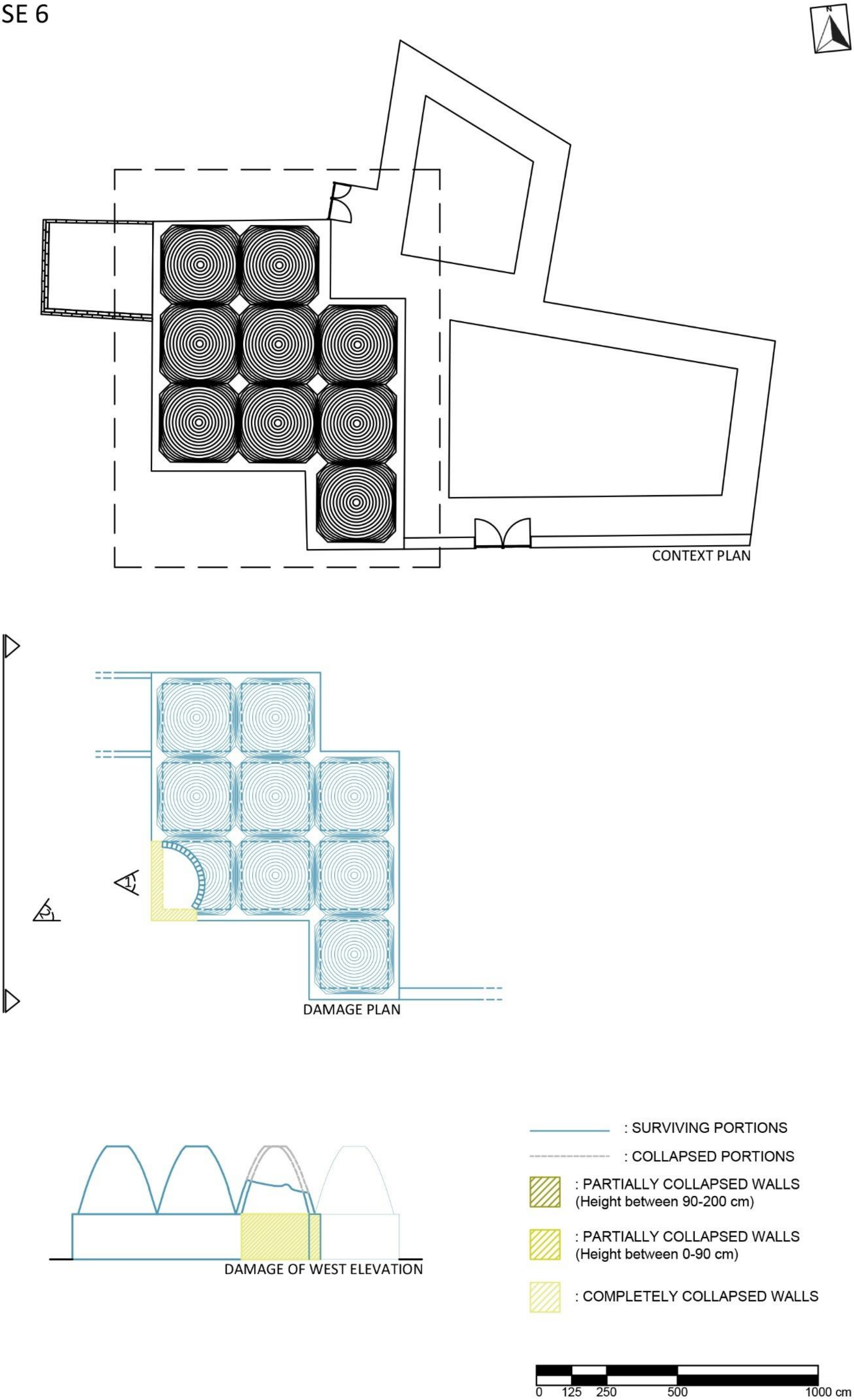

Figure 73 : Damage Drawings of House 6 (2025).

HOUSE 6

①

②

Figure 74 : Damage Photos of House 6 (2025).

HOUSE 7

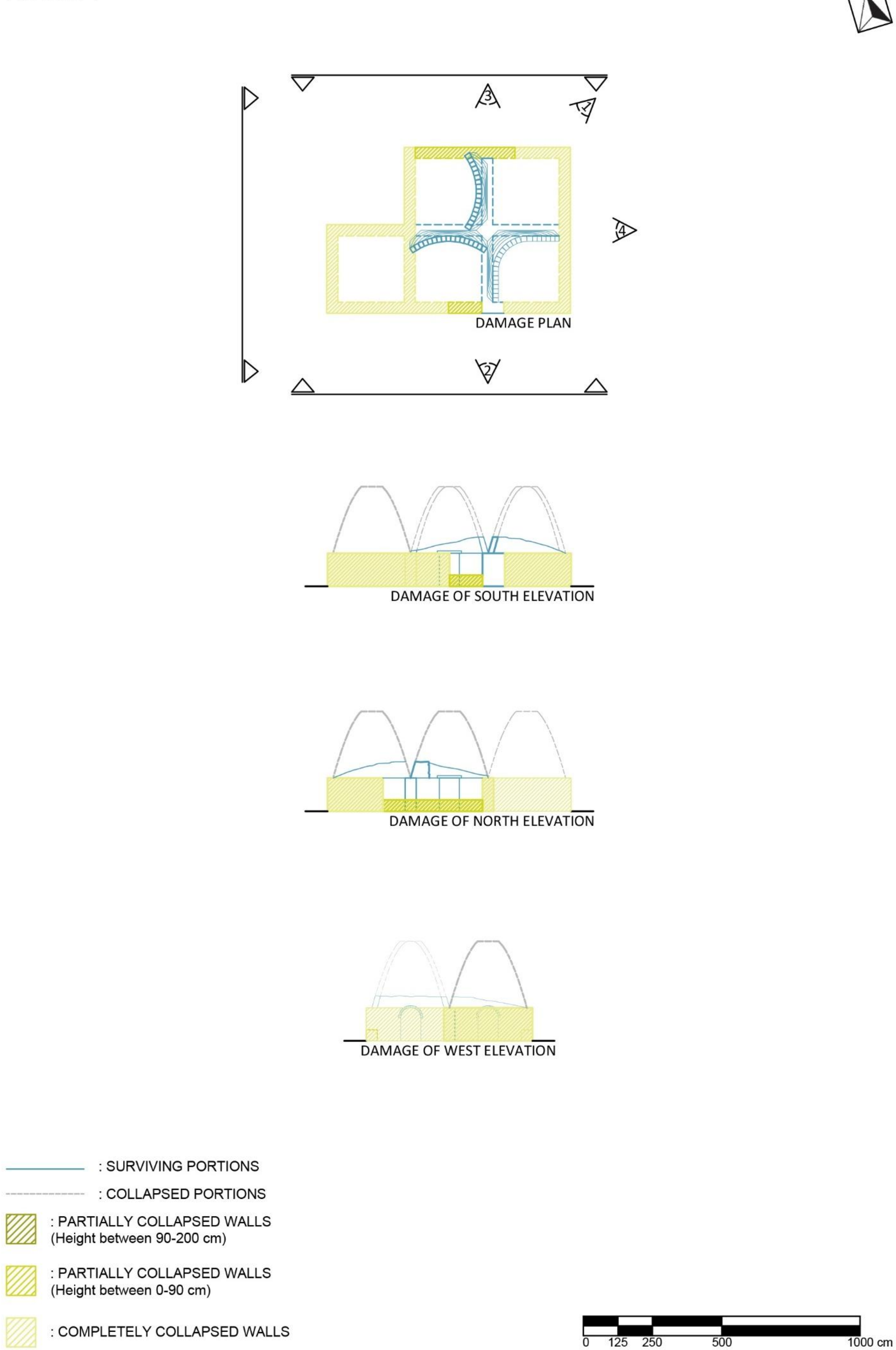

Figure 75 : Damage Drawings of House 7 (2025).

HOUSE 7

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Figure 76 : Damage Photos of House 7 (2025).

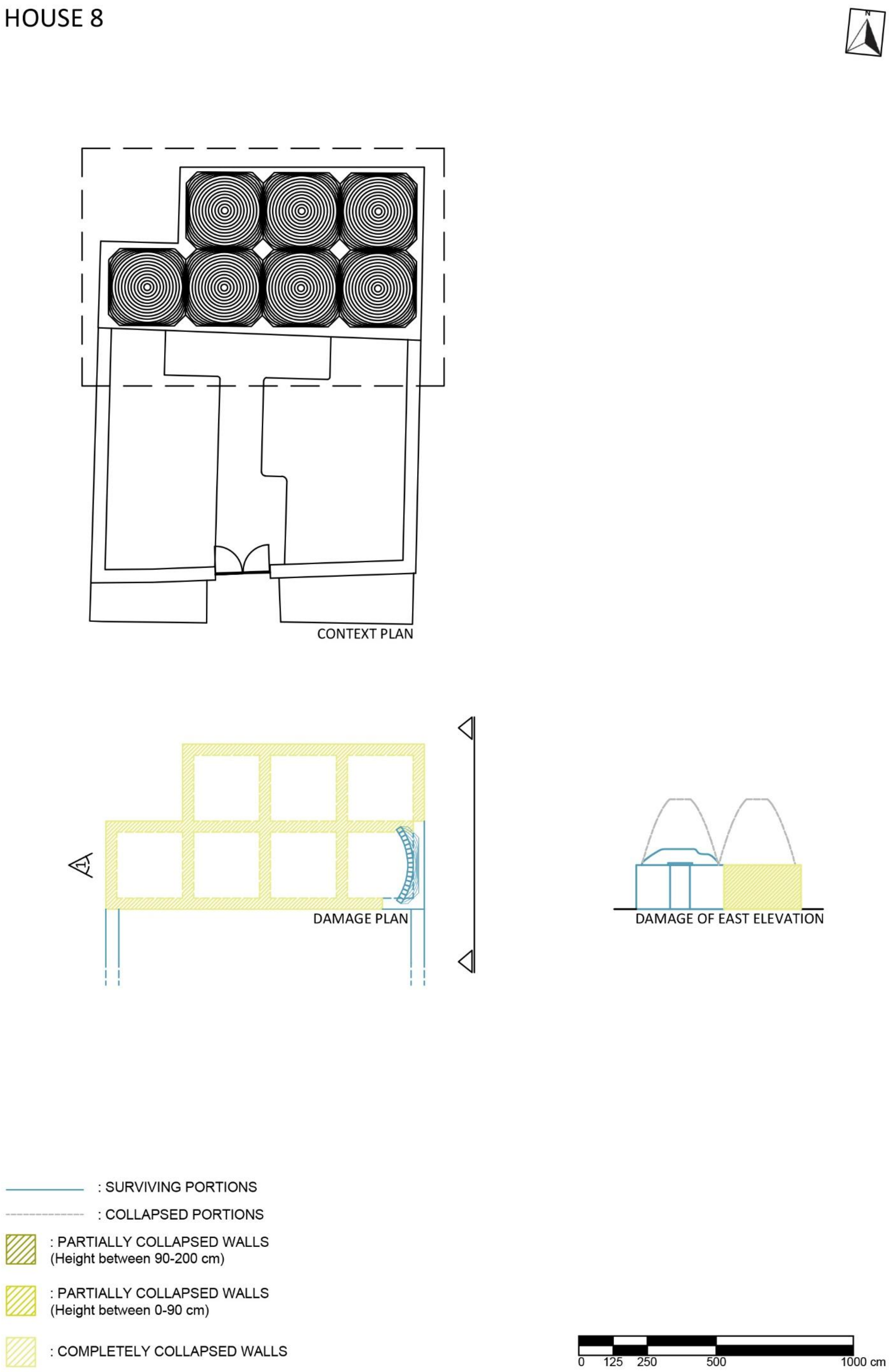


Figure 77 : : Damage Drawings of House 8 (2025).

HOUSE 8

①

Figure 78 : Damage Photo of House 8 (2025).

HOUSE 9

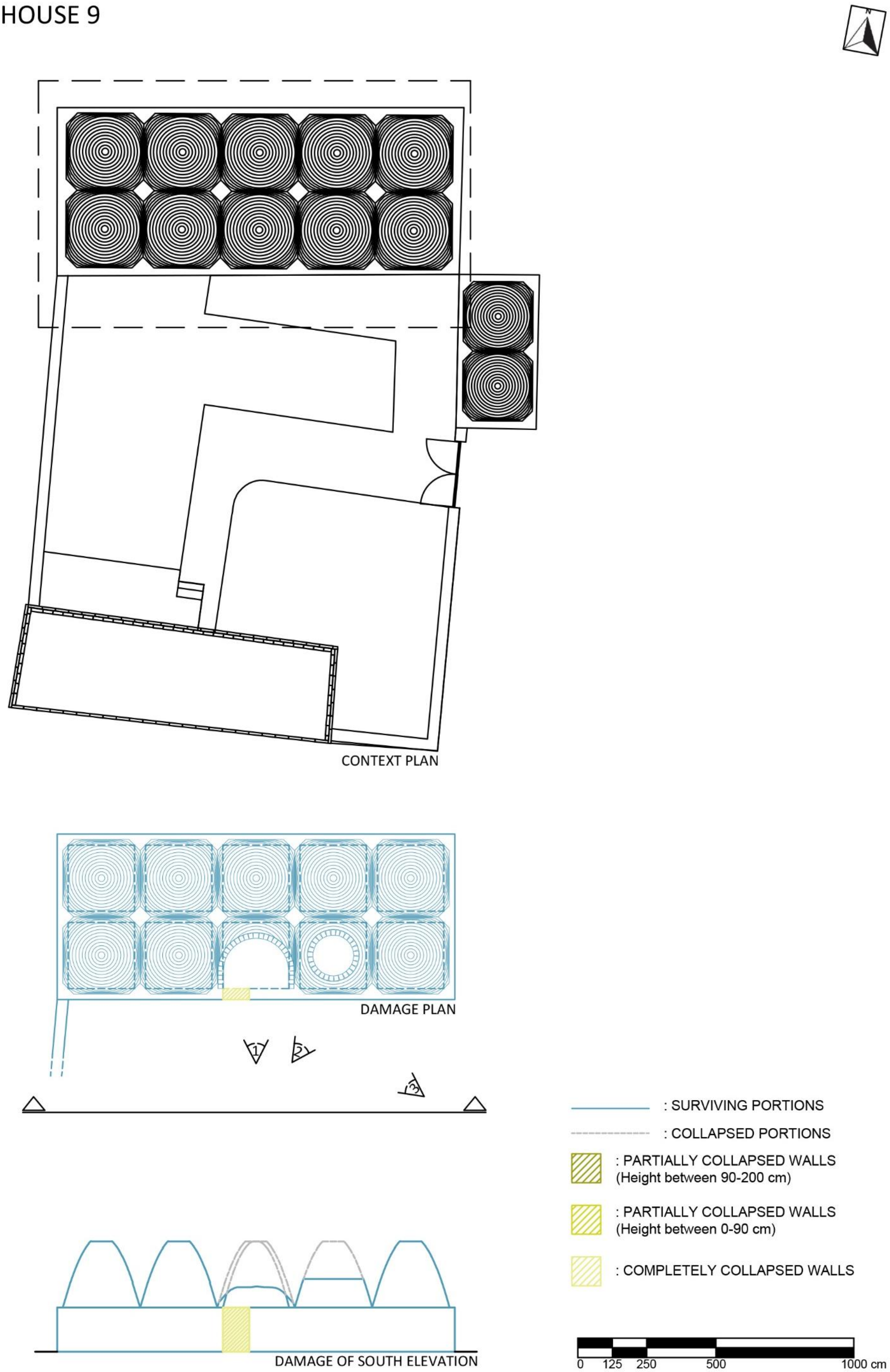
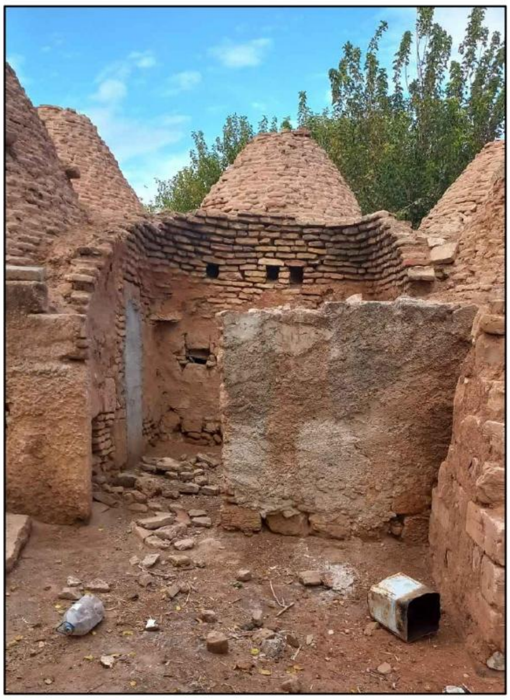


Figure 79 : : Damage Drawings of House 9 (2025).

HOUSE 9

①



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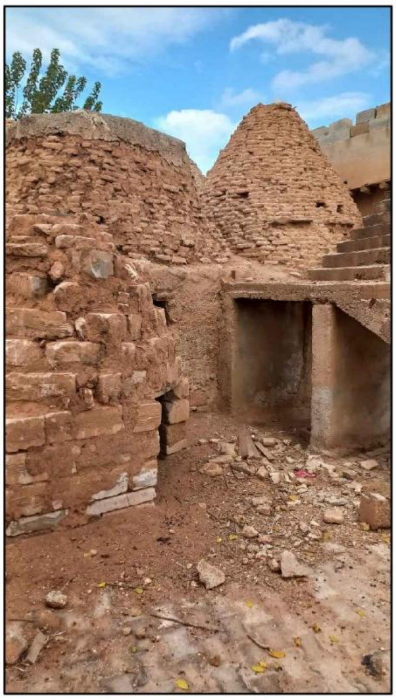


③

Figure 80 : Damage Photos of House 9 (2025).

3.2.2 Classification of Damage in Harran Domed Houses

Based on the technical drawings of the damaged domed houses shown above, it was observed that some walls and domes were partially or mostly damaged, some were completely destroyed, while others are still standing.

Firstly, a classification was made based on the overall damage situation of the houses, as shown in Table 6.

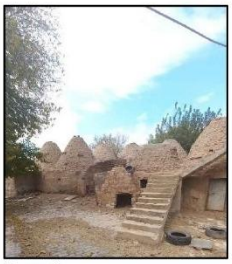
DAMAGE LEVEL	HOUSES		DESCRIPTION
SLIGHT	 House 6	 House 9	Most of the house's walls and domes remained undamaged. In other words, no more than two walls and domes are collapsed.
MODERATE	 House 3		More than half of the house's walls and domes remain undamaged, but the level of destruction in the other portions is severe.
HEAVY	 House 4	 House 5	Most of the house's walls and domes have collapsed.
COLLAPSE	 House 7	 House 8	The house is almost completely collapsed, and none of the domed units are in usable condition.

Table 6 : General damage levels of the houses (2025).

Secondly, the analysis focused on the damage types, distinguishing two main scenarios on the basis of the partial or complete collapse of the domes (Table 7).

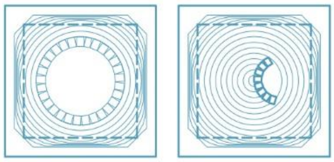
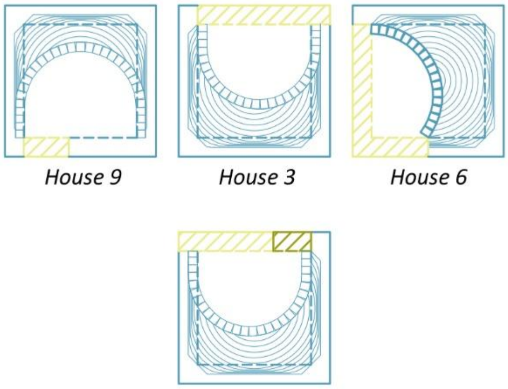
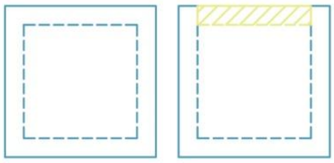
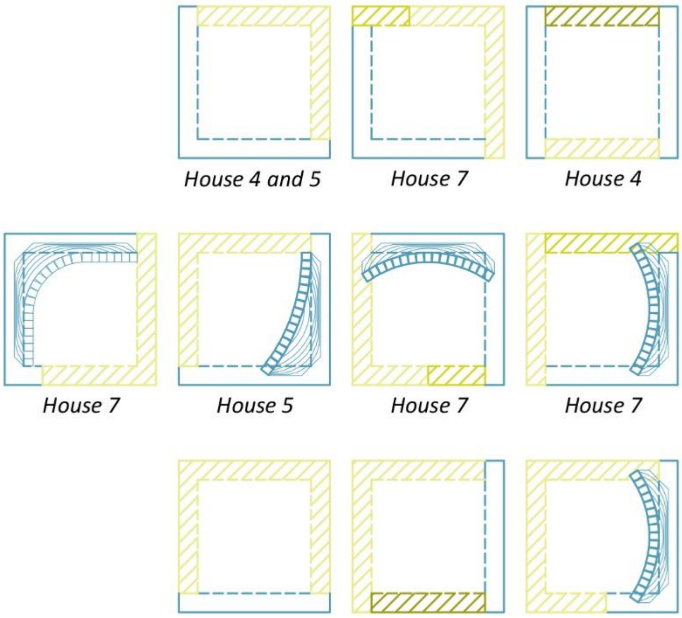
DAMAGE TYPE		CAUSE
PARTIALLY COLLAPSED DOME	due to	1- INTRINSIC PROBLEMS OF THE DOME →  *House 4 and 9* · *House 5*
		2- COLLAPSE OF ONLY ONE WALL →  *House 9* · *House 3* · *House 6* · *House 3*
COMPLETELY COLLAPSED DOME	due to	1- INTRINSIC PROBLEMS OF THE DOME →  *House 4 and 5* · *House 4*
		2- COLLAPSE OF AT LEAST TWO WALLS →  *House 4 and 5* · *House 7* · *House 4* · *House 7* · *House 5* · *House 7* · *House 7* · *House 4 and 5* · *House 5* · *House 8*

Table 7 : Classification of all the damage scenarios (2025).

3.2.3 Collapse Mechanism - How did they collapse?

Understanding the mechanical behavior of masonry structures—which includes Harran domed houses—is essential before analyzing their collapse mechanisms.

A masonry structure should be analyzed stone by stone, assuming each transfers linear normal stresses to those below. While only horizontal contact is typically considered, shear can also be transmitted, and if a stone is loaded eccentrically, it may gain support from an adjacent stone via vertical joint contact. Figure 81 reveals that the masonry's limited capacity to resist tension prevents it from spreading the load properly. Consequently, stress is concentrated only on the masonry area directly beneath the applied force, along its line of action, whether in vertical or diagonal orientation (Giuffrè, 1989).

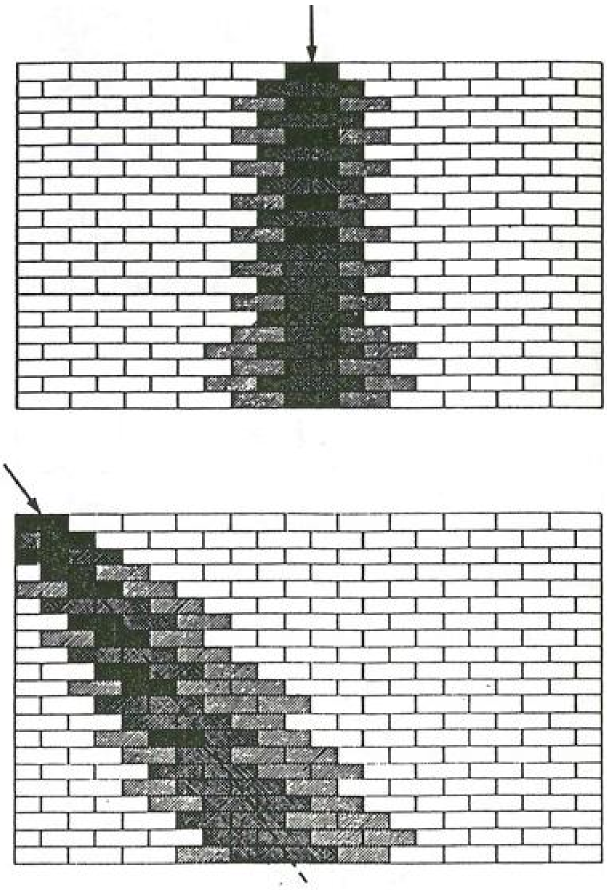


Figure 81 : Vertical and diagonal load on a masonry wall (Giuffrè, 1989).

Friction enables masonry to resist some horizontal tensile forces, especially near supports in domes (Figure 82). This pseudo-tensile strength depends on the vertical load because stones are pressed between those above and below. Sliding requires horizontal stress proportional to vertical pressure, friction, and overlap length. Longer overlaps increase tensile capacity. This principle allows squared stone masonry to act like a chain, a fact well understood by ancient builders (Giuffrè, 1989).

Figure 82 : Parallels in the domes require tensile strenght (Giuffrè, 1989).

The most distinctive features of squared stone masonry are its horizontal lies and regular transversal connections, which enable it to act as a monolithic body rocking on horizontal straight lines. Squared stone masonry may be considered the mechanical idealization for the majority of historic masonry structures (Giuffrè, 1989).

A wall's resistance to out-of-plane forces is influenced by how the stones are organized. When the stones are arranged systematically (following the rule of art), the wall can perform like a monolithic body. It can be observed that the further the stone arrangement deviates from the rule of art, the lower the maximum lateral force the wall can withstand. Masonries with irregular patterns tend to lose equilibrium sooner due to uneven stress distribution among the stones (Giuffrè, 1989).

Rule of art is derived from an ancient Italian idiom, *'regola d'arte'*, and this expression refers to the established standards of detailing applied across all areas of construction. In the context of masonry structure, the "rule of art" encompasses all the necessary construction details required to achieve a monolithic body (Giuffrè, 1989).

A properly constructed masonry wall may act as a rigid body, toppling over its base without fragmenting before losing its equilibrium. When collapse occurs, the initially monolithic structure breaks down into a series of rigid segments connected like a kinematic chain (Figure 83), (Giuffrè, 1989).

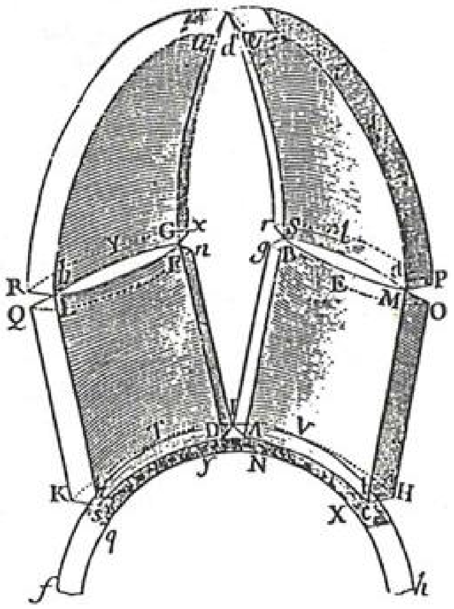


Figure 83 : Kinematic mechanism of domes (Giuffrè, 1989).

Damage typically occurs where the structure is weakest, and identifying the geometrical mechanism makes it possible to determine this vulnerable part and how it might move. The discontinuous nature of ancient masonry makes it particularly fragile. As a result, the most likely and hazardous effect of an earthquake is the out-of-plane collapse since masonry walls are least resistant in that direction when subjected to horizontal loads. (Figure 84), (Giuffrè, 1989).

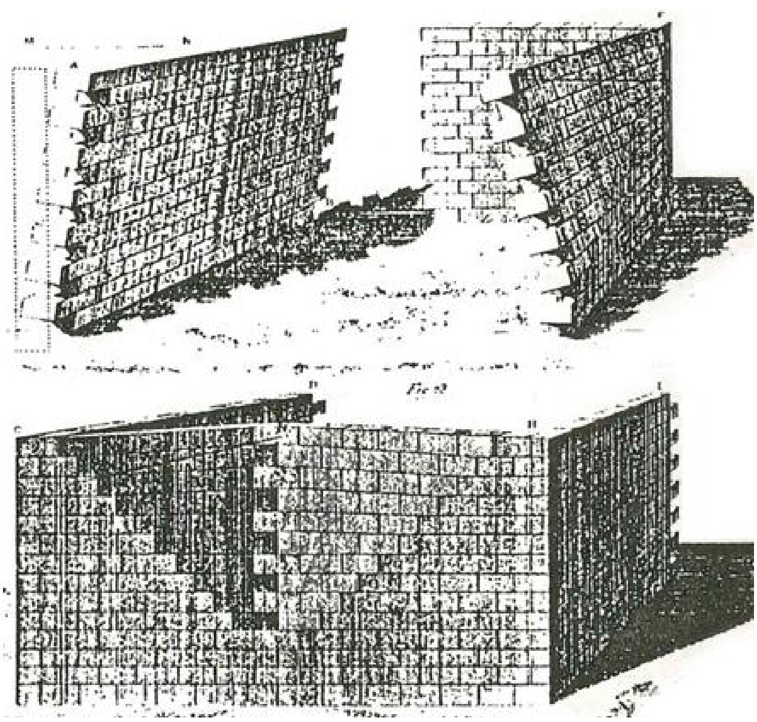


Figure 84 : Collapse mechanisms (Giuffrè, 1989).

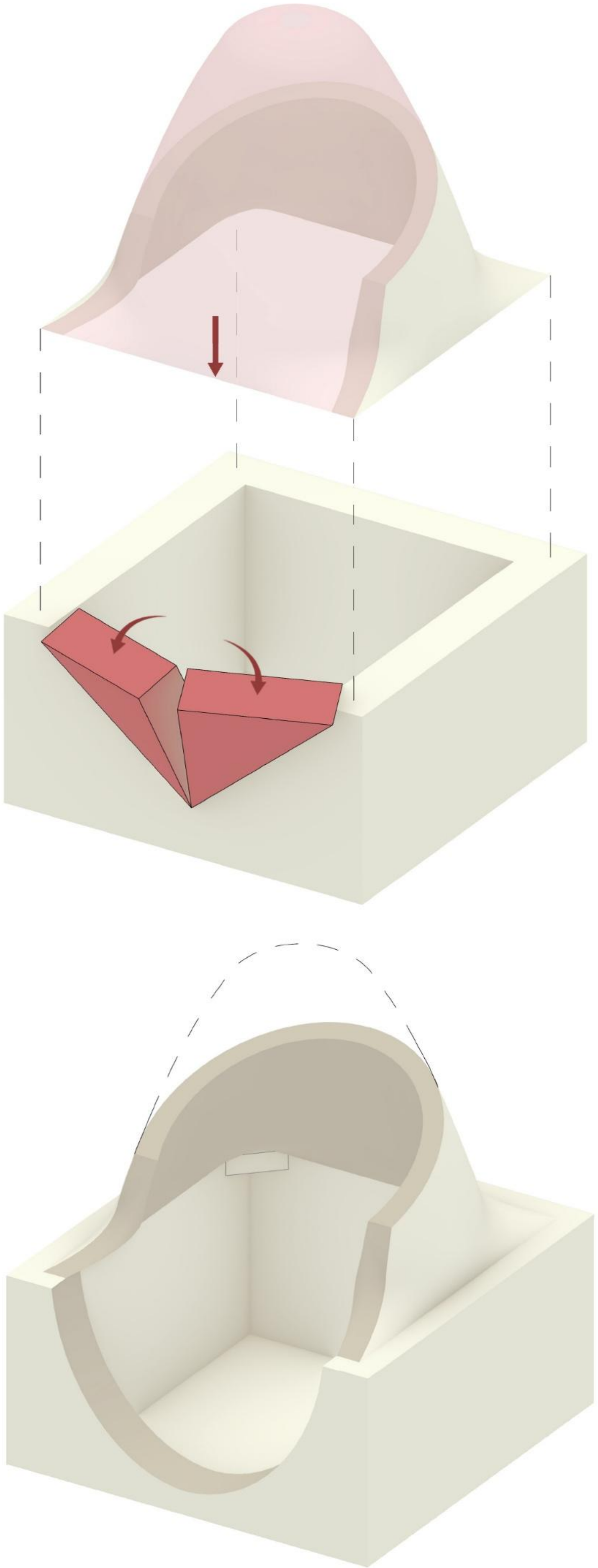
The insights gained from the collapse mechanisms of masonry structures—particularly domes—highlight the importance of vertical and horizontal support, as well as the role of stone arrangement and friction in maintaining structural integrity. These principles not only explain how stresses are transmitted and resisted but also clarify why certain areas are more prone to failure. Building upon this theoretical framework, it becomes possible to analyze how domes behave in relation to the number of surrounding walls that remain standing.

There are some essential points that can be understood from Table 7 :

- It is expected that the dome should not collapse in case of four surviving walls. However, strikingly, the dome can partially or completely collapse because of its inherent structural issues.
- It can be supposed that if there are three surviving walls, the dome can still survive partially but notably, the dome can collapse completely because of its inherent structural issues.
- A dome can survive partially if a maximum of one and a half walls collapse (in other words, if at least two and a half walls remain standing).
- If the number of collapsed walls is two or more, the only possibility is the complete collapse of the dome.

Moreover, it is irrelevant whether the walls partially or completely collapse, since the dome loses its support in both cases. Thus, both are considered as collapsed walls.

In the following pages, models illustrating the collapse mechanisms and photos related to the types of collapse will be included. The collapsed parts of the walls in models are shown in red with their collapse directions and accordingly the collapse parts of the domes are shown in transparent red.



1)

2)

Figure 85 : Models of collapse mechanism of partially collapsed dome :

1) Movement of the walls – 2) Remaining portions (2025).

House 3

House 6

House 9

Figure 86 : Examples of houses with partially collapsed dome (2025).

Figure 85 and 86 shows that the loss of supports on the collapsed wall side of the dome causes the portion of the dome on that side to collapse, but the remaining portion still stands.

1)

2)

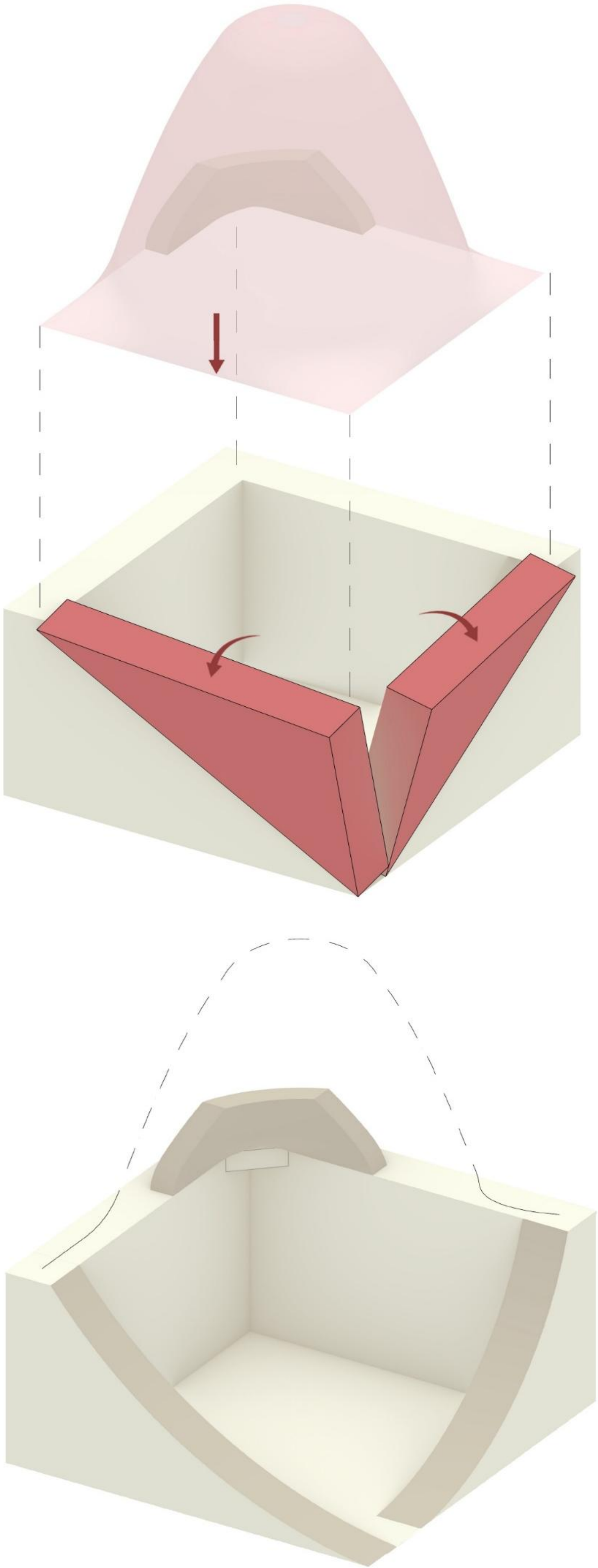


Figure 87 : Models of collapse mechanism of completely collapsed dome :

1) Movement of the walls – 2) Remaining portions (2025).

House 5

House 7

Figure 88 : Examples of houses with completely collapsed dome (2025).

Figure 87 and 88 shows that when two or three walls collapse, the dome will also completely collapse as it will have no remaining supports.

Conclusions

Observations made during on-site assessment, which is one of the research methods of the thesis, revealed that there are no legal regulations aimed at conserving Harran domed houses after the earthquake, nor have there been any efforts to preserve or restore these houses.

The primary objective of the thesis is to understand the collapse mechanisms of the damaged houses after the earthquake. To this end, the damages of seven selected houses in the area with Harran domed houses were documented through plans, elevations, and photographs, and damage categorization was carried out based on these drawings. The classification was grouped under two main categories: partial or complete collapse of the dome. The key findings from this classification are as follows:

- Although expected to completely stand with four surviving walls and partially collapse with three, the dome partially or completely collapsed in the four-wall scenario and completely collapsed in the three-wall scenario due to inherent structural issues.
- A dome can partially survive if there are at least two and a half walls.
- If two or more walls collapse, the dome completely collapses.

Since walls serve as the support points for domes, the partial or complete collapse of a dome depends on how many walls have collapsed or in other words, how many support points have been lost.

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