THE REINTRODUCTION AND INNOVATION OF EARTH FAÇADE CONSTRUCTION IN WILDFIRE RISK VILLAGES IN TURKEY

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ABSTRACT

This paper concerns the reintroduction and innovation of vernacular earth façade construction methods as a contribution to a wildfire resilient rebuilding strategy for burned down villages in the Mediterranean region of Turkey. There is no wildfire resiliency involvement in current building plans and earth construction knowledge became outdated. This research was done by conducting architectural ethnography, geobased local mining, consistency tests and literature. The findings showed the historical use of straw-mudbricks, the villagers' interest in innovated earth methods, their advanced skills, knowledge and preference on self-building. The local soils were suitable for innovative earth façade construction methods without binders. Rammed earth was proposed as the innovative construction method, in order to enhance a wildfire resilient way of (re)building on the scales of community and construction detail. Rammed earth is liked by the villagers, is loadbearing on its own, does not need combustible fibres like straw, needs relatively cheap building tools and has chemically the most earth particles per cubic meter for wildfire ember resistance. All in all, the introduction of rammed earth façade construction methods could contribute to a wildfire resilient rebuilding strategy, because wildfire damage will be reduced by non-combustibility and villagers will be able to rebuild and repair their houses easily with this newly introduced method.

KEYWORDS: *Rebuilding, Earth construction, Local building knowledge and skills, Wildfire resilient rebuilding, Mediterranean region Turkey*

I. INTRODUCTION

1.1 Background

In the summer of 2021, an exceptional number of 270 wildfires took place along the entire Turkish coast (Turkish Red Crescent, 2021). Multiple villages have been partly or completely destroyed spread over 53 provinces. Villagers lost their houses, but also their income sources from agriculture, machinery and animals, which complicates their restarting process and ability to rebuy houses (BBC News Türkçe, 2021). This emerges the question on how these destroyed villages should be rebuilt. According to climate scientists, the amount of wildfires will increase in the future because of hotter summers (KNMI, 2021). Therefore, it is important to research wildfire resiliency strategies while planning rebuilding plans in inhabited settlements. In this paper, a wildfire resilience rebuilding strategy is a step-by-step rebuilding plan with the aim of making a village and its community wildfire resilient. This strategy consists of multiple scales, namely: construction detail, building typology, village typology, landscape and community. The definitions of wildfire resilient villages are explained in appendix 1.

1.2 Problem statement

1.2.1 No involvement of wildfire resiliency strategy in future village building plans of:

Government and municipalities- Many challenges arise in the recovery planning after a wildfire. Currently, the government offers rebuilding projects. However, these evoke doubts with local inhabitants, architects, building engineers and politicians. The government ordered TOKI, Turkey's Housing Development Administration, to mass-build village houses, but does not involve villagers and is unclear about final purchase costs. Besides, the housing projects lack wildfire resiliency aspects (Öz, 2021). The local municipality offers ready-made building plans for the villagers to rebuild independently. Unfortunately, these plans also do not involve villagers or wildfire resiliency.

Locals from destroyed villages- Communities that are victims of the wildfires desire to return to normality as soon as possible and rebuild the village as it was before, in the wake of the trauma (Next10, 2021, p.8). However, this limits opportunities to bring changes in the villages in order to reduce future risks during wildfires.

Researchers **-** There is worldwide research on how to rebuild communities in a fire resilient way, but only on the scale of wildlands, cities and buildings (SOM, 2021). "*Designing Communities for Wildfire Resilien*ce" is an example by architectural, urban planning and engineering firm Skidmore, Owings & Merrill (2021). The outcome of this project presents wildfire guidelines for managing wildfire vulnerability at the three mentioned scales of application. Villages are a missing scale in the current available studies, even while they are very vulnerable to wildfires as seen during the summer of 2021.

There are no alternatives yet for rebuilding the damaged villages other than the governmental plans or villagers rebuilding the demolished houses like the pre-wildfire situation. Appendix 2 depicts all current plans with examples.

1.2.2 Local earth construction practices almost disappeared overtime

Looking at Turkish villages on national scale, the Turks always historically provided themselves with self-built dwellings, such as yurt-tents or houses made of stone, earth or wood (Günay, local architect, from personal interview, 2021). A national change was made in the building structure into brick or concrete in the second half of the 20th century (Ada, 2021). Appendix 3 provides insights on the dominating contemporary way of village building. Despite the many destroyed woods, earth is still harvestable as a building material in the Turkish villages. The practices of earth construction used to be very common in Turkey, but almost disappeared overtime because the knowledge and skills became degraded or outdated. Earth is sometimes associated with poverty and the innovated ways of earth construction techniques are commonly unknown in Turkish villages (Ceylan, from personal interview, 2021). The disappearance of earth construction methods seems contradictory for wildfire risk areas, since earth is a non-combustible material (Minke, 2000, p.36).

1.3 The potentials and objective

Actually, the fact that Turkish villagers have built their homes themselves with local materials in the past provides insights on new possibilities and opportunities in the rebuilding process of the destroyed villages, involving the villagers and with the perspective of doing this in a fire resilient way. Besides, there is a greater chance of success in wildfire rebuilding programs if the locals are involved in the plans (Zafar, 2020).

Introducing earth as the main building method in wildfire risk areas is potentially valuable for fire resiliency because it does not burn. Earth also has other valuable and sustainable characteristics, like the good humidity regulations, sound insulation, thermal mass and insulation. It has very low embodied energy, especially when it is harvested on the site (Grey, 2021).

This research aims to explore innovations for local earth construction methods with a fire resilient perspective, and to reintroduce this to villages in wildfire risk areas in the Mediterranean region of Turkey. It is aimed to contribute to the overall wildfire resilient rebuilding strategy, on the scale of community based construction methods. The reintroduction and improvement of vernacular earth construction methods might provide a sustainable future for the villages. With modern techniques and present-day earth construction, the new generations might be able to rebuild their own homes that can co-exist with future wildfires. This implements houses that resist wildfire embers and that the knowledge and skills to rebuild are re-installed, which makes the community wildfire resilient.

1.4 Research area

The Mediterranean region of Turkey is chosen as the research area for this paper, because it is one of the riskiest wildfire areas and prone to future fires, seen on the maps in appendix 4 and 5. Kalemler village, attached to Manavgat city, is one of the most damaged villages of 2021' wildfires (DW Türkçe, 2021), therefore chosen as exemplary in this research. Appendix 6 shows the geographical location of Kalemler. It is representative for burned down villages in the Mediterranean region of Turkey in terms of community and settlement in the landscape. It is characterized by its positioning close to the Taurus mountains, at the countryside and nearby popular touristic cities like Antalya. The main building method in the village centre was mainly evaluated into self-built brick or concrete houses. This building method appeared to be unsuitable for risk areas during the wildfires, which resulted in uninhabitably damaged houses and demolishment. Kalemler is one of the villages waiting for a wildfire resiliency strategy for its reconstruction in order to become a wildfire resilient village in the future, where self-built houses can co-exist with fires.

1.5 Focus on façade within construction methods

One building element was chosen to focus on in-depth, namely the façade. This part of a building occupies the largest percentage of the total building and mainly forms the spaces within the building. The façade is also a large fuel source for wildfires. Exterior walls should prevent or delay embers and flames from burning into interior walls, rooms and household effects (Federal Insurance and Mitigation Administration, 2016). Flames may be stopped by other measures from the overall wildfire resilient rebuilding strategy, but embers will always be spread by wind influences. Façades are vulnerable to wildfires' radiant and convective heat. Besides, fires on exterior walls can act like a 'bridge' to other areas in the building.

1.6 Research questions

This research explores the possibilities for harvesting local earth in the area of Kalemler and how to strengthen the skills of the villagers in an improved fire resilient way in the rebuilding process. Hence, the thematic research question is *"How could innovation of vernacular façade earth construction methods contribute to a wildfire resilient rebuilding strategy for burned down villages in the Mediterranean region of Turkey?".* This is developed further with the sub questions: "*What earth construction methods were used in this region historically, focused on the façade?", "To what extent are earth construction skills and knowledge present within the current building culture of self-built village houses and which potentials are there to reintroduce earth construction to builders who now use other materials?", "How is the regional landscape with corresponding soil types characterised and how can this local earth be formed into façade building materials?"* and "*How can vernacular earth façade construction methods be innovated in order to enhance a wildfire resilient way of (re)building?".*

1.7 Research paper structure and hypothesis

To address these questions, this paper provides an architectural ethnography study, which shows the historically used earth construction methods in *chapter three,* focused on the façade. Personal interviews on the site were conducted to gain more insight on the local building knowledge and skills on earth construction methods, and the potential to reintroduce earth construction to the villages, which is provided in *chapter four*. Furthermore, geobased local mining was used in *chapter five* to explore the local landscape and earth qualities. Various experiments from literature were performed to analyse the suitability for potential use of innovated façade earth construction. Finally, *chapter six* discusses how local earth façade construction methods can be innovated, comparing four innovative methods with literature research.

The outcome of this technical research provides new insights on façade construction methods to build houses that can co-exist with fire. This paper argues the different scales in which this innovation could contribute to the overall wildfire rebuilding strategy and how to innovate the degraded vernacular earth façade construction knowledge and skills of the villagers, resulting in revived local building methods so that villagers can build their own houses in a potentially sustainable, easy, adaptable, affordable and fire-resilient way.

It is hypothesised that the reintroduction of vernacular earth façade construction contributes to the wildfire resilient rebuilding-strategy in two scales when it is innovated. Firstly, the material is non-flammable and the building gets minimum damage due to fire. The second way embraces the sustainable knowledge of the village community to be able to rebuild by themselves with earth, and therefore also be able to responsibly return to their daily lives.

II. METHODOLOGY

In this paper, four sub questions were explored to answer the main research question. Each of them needed qualitative research with a different approach. The main methods used to conduct the data were architectural ethnography research, geobased local mining and literature research. Most data were collected during a site visit of seven days. All methods are step-by-step explained in sequence of usage in this paper. Figure 1 shows the boundaries of the researched area.

Figure 1: Boundaries of researched area. (Own image, from Google Earth, 2021)

2.1. Architectural ethnography research

The overarching methodology in this paper is architectural ethnography. Within the theory on ethnography, there is architectural ethnographic research. Powell (2017, p.45) describes ethnography as "*a process of inquiry that involves the description and interpretation of the cultural and social practices of people, […] that emerges from a lengthy period of in-depth study and, often, residence in, a particular setting*". This method would take many years to research, therefore micro-ethnographic research was applied in this paper. This is ethnographic research but in a shorter timeframe due to the time limitation of the project (Powell, 2017). 'Architectural' ethnography in this research differentiates itself by the focus on the built environment and depicts the way of assembling buildings and the environmental aspects (Kaijima, 2018). It applies drawings as a communicating medium and can consist of different architectural characteristics, such as details, plans, sections, concepts, empirical and abstract data. Furthermore, it contains practices and cultural norms (Ronald, 2011). Buildings influence behaviour, which makes it important to design housing that fits the cultural practices (Cranz, 2016). The vernacular and local craftmanship is inseparable with the culture in the villages.

2.1.1 Historic earth construction methods: site visit mapping and interviews

During the site visit, a critical architectural ethnographical research was performed to gain insight on local earth construction methods, focused on the façade. Critical ethnography goes beyond observing and tries to interpret and analyse the researched element (Mantzoukas, 2012). Considering current findability of earth construction buildings, the houses in the Sonsuz Şükran village were observed because there were many houses available representing the local historic earth building method in the Mediterranean region. Personal interviews with locals provided more detailed information. The results were processed in photography and textual explanation of the local references on earth construction methods. In addition, literature was used to find more detailed information: "*Yenilenebilir bir malzeme: kerpiç ve alçili kerpiç" ("A renewable material: mudbrick and gypsum mudbrick")* (Acun & Gürdal, 2003), "*Anadolu'da Kerpicin Kullanım Geleneği ve Kerpiç Konut Yapı Sistemlerinin Karşılaştırılması*" *("A Comparison of the Traditional Mudbrick Use and Mudbrick Housing Construction Systems in Anatolia")* (Tuztasi & Çobancaoglu, 2006).

2.1.2 Knowledge, skills and potential to reintroduce earth construction methods: interviews

Inhabitants and their houses in Manavgat city, Kalemler village and adjacent Evrenseki Village were interviewed and observed to gain insight on their knowledge and skills on (earth) construction methods, the local building culture and daily life of this area. An interpretive architectural ethnographical research was performed by doing personal interviews. Within interpretive ethnography, there is more engagements with the participants to get very detailed, nuanced and emotional imaginations of the participants' world (Mantzoukas, 2012). Interviews were conducted with 26 local stakeholders in total, consisting of village inhabitants, city inhabitants, construction workers, architects, building engineers and politicians. The table in appendix 7 provides the list of the participants and their additional information. The leading interview questions are in appendix 8. The interview groups were not divided in builders and non-builders, because self-built village house construction quickly appeared to be basic knowledge of all interviewed locals. Finally, the future of Kalemler village, willingness to self-building and the potential reintroduction of earth construction were part of the interviews. Images of rammed earth construction were shown as an example of innovative earth construction method in appendix 9. The results were processed in drawings and textual explanation.

2.2. Geobased local mining: regional landscape, soil type and consistency tests

The third question on local harvestable earth was conducted with geobased local mining. The regional landscape was determined with soil maps and additional literature explaining geographic terms: "*The Pressures on, and the Responses to, the State of Soil and Water Resources of Turkey*" (Kük & Burgess, 2010). In order to know more specifically what the local soil type was, mountain ranges revealing the earth consistency were observed and photographed. Before analysing the possibilities of forming local earth into building materials for potentially innovated façades, it must be analysed whether the soil is suitable for innovative earth construction. The soil was tested for potentially innovated general brick-based and rammed earth façade construction. Methods from the following literature were used to perform experiments: "*Rammed Earth Structures: a code of practice*" (Keable & Keable, 2011), "*The Barefoot Architect*" (Van Lengen, 2007) and "*Building with Earth: A Handbook*" (Norton, 1997). These books show step-by-step how to test the consistency and how to form the earth into samples of mudbricks and rammed earth as building elements for façades. The performed tests, purposes, used materials and their step-by-step explanations were recorded in appendix 10.

2.3. Literature research

Literature research was conducted to collect the needed tests for the geobased local mining during the site visit. Furthermore, the last sub question on the innovation of vernacular earth façade construction methods in order to enhance a wildfire resilient way of (re)building was tackled with literature research. The historical earth façade construction method was compared with four innovated methods for earth façades, namely rammed earth façade construction, light earth façade construction, cob façade construction and compressed earth block façade construction. The previously mentioned literature was used to understand rammed earth construction. The literature "*Building with earth*" (Minke, 2009), "*Earth construction handbook*" (Minke, 2000) and "*Earth as Building Material*" (Vyncke, 2018) gave insights on earth construction methods, with physical characteristics and qualities. The works "*Light Earth Building*" (Volhard, 2016) and "*Light earth construction*" (Gaia Architects, 2003) were used to explore light earth façade construction. The book "*Earth architecture*" (Rael, 2009) was consulted to analyse compressed earth block and cob in façade construction. Additionally, "*The Complete Guide to Alternative Home Building Materials & Methods*" (Nunan, 2010), "*Cob, a vernacular earth construction process in the context of modern sustainable building*" (Hamard et al., 2016) and "*Engineering Properties of Cob as a Building Material were references for cob construction"* (Akinkurole et al., 2006) were references for cob construction. Furthermore, the works "*Compressed Earth Blocks: Vol. II: Manual of Design and Construction*" (Guillaud et al., 1995) and "*Dry-stack and compressed stabilised earth-block construction*" (Uzoegbo, 2016) were used to analyse compressed earth blocks. Besides, "*Modern earth building codes, standards and normative development*" (Schroeder, 2012) showed standards for those methods. The method comparison displayed similarities between the historic and innovated construction methods, to determine which method had more advantages and therefore more feasible for reintroduction. This last qualitative part of this paper concerned whether the selection of innovated methods could be built with the already available set of skills and experience of local building, and how this might enhance a wildfire resilient way of rebuilding, using the following literature: "*Rebuilding for a Resilient Recovery"* (Next10, 2021) and "*The house that doesn't burn"* (UC Davis, 2021). The outcome was documented in a comparison matrix. The proposal on which innovative method transition is most feasible arose from the comparison matrix and wildfire resiliency aspects. Altogether, the abovementioned individual methods formed the building blocks to answer the four sub questions and led to the conclusion on the main question.

III. HISTORICALLY USED EARTH CONSTRUCTION METHODS IN MEDITERRANEAN REGION OF TURKEY, FOCUSED ON THE FAÇADE

This chapter answers the first sub question: *"What earth construction methods were used in this region historically, focused on the façade?"*. Figure 2 shows a self-built village house made with earth construction from the Sonsuz Şükran Village. This village is specially built with the historic earth construction methods, by people who missed the feeling of living in earth houses. Appendix 11 shows explanatory drawings of the typical village houses, with detailed photographs of the historic earth construction method from the area. As this chapter only focuses on the façade, other building elements were briefly distinguished in appendix 11.

3.1. Mudbrick houses: preparation of the mud into mudbricks

Historically, Turkish villagers used to build with 'kerpiç' (mudbricks) for centuries. Mudbricks are sun-dried bricks, consisting of loam and water. The loam is excavated from the local site or from mountains nearby. Straw is added as a binding fibre in the mixture. It also increases the strength and prevents the mudbricks from cracking. Loam-soils consist mostly of sand, silt and a small amount of clay. A standard ratio for the loam is 10% clay, 70% silt and 20% sand. The binding qualities are determined by the amount of clay. When the soil is too clayey, extra sand is added to balance the mixture. When the local soil is sandy, extra clay is added. This way, the preparation of mixing local soil can be adjusted by the locals up to necessity. Before the 20th century, ground eggshells were also used in the mixture to strengthen it. Villagers are trained to identify whether the ideal mixture is reached with the naked eye. The mixture should not stick to the hands. After mixing the soil with the right amount of water and straw, this mixture is set for yeasting a few days, depending on the sun intensity. Approximately, 10 kgs straw is added per 1 m^3 mud. The consistency changes with the amount of added water. The strength of the mudbricks decreases when too much water is added. The drying process becomes difficult and it can cause excessive shrinkage and cracking. Reducing the mixture water as much as possible prevents these effects.

Followingly, the mud-straw mixture is placed in wooden moulds, tamped and levelled out. Finally, the blocks are turned out of the moulds to dry for several days on the site of the house to be built. This drying process also depends on the sun intensity. There are no official design standards for the village houses made from mudbrick, therefore the dimensions of the moulds and bricks vary. The most commonly used sizes for the moulds are the following: a mould with space for two 'ana'-bricks (mother) and two 'kuzu'-bricks (lamb). The 'ana'-bricks vary between *30-35cm x 30-35cm x 10-12cm* and the 'kuzu-bricks vary between *30-35cm x 15-17cm x 10-12 cm.* The variations of the wooden moulds are in appendix 12. The mudbricks strengthen while drying in the open air and become suitable for building the exterior and interior walls of a building. The mudbricks already show maximum shrinkage during the drying process, which limits the malformation afterwards. Deformed mudbricks are replaced in advance before building. These mudbrick walls are load bearing and can bear up to two stories. However, the load bearing structure is supported by tree trunks as a skeleton to carry the roof. During construction, often four builders work on the site. The 'usta' (master) takes the lead and divides the tasks. One builder makes mud for mortar, one builder does the bricklaying and one carries all materials back and forth to the others. These builders are called 'ameli' and are usually men from the local village. Building an earth house in a village was regarded as a community activity. Villagers helped each other and together they built a whole village. It took approximately 15 days in total to finish the casco version of the mudbrick house, without the mudbrick drying process.

Figure 2: Contemporary example of historically built 2-story high mudbrick house in Sonsuz Şükran. (Own image, 2021)

3.2 From mudbrick to façade

As abovementioned, there are no official building rules for the self-built village houses. Therefore, the façade earth construction can vary per house or village in the way of stacking the bricks. However, the overall building method is the same for all.

3.2.1 Base layer of the façade

The foundation is an important element in the façade as well, because the first 0,5m above the ground of the façade is not made with mudbrick, but natural large stones harvested from local mountains. This part pertains both the façade and the foundation and is called a subbasement or splash zone, see appendix 13. The purpose is protection against external factors like water. It is also needed to even out the mountainous landscape surfaces in Turkish villages. While digging this foundation pit, the corners must be made perpendicular. The foundation starts from the bedrock or solid soil. A layer of 10cm sand is often put under the stone foundation to prevent direct settlement on the soil. The largely harvested stones are broken down into smaller stones, which are smooth-surfaced and angular, then stacked with a mud mortar between them. This mortar was historically the same as the mixture for the mudbricks with straw, but after 1950, cement was also used to bind the stones in the subbasement. With this subbasement, the ground level of the building is built higher than the natural ground hight, which is the possible flood level in the region. The ground soil level equals 0,0 m, but the entrance to the house is at the height of 0,30-0,45m for example.

3.2.2 Mudbrick laying

Followingly, when the mudbricks are ready to use, the mudbricklaying begins on this stone-wall as the base layer. Between the subbasement wall and mudbrick wall, one layer of the mud-straw mixture is applied. The exterior walls are usually 500mm thick. The bricklaying is done with the same mud-straw mixture as the mudbricks, because it shrinks and swells the same way as the mudbricks during weather changes. The mortar must have the same thickness everywhere and the vertical joints must be fully filled. These measures increase the load bearing quality of the façade. Figure 3 shows an overview of the most common façade mudbricklaying methods. All connection joints between façade, roof and lintel openings are filled-in with mudbricks and layers of mud. This way, the whole façade construction is free of unwanted openings.

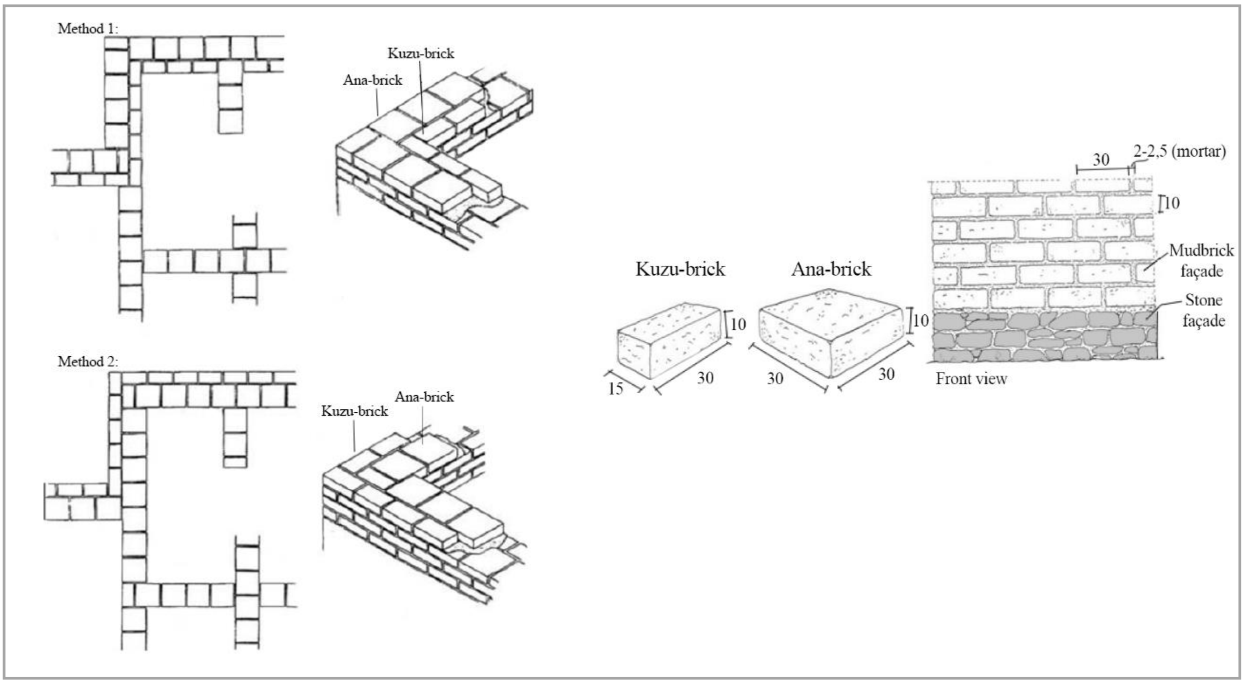

Figure 3: Commonly used façade mudbricklaying methods. (Adjusted from Google Images Databank and Acun & Gürdal, 2003, p.76)

3.3 Finishing off the façade

The exterior walls are often plastered on the inside and outside with the same soil used for the mudbricks, with a trowel. Often, straw is added to prevent capillary cracks in the plaster. Also, it can consist of lime plaster, cement stucco, gypsum or whitewashing. The latter is a coating made from white lime excavated from the mountains, mixed with water and clay. This variable ‘coating’ protects the bricks from external factors like water erosion and mice. The finishing off mud plaster is often applied to the entire façade including the subbasement part, which makes the whole exterior wall look like everything is built with earth. During the yearly ‘spring cleaning’, a new layer of mud is plastered on the façade to renew the damaged plaster. After 1950, villagers started using cement for plastering, to create a ‘concrete look’, but also for easier maintenance. The plaster choice varies per personal preference and availability of the materials.

3.4. Openings in the façade

The openings are created with wooden moulds. These moulds are placed for the door and window openings, to be taken out later. This framework has the same thickness as the walls. These openings start at least 100-150cm from the façade corners, and widths are maximally 100cm according to generally known Turkish earthquake building rules. Commonly used window openings were 100cm x 70cm. The mudbrick filled façade parts between the openings must be at least 60cm. The living rooms usually had two windows for daylight purposes. The windows were split into smaller parts of 25cm with wooden frames, to protect against thieves entering through the windows. The window openings must be placed linear in-between the main tree trunk beams of the roof. Square-cut tree trunks were used as lintels with at least 10cm x 10cm frames for windows and doors, which were placed above and under the openings. These can be covered with mud plaster or painted decoratively. Usually, the placement of the door and window frames is in the middle of the façade opening, but the frames can also be placed on the outer or inner face with no structural difficulty. When the building has a second floor, there can optionally be a hanging window part that rests on longer tree trunks of the second-floor construction. Explanatory photographs are shown in appendix 11.

3.5 Benefits and disadvantages of mudbrick earth façade construction

With good maintenance, a self-built village house made of mudbricks can last for hundreds of years. This earth façade construction method with mudbricks from local loam and straw is also used in other regions in Turkey and a nationally known construction method by villagers. Earth is a natural harvestable material, cheap if not free, and is endlessly available, therefore sustainable. The builders, inhabitants and environment are not presented to any toxicity, which makes it a healthy building material in multiple ways. It prevents accumulation of condensation on the walls, because it can absorb a large amount of moisture. It also absorbs polluted air, such as tobacco air. Building errors can be solved quickly by replacing the malformed mudbricks before building. Besides, summers in Turkey are known for high temperatures, especially in the Mediterranean region. Mudbrick walls are thick and offer thermal mass, which keeps the heat outside, thus the inside spaces are passively cooled. A stable indoor climate is regulated during all seasons, with no mechanical systems. Also, it regulates the internal humidity very well, which prevents from mould forming inside the houses. Lastly, it strengthens the bond with the community because local building with earth is a group activity. One of the disadvantages is that mudbrick walls cannot support more than two storey-buildings. Besides, it is very labour intensive and needs relatively much maintenance.

IV. EARTH CONSTRUCTION SKILLS AND KNOWLEDGE WITHIN CURRENT VILLAGE HOUSES AND THE POTENTIAL TO REINTRODUCE EARTH CONSTRUCTION TO THE VILLAGERS

This chapter answers the second sub question: “*To what extent are earth construction skills and knowledge present within the current building culture of self-built village houses and which potentials are there to reintroduce earth construction to builders who now use other materials?”* Resumptive drawings of the interviews are in appendix 14.

4.1. Current skills and knowledge on earth construction methods

Even when village houses are nowadays made of baked bricks and concrete construction, the knowledge and expertise on the historical earth building methods are still present in almost every Turkish village.

In the village of Kalemler, 100% of the interviewees still could explain the whole process on how to build with mudbricks, while nowadays they do not build with it. Earth construction methods is common knowledge in the generations between 35 and 100+ years. Younger generations mostly do not know the whole process, because they never experienced building an earth house and mostly moved to cities. However, they heard stories from their parents or grandparents about the self-building culture. In general, building a house is considered a 'basic skill', especially for the men in the villages. Some of them attended practical or technical high school, but learned building from their dads, uncles and grandfathers. The village women also know to whole process of building, but it is usually regarded as a 'men job' because working with stone, mudbricks and tree trunks can get 'heavy' to carry. The women help with 'less heavy' tasks and with the maintenance.

So, the skills and knowledge are present within the current building knowledge of villagers in full extent. Some villagers still live in earth houses, but others have completely abandoned it or have always had the money for the more expensive stone construction. The overall result from the personal interviews is that every villager is a builder. The only distinction that can be made are the generations younger than 35 years, because this generation moved to the cities and lacks the experience of traditional self-building in the villages.

4.2. The potentials to reintroduce earth construction methods to the villagers

Approximately, 75% of the Kalemler inhabitants are older than 35 and the majority comes from diverse areas from the Mediterranean region. This indicates the skills and knowledge on building with earth construction is intact. Besides, the men also have a lot of knowledge of building with other materials like stone, brick and concrete construction. In fact, most of the interviewed men on the site were busy building barns or reconstructing less-damaged houses. This alludes that the reintroduction of earth construction methods depends on the wishes and opinions of the local villagers. Some interviewees mentioned missing the natural atmosphere and 'a good and deep sleep' was often answered as a desire they missed from living in mudbrick houses. Some of the villagers mentioned not building with earth because it was for the 'poor'. They mentioned their affordability nowadays on stone, steel or concrete construction. The opinion depended on who was interviewed. Building with mudbrick from loam and straw was associated with poverty, which is an argument not to reintroduce that particular method.

After showing the villagers some images of newer earth construction like innovated rammed earth houses, the villagers with the latter opinion reacted surprisingly interested. They mentioned liking the aesthetics and first did not think it was made from earth at all. This indicates the importance of showing that earth construction does not have to look 'poor'. 100% of the interviewees was interested in rammed earth construction and some even asked further on how it was constructed and what binders were used. The local architects, construction workers and politicians gave similar arguments within the discussion to build or not to build with earth again, namely the need for change of the poverty image by introducing innovations in earth construction methods. It was discussed to introduce regulations for a potential new earth building method, to prevent chaotic mixes and poorly built houses, to take away the poverty image.

For the younger generations, some of the 'city movers' mentioned their life was too busy to build or maintain a house, others mentioned their consideration of moving back to their parents and family in the village, when they retire from working in the future, or sooner if there were more work opportunities there. The latter group was interested in self-built earth houses for the purpose of future survival during fires.

Followingly, the locals were asked about their opinion on self-building the villages again with newer earth construction methods. This received mostly positive reactions. The majority of the villagers already wanted to build their houses by themselves, but had to wait a long time due to political paper issues regarding the properties.

So, these interview results show advanced presence of the villagers' knowledge and skills on earth construction within the current building culture of self-built village houses, especially among villagers older than 35 years. The interest in self-building was also clearly visible among the villagers. The consideration of doing this with earth as a building material, with the condition of introducing regulations on new innovated building methods, suggests the poverty image could be taken away. The positive reactions on the shown rammed earth images shows there is potential to reintroduce earth construction. It is also important to show the qualities of earth construction in terms of thermal mass, fire resiliency properties and health benefits. Many interviewees already were aware of these aspects, but there were villagers who were not aware of them.

The combination of local knowledge, skills, willingness to self-build and interest in newer earth construction method innovations show the potentials for reintroducing earth construction methods into risk area villages in the Mediterranean region of Turkey.

V. REGIONAL LANDSCAPE, SOIL TYPE AND FORMING IT INTO FAÇADE BUILDING MATERIALS

This chapter answers the third sub question: "*How is the regional landscape with corresponding soil types characterised and how can this local earth be formed into façade building materials?"*

5.1. Regional landscape with corresponding soil types

The soil type map in appendix 15 shows the regional landscape contains mainly three types of soil. The first is a calcisol-soil, which has mostly an accumulation of lime. The second is leptosols-soil, which represent a soil with earth layered on deeper stony soils. The third is a fluvisol-soil, which is young soil near water, rivers and marine areas. The calcisol is the same soil as in middle and eastern-Anatolia, where mudbrick houses are still present in the villages. Leptosols are explainable because the Taurus mountains are in the Mediterranean region. The fluvisols are mainly sandy and directly next to the Mediterranean Sea. Only the calcisol- and leptosol-soils are usable for earth construction. Loam is the most common composition of the soil. This exists of mostly sand, silt and a smaller amount of clay. The ratio is respectively 40/40/20%. This can differ every few meters in the ground, and can be sandy loam, clayey loam, silty loam et cetera. It is also very suitable for farming, explaining the settlement of all farmers in the researched region. Loam retains nutrients well and retains water while allowing the excess to drain away. Photographs of the soils are shown in appendix 16.

A map of the local landscape is implemented in appendix 17. The landscape in the Mediterranean area is different per location. Along the coast, the landscape is very flat and sandy, filled with mostly large hotels for tourists. To the north from the coastline is the countryside at first, where animals are kept and crops are planted, such as olives, oranges and lemons. From here, the settlements of the villages begin on the skirt of mountains. The altitude varies between 80 and 200meters above sea level. Higher in the mountains the farmers still have small settlements where they only stay to take care of the animals that graze in the mountains (so that they do not have to constantly go up and down the mountain). They also maintain agriculture in this area. The mountains are covered with, for example, coniferous trees. The higher the location in the Taurus Mountains, the colder the temperature gets. The inhabited settlement is negligible here, but previously there used to be 'Yörüks' (nomads) living in 'Yurts' (tents). On the northside of the Taurus Mountains, the inhabited part of the Mediterranean area begins again and the provincial border from Antalya to Konya is passed. Here the landscape is the same as in the southside of the mountains, except there is no coastline anymore.

5.2 Forming the local earth into façade building materials

5.2.1 Initial impression test with three senses

The locations where the samples are taken are in appendix 18. Three samples are excavated from Kalemler village on different locations and one sample comes from the historic earth construction village from Sonsuz Şükran village. The 'initial impression'-test showed all samples are suitable for earth façade construction, according to the used literature method. Since no other methods were historically used besides mudbrick façade construction, the soil was tested for potentially innovated general brick-based and rammed earth façade construction. Appendix 19 shows the results of the 'initial impression'-test, performed with the senses: 'touch', 'smell' and 'sight'.

5.2.2 Field tests with tools

Based on the used literature, it was decided to make a mixture of the first three samples in order to perform the field tests with tools. The mixed ratio was respectively $\frac{1}{3}$ - $\frac{1}{3}$ - $\frac{1}{3}$ of all three examples from Kalemler. Sample 4 was not tested further, because it was already recently used for buildings, which indicated the suitability. All test results are photographed and documented in appendix 20.

The 'particle size by sedimentation'-test showed that any type of soil mixture can be made, since all 'ingredients' were present: sand, gravel, silt and clay. The sandy sample can be balanced out with the clayey sample and vice versa. The percentages are up to the preferred innovated earth façade construction method, but also the preferred colour of sand for the façade aesthetics. The results from the composition showed that the mixture contained 25,2% clay, 13,9% silt and 60,9% sand and gravel. These percentages are ideal proportions for general brick-based construction and rammed earth construction.

The mixture also passed the preparation for the 'roll'-test, because it did not break into pieces after drying. This means there is enough clay as a binder in the mixture to use it for the 'roll' test. The roll broke off at 9,5cm, which means the mixed sample also passed this test and there is enough clay.

The 'soap'-test was also passed, because the soil did not stick to the hands and washed off easily, which suggests the mixture is suitable for earth building.

Followingly, the mixture passed the 'shrink box'- test as well. The shrinkage of the dried earth in the box was less than 12mm, which indicates the soil is satisfactory for earth façade construction without stabilizer. All tests are passed based on the requirements from the used literature.

Finally, little pieces of rammed earth were made as examples, also seen in appendix 20. The sample with all different soils layered on top of each other came out in best condition. These tests indicate the local earth is suitable for innovated earth façade construction, especially innovations based on bricks, blocks and rammed earth. Different mixes of soil can be made for forming the local earth into any type of earth-based façade building materials.

VI. INNOVATION OF VERNACULAR EARTH FAÇADE CONSTRUCTION METHODS IN ORDER TO ENHANCE A WILDFIRE RESILIENT WAY OF REBUILDING

This chapter answers the last sub question: "*How can vernacular earth façade construction methods be innovated in order to enhance a wildfire resilient way of rebuilding?"*

6.1. Innovating local mudbrick façade construction

In order to introduce a new earth façade construction method, four earth façade construction methods were analysed. These methods were yet unknown or not used in the researched villages, therefore considered a potential innovation. The four compared methods were: rammed earth, cob, light earth and compressed earth block. These were projected side by side to the historically used mudbrick method, to gain insight on the methods, similarities and differences. The comparison table in appendix 21 shows the compared aspects per method. This matrix showed most earth façade construction methods are similar in terms of materialism, labour intensity and place of fabrication. The main differences were the main building principle (masonry, monolithic or infill), soil consistency, wet or dry construction and building equipment. Based on the skills and knowledge of the villagers, all compared innovations for rebuilding the burned villages were expected feasible, since all compared methods are relatively easy to teach and learn.

6.2. Innovating earth façade construction method to enhance the wildfire resilient way of rebuilding

6.2.1 Repairing after fires

Since this paper also focused on rebuilding after fires, the repair methods of above compared earth façade constructions were compared explicitly. The result matrix is in appendix 22. In all methods, the earth repair material must have similar characteristics to the existing wall material. All plaster or mortar fill-ins must be applied in wet condition, with a float tool. The repair area on the façade must also be wettened before repairing. Mudbrick, compressed earth block, light earth and cob often have plasters, which could be enough to renew after wildfires. If the damage penetrated deeper in the exterior walls, the damage can be filled-in with earth mixture before replastering. In extremer scenarios, the damaged elements could be replaced, while the structure is supported by additional timber frames until new bricks, blocks or panels are placed. These bricks and blocks could be stocked beforehand, to reduce repair time. Cob and rammed earth are both monolithic and have no smaller replaceable elements. However, damaged areas in the wall could be filled-in with the specific soil used for the wall construction. After drying, the repaired area works as a wall system again. When different repair mixtures are used, this might become visible in the esthetical finish.

6.2.2 Practical aspects

Also, the availability of the building materials should be considered. Most local woods were destroyed and cut down after the wildfires in the riskfull areas. The process to get local tree trunks or timber beams and columns became harder and more expensive. Light earth façade construction is not load-bearing and the exterior walls depend on a timber structural system. Compared to other methods, it would be the most intensive in terms of timber availability.

Furthermore, the implementation of straw could be contradictory, because loose straw is very combustible and an ideal fuel to spread wildfires. One of the reasons why the village houses got destroyed, was the spread of wildfires by strawbales in the village houses' gardens. In case of building with earth-straw mixtures, the earth layer protects the straw fibres or woodchips. Therefore, the straw-mudbrick is not easily flammable or non-combustible. Inorganic fibres could also be used, which is non-combustible. However, this is less easily accessible than ordinary straw, which already grows locally. If an earth façade construction method with straw in the mixture becomes the main rebuilding culture in riskfull areas, then relatively more presence of (loose) straw will occur in the villages. This also indicates a higher production of straw in the villages, especially for the annual replaster maintenance. The presence of a significant amount of more straw production and more loose straw fibres around the houses would contribute to wildfire fuel, unless it is strictly regulated. Therefore, earth façade construction methods with straw in the mixture would not be ideally fitting in the wildfire resilience rebuilding strategy. Thus, cob and light earth would not be regarded as proper innovations for the area.

The methods without implementation of fibres are compressed earth block and rammed earth. For compressed earth blocks, a special compressor equipment is mandatory and for rammed earth, a rammer is mandatory. Both could be done manual or mechanical. Manual compressing machines start from 1.500 euros and manual rammers from 50 euros (conducted from Google Shopping, 2022). Considering power cuts after wildfires or local expensive gasoline prices (from personal interviews, 2021), manual tools would be safer choices at forehand. This suggests the investment in compressed earth façade construction methods could end up more expensive than rammed earth façade construction methods.

Rammed earth is relatively heavy to transport, therefore must be built on site to keep the costs low. This corresponds to what locals were historically used to. Other practical aspects to consider are the holes created by locally excavating earth. More specific attention is needed to the soil consistency since no binders are needed. Also, rammed earth has in chemical terms more earth particles per cubic meter due to the ramming process. Thus, it could be considered to provide a denser building envelope against wildfire flames and embers.

6.2.3 Local opinion

During the personal interviews, examples of rammed earth façade construction were shown to the locals. These were very popularly welcomed by both inhabitants of Kalemler as others, like the local architect, building engineers, politicians and construction workers. One of the admired aspects were the monolithic wall appearance, which was reminiscent of concrete buildings in Turkish cities. The inhabitants were also inspired by the different coloured layers of earth. Rammed earth construction could contribute to making earth construction attractive again in the villages.

6.2.4 Proposed innovation for earth façade construction method in wildfire risk areas

This research shows vernacular mudbrick façade construction method could be innovated into four possible newer methods, namely rammed earth, compressed earth block, light earth and cob. However, considering the practical aspects and local opinions, rammed earth construction was expected to be the most feasible in enhancing a wildfire resilient way of rebuilding. This way, the degraded knowledge is innovatively renewed before it disappears among the younger generations in the villages. This building construction method must be applied consistently, with building regulations in the whole village, to make the village wildfire resilient on a long-term base.

VII. CONCLUSION AND DISCUSSION

This paper outlined the reintroduction and innovation of vernacular earth façade construction and its contribution to the wildfire resilient rebuilding strategy for burned down villages in the Mediterranean region of Turkey. It aims to innovate degraded skills and knowledge of mudbrick construction and make building with earth attractive again, taking away the association with poverty in Turkish villages. As discussed, earth is a suitable building material for wildfire risk areas, because it does not burn and it is also easily accessible by the locals. Right now, the villagers are falling back to the concrete building habit if no other potential solutions are introduced. Their current methods proved unsuitable during the wildfires because the steel reinforcement bars collapsed and made the buildings inhabitable.

7.1 Analysis, interpretation and meaning of the results

An architectural ethnographic research was performed during a site trip to villages in the Mediterranean region in Turkey. The village and locals of Sonsuz Şükran were analysed to gain insight on the historic earth construction methods in this region. These houses represented the old method of mudbricklaying.

During the site visit, the village of Kalemler was researched, representative for burned down villages. Locals were interviewed on their current skills and knowledge on earth construction. The locals all knew how earth houses were made from mudbrick, especially generations older than 35 years. However, they associated mudbrick construction with the less prosperous times in the past. Furthermore, the interviews covered the aspects about their general building knowledge and experience. It appeared that self-building village houses is ‘common knowledge’ for villagers and they have experience on building with other materials as well, like concrete, stone and brick. Subsequently, they were exposed to images of rammed earth construction, exemplary for innovated methods. All interviewees were attracted and showed their interest by asking about the building process in depth. This shows there is potential to introduce innovated earth construction. The willingness of self-building was also present within the local community, especially the older generations. Clearly, changing the local mindset that earth construction does not have to look poor is the fundamental aspect to make earth construction a future potential in the area.

Furthermore, geobased local mapping was performed to explore the landscape of the village areas, including soil type and the consistency. The ‘initial impression’-test with senses suggested the loam soil under Kalemler is suitable for earth construction in general. However, a set of field tests were further performed to get more specific insight on the consistency and to test the soils’ suitability. All tests results were positive, which means the local soils consist of enough clay, sand, silt and gravel for innovative earth façade construction methods. The percentages can be adjusted upon the specific construction method and any façade building material can be made. Also, different colours for the earth façade construction can be obtained by mixing specific colours.

Lastly, four innovated earth façade construction methods were compared to mudbrick façade construction, namely rammed earth, compressed earth block, light earth and cob. Based on practical aspects regarding wildfire resiliency and the local opinions, rammed earth façade construction was proposed as the potential innovation. The destroyed village houses can be self-built by locals who have a lot of experience with building. The ‘usta’s’ (masters) can be taught the rammed earth methods. Thereafter, they can teach the ‘ameli’s’ (workers; all locals). The rammed earth façade construction method is very easy to learn, does not require combustible straw and can be made with relatively cheap tools, which makes it a feasible innovation.

7.3 Answer to the research question

The innovation of vernacular façade earth construction contributes to the wildfire resilient rebuilding strategy for burned down villages in the Mediterranean region of Turkey on two scales from the total strategy. The first is the scale of construction detail, because the introduction of rammed earth façade construction mainly consists of earth, which is a non-combustible material and the houses will get minimum damage. It is easily accessible from the local site, affordable when practised on site and does not produce toxic smoke or fumes when in contact with wildfires, which is a health benefit of living in earth houses. Also, the animals and local crops will not store up toxic gasses. Besides, rammed earth does not require the use of combustible fibres and has in chemical terms more earth particles per cubic meter than other earth construction methods, which provides a denser wildfire building envelope. Furthermore, focusing on one specific construction material provides an easier process of rebuilding and repairing for the villagers, unlike the current situation of building with many different materials.

The second is on the community scale, because villagers in wildfire risk areas learn sustainable knowledge on how to preventively self-build with the innovative rammed earth façade construction methods. Besides, they can directly repair façade damages and get their hands on the earth in cases of unforeseen destruction after wildfires. This way, they can continue their daily lives or pick it up immediately after a wildfire happens, in a responsible way. Living in innovated earth houses can act as a revitalization or stress-remedy after the trauma from the 2021' wildfires, since it provides better sleep circumstances according to the experienced villagers. Lastly, introducing rammed earth façade construction creates community bonding, because it is a group activity for all neighbours. This increases the chances of success of future wildfire resilient building plans.

All in all, these two scales contribute to designing the wildfire resilient village of the future and the total strategy. When applied consistently in the villages, it becomes a sustainable long-term strategy.

7.4 Appropriateness of method

The hypothesis was proven correct. The used methods were appropriate to conduct this research, resulting in reliable and valid results. With the architectural ethnographic research method, very valuable conversations were held with the locals and personal interactions were made. A lot of insights were gained on their daily lives, struggles, wishes, personal views and opinions. Without this method, all of this specific data would not be easily collectable.

7.5 Limits of the method

However, there were some limitations in the methodology of this research. Firstly, the time frame of visiting the site was limited. A longer stay could perhaps give other results. For example, a 1:1 rammed earth wall could be built on the site and if special equipment was available, the tests could have been done more professionally. Also, more images of other innovative façade methods could have been discussed with the villagers. Some parts of the village areas were not reachable, because of fallen burned trees and poor mountainous roads. More areas could have been explored if they were safely reachable. Unfortunately, the step of oiling the wooden moulds was forgotten, which made it hard to take out the dried examples. It had to be 'tapped' out with much force, eventually resulting in the mould and some bricks to break in pieces. Normally, the drying process happens without the moulds during constructions. This is a learning moment for further research. Furthermore, the earth was pressed by hand because there was no ramming tool.

7.6 Generalizability

The methodology and concluded outcome of this paper is valid for other villages in Turkey as well. In that sense, it adds value to other burned down villages waiting for a future perspective. This research methodology could also be applied to other countries with villages in wildfire risk areas. Furthermore, this paper could help with designing for the housing need in villages with similar circumstances, in that sense generalizable for other researchers or designers. All in all, it might have an impact on the future of wildfire risk villages.

7.7 Comparing with other results

In comparison to previously mentioned state of the art research on designing for fire resilient communities, this research adds value on the scale of villages. Villages were a forgotten scale in worldwide work.

7.8 Suggestions further research

Suggestions for further research is building a 1:1 rammed earth construction wall on the site and let the villagers test it by exposing it to self-made fires. Another suggestion is to analyse the effects of establishing the prohibition on using other materials than earth. It could be examined if regulating this in official municipal paperwork prevents chaotic mixes of building materials. Furthermore, it is interesting to research the attraction of tourists into villages with an explicit earth-concept. Lastly, the innovation of other building elements such as the roof, foundation and secondary flooring must be researched explicitly to get insights on renewing those with potential other innovative methods.

VIII. ACKNOWLEDGEMENTS

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IX. References

Acun, S., & Gürdal, E. (2003, May). *Yenilenebilir bir malzeme: kerpiç ve alçili kerpiç (A renewable material: mubrick and gypsum mudbrick).* TMH. Retrieved from https://www.imo.org.tr/resimler/ekutuphane/pdf/221.pdf

Ada, M. S. (2021, September 22). TOKİ, Antalya'da yanan düğmeli evlerin yerine betonarme ev yapacak – Mimar Recep Esengil: "Yüzlerce yıllık tarih yok olacak". (Toki will build concrete housing instead of traditional houses – Architect Recep Asengil: "History will be demolished."). Retrieved 26 October 2021, from https://medyascope.tv/2021/09/13/toki-antalyada-yanan-dugmeli-evlerin-yerine-betonarme-ev-yapacak-mimar-recep-esengil-yuzlerce-yillik-tarih-yok-olacak/

Akinkurole, O., Jiang, C., Oyediran, A., Salawu, O. D., & Elensinnla, A. (2006). Engineering Properties of Cob as a Building Material. *Journal of Applied Sciences*, *6*(8), 1882–1885. https://doi.org/10.3923/jas.2006.1882.1885

BBC News Türkçe. (2021, August 3). *Manavgat: Yangında kül olan köyler* [Video file]. Retrieved from https://www.youtube.com/watch?v=rCcHGmm6Uaw

Cranz, G. (2016) *Ethnography for Designers*. New York, Routledge, 3.

DW Türkçe. (2021, August 2). *Kalemler köyü tamamen yandı | 'Cenneti cehenneme çevirdiler' - DW Türkçe* (Kalemler village is fully burned) [Video file]. Retrieved from https://www.youtube.com/watch?v=xFGyvNih95w

Federal Insurance and Mitigation Administration. (2016). *Rebuilding After a Wildfire*. FEMA. Retrieved from https://www.fema.gov/sites/default/files/documents/rebuilding-after-a-wildfire_2016.pdf

Gaia Architects. (2003, January). *Light earth construction*. Milestone 5. Retrieved from http://www.gaiagroup.org/assets/pdf/publications/light%20earth%20compressed.pdf

Google Shopping. (2022). Rammer - Google Shopping. Retrieved 11 January 2022, from https://www.google.com/search?q=rammer&source=lmns&tbm=shop&bih=852&biw=1745&hl=nl&sa=X&ved=2ahUKEwjulfOSqqr1AhUA6LsIHcOHBJgQ_AUoAnoECAEQAg&ucbcb=1

Grey, J. (2021). Earth building. Retrieved 29 October 2021, from https://www.designingbuildings.co.uk/wiki/Earth_building

Guillaud, H., Odul, P., & Joffroy, T. (1995). *Compressed Earth Blocks: Vol. II: Manual of Design and Construction.* Bad Hersfeld, Germany: Hoehl-Druck.

Hamard, E., Cazacliu, B., Razakamanantsoa, A., & Morel, J. C. (2016). Cob, a vernacular earth construction process in the context of modern sustainable building. *Building and Environment*, *106*, 103–119. https://doi.org/10.1016/j.buildenv.2016.06.009

Kaijima, M. (2018) *Learning from Architectural Ethnography*. In: Architectural Ethnography. Tokyo, Toru Kato, 8-14.

Keable, J., & Keable, R. (2011). *Rammed Earth Structures: A Code of Practice* (2nd ed.). Warwickshire, United Kingdom: Practical Action Publishing Ltd.

KNMI. (2021). Bosbranden. Retrieved 1 October 2021, from https://www.knmi.nl/kennis-en-datacentrum/uitleg/bosbranden

Kük, M., & Burgess, P. (2010). The Pressures on, and the Responses to, the State of Soil and Water Resources of Turkey. *Ankara Üniversitesi Çevrebilimleri Dergisi*, 199–211. https://doi.org/10.1501/csaum_0000000036

van Lengen, J. (2007). *The Barefoot Architect* (1st ed.). Bolinas, California , United States: Shelter Publications Inc.,U.S.

Mantzoukas, S. (2012) Exploring ethnographic genres and developing validity appraisal tools. *Journal of Research in Nursing*, 17(5), 420-435.

Minke, G. (2000). *Earth Construction Handbook: The Building Material Earth in Modern Architecture* (1st ed.). Southhampton, United Kingdom: WIT Press.

Minke, G. (2009). *Building with Earth. Design and Technology of a Sustainable Architecture (2nd ed.).* Basel, Switzerland: Birkhäuser.

Next 10. (2021, June). *Rebuilding for a Resilient Recovery*. Author.

Norton, J. (1997). *Building with Earth: A handbook*. London, United Kingdom: Intermediate Technology Publications.

Nunan, J. (2010). *The Complete Guide to Alternative Home Building Materials & Methods: Including Sod, Compressed Earth, Plaster, Straw, Beer Cans, Bottles, Cordwood, and Many Other Low Cost Materials.*

Öz, S. [Medyascope]. (2021, August 7). *Manavgat'ın Kalemler Köyü büyük yangında yok oldu (Manavgat's Kalemler Village burned down during big fire)* [Video file]. Retrieved from https://www.youtube.com/watch?v=zriX5Hi1wCE

Powell, K. (2017) Viewing Places: Students as Visual Ethnographers. *Art Education*, 63(6), 44-53.

Rael, R. (2009) Earth architecture. New York, N.Y.: Princeton Architectural Press.

Ronald, R. (2011) Ethnography and Comparative Housing Research. *International Journal of Housing Policy*, 11(4), 415-437.

Schroeder, H. (2012). Modern earth building codes, standards and normative development. *Modern Earth Buildings*, 72–109. https://doi.org/10.1533/9780857096166.1.72

Skidmore, Owings & Merril. (2021). *Designing Communities for Wildfire Resilience*. Retrieved from https://www.som.com/wp-content/uploads/2021/09/Designing-Communities-for-Wildfire-Resilience_reduced_FINAL-1632896152.pdf

Turkish Red Crescent. (2021). *Turkey wildfires.* Retrieved from https://reliefweb.int/sites/reliefweb.int/files/resources/Turkish%20Red%20Crescent%20Turkey%20Wildfires%20Information%20Bulletin%20-%20Date%2010.08.2021.pdf

Tuztasi, U., & Çobancaoglu, T. (2006, December). *Anadolu'da Kerpicin Kullanım Geleneği ve Kerpiç Konut Yapı Sistemlerinin Karşılaştırılması. (A Comparison of the Traditional Adobe Use and Adobe Housing Construction Systems in Anatolia)* (5). Retrieved from https://dergipark.org.tr/en/download/article-file/209205

Uzoegbo, H. (2016). Dry-stack and compressed stabilised earth-block construction. *Nonconventional and Vernacular Construction Materials*, 205–249. https://doi.org/10.1016/b978-0-08-100038-0.00008-1

UCDavis. (2021, October 20). The House That Doesn't Burn. Retrieved 11 January 2022, from https://www.ucdavis.edu/climate/news/wildfire-resistant-housing

Volhard, F. (2016). *Light Earth Building* (1st ed.). Berlin , Germany: Walter de Gruyter GmbH.

Vyncke, J., Kupers, L., & Denies, N. (2018). Earth as Building Material – an overview of RILEM activities and recent Innovations in Geotechnics. *MATEC Web of Conferences*, *149*, 02001. https://doi.org/10.1051/matecconf/201814902001

Zafar, S. (2020, October 16). How Towns Can Rebuild After a Wildfire. Retrieved 21 December 2021, from https://www.ecomena.org/how-towns-can-rebuild-after-a-wildfire/

APPENDICES

APPENDIX 1: GLOSSARY OF TERMS AND DEFINITIONS

<u>Own definitions:</u>

- **Wildfire resilience**

"*The ability to cope with wildfires in such a way that as little damage as possible is caused to the environment, including buildings, people, flora, fauna, work and daily life. This concept encompasses several aspects, one of which is architectural resistance to fires. Other aspects are the urban layout, social collaboration and landscaping*." (Own definition, 2021)

- **Wildfire resilient rebuilding strategy**

"*A step-by-step rebuilding plan with the aim of making a village and its community wildfire resilient. This strategy includes the following scales: construction details, building planning, village typology, landscape and the community."* (Own definition, 2021)

- **Wildfire resilient village**

"*A village is wildfire resilient when it meets the following requirements: the community is able to (re)build their houses and other buildings with local building knowledge and skills, with materials that prevent damage in terms of a little or no demolishment. They can continue their daily lives or pick it immediately after a forest fire happens. In case of unforeseen destruction, they can easily repair the damage themselves. The typology and landscape of the village is designed specifically in a way that it prevents wildfires from spreading. These requirements are the indicators of measurement."* (Own definition, 2021)

<u>Definitions from dictionaries and other sources:</u>

- **Building culture**

"Building culture encompasses any human activity that changes the environment. Not only the buildings and their designs (including infrastructure, urban planning, public space and landscape) belong to the building culture, but also the process − which consists of regulations, planning and collaboration in building and the architecture culture (thinking about/reflecting on). A high-quality building culture also builds social cohesion, focuses on sustainability and contributes to the health and well-being of everyone." (Ten Cate, 2020)

- **Earth**

"Earth is excavated soil and comprises clay minerals and other constituents ranging from fine sand to stony particles. Soils that are cohesive (i.e. have a strong binding capacity) are termed rich, or clayey, those with low cohesion, lean or sandy. Depending on the predominant grain fraction (the most common particle size) in the soil texture, soils are known as 'stony', 'gravelly, 'sandy' , 'silty' and so on. The clay serves a natural binder." (Volhard, 2016, p.41)

- **Earth building / construction:**

"The practice of construction using raw earth. Earth buildings are highly durable, have good humidity regulations and sound insulation. They are non-toxic, non-allergenic and fireproof. It provides thermal mass and insulation when built as thick walls and usable as passive solar design. The techniques and methods for earth construction vary with culture, climate and resources. Some are: cob, rammed earth, wattle-and-daub, light straw, earthbags, earth bricks, earthen floors and earth plasters and finishes." (Grey, 2021)

- **Fire resistant**

"So resistant to fire that for a specified time and under conditions of a standard heat intensity it will not fail structurally or allow transit of heat and will not permit the side away from the fire to become hotter than a specified temperature." (Merriam Webster Dictionary, 2021a) → the chosen material earth also has resistance properties within the resilience context.

- **Geobased:**

"*Based on geographical data"* (Your dictionary, 2021)

- **Resilience:**

"*The ability to recover from or adjust easily to misfortune or change"* (Merriam Webster Dictionary, 2021b)

- **Rebuilding:**

"The process of building something (such as a city, building, etc.) again after it has been damaged or destroyed" (Collins Dictionary, 2021)

- **Turkey's Housing Development Administration:**

"*Housing Development Administration of Turkey (TOKI) aims fundamentally at producing solutions to the problems regarding housing and urbanization in Turkey at national scale. With its rapid housing production practices, it aims to meet 5% -10% of the housing need of Turkey*." (TOKI, n.d.).

Glossary references:

Collins Dictionary. (2021). Rebuilding definition and meaning | Collins English Dictionary. Retrieved 28 October 2021, from https://www.collinsdictionary.com/dictionary/english/rebuilding

ten Cate, F. (2020, February 3). Bouwcultuur: Elke ruimtelijke ingreep is een culturele daad. Retrieved 29 October 2021, from https://www.archined.nl/2020/02/bouwcultuur-elke-ruimtelijke-ingreep-is-een-culturele-daad/

Grey, J. (2021). Earth building. Retrieved 29 October 2021, from https://www.designingbuildings.co.uk/wiki/Earth_building

Merriam Webster Dictionary. (2021a). Fire-resistant. Retrieved 29 October 2021, from https://www.merriam-webster.com/dictionary/fire-resistant

Merriam Webster Dictionary. (2021b). Resilience. Retrieved 10 October 2021, from https://www.merriam-webster.com/dictionary/resilience

TOKI. (n.d.). TOKİ. Retrieved 21 October 2021, from https://www.toki.gov.tr/en/

Volhard, F. (2016). *Light Earth Building* (1st ed.). Berlin , Germany: Walter de Gruyter GmbH.

Your Dictionary. (2021). Geobased Meaning. Retrieved 28 October 2021, from https://www.yourdictionary.com/geobased

APPENDIX 2: LIST OF CURRENT HOUSING BUILDING PLANS FOR KALEMLER

	TOKI Housing	**Manavgat Municipality Housing**	**Private Plans**
Example	 *(From Google images databank, 2021)*	 *(Own image, 2021)*	 *(Own image, 2021)*
Main principle	-Already made housing plans with no-interest loans	-Free designs and details for villagers, they must arrange the building-process themselves -18 types to choose from	-Renovating less-damages housed -New construction
Costs	No clarity	No clarity	No clarity
Main façade materials	Stone, concrete structure with steel reinforcement bars	Stone, brick, concrete structure with steel reinforcement bars	Stone, brick, concrete structure with steel reinforcement bars
Fire resiliency aspect	No clarity	No clarity	No clarity
Involvement locals	Not involved in the entire process	Not involved in design, but involved in building process	Fully involved / self-built

Table: Current housing plans in Kalemler village. (Own work, based on personal interviews, 2021)

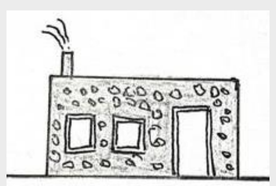
Appendix 3: dominating building culture of self-built village houses in Kalemler and Evrenseki

Collage of mixed houses: old & new under one roof

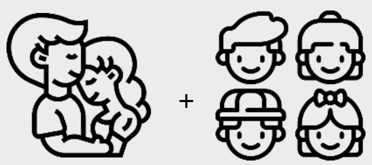
Enlargement process: a chronological explanation about mixed material houses

1.
Marry = buy or build house

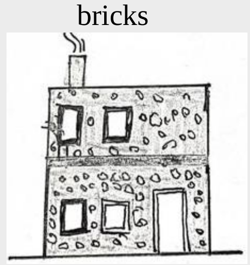
1900-1950
Main building materials: Stone, wood and mud



2.
Children = build extra rooms with the new available and affordable materials

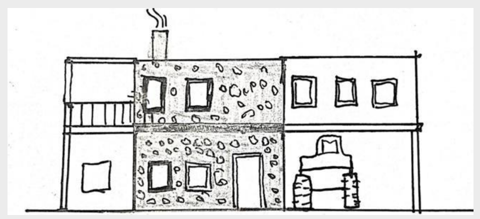


1950-2010
Main building materials: Stone, steel, concrete, bricks

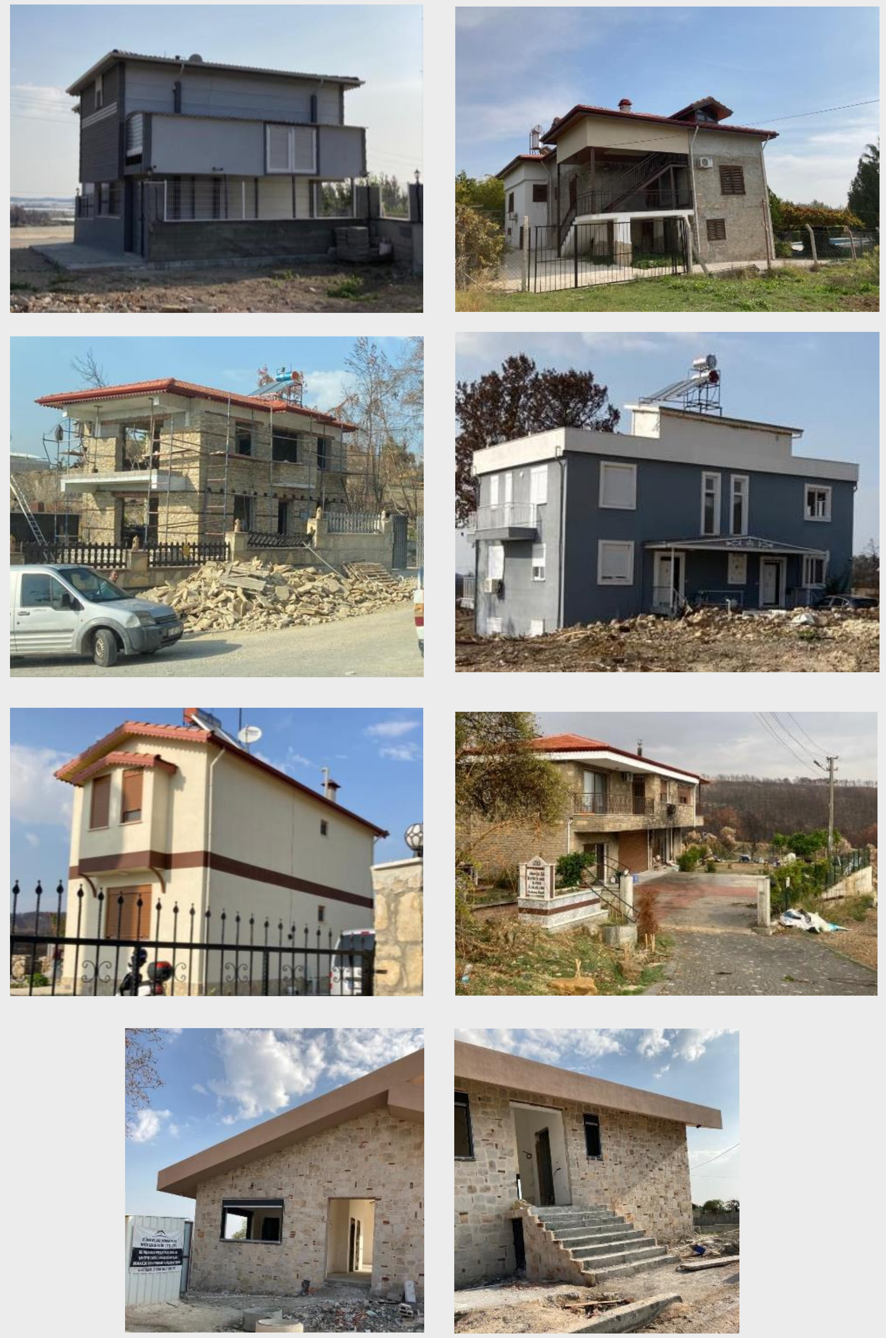


3.
-Children grow up & marry
-Partner moves in
-More children
Nowadays: move to own house

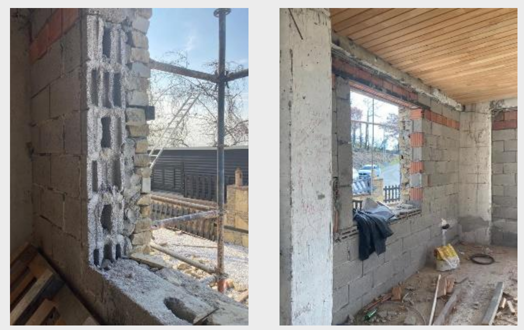
2010-2021
Main building materials: Stone, steel, concrete, bricks



Collage of new houses



Detail exterior wall: brick masonry and stony finish

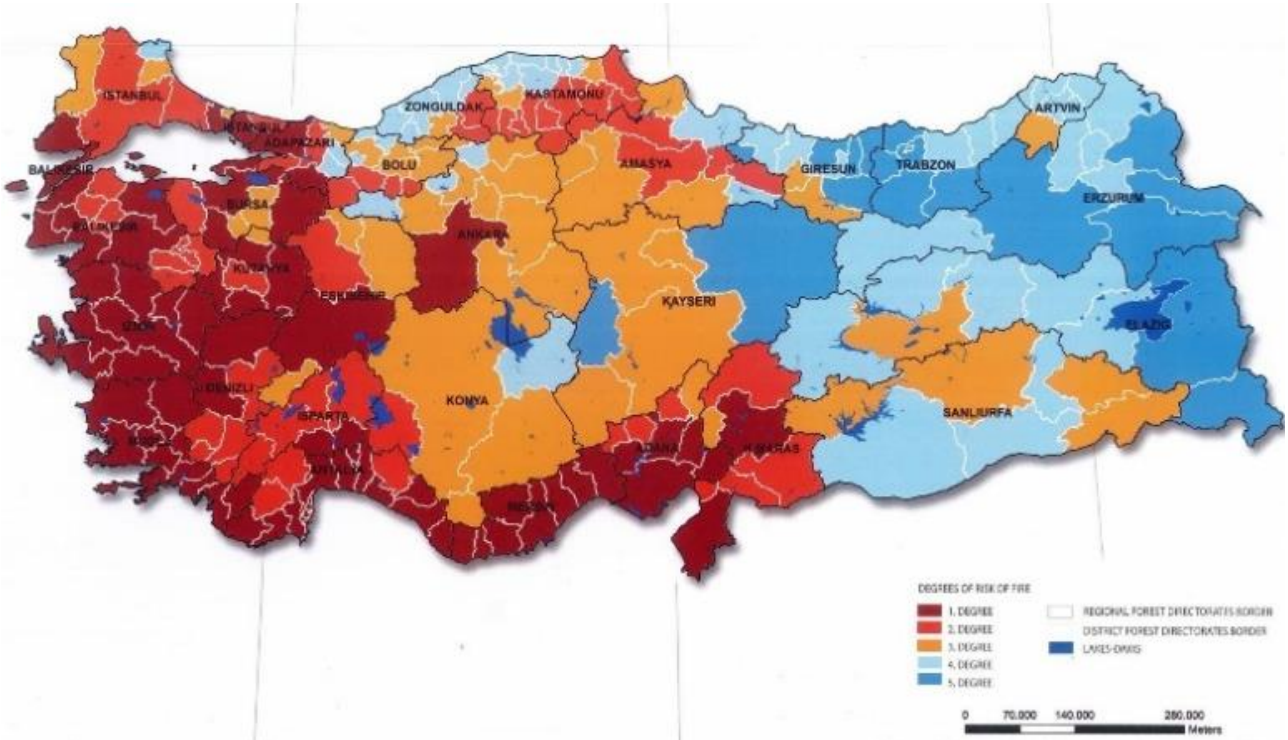


(Own images, except images with *: houses before wildfires, from Sadi Öz, 2021)

APPENDIX 4: MAP OF MEDITERRANEAN REGION IN TURKEY (AKDENIZ BÖLGESI, YELLOW COLOURED REGION)

From: Bilgivitrini (*Knowledge window*), 2021.
https://bilgivitrini.com/akdeniz-bolgesi-cografi-ve-ekonomik-ozellikleri-nelerdir/

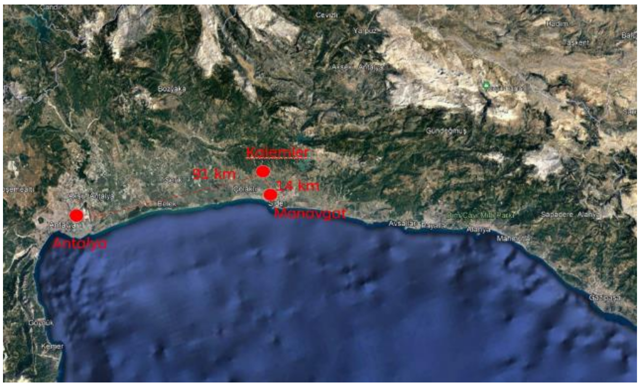
APPENDIX 5: MAP OF WILDFIRE RISK AREAS IN TURKEY



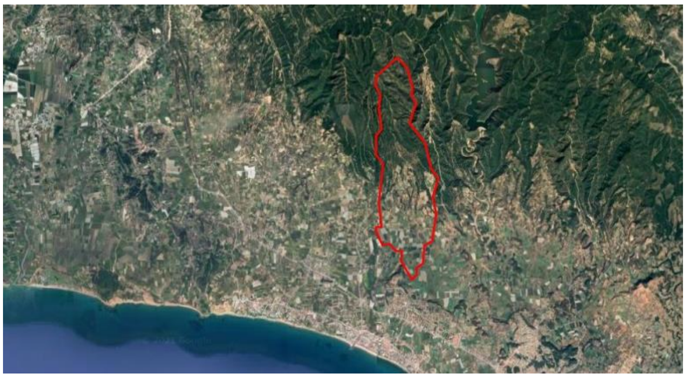
From: IAWFOnline, 2021.
https://www.iawfonline.org/article/fire-globe-wildfire-in-turkey/

APPENDIX 6: GEOGRAPHICAL LOCATION KALEMLER

National scale (Own notes, Google Earth, 2021)



Regional scale (Own notes, Google Earth, 2021)



Village scale (Own notes, Yandex maps database, 2021)

Zoomed in Kalemler (Own notes, Yandex maps database, 2021)

Zoomed in Kalemler village center (Yandex maps database, 2021)

APPENDIX 7: PERSONAL INTERVIEW PARTICIPANTS LIST

Interviewee	**First Name** **due to privacy, some names were replaced by anonymous names.*	**Gender:**	**Age indication:**	**Lives in:**	**Daily activities / Job:**
1	Sadi	M	60-70	Kalemler	Farmer / builder
2	Kezban	F	50-60	Kalemler	Farmer
3	Kader*	F	70-80	Kalemler	Farmer
4	Semih	M	50-60	Kalemler	Construction worker
5	Gülsüm	F	40-50	Kalemler	Farmer
6	Dursun*	F	40-50	Kalemler	Construction worker
7	Senel	F	40-50	Kalemler	Teacher
8	Emine*	F	70-80	Kalemler	Farmer
9	Ramazan	M	40-50	Kalemler	Imam
10	Hasan	M	50-60	Kalemler	Farmer
11	Emrah	M	30-40	Manavgat	Architect
12	Ahmet*	M	50-60	Ankara	Building constructor, contractor
13	Mehmet*	M	30-40	Ankara	Construction contractor
14	Mahmut*	M	60-70	Kalemler	Usta (Master builder)
14	Hicran	F	40-50	Sonsuz Şükran	Photography artist
15	Yavuz	M	40-50	Sonsuz Şükran	Municipality worker, interest in architecture
16	Sami*	M	60-70	Sonsuz Şükran	Construction worker
17	Mehmet	M	20-30	Evrenseki	Car dealer / interior architect
18	Ali*	M	30-40	Manavgat	Architect
19	Melis*	F	30-40	Manavgat	Architect
20	Mustafa	M	50-60	Manavgat	Mayor assistant
21	Murat	M	30-40	Manavgat	Cartograph/ Map technician
22	Aysel*	F	30-40	Kalemler	Farmer
23	Selim*	M	20-30	Ilica	Car mechanic
24	Kadir*	M	20-30	Evrenseki	Architect assistant
25	Mesut	M	60-70	Evrenseki	Retired Teacher
26	Mehmet	M	40-60	Kalemler	Farmer

Table: Interviewees list. (own work, 2021)

APPENDIX 8: LEADING INTERVIEW QUESTIONS

Interviewees: both people whose houses have been burned down and people whose houses are still standing.
Date: 16, 17, 18, 19, 20 November 2021
Interviewer: Ecem Kiliçaslan
Language of interview: Turkish
Short introduction explanation:
Hello Sir / Madam …,
I am going to interview you about the local building culture in your village. I am also going to ask you about the wildfire damages from last summer. And I would also like to hear your opinion on the current plans that are being made for your house by the government. If you don't have questions for me, I would like to start with the questions.

1. Can you tell something about yourself (name, age, education, work, family, daily activities)?
2. How long have you been living in this village?
3. Do/did you own a house in this village?
4. Who or which company constructed your house?
5. How were the houses built in your village?
6. Do you know any craftmanship or building skills?
7. Can you tell something about the building skills of your (grand-) parents?
8. When did you buy / start renting this house?
9. What did it the house look like? Façade? Plan? How many rooms?
10. How many people did you share your house with?
11. Is earth construction a known phenomenon for you?

    No → Further to question 13
    Yes → Further to question 12

12. Can you tell something about what you know about earth construction?
13. Do you have any experience with building?
    Yes? → What kind of experience?
    No? → Further to question 16
14. Do you have any knowledge on building?
    Yes → What do you know?
    No? → Further to question 16
15. Have you ever thought about rebuilding your burned down house yourself?
16. What do you think about houses made of earth?
17. Do you know any houses in the village that are self-built with earth?
18. What do you think of the housing plans made by TOKI?
19. Are you happy with the village you live in?
20. What things could be done differently in your village?
21. What do you like about your village?
22. What do you dislike about your village?

**These questions had a leading purpose, other various topics had been discussed as well.*

APPENDIX 9: IMAGES OF INNOVATED RAMMED EARTH FAÇADE CONSTRUCTION METHODS





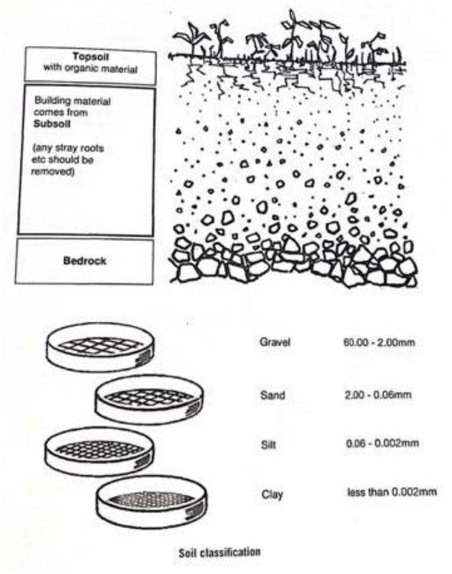

(All images from: Google images Databank, 2021)

APPENDIX 10: PERFORMED TESTS, EXPLANATIONS, PURPOSES, MATERIALS AND DOCUMENTATION

<table>
<tr><th>Test:</th><th>Purpose:</th><th>Materials used:</th><th>Documented in:</th><th>Explanation</th><th>Explanatory drawing:</th></tr>
<tr><td>Take samples</td><td>To have samples for the tests</td><td>Shovel, transparent bucket, wooden trays, water</td><td>Photography, textual explanations</td><td>“Samples for analysis should be taken from the subsoil and never from the topsoil. Soils vary over short distances, and therefore several samples should be taken from the area where you expect to get soil for building. You can mix the soils of different layers, and this can be helpful in getting a good soil composition.”

(From: Building with earth. Norton, 1997, p.11)

“Several points on a site need to excavated to perform tests. First remove the upper layer of earth that contains organic materials and vegetation. Then remove samples of earth from different depths.”

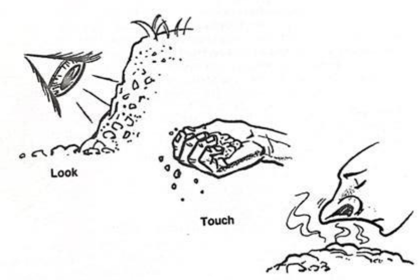
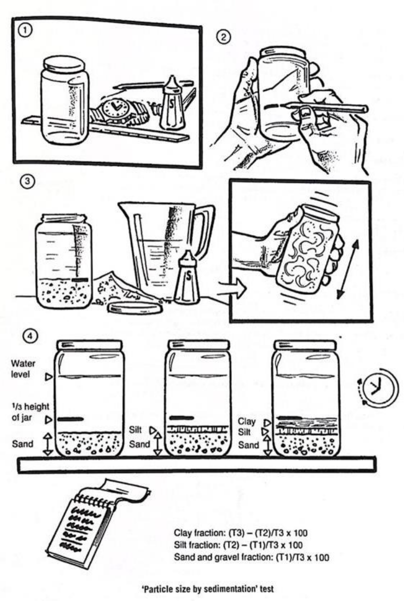
(From: The Barefoot Architect. Van Lengen, 2007, p.298)</td><td>
(From: Rammed Earth Structures. Keable & Keable, 2011, p.9)</td></tr>
<tr><td>Initial impression

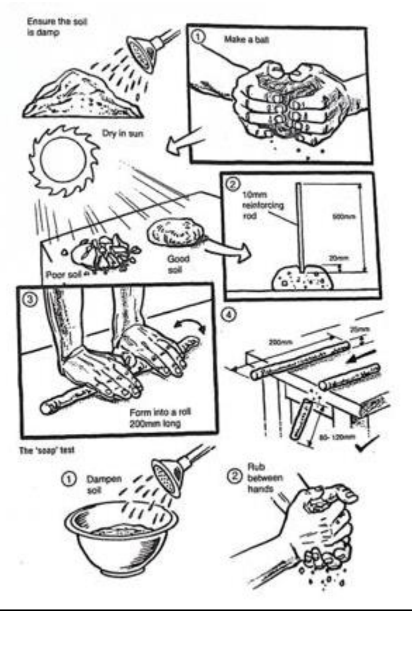
(Touch/smell/sight)</td><td>To conduct first impressions of the soil qualities and suitability for (façade) earth construction methods</td><td>Senses, paper, pen</td><td>Photography, table, textual explanations</td><td>Touch: rub the soil between the fingers to feel if the soil is coarse or fine.

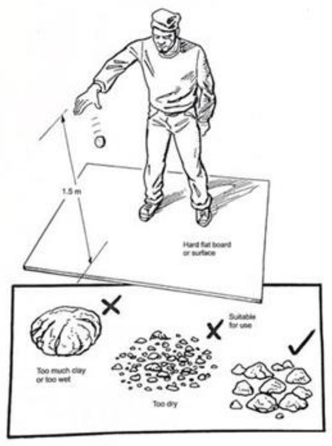
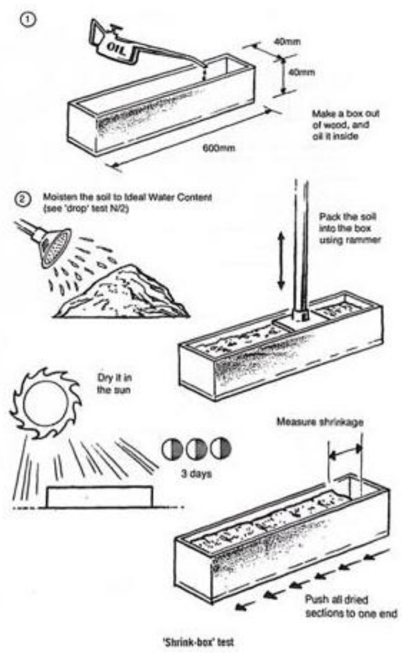
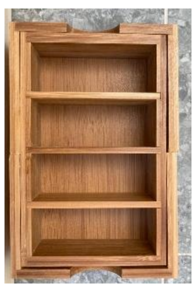
Smell: avoid musty smells, which indicates organic matter

Sight: look for cracks, surface, colours

(From: The Barefoot Architect. Van Lengen, 2007, p.298)

(From: Rammed Earth Structures. Keable & Keable, 2011, p.12)</td><td>
(From: Rammed Earth Structures. Keable & Keable, 2011, p.13)</td></tr>
<tr><td>Particle size by sedimentation</td><td>To explore the particle composition of the mixed soil samples</td><td>Two clear jars with flat bottom and covering lid, marker, water, salt, timer, ruler</td><td>Photography, textual explanations</td><td>“Mark off on the side of the jar one third of its hight. Fill the jar with dry soil to just over the one-third mark; compact the soil slightly and remove any soil from over the mark. Then fill the jar until it is two-thirds full with water. Add the pinch of salt. Mix the soil, water and salt together, then seal the top, and shake the jar vigorously until the soil particles are in suspension. Now let the jar stand for one hour.”
“At the end of one hour, again shake the jar vigorously, put it down, and time one minute. When one minute is up, mark the point at which the soil has settled on the side of the jar without moving it. This is (T1), the gravel and sand fraction. Keep timing, and after 30 minutes make another mark at the point the soil is settled. This is T2, the gravel, sand and silt combined. After 24 hours, make a third mark at the point the soil has settled. This is (T3), the gravel, sand, silt and clay fraction.”
(From: Rammed Earth Structures. Keable & Keable, 2011, p.20)</td><td>
(From: Rammed Earth Structures. Keable & Keable, 2011, p.21)</td></tr>
<tr><td>Roll</td><td>To find out if soil is suitable for (façade) earth construction methods</td><td>Ruler</td><td>Photography, textual explanations</td><td>“Take a handful of unsieved soil, moisten, make a ball, and leave to dry in the sun. If it falls apart it has too little clay, and thus unsuitable for rammed earth: look for another soil source.”
“Take enough of the damp soil to form a ball in your hands; then between your hands form into a roll 25mm thick and 200mm long. Place the roll on a table, and push it gently over the edge. Measure how long it gets before it breaks off. Check the length of the piece that drops.” If the roll beaks off less than 80mm, there is not enough clay. If the roll break off longer than 120mm, there is too much clay.’

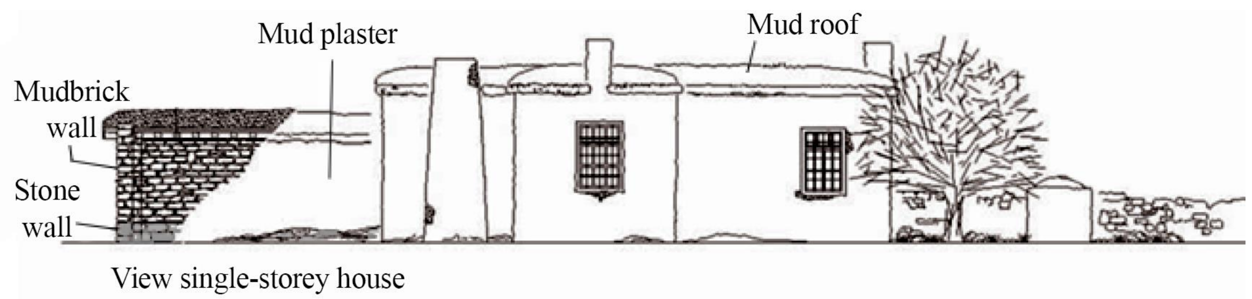
(From: Rammed Earth Structures. Keable & Keable, 2011, p.18)</td><td></td></tr>
</table>

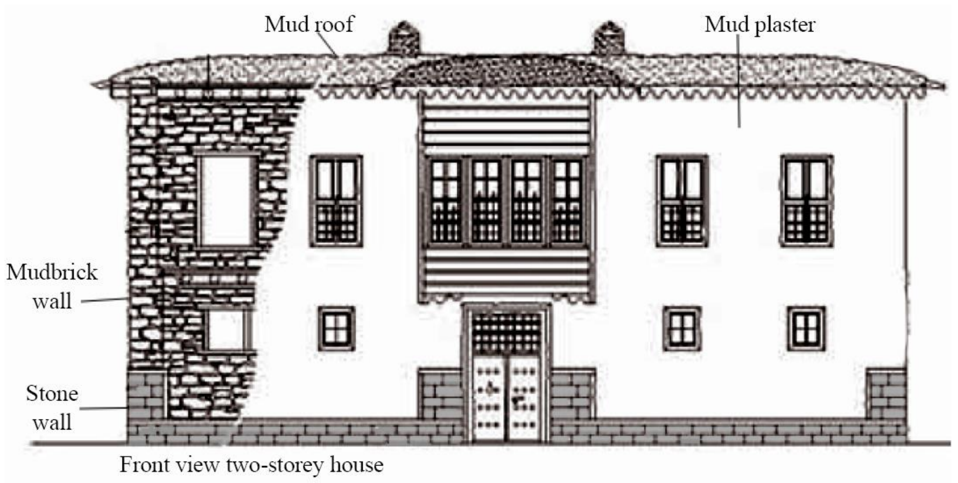
Soap	To find out if soil is mainly clay or silt and suitability for (façade) earth construction methods	No extra tools	Photography, textual explanations	"Take a handful of the soil you are testing, and damp it slightly in a bowl. Take a lump of this soil and rub it between your hands as if washing with soap. If the soil sticks to your hands and washes off only with difficulty, the soil contains too much clay. It might need mixing with another soil before it can be used for rammed earth. If the soil does not stick much and washes off easily, the soil is sandy or silty: it may be usable as it is for rammed earth." *(From: Rammed Earth Structures. Keable & Keable, 2011, p.18,20)*	*(From: Rammed Earth Structures. Keable & Keable, 2011, p.19)*
Drop	To find out the 'ideal water content' and to check this on the site	No extra tools	Photography, textual explanations	"Take soil that has had some water added to it. Squeeze the damp soil into a ball 40mm diameter in your hand, with your arm straight out at 1,5m high, drop the soil ball onto the ground and observe: if the soil stays in one piece it is too wet or has too much clay. If the soil breaks into many pieces, it is too dry. When the dropped ball breaks into only a few pieces, it is suitable for construction." *(From: Rammed Earth Structures. Keable & Keable, 2011, p.24)*	 *(From: Rammed Earth Structures. Keable & Keable, 2011, p.25)*
Shrink box	To find out if soil is satisfactory without stabilizer for (façade) earth construction methods	Wooden mould, sizes: 4cmx4cmx40cm (Self-built), ruler 	Photography, textual explanations	"Make a wooden mould of 4cmx4cmx40cm (3cmx3cmx30cm or 4cmx4cmx60cm also works). Fill the box with the soil sample and leave it to dry in the shade. The earth should shrink and crack. Measure the shrinkage. If the mixture shrinks more than 1/10th of the whole length, it is suitable for brick construction. If the shrinkage is less than 12mm, the soil is satisfactory without stabilizer for rammed earth façades. Between 12mm-24mm, 5% lime should be added, or low-clay soil (sand/aggregate). When over 24mm, there is too much clay, thus low-clay soil must be added." *(From: Rammed Earth Structures. Keable & Keable, 2011, p.30)* (*From: The Barefoot Architect. Van Lengen, 2007, p.300)*	 *(From: Rammed Earth Structures. Keable & Keable, 2011, p.31)*
Samples in moulds	To model the different samples in smaller bricks	Wooden moulds, water 	Photography, textual explanations	"The wood used for the moulds must be clean and smooth. Make the mold impermeable by applying a layer of burnt oil. Let the mixture settle with a little bit of water for 3 days to cure. Then add more water until it is malleable enough into the molds." (*From: The Barefoot Architect. Van Lengen, 2007, p.304)*	

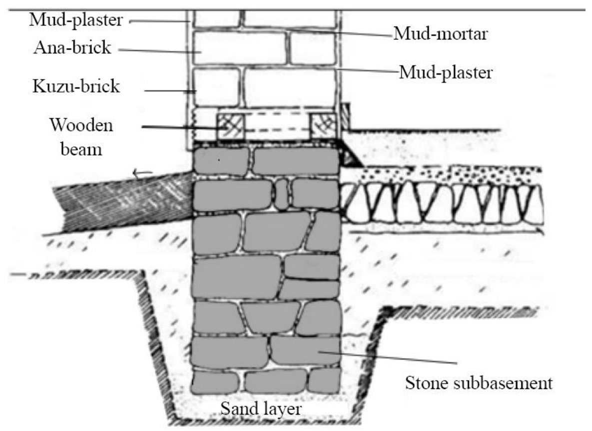
Tests from three books:

1. "*The Barefoot Architect*" (Van Lengen, 2007, p.298-300, p.304-306)
2. "*Building with Earth, A Handbook*" (J.Norton, 1997, p.9-15)
3. "*Rammed earth structures: A code of practice*" (Keable & Keable, 2011, p.16-22, p.24,25, p.30-31)

APPENDIX 11: EXPLANATORY DRAWINGS AND PHOTOGRAPHY OF TYPICAL VILLAGE EARTH HOUSES & BRIEF INFORMATION ABOUT OTHER BUILDING ELEMENTS







(Adjusted from Tuztasi & Çobancaoglu, 2006, p.98,111 and Acun&Gürdal, 2003, p.76.)

(Own images, from Sonsuz Sükran Village, 2021)

Brick oven ('tandir') and cold rooms: Because villagers often baked their own bread, a baked mudbrick oven from red coloured earth in the corner of a living room or in the garden became a fixed element in the historic earth houses. Every house had a dark and cold room where this bread and other food was kept because there were no refrigerators. This room had no windows or one very small one. Food used to last longer in these rooms than is does now is the experience of the villagers. A dried-out supply of bread lasted a whole winter and was wettened before usage.

Second story floor: The second story is optional, used by larger families, or for farm houses. For the latter, the ground floor was in use for the animals and storage for straw or wood. It was built the same way as the roof, but finished after the step of putting 'hasir' or wooden planks.
The finishing layer was always rugs. Stairs were made from wooden planks. It could also be made from stone or mudbricks. In the historic way of building, people placed the stairs outside. This meant they had to go outside to reach the second floor. The ground floor was not for living, but farming. In other cases, the house was only one-storey high and the farming area was in a separate building next to the house.

Roof*:* The roof was constructed by first placing a large tree trunk on the right size from one exterior wall to another side. This tree trunk was often from juniper or beech trees and was bought user-ready. Smaller logs were then placed on top of his, each about 15-20cm in diameter. The distance between each smaller tree trunk was approximately 0,25m centre to centre. The tree trunks were first cut into squares by sawing off the sides, but the force distribution turned out to be more equal when the round tree trunk were kept intact. On top of the smaller trunks, mats were placed, which are locally called 'hasir' (wicker mats). Sometimes, instead of these wicker mats, wooden planks were used. As a water resistant layer, a nylon or plastic foil was placed on top of the mats or planks. Finally, a mud layer of approximately 25cms was applied on the roof. When this layer dried out, a last finishing layer was applied. The roof had a sloping angle, to let the water drip off into a groove and through a water pipe to the ground. This system was made from carved wood trunks or steel pipes.

Foundation: Historically, the foundation was dried ground. On top of it, wooden planks were added, finished off with 'kilims' (rugs) and 'sedirs' (traditional Turkish living room furniture set). After 1950, there was a switch into concrete foundations.

Toilet: Historically, the toilet used to be in the garden, not in the house. It was a traditional squat toilet in a booth made from wood or mudbricks. The pit for feces was emptied once a week by the owners of the house or in some villages it was emptied by the municipality. Since the 60's and 70's these toilets were replaced by toilets as we know them today and were built in the houses as most villages got sewage systems.

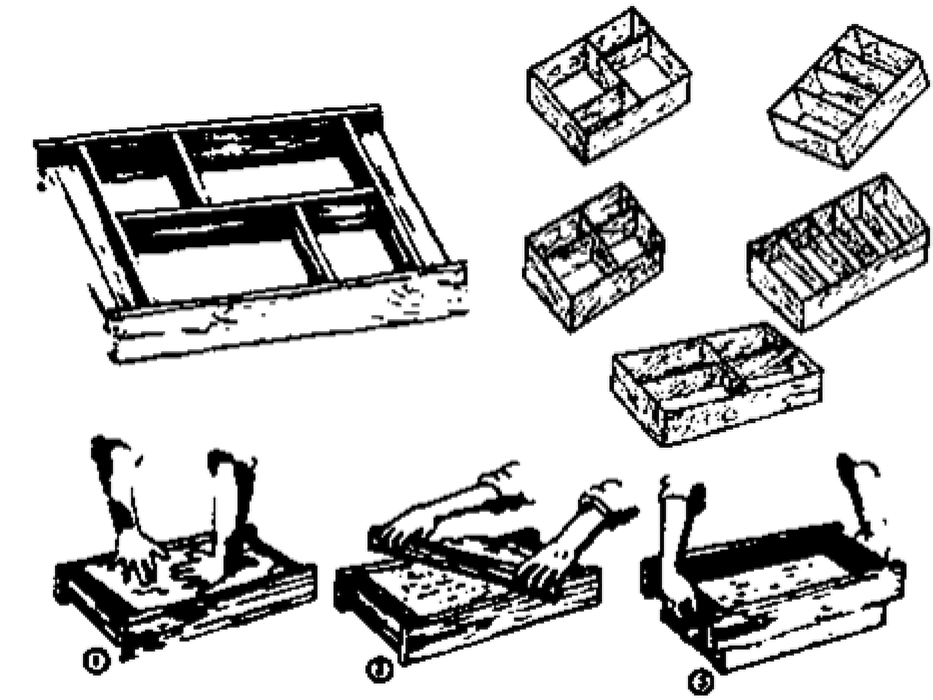
Snow and rain maintenance: The roof must be cleaned with shovels, to make it free of snow before the roof can't handle the weight. A special tool was used to harden the roof again after rainy days, called the 'loğ'-stone. This is a round shaped heavy stone, which puts pressure to compact the soil on earth roofs. It prevented rainwater from leaking through the roof. During the yearly 'spring cleaning', a new layer of mud was plastered on the façade and roof in order to renew the damaged plaster. Very occasionally, tree trunks from the roof construction started to rot, which were then replaced with new trunks.

Heating system and hot water: There were three ways for warming the house. With two-storey houses, the cows in the barn on the ground floor produced a lot of heat and this heat entered the upper living space. Also, there was a stove in every house in which blocks of dried cow dung ('ahpun'), pieces of wood, coal or daily papers were burned. The exhaust gases left the house through a pipeline that exited through a hole in the exterior wall and also out the chimney. The air for the combustion process was supplied from the living room, so good ventilation through windows was important. Heating the 'soba' for a few hours was enough for the whole day.

Chimney*:* In order to exhaust cooking gasses, combustion gases or dirty air, a chimney was built from also mud bricks. When affordable, fire bricks were chosen as a replacement because it was easier to clean and had less maintenance.

(From personal interviews, 2021)

APPENDIX 12: MOULD EXAMPLES



(All images from: Google Images Databank, 2022)

(All images from: Google Images Databank, 2022)

APPENDIX 13: SUBBASEMENTS / SPLASH ZONES

(Own images, from Sonsuz Şükran village, 2021)

Appendix 14: Resumptive interview results

Local opinions on Earth Houses and Exemplary Rammed Earth Construction

"It is historical, everybody has money for concrete houses now."

"Is this really earth? Looks very expensive and mesmerizing to the eye."

Mehmet, 40
Inhabitant Kalemler

"It would be nice if villagers could innovate their traditional way of building. Earth houses have a poverty image, which it does not need to have. People here follow trends in the cities, which is concrete. I am personally not a fan of systemized concrete houses."

"It could be built here too!"

Emrah, 30+
Local Architect
Kalemler

"I know that it is much healthier, you will get a very deep quality sleep in an earth house. Villagers follow the city-way of building, a bit Westernised. We have a long way to go before people realise that you have to break through the mindsets."

"Never seen this before. Looks beautiful, way better than mudbricks."

Mustafa C., 50+
Local politician
Kalemler

"I know it from my birth town, my father and uncles used to build it. Now we all use concrete or stone. Kind of unhealthy actually."

"I have seen this on pictures but never realised it was just earth."

Semih, 53
Local Builder
Kalemler

"We wanted to get out of our concrete apartment in Istanbul. That is why we built this earth house from mudbricks. We live here 6 months per year. We sleep better here, It is a real zen-place. We feel connected to nature and recommend the benefits of an earth house, as our grandparents always did."

Yavuz & Hicran, 40+
Inhabitants Sonsuz Şükran

"This is a very old way of building, it was fun watching my parents build this in Sivas"

Emine, 70+
Inhabitant of Kalemler

"I hate concrete houses. I build them because that's what the customers want. I would love to see earth houses come back. I miss that good feeling and deep sleep. I felt much healthier back then."

"Looks easy to build."

Ahmet, 50+
Local constructor / contractor
Kalemler

Local Opinions on Current Building Plans by TOKI

Ahmet, 50+
Local constructor & contractor
Kalemler

"Not good quality housing"
"Just cheap and fast"
"Construction time is 4 months, but if villagers want to build themselves, the paperwork for permission only would be 4 months."

Kezban & Sadi, 60+
Inhabitants Kalemler

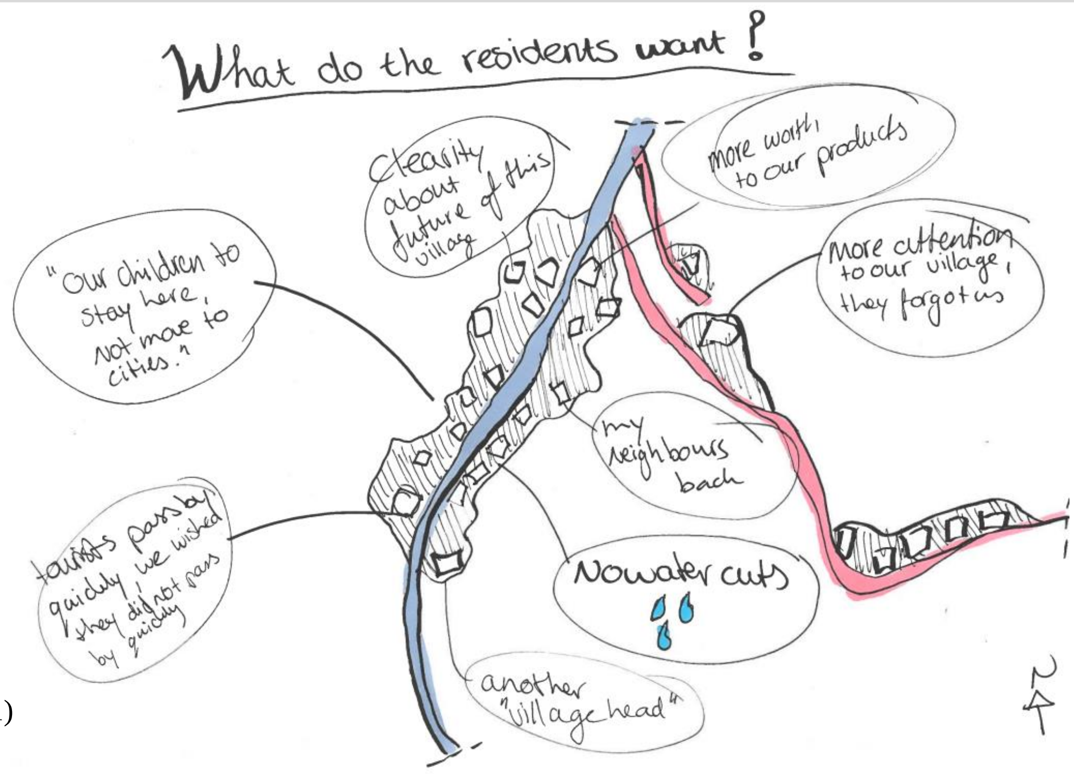
"We are just endlessly waiting for information. No price information or construction information is provided to us."

Gülsüm, 40+
Inhabitant Kalemler

"As long as I have a home again."

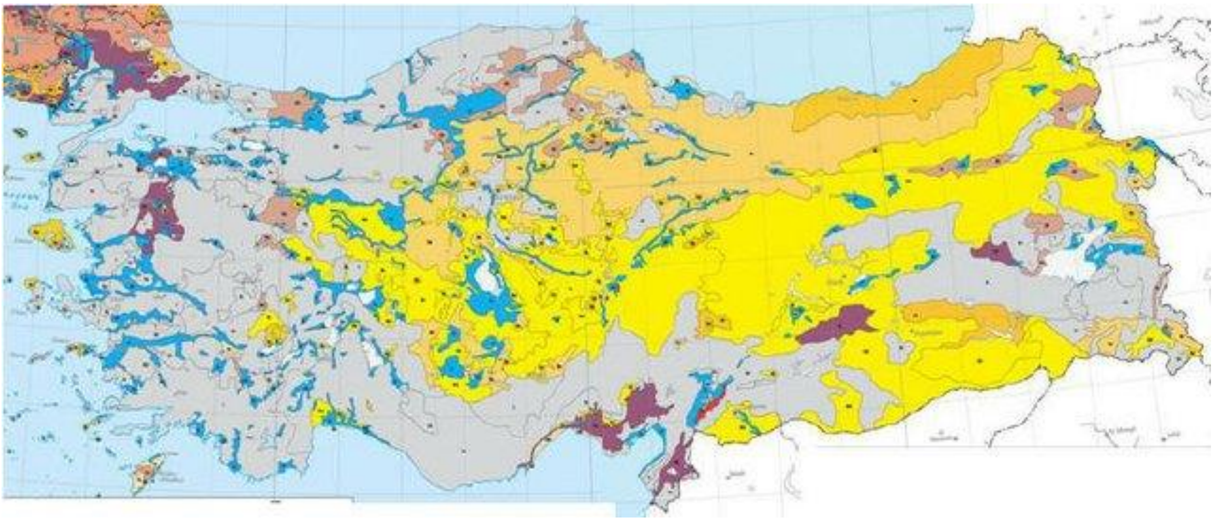
Emrah, 30+
Local Architect
Kalemler

"The new plans are all mass-housing. They all look the same. The old houses were all unique, wish they had paid more attention to renovation instead."



(Own work based on personal interviews, 2021)

APPENDIX 15: PRINCIPAL SOIL TYPE MAP TURKEY



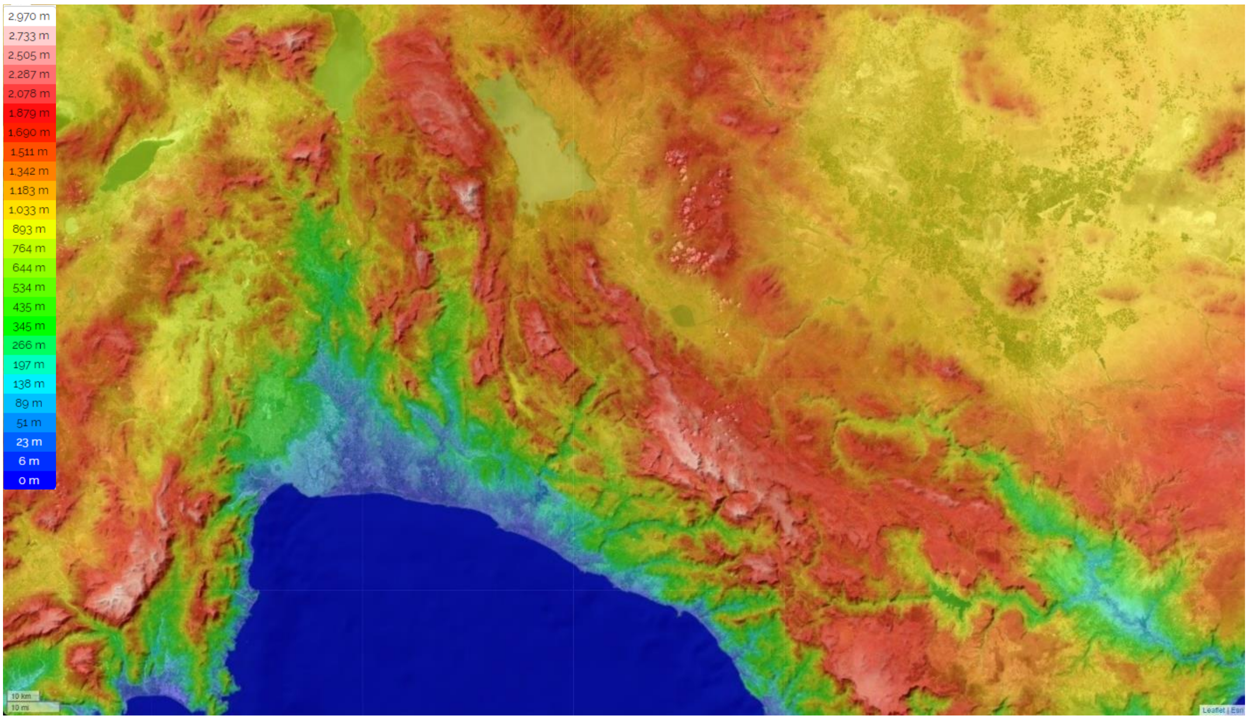
- Yellow = Calcisols (accumulation of lime)
- Gray = Leptosols (inability to hold water, earth on deeper stony soil)(stony soil explains the building culture)
- Blue = Fluvisols (young soil, near water/rivers/marine areas)

(From: Kük & Burgess, 2010, p.205. https://www.researchgate.net/publication/268368874_The_Pressures_on_and_the_Responses_to_the_State_of_Soil_and_Water_Resources_of_Turkey)

APPENDIX 16: PHOTOGRAPHY OF LOCAL SOILS

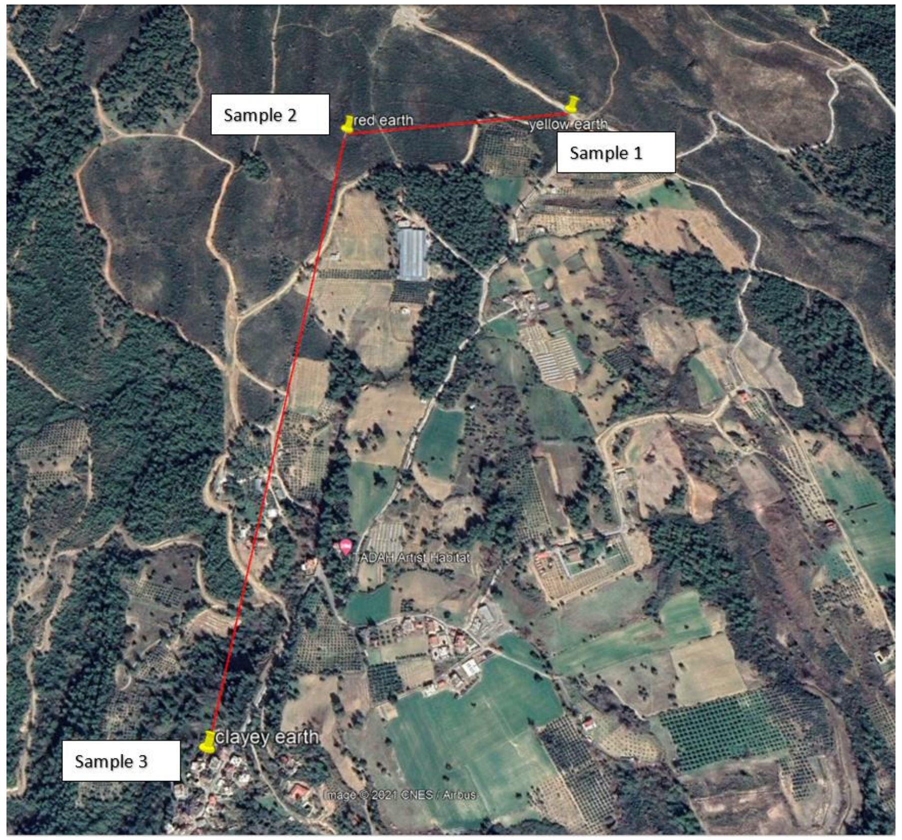
(Own images, 2021)

APPENDIX 17: LOCAL LANDSCAPE MAP



(From: Topographic-Map, 2021, https://en-gb.topographic-map.com/maps/jdas/Antalya/)

APPENDIX 18: LOCATIONS OF THE TAKEN SOIL SAMPLES



Local map of sample excavation points in Kalemler (Own notes, Google Earth, 2021)

Sample 1

Sample 2

Sample 3

Local map of sample excavation point in Sonsuz Şükran (Own notes, Google Earth, 2021)

Sample 4

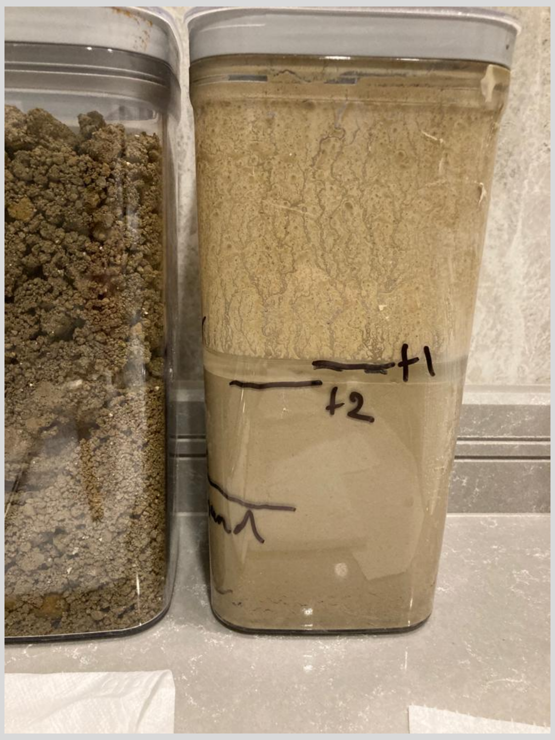
APPENDIX 19: RESULTS OF THE 'INITIAL IMPRESSION'-TEST

	Location:	**Touch/Texture**	**Smell**	**Sight/colour**	**Depth excavation:**
Sample 1	Kalemler village; *higher up in the mountains*	Sandy, dry	No smell	- Light Yellow - Best for earth bricks / blocks and rammed earth construction *(Barefoot Architect, p.298)* *(Rammed earth construction, p.16)*	1 meter; *with shovel*
Sample 2	Kalemler village; *higher up in the mountains*	Sandy, dry	No smell	- Red brownish/yellow - Suitable for earth bricks / blocks and rammed earth construction	1-2 meter(s); *freshly ploughed*; *with shovel*
Sample 3	Kalemler village; *centre*	Wet, clayey	No smell	- Gray → clayey - Balance out with sand, then suitable for earth bricks / blocks -Use as binder for rammed earth construction -Not suitable on its own	3 meters; *already excavated by machine*
Sample 4	Infinite Gratitude village; *centre*	X	No smell	-Red and Yellow -Best for earth bricks / blocks or rammed earth construction	From building site; *already excavated*

Table: Results 'initial impression'-test. (Own work, 2021)

Appendix 20: Results 'Field tests with tools"

"Particle size by sedimentation" – test *from sample 3*

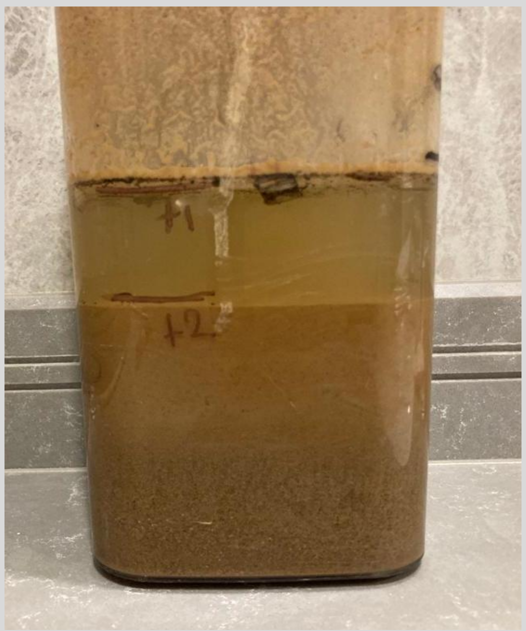


Too clayey

"It is often necessary to combine earth from one area with some from another part of the site" (Barefoot Architect, Van Lengen, 2007, p.298) →

Mixed sample 1,2 and 3 to balance out the clayey and sandy samples to make a 'suitable recipe'. One can play the percentages of sand-clay, alternating how you mix the samples together.

"Particle size by sedimentation" – test *from samples 1, 2 and 3 mixed equally*



Results composition:

T1= 7cm
T2= 8,6cm
T3= 11,5cm

Clay: 25,2%
((11,5-8,6)/11,5 x 100=25,2)

Silt: 13,9%
((8,6-7)/11,5x100 = 13,9)

Sand & Gravel: 60,87%
(7/115x100=60,87)

"Roll"-test

Preparation: Ball dried in sun, did not break into pieces, passed the test. This means there is enough clay in the sample to take the roll-test.

Roll broke off at +- 9,5 cm , which means the mixed sample passed this test. There is enough clay for earth façade construction methods.

"Soap"-test

Purpose: to find out if the soil is mainly clay or silt.

Soil does not stick much to hand and washes off easily. It may be usable for innovated earth façade construction methods as it is.

"Drop"-test

Purpose: to find the 'Ideal Water Content' and to check this during construction.

Did break, and not into a lot of small pieces: suitable for use, water content is sufficient for earth façade construction methods.

“Shrink box”-test

The shrinkage was less then 12mm: soil is satisfactory for innovated earth façade construction methods without additional stabilizer.

“Tests with moulds”

Mixed sample 1,2,3: Best

Sample 1

Sample 2

Sample 3

Appendix 21: Comparison table of innovated earth façade construction methods

Façade construction:	Mudbrick	Rammed earth	Compressed earth blocks	Light earth	Cob
Main façade construction principle	Mixing excavated soil(s) with water and straw into a timber mould for bricks. After air drying, the façade is built by bricklaying the dried mudbricks with earth mortar.	Ramming a moistened mixture of excavated soils into timber formwork. The soil mix is poured to a depth of approx. 20cm and rammed to 50% of its original volume. Lime mortar used horizontally when 50-80cm high layers are finished.	Compressing damp excavated soil and aggregate at high pressure to form blocks. Blocks stapled up after drying with minimal amount of earth mortar without aggregate.	Light earth wall infill in timber structures. Multi-purposed: wet infill, dried bricks, blocks, panels.	Mixing excavated soil with straw and water. Building up walls by stacking hand-shaped balls of the mixture. 45cm dried high layer, then next layer.
Loadbearing ability on its own	Load bearing, 50cm thick	Load bearing, 40-60cm thick	Load bearing, 50 cm thick	Not load bearing, thickness varies	Load bearing, 40-60m thick walls
Wall thickness : Wall high ratio	1:10 (2 storeys)	1:8-1:12 (2 storeys)	1:10 (2 storeys)	>1:15 (multiple storeys)	1:10 (2 storeys)
Structural support	Not necessary *Tree trunks or timber columns and beams for roof*	Not necessary *Tree trunks or timber columns and beams for roof*	Not necessary *Tree trunks or timber columns and beams for roof*	Timber beams and columns	Not necessary *Timber beams and columns for roof*
Splashing zone	Stone masonry	Stone masonry/concrete plinth	Stone masonry	Stone masonry/concrete plinth	Stone masonry
Masonry unit/ Monolithic/ Panel	Masonry unit	Monolithic	Masonry unit	Infill: masonry unit/ panel based	Monolithic; sculptured
Implementation	After drying	Moist	After drying	Wet or after drying	Wet
Soil consistency	10%-30% clay *(if more, straw becomes necessary to prevent cracks by clay amount) (if less, clay or other stabilisers are needed)* 70% silt, sand, gravel	10%-30% clay 50%-70% gravel, sand 15%-30% silt	10%-30% clay 15%-35% coarse or fine sand 10%-70% fine gravel 15%-25% silt *(coarse gravel may disrupt or damage machine)*	*Varies upon method* 10%-30% clay 70% silt, sand, gravel *(clayey consistency)*	35% silt and clay 35% sand 30% gravel *(clayey consistency)*
Mixing material	-Straw -Water Additional: ground egg shells	-Water *Optional: Lime or cement*	-Water *Optional: cement, emulsified asphalt, or lime*	-Fibres: straw/ fine fibres/ woodchips -Water *Optional: Lime, lime mortar*	-Straw -Water *Optional: lime*
Main equipment	Pitchfork, tamper, shovel, construction ladder, wheelbarrow	Tamper, ramming pole, construction ladder, wheelbarrow, shovel	Compressing machines, construction ladder, wheelbarrow, shovel	Tamper, pitchfork, construction ladder, shovel, wheelbarrow	Pitchfork, shovel, trowel, construction ladder, wheelbarrow
On site / prefabrication	On site *Optional: pre-fab bricks*	On site	On site *Optional: pre-fab blocks*	On site	On site
Labour intensity	Intensive	Intensive	Intensive	Intensive	Intensive
Mechanical /manual	Manual	Manual *Optional: mechanical tampers*	Manual or mechanical compressing machines	Manual *Optional: machinery*	Manual
Window and door opening principle	Timber framework	Timber frameworks or pisé saw	Timber framework	Timber framework	Timber framework
Insulation	No additional insulation needed	No additional insulation needed	Additional insulation needed when walls are less than 50cm thick	Additional insulation needed when walls are less than 50cm thick	No additional insulation needed
Waterproofing	Overhanging roof and exterior lime plaster protects walls	Overhanging roof protects walls	Overhanging roof protects walls, lime as stabilizer	Overhanging roof protects walls, lime as stabilizer or lime plaster	Overhanging roof protects walls, lime as stabilizer or lime plaster
Surface treatment	-Earth plaster -Lime, stucco, whitewash plaster	Often no plaster	Often no plaster when stabilised with cement. Not stabilised: -Plaster: lime, stucco	Plaster: lime / lime-gypsum / earth-sand	Plaster: lime wash, river sand and animal hair binder like cow or goat
Maintenance	Renew plaster	Use soil mixture to mortar / fill in damage	Repair with clay mortar	Renew plaster/ infill mixture, brick, block or panel	Renew plaster/ apply cob mixture
Design standards	No official design standards	No official design standards	Blocks 295mm x 140mm x 90mm	No official design standards	No official design standards
Thickness and fire durability	50 cm thick walls; 4 hours	50 cm thick walls; 4 hours	50 cm thick walls; not fully quantified	30-50cm thick walls; not fully quantified Solid masonry walls 44 cm thick - 180 mins Half-timber structured walls with panel infill and 15 mm plaster: 30 mins	40cm-60 cm thick walls; not fully quantified
Combustible	Non-combustible	Non-combustible	Non-combustible	'Not easily flammable'	Non-combustible
Thermal mass	Provided	Provided	Provided	Provided	Provided
Sound insulation	Provided	Provided	Provided	Provided	Provided
Self-building feasibility	Feasible: easy to learn with local skills & materials	Feasible: easy to learn with local skills & materials	Feasible: easy to learn with local skills & materials	Feasible: easy to learn with local skills & materials	Feasible: easy to learn with local skills & materials

Example:	 (Own image, 2021)	 (Google Images Databank, 2022)	 (Google Images Databank, 2022)	 (Google Images Databank, 2022)	 (Google Images Databank, 2022)

Table: Comparison matrix mudbrick, rammed earth, compressed earth block, light earth and cob. (Own work, 2021)

APPENDIX 22: COMPARISON TABLE OF REPAIR METHODS

Earth façade construction method	Mudbrick	Rammed earth	Compressed earth block	Light earth	Cob
Repair method exterior walls	-Renew plaster -Change bricks if necessary	-Use soil mixture to fill in / mortar crack damage	-Repair with clay mortar -Change bricks if necessary	-Renew plaster - Renew infill mixture / brick/ block or panel if necessary	-Renew plaster -Repair cracks with cob mixture

Table: Repair methods of mudbrick, rammed earth, compressed earth block, light earth and cob. (Own work, 2021)