Eszter Bence-Molnár

TRADITIONAL BUILDING MATERIALS IN THE HERITAGE INTERPRETATION OF THE MEDIEVAL SITE AT POMÁZ-NAGYKOVÁCSI-PUSZTA

MA Thesis in Cultural Heritage Studies: Academic Research, Policy, Management.

Central European University

Budapest

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TRADITIONAL BUILDING MATERIALS IN THE HERITAGE INTERPRETATION OF THE MEDIEVAL SITE OF POMÁZ-NAGYKOVÁCSI-PUSZTA

by

Bence-Molnár Eszter

(Hungary)

Thesis submitted to the Department of Medieval Studies,

Central European University, Budapest, in partial fulfillment of the requirements

of the Master of Arts degree in Cultural Heritage Studies: Academic Research, Policy, Management.

Accepted in conformance with the standards of the CEU.

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Chair, Examination Committee

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Thesis Supervisor

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Examiner

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Examiner

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External Reader

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External Supervisor

Budapest

I, the undersigned, **Eszter Bence-Molnár**, candidate for the MA degree in Cultural Heritage Studies: Academic Research, Policy, Management declare herewith that the present thesis is exclusively my own work, based on my research and only such external information as properly credited in notes and bibliography. I declare that no unidentified and illegitimate use was made of the work of others, and no part of the thesis infringes on any person's or institution's copyright. I also declare that no part of the thesis has been submitted in this form to any other institution of higher education for an academic degree.

Budapest, 26 May 2019

Signature

Abstract

Pomáz-Nagykovácsi-puszta is a heritage site with medieval ruins of a Cistercian grange, built with the mixture of monastic and vernacular techniques. The area was used for different purposes during its long history, therefore several buildings stand there without a proper function. The territory is under the management of CEU (Central European University) and KÖME (Association of Cultural Heritage Managers), who intend to revitalize the site. In this thesis I make a proposal for the transformation of a former barn, standing next to the ruins, into a visitor's facility building, with the use of sustainable solutions that refer to the heritage aspects of the site.

Therefore, I study materials of Hungarian vernacular architecture, such as stone, straw, earth and wood, answering the questions, if their use is sustainable today, what the applicable practices of their traditional use are, and if they are able to form structures suitable for the needs of the visitor's facility. As the walls of the planned building will be constructed with the help of volunteers, I analyse the wall techniques of the present-day practice based on traditional methods from the viewpoint of their feasibility in a construction camp. For this reason, I made interviews with experts of these structures. As a result of the research, I present the design, which keeps parts of the original barn, and uses for the new structures loadbearing timber frame infilled with several wall techniques, made of earth, wood and straw.

The popularity of low-tech constructions using natural materials is increasing in Hungary, therefore this topic gets special attention today. My personal experience with these techniques motivated me to conduct a research regarding their sustainability and their feasibility in a small-scale heritage project.

Acknowledgements

I would like to say special thanks to my supervisor, József Laszlovszky, for leading me through the journey of writing a thesis, as well as to Eszter Tímár for following and advising my work closely. I am grateful to Zsuzsa Reed and Alice Choyke for their remarks and to Dóra Mérai for her support on the management aspects of my thesis.

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Table of contents

List of Figures

List of Tables

Introduction

Natural materials were used in Hungarian vernacular architecture in a traditional way from the Middle Ages to the middle of the twentieth century. They were supplied from local sources and the buildings were erected without the use of modern technology, which had low ecological impact. In vernacular architecture firstly the geographical location and agricultural characteristics, secondly trade relations and industrial circumstances determined the choice of building materials, as well as the typical structures of a region.[1] In the territory of Hungary these materials are: earth, wood, stone and straw. [2]

I have some personal experience with traditional construction materials, as I have participated as a volunteer and as an organizer in construction camps working with wood, earth and straw. This work has a special atmosphere that I believe is caused by the "natural characteristic" of these materials. This experience has attracted me to the questions of their applicability in modern building practice. The approach of this thesis however, is not general: I will focus on the Pomáz-Nagykovácsi puszta heritage site, designing the transformation of a barn, – located next to medieval ruins – into a visitor's facility building. (See Chapter 4) In the plans I use traditional materials, therefore I study applicable vernacular practices and the sustainable aspects of their modern use in Hungary. (See Chapter 2) Furthermore I analyse the traditional and semi-traditional techniques of present-day architectural practice from the point of constructing buildings with the help of volunteers. (See Chapter 3)

[1] Buzás Miklós and Sabján Tibor, *Hagyományos falak* [Traditional Walls] (TERC Kiadó, 2005), 5.
[2] I consider Hungary according to its present-day borders, but a number of secondary sources go beyond these borders due to historical reasons.

History of the site

The Pomáz-Nagykovácsi-puszta site is in the Pilis Mountains, north of Budapest. (Figure 1) "The architectural remains hidden in a clump of trees on a small hill rising 15-20 metres above the valley of a stream and the modern road cover a territory that measures approximately 60x60 metres. The hill is bordered by a gully on the north, and by cultivated fields and meadows at the southern foot of the hill and on the other side of the road."[3] – This is how the latest article about the history of the ruins by József Laszlovszky and his colleagues describes the site.

According to this research, in the twelfth century a royal parish church was built on the Nagykovácsi site that was used by the inhabitants of the medieval village of Kovácsi.[4] Near present-day Pilisszentkereszt, 5.4 kilometres away from Kovácsi, a Cistercian monastery was founded by the Hungarian king in 1184, which later played a crucial role in the history of the Pomáz-Nagykovácsi-puszta site. "Soon it became one of the most powerful monasteries in the kingdom."[5] (Figure 1)

[3] Laszlovszky József et al., "The "Glass Church" in the Pilis Mountains - The Long and Complex History of an Árpád Period Village Church," *Hungarian Archaeology*, 2014, 1, accessed 11 May 2019, http://www.hungarianarchaeology.hu/?page_id=279#post-5582
[4] Laszlovszky et al., 3.
[5] Szabó Péter, "Woodland and Forests in Medieval Hungary," (doctoral dissertation), (Central European University Budapest, 2003), 189.

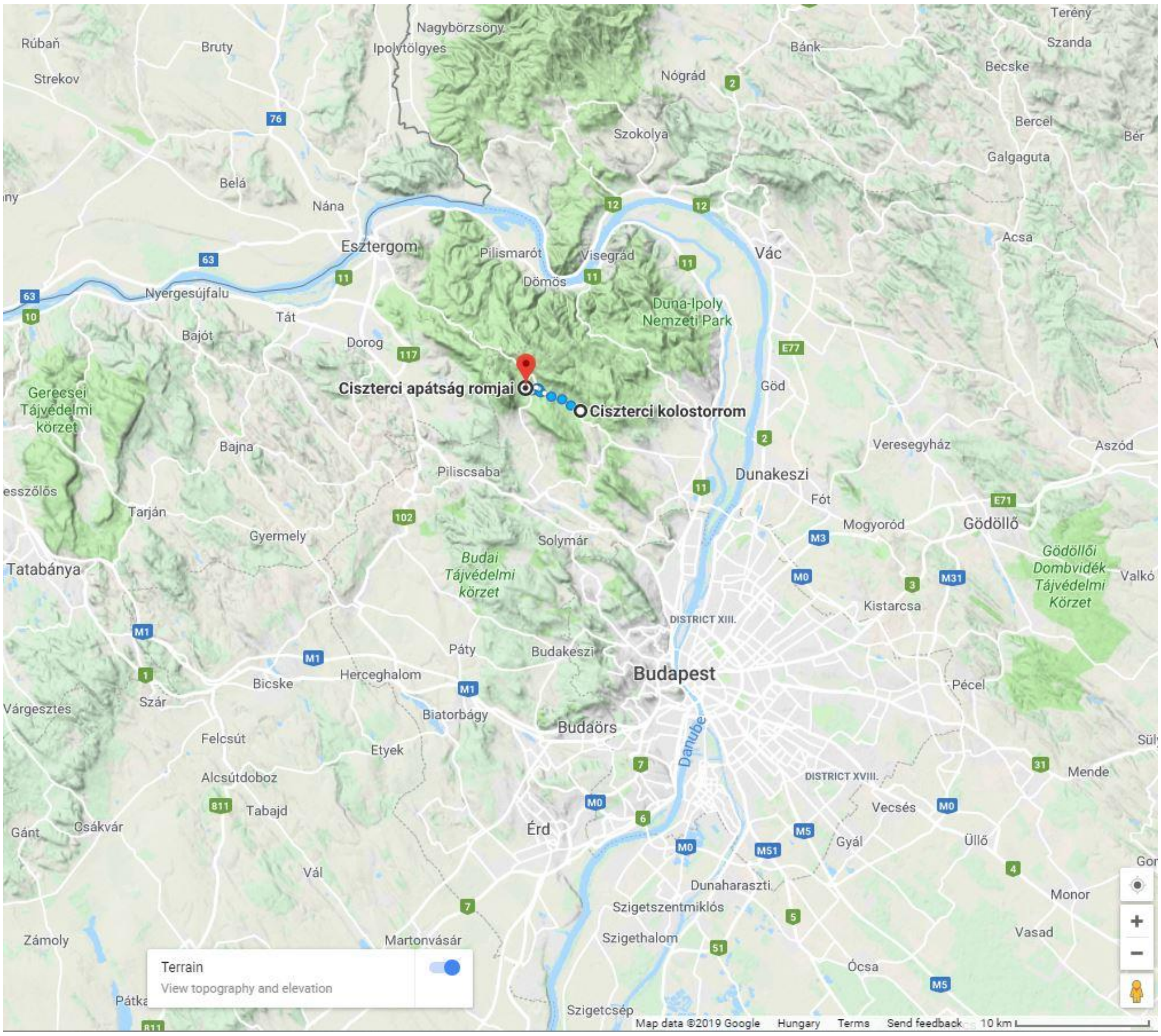

Figure 1: The ruins of the Cistercian Abbey near present-day Pilisszentkereszt and the ruins of the Cistercian grange in Pomáz-Nagykovácsi-puszta
Legend: Ciszterci apátság romjai indicates the ruins of the Cistercian Abbey near present-day Pilisszentkereszt, and Ciszterci kolostorrom indicates the ruins of the Cistercian grange located in Pomáz-Nagykovácsi-puszta site.
Source: Google Maps, "Ciszterci kolostorromtól ciszterci apátság romjaiig [From the Ruins of the Cistercian Monastery to the Ruins of the Cistercian Abbey]," accessed 4 April 2019, https://www.google.hu/maps/dir/Pom%C3%A1z,+Ciszterci+kolostorrom/Pilisszentkereszt,+Ciszterci+ap%C3%A1ts%C3%A1g+romjai,+k%C3%BClter%C3%BClet,+2098/@47.6330162,18.4380802,10.25z/data=!4m14!4m13!1m5!1m1!1s0x476a79168b5bbba3:0xca3c4c33b70682af!2m2!1d18.9461907!2d47.6772819!1m5!1m1!1s0x476a7beb0ee932ef:0xa5254446535c9433!2m2!1d18.89135!2d47.692883!3e2!5m1!1e4?hl=en.

Because of the Mongol invasion, in the thirteenth century the abbey near Pilisszentkereszt suffered great harm, but after the invasion the rights of the Order to the territory were further ensured and the monks were able to return. (Figure 2) By this time Kovácsi had become an abandoned settlement.

Figure 2: The abbey and its protecting walls.
Legend: 1. Church of the abbey 2. The yard of the monastery 3. Artificial lake 4. Workshop house 5. Water mill and its canal 6. Guesthouse (?) 7. Deep cellar 8. Gatehouse and equerries 9. Entrance gate 10. Cloister-spring
Source: Pilisszentkereszti római katolikus szent kereszt plébánia, "Pilisszentkereszt - Ciszterci Apátság [Pilisszentkereszt - Cistercian Abbey]," accessed 8 January 2019, http://pilisszentkeresztplebania.blog.hu/2013/12/12/ciszterci_apatsag.

The Cistercians took over the former parish church of the village, used it as a monastic chapel, establishing a grange of the abbey around, traces of which are still visible in the Nagykovácsi site. The monks who lived here produced glass and cultivated the land. They had three buildings for their domestic needs and for the glass industry, they created fishponds and cultivated the land in artificial terraces. In Figure 3, a measurement of the present-day ruins made in 1996 can be seen, showing how the chapel in the middle was surrounded by the workshop. During the Ottoman period the grange was abandoned. In the seventeenth century its remains were in military use, and later they became a stone quarry.

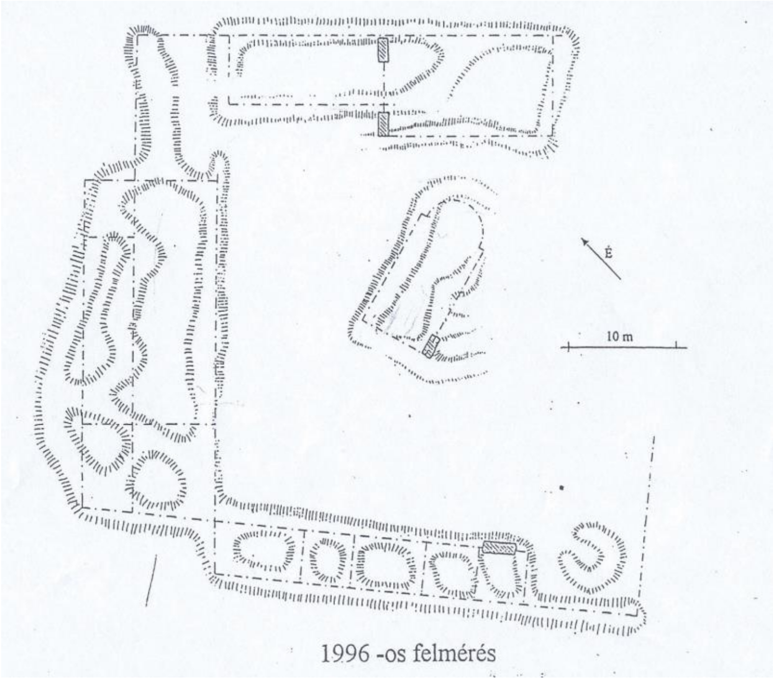

Figure 3: Ruins visible on the surface in the mid-1990s (survey by Bálint Ásztai and Beatrix Szabó)
Source: Laszlovszky József et al., "The "Glass Church" in the Pilis Mountains - The Long and Complex History of an Árpád Period Village Church," Hungarian Archaeology, 2014, 18, accessed 11 May 2019, http://www.hungarianarchaeology.hu/?page_id=279#post-5582

The ruins of the grange first attracted the attention of some local historians in the nineteenth century. In the twentieth century, several researchers tried to identify the origin of the remains. After the Second World War the area was nationalized, used by a pharma trade company. During this period the research was halted, and several buildings were built near the ruins. In 1990 the territory was bought by a private owner who used it for agricultural purposes. Around 2009 the ownership changed and since then it has been operating as a bio farm.[6] In 2011 with the permission and support of the owner, new excavations started. The article by Laszlovszky and his colleagues was published based on the latest research results.

[6] Laszlovszky et al., "The "Glass Church" in the Pilis Mountains," 2–4.

Architectural aspects of the monastery

Distinguishing different architectural areas within a typical Western Christian monastery, the first, spiritually most important space is the church, which is the most elaborated, well-designed building. The second area consists of the claustral buildings, which are less emphasized in their outlook, but they are usually well-planned. The third, in the immediate neighbourhood of the monastery, is the ‘precinct’, which was important for the economic life of the monastic community.[7] Its buildings, – stables, barns, bakeries, workshops, gardens, fishponds, – were architecturally poorly designed.

An example of the different architectural areas is the plan of St. Gall monastery in Switzerland, which show that the church and the claustral building have a detailed structural design, while the precinct was planned only as functional units. (Figure 4) Most probably these buildings were arranged more precisely on the spot, using simple structures, which can be easily built based on the constructors’ experience.

[7] Michael Aston, *Know the Landscape Monasteries* (London: B.T. Batsford, 1993), 89.

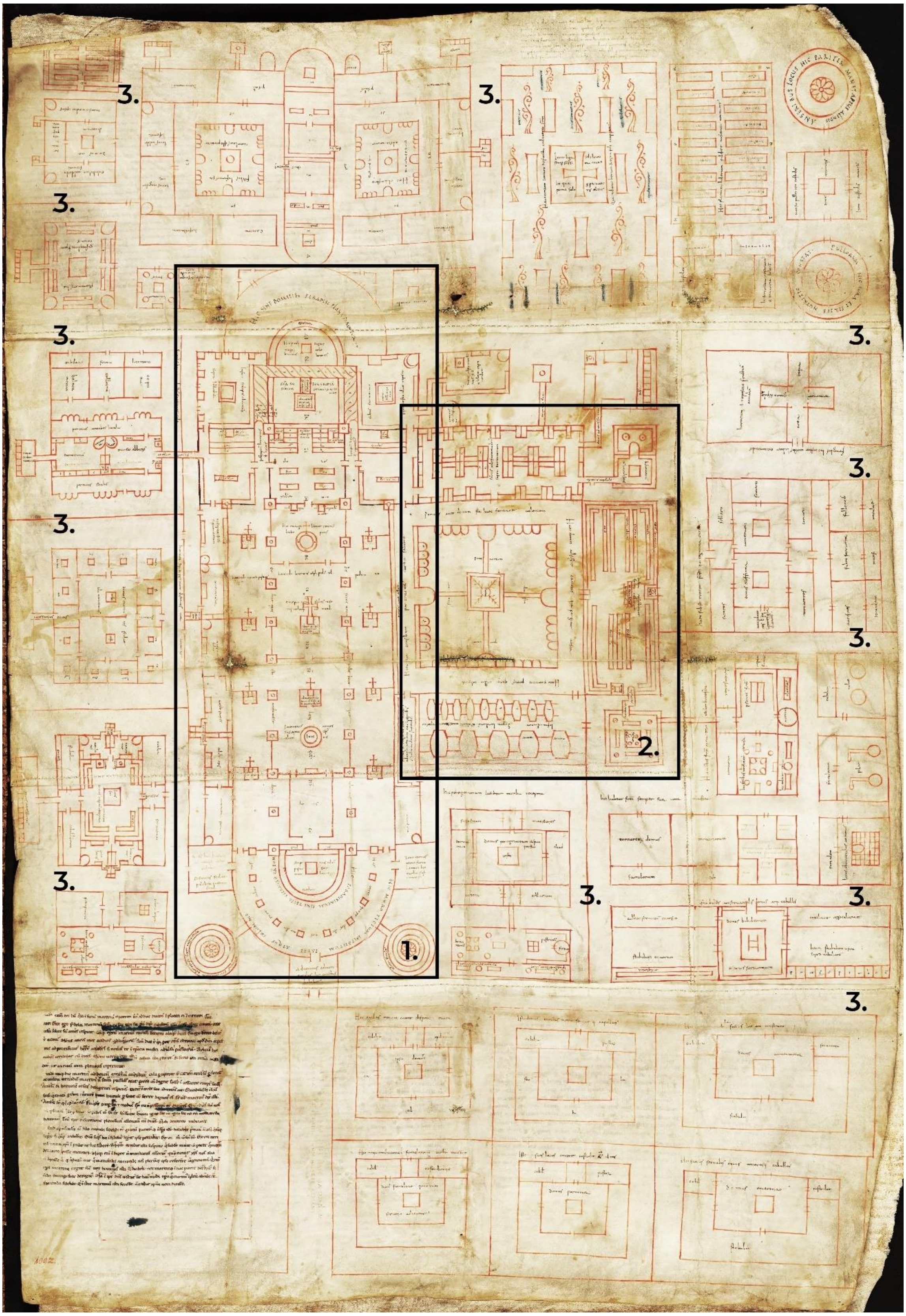

Figure 4: Plan of Saint Gall. Reichenau, early ninth century (ca.820–830)
Legend: 1. church 2. claustral building 3. buildings of the precinct
Source: Wikipedia, "Plan of Saint Gall," Wikipedia, 30 March 2019, https://en.wikipedia.org/w/index.php?title=Plan_of_Saint_Gall&oldid=890095255.

A separate unit, which is connected to the monastery in function, is the grange. There are various types in their scale, rank and architectural quality within Europe. In general, they served agricultural and industrial purposes. According to James Bond some of them were used as places for relaxation and healing, or they accommodated guests.[8] These types of granges represented a higher architectural quality.

The case of the Pomáz-Nagykovácsi-puszta monastery is different. Looking at the scale of the buildings and the archaeological traces, it was only an industrial and agricultural unit. The monks inhabited a small (14x7 m) single-nave parish church that was built with less sophisticated techniques. This assumption is based on the examination of the stone construction of the walls.

> "Though the ground surface was uneven, it seems that they did not do any levelling prior to the construction. As the ashlar stones were laid on the ground, the stone rows followed the natural slope of the surface towards the south. The problem was solved at the third row of stones: they increased the size of the ashlar from the central axis towards the south, and then switched to two smaller stones, thus doubling the row. The same method must have been repeated in the following rows, and thus the 30-40 cm difference was gradually eliminated, resulting in a horizontal top of the wall."[9] (Figure 5)

A non-elaborated building method was also used for making foundations. The stone walls consisted of three parts: and inside and an outside ashlar wall and between them an infilling layer of rubble stones. Only the inner layer had a foundation, – filling a trench with rubble stones. The stones of the outer layers were placed on the clay ground surface on a thin layer of mortar.[10]

[8] James Bond, *Molnastic Landscapes* (Gloucestershire: Tempus, 2004), 101–2.
[9] Laszlovszky et al., "The "Glass Church" in the Pilis Mountains," 6.
[10] Ibid., 5–6.

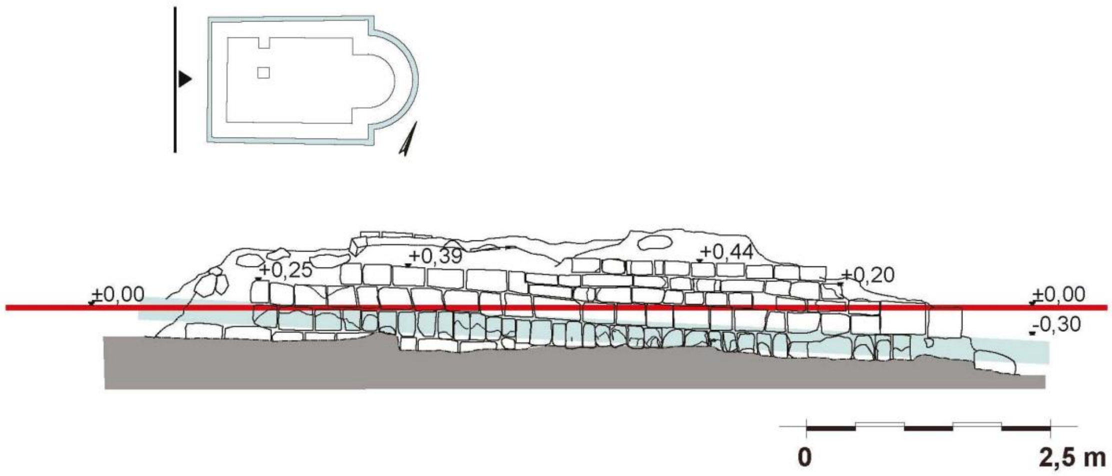

Figure 5: The western wall of the church displaying the ashlar rows following the sloping ground level and the method of eliminating the divergence (survey by Beatrix Szabó)
Source: Laszlovszky et al., "The "Glass Church" in the Pilis Mountains," 8.

We do not have data about the builders of the church, but it was first used by the inhabitants of Kovácsi, which could be a reason for the non-sophisticated construction methods. The fact that the Cistercians found this former parish church suitable for the purposes of a grange, also confirms the assumption that this monastery served only agricultural and industrial purposes without a representative role.

About the building structures of the workshop there is no study available. What I know about these buildings from József Laszlovszky, the leader of the excavations, is that the excavated northwest wing originally consisted of three rooms and the forth room was attached in a later construction period. During the excavation of the monastery clear traces of medieval glass production were found, among them "remains of the furnaces (bricks made of specific fireproof clay and that display characteristic shapes). The foundation of a kiln was unearthed in the courtyard enclosed by the buildings, attached to the facade of the western wing."[11]

[11] Laszlovszky et al., "The "Glass Church" in the Pilis Mountains," 10.

The non-elaborated building techniques of the church and the additive architectural approach to the monastic site, – whose focus was functionality, – gives the basis of my statement, that this grange in architectural quality can be compared with a precinct. An important aspect of precincts is that in their constructions structures of vernacular architecture were often used. An example of this phenomenon is the Franciscan Mount Beuvray monastery in France.

This monastery was built around 1400 and it served monastic purposes until the seventeenth century. The building of its precinct (circled in Figure 7 and Figure 8) is similar to the excavated workshop of Pomáz-Nagykovácsi-puszta site. (Circled in Figure 6) The two buildings are same in their scale, and in both cases a three-roomed building was extended with another room with the same additive architectural method. The similarity is the most outstanding in the case of the fourth and the fifth building phases of Mount Beuvray monastery, therefore I present only these phases among the eight, that the archaeological studies distinguished. (Figure 7 and Figure 8)

Figure 6: The excavated northwest workshop wing of Pomáz-Nagykovácsi-puszta site
Source: Google Earth, "Ciszterci kolostorrom [Ruins of the Cistercian Monastery]," accessed 16 May 2019, https://earth.google.com/web/@47.6772503,18.94601133,245.30551899a,224.86663534d,35y,12.9793907h,0.56773883t,-0r.

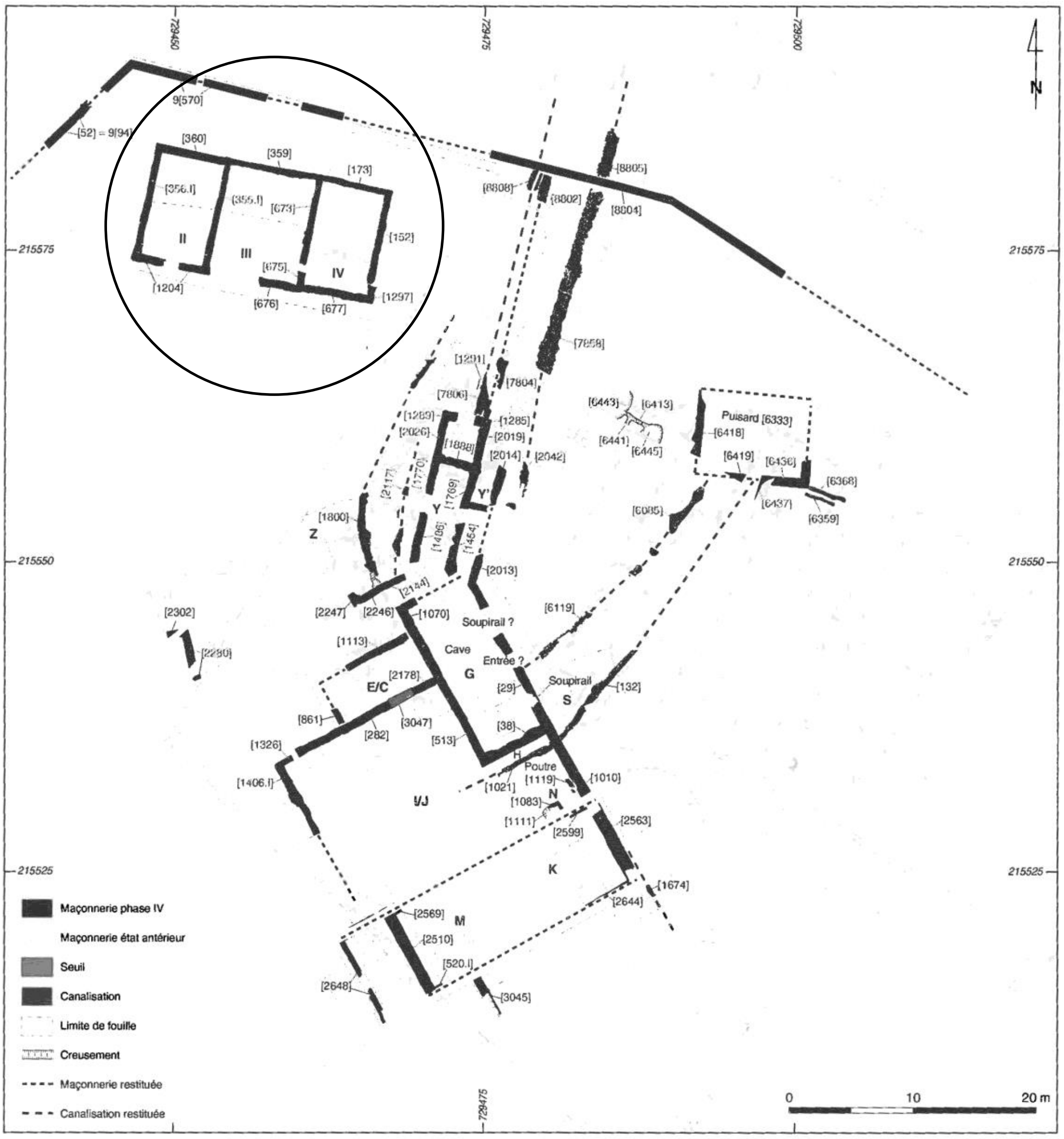

Figure 7: Bibracte, Mount Beuvray Monastery, Phase IV
Source: Patrice Beck and Benjamin Saint-Jean-Vitus, "Le Couvent Des Cordeliers Du Mont Beuvray - Histoire et Archéologie [The Convent of the Mount Beuvray Monastery - History and Archaeology]," Collection Bibracte 27 (2017): 80.

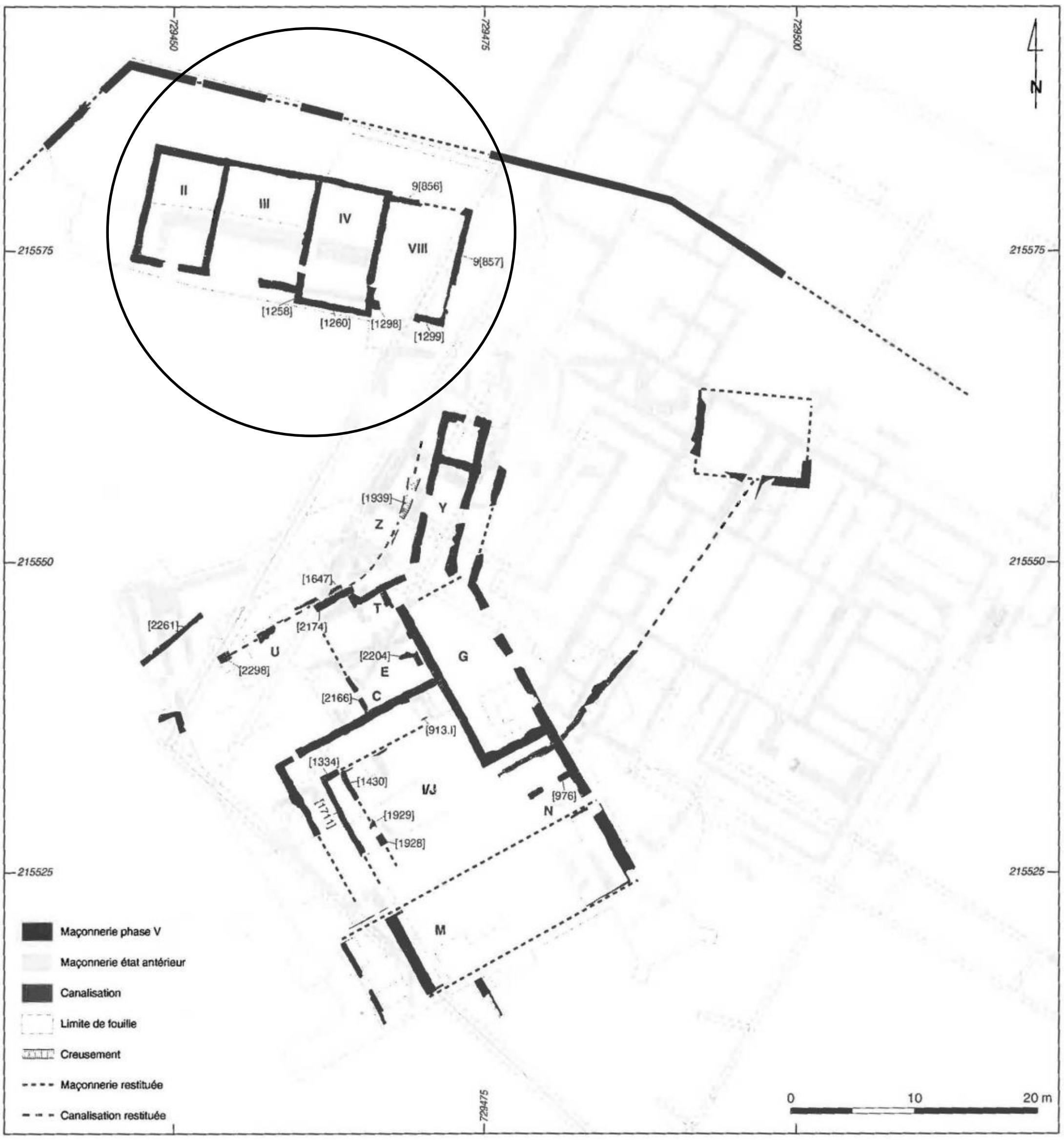

Figure 8: Bibracte, Mount Beuvray Monastery, Phase V
Source: Beck and Saint-Jean-Vitus, "Le Couvent Des Cordeliers Du Mont Beuvray," 88.

The historical and archaeological research of the Mount Beuvray monastery applied a special method in recreating the image of the precinct. Existing examples of vernacular architecture of the area were examined and used in the architectural reconstruction of the annex. (Figure 9 and Figure 10) According to researchers the building is based on a vernacular archetype that is still present in the region.[12]

[12] Patrice Beck and Benjamin Saint-Jean-Vitus, "Le Couvent Des Cordeliers Du Mont Beuvray - Histoire et Archéologie [The Convent of the Mount Beuvray Monastery - History and Archaeology]," *Collection Bibracte* 27 (2017): 168–74.

Figure 9: Aspect of vernacular architecture today around Beuvray: facade of a recently abandoned railway at Fontaines near Autun (photo P. Beck)
Source: Beck and Saint-Jean-Vitus, "Le Couvent Des Cordeliers Du Mont Beuvray," 168.

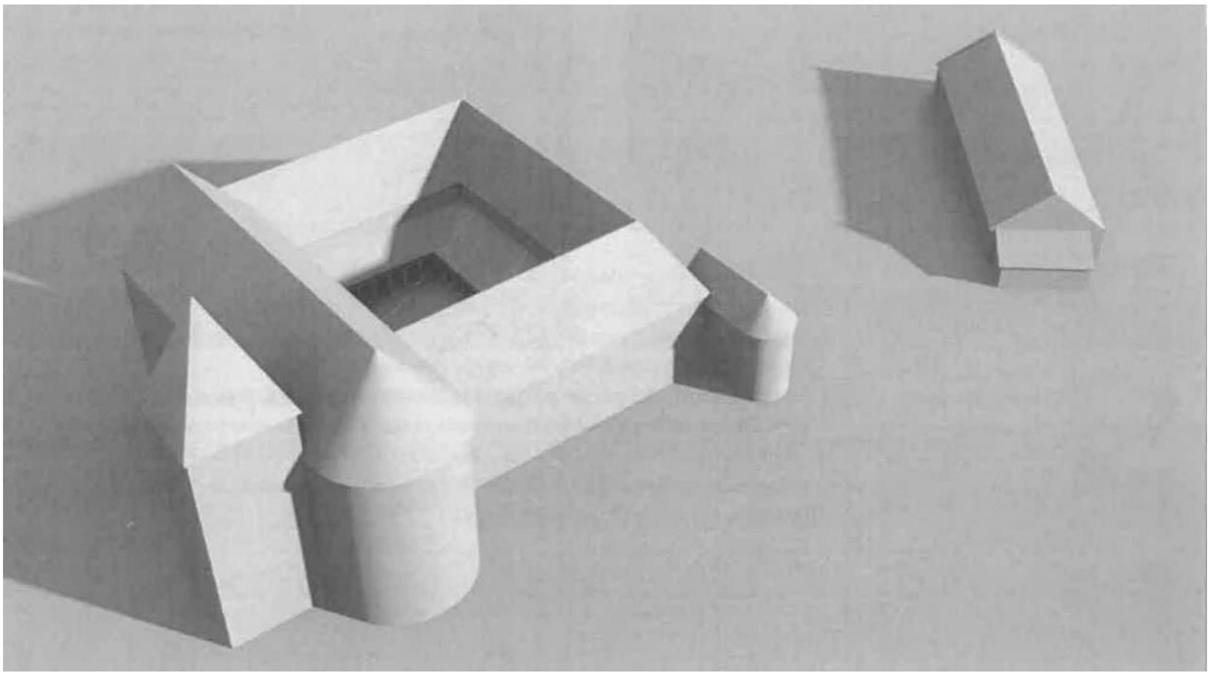

Figure 10: Bibracte, Mount Beuvray Monastery, Architectural reconstruction
Source: Beck and Saint-Jean-Vitus, "Le Couvent Des Cordeliers Du Mont Beuvray," 174.

Examining the scale and the quality of the buildings based on the archaeological results in the monastic site of Pomáz-Nagykovácsi-puszta, it can be assumed that some structures were built with vernacular techniques, like the building of the precinct of Mount Beuvray monastery. Therefore, I find the study of the vernacular building methods appropriate in context of this site.

Heritage aspects of the site

The Pomáz-Nagykovácsi-puszta site has complex heritage values. The monastic period is determinant in the interpretation of the site. The church, after serving as a parish church of a former settlement, was used by the Cistercian monks, who maintained this already existing building physically and spiritually. Creating a manorial grange here, they mixed monastic and vernacular techniques in the construction of their three buildings.

It was a location where important industrial activity took place, as a glass workshop was operated in the buildings making the grange ”one of the few examples of monastic glass production centres known from the Middle Ages.”[13] It connects the site with other European Cistercian monasteries as recent studies have demonstrated that the Order established several “important economic centres specialized on various types of crafts, often applying innovative technologies” within Europe.[14]

The Cistercian land use, characteristic of the Order, ensured an elaborated and sustainable farming system. The Cistercian Order, being an international, early-twelfth-century organization, was “known to have invented and used new agricultural methods and was also

[13] Mérai Dóra, “Pomáz-Nagykovácsi-puszta Cooperative Heritage Lab, Site Visit OpenHeritage First Consortium Meeting June 24, 2018,” (project documentation), (Cultural Heritage Studies Program Central European University Budapest, 2018), 13.

[14] Ibid., 13.

remembered as the Order that cleared and cultivated much previously “pristine” land.”[15] However in Hungary, according to Beatrix Rományi, Cistercians had problems with the lack of work-force, therefore Hungarian monasteries differed from other European ones. The Pilisszentkereszt monastery had incomes from toll, which means, they “did not need to live on the incomes produced by their immediate environment. But they still had to live somehow, that is they had to cultivate the land surrounding the monastery.”[16] This means that the agricultural use of land in Pilisszentkereszt and Nagykovácsi monasteries was a low-scale activity compared to other European Cistercian monasteries. It can be assumed that they might have cultivated the land for their own needs or for small-scale trading. The analyses of the landscape archaeological features of the Pilis grange showed that the monks “established a water management system consisting of three fishponds, dams, and channels, and created terraces for agricultural cultivation.”[17] This means that the medieval land use of Pomáz-Nagykovácsi-puszta site consisted of sustainable, and relatively small-scale agricultural activities.

The monastic period of the site has architectural, industrial, land use and natural values that are also connected to the present-day issue of sustainability. This idea plays an important role in the interpretation of the Nagykovácsi site.

[15] Szabó, “Woodland and Forests in Medieval Hungary,” 183.
[16] Ibid., 192.
[17] Laszlovszky et al., “The “Glass Church” in the Pilis Mountains,” 9.

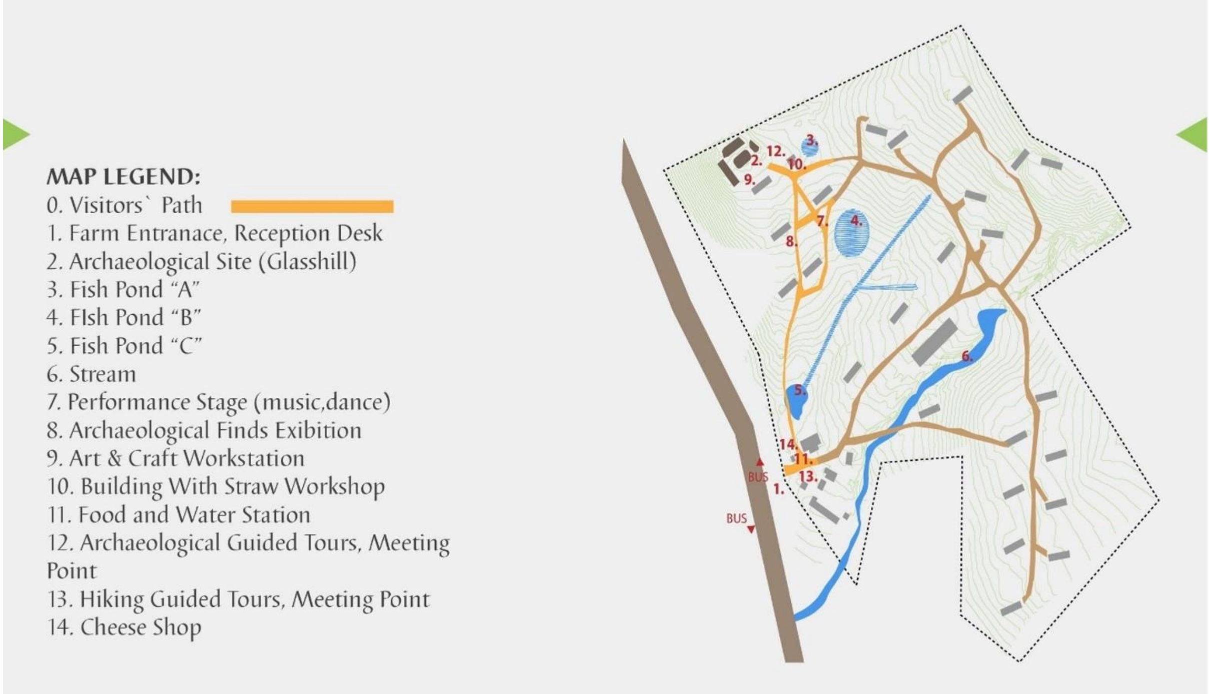

Figure 11: The map of Pomáz-Nagykovácsi-puszta site made by Aleksandar Pantic
Source: Mérai Dóra, "Pomáz-Nagykovácsi-puszta Cooperative Heritage Lab, Site Visit OpenHeritage First Consortium Meeting June 24, 2018," (project documentation), (Cultural Heritage Studies Program Central European University Budapest, 2018), 23.

In the later history of the place several buildings were built around and near the ruins of the monastic complex. (Figure 11) After the Second World War, due to the agricultural and pharma trading activities, barns and depot buildings were erected in the area, still standing on the site, most of them in a poor condition, without a proper function. (Figure 12) These buildings do not represent outstanding historical value in Hungary, unlike the monastic complex, but they belong to the history of the site. Furthermore, they have ecological value, regarding the inbuilt energy they have, therefore their demolition would not be an environmentally friendly solution.

Figure 12: The barn (right) with the guardhouse (left)
Source: photo made by Eszter Bence-Molnár, 2018

Finding a proper function for these buildings serves the idea of sustainability. This process has already started with the reconstruction of a guardhouse that serves as a place for exhibition, workshops and it will host researchers and volunteers after the construction works are finished. (Figure 12) The new structures are made of natural materials, – such as earth and straw, – or artificial materials that have a relatively low ecological impact, – like aerated concrete. (Figure 13)

Figure 13: Construction of the guardhouse
Source: Magyar Szalmaépítők Egyesülete, "Szalmaház Pomáz [Strawbale House Pomáz]," Magyar Szalmaépítők Egyesülete, accessed 8 April 2019, http://www.szalmaepitok.hu/6-hazak/hazak/133-szalmahaz-pomaz.

The Nagykovácsi site is located in the territory of the Pilis Biosphere Reserve, a status due to the uninterrupted history of the region. The whole area of the Pilis was under royal ownership, thus its use was "characterised throughout the Middle Ages by unified, organised operation and territorial separation". [18] Its forests were used for hunting, in its territories

> "only a few villages were built, primarily providing services related to the forest function. (…) In the modern history of royal seats, villages, and monasteries that perished in the Turkish Era, the royal forest area continued to be under special protection and was used in a special manner. Its settlement network remained unimpaired by the negative effects of modern industrialisation and mass immigration. In the Pilis, a natural landscape, such elements (flora and fauna) have been preserved which warranted the highest level of nature conservation ranking for the area (national park), thus ensuring that the historic landscape values (going back to the Middle Ages) have been fully preserved almost without exception."[19]

[18] UNESCO World Heritage Centre, "Royal Seats in Esztergom, Visegrád with the Former Royal Wood in the Pilis Mountain," UNESCO World Heritage Centre, accessed 16 February 2019, https://whc.unesco.org/en/tentativelists/6267/.
[19] Ibid.

The two most important heritage values of the Pomáz-Nagykovácsi-puszta are its historical and its natural values, which cannot be separated from each other. The forests around the site had a significant role in the medieval history of Hungary, now they are under natural protection. In the Middle Ages the Cistercian monks formed the landscape for their own needs in a sustainable manner. Only natural materials were applied here in the past and similar materials are used in the interpretation of the heritage site today, enabling us to draw attention to sustainability.

Management of the site

The "Royal Seats in Esztergom, Visegrád with the former Royal Wood in the Pilis Mountain" is in the Tentative List of UNESCO World Heritage Centre. This means that Nagykovácsi site is within an area that is applying to be a part of the World Heritage List.[20]

Today CEU (Central European University) and KÖME (Association of Cultural Heritage Managers) work in the field running various projects to revitalize the territory. [21] The aim of their activities is formulated by József Laszlovszky in an interview saying:

> "We would like the site to be open for visitors more often than only on one or two occasions a year, to be a living area offering different programs every month, every week." [22]

For this reason, events such as Earth Day and various straw and earth workshops are organized.

The site is in a private territory surrounded by a closed fence, which influences the methods of heritage interpretation, as the area is accessible only for organized events. This means that on the days when the gate is open, a great number of people are expected to come, who should be

[20] UNESCO World Heritage Centre, "Royal Seats in Esztergom".
[21] Association of Cultural Heritage Managers, "Kulturális Örökség Menedzserek Egyesülete [KÖME Association of Cultural Heritage Managers]," accessed 15 April 2018, http://www.heritagemanager.hu/?tag=kome-hu.
[22] Heritage Manager, "Az Üveghegyen túl – Tárd fel a Pilis szívében rejlő örökséget! [Beyond the Glasshill – Explore the Heritage Hiding in the Heart of the Pilis Mountains]," accessed 15 April 2018, https://www.youtube.com/watch?v=XtqEDW3Gv4Y&vl=hu.

engaged by numerous programs happening at once. The complex values of the site enable various projects in its territory, that is advantageous for this type of visitor engagement. Today, several projects are in process in Pomáz-Nagykovácsi-puszta, such as:

- the excavation of the manorial complex of the Cistercian monastery
- the protection of the landscape that was cultivated by the monks
- the reconstruction of a monastic garden
- the establishment of a nature trail
- the revitalization and expansion of the old guardhouse

Since 2018 the site has been involved in the four-year-long Open Heritage program, gaining international support in finance and assistance. Therefore, a management group has been established within CEU, who have articulated the aims of the Cooperative Heritage Lab, that works on the programs. These goals are:

- "Finding a complex, and economically sustainable functionality (…)
- Integrating it [the site] regionally and nationally into heritage paths
- Building co-operation with local institutions using the concepts of local historical heritage
- Inviting the local community and creating a virtual community (…)"[23]

The approach of the managers, – articulated in these goals, – is called adaptive heritage reuse. This method focuses on the use of the site, adding new layers, – values and functions, – while preserving and building on earlier ones. It aims to give a new life to a heritage site, considering the present-day situation as a stage in its history.[24]

[23] Mérai, "Pomáz-Nagykovácsi-Puszta Cooperative Heritage Lab," 1.
[24] Justine Clark, Helen Lardner, and Tanya Wolkenberg, "Adaptive Reuse of Industrial Heritage: Opportunities & Challenges" (Heritage Council of Victoria, 2013), 4.

My project, dealing with vernacular structures in the interpretation of the site, follows the ideas of adaptive reuse. Vernacular architecture is an additional layer in the life of the site, at the same time it is connected to the present-day issues of sustainability and to the historical heritage of the site. Furthermore, the goal of my project, the design of a visitor's facility building contributes to the use of the site. (See Chapter 4)

Chapter 1 – Issues of sustainable and traditional building methods

1.1 Interest in traditional and sustainable building methods

Hungarian traditional rural culture started to get attention at the beginning of the twentieth century. Vernacular architecture became the topic of cultural debates, which was a catalyst of scientific work. In 1949 Hungarian monument protection experts decided to protect traditional rural architecture, therefore research and documentation were started. Ethnographers analysed the results and defined the directions of research. In 1967 Hungarian Open-Air Museum was established, which collected and rebuilt vernacular houses.[25] Thanks to these processes there are numerous written resources and existing examples in museums of vernacular architecture. Research results about building techniques using natural materials, including traditional building techniques are published even nowadays.

On the other hand, houses built with traditional techniques exist not only in museums. According to the Hungarian Central Statistical Office, the proportion of earth-walled houses was 13 per cent in 2016.[26] Most of them are old constructions, as modern earth technique is not significant in the building industry today. The presence of a significant number of houses made of traditional earth structures is not only a heritage issue, but also an issue of sustainability, as in case of their unnecessary demolition, energy and natural resources are wasted. Therefore,

[25] Hungarian Open-Air Museum, "A Szentendrei Skanzen története [The History of Hungarian Open-Air Museum in Szentendre]," accessed 18 March 2019, http://skanzen.hu/hu/a-skanzen/kik-vagyunk/a-szentendrei-skanzen-tortenete.
[26] Portfolio, "Annyian élnek vályogházban, mint panelben Magyarországon [The Same Amount of People Live in Panel Houses Than in Earth Houses in Hungary]," accessed 18 March 2019, https://www.portfolio.hu/ingatlan/lakas/annyian-elnek-valyoghazban-mint-panelben-magyarorszagon.252141.html.

experts of the building industry are dealing with problems of renovation, reconstruction and protection of earth walls.

The growing need for a sustainable lifestyle makes people search for sustainable building solutions. This means that there is a demand for houses with a low ecological impact. In Hungary a number of people's attention turns towards natural building structures. Although, the approach of the various groups and individuals differs, there are serious attempts to make the use of natural building materials popular and available. Considering walling techniques, the main topics of these movements are earth and straw bale structures. Earth wall structures usually follow traditional building methods, or a modern, developed version of traditional techniques. Straw bale structures follow the logic of vernacular architecture as they reuse a by-product of agriculture. Furthermore, straw bale is daubed with a thick layer of earth, most often using traditional methods. It means that low-tech, sustainable architecture and traditional architecture are similar not only in their main ideas but also in practice. Furthermore, organizations and firms dealing with earth walls are often involved in heritage projects as modern and traditional structures are similar.

1.2 Building regulations

For making houses of traditional and natural building materials popular, public awareness and accessibility need to be increased. Therefore, some legislative issues need to be solved, research and publications are necessary, architects trained, and constructors found or trained. The Hungarian legislation has changed in the last decade positively in relation to natural building materials due to the activity of organizations and individuals promoting natural building technologies. According to a recent article of Péter Medgyasszay and his fellow architects, the regulations provide a sound legal basis for most of these constructions, although they could be further improved.[27] The recent building regulations offer three possible solutions to prove the eligibility of a natural building product or technology.

- Providing a license of the European Technical Assessment (ETA)
- Providing a license of the National Technical Assessment (*Nemzeti Műszaki Értékelés – NMÉ*)
- Providing a certification of the technical manager in charge (*felelős műszaki vezető – FMV*)[28]

Providing an ETA or NMÉ license for natural building products, – such as earth brick, – is expensive, therefore only big factories can be present in the market, which are often foreign companies, increasing the distance of transportation compared to local factories. In the case of the certification, the lack of the methods and measures, which could help in specifying the eligibility of the structures, make the responsibility of the technical manager in charge too high. This can contribute to low quality construction practices which risk the suitability of the structures and affect the public opinion in a negative way.[29] Regarding loadbearing structures, according to the 275/2013 7. § (3) regulation, an accredited laboratory needs to be involved, which due to its expenses makes the legal construction of monolithic loadbearing earth walls impossible in practice.[30]

1.3 Professional activity

Considering earth building, – the most frequent traditional walling technique, – the knowledge about the location of the deposits and about the appropriate mixture was based on hundreds of

[27] Medgyasszay Pérer, Bihari Ádám, and Medvey Boldizsár, "Természetes építőanyagok szabályozása, különös tekintettel a vályog építési anyagokra és technológiákra [The Regulation of Natural Building Materials, with a Special Emphasis on the Earth Building Materials and Technologies]," *Metszet* 6 (2018): 84–91.
[28] Hungarian Government, "275/2013. (VII. 16.) Korm. rendelet [275/2013. (VII. 16.) Governmental Order]" (2013), https://net.jogtar.hu/jogszabaly?docid=A1300275.KOR.
[29] Medgyasszay, Bihari, and Medvey, "Természetes építőanyagok szabályozása," 84–87.
[30] Hungarian Government, "275/2013. (VII. 16.) Korm. rendelet".

years of experience. Today, finding a person in a village who has technical knowledge of earth building and local techniques is rare, however not always impossible. Vera Holczer did a two year-long research on traditional building techniques, searching masters in rural areas of Hungary.[31] Among others, she worked with János Gáspár, a well-known earth builder, who has learned the technique from an old professional at his age of twenty-two.[32] Traditional techniques are also researchable not only in the field but on paper as well, as they were documented by ethnographers and architects. Furthermore, the Open-Air Museum in Szentendre has preserved these old structures as they have collected and rebuilt vernacular houses.[33]

The building industry using natural materials is growing in present-day Hungary. The activity of this special sector is nicely summarized in Bihari and his colleagues' article:

> "The advantages of natural building structures, – humidity and heat management capability, low embodied energy, natural post-use degradation, is widely known. Therefore, the number of investors, deciding to use natural materials, is increasing. Recognizing this need, numerous Hungarian building service cooperatives made the use of these materials a significant element of their brand, acquiring the relevant knowledge of this field. Among others, such architect offices are: *Belső Udvar 2008 Építész, Kutató és Szakértő Kft.* [Belső Udvar 2008 Architect, Research and Expert Kft.],[34] *Környezet és Energiatudatos Építészeti Stúdió* [Ecological and Energy Efficient Architect Studio],[35] and Zsuzsanna Kozma architect.[36] Significant constructors of the field are Árpád Bíró[37] and János Gáspár earth craftsmen,[38] and the *Vályogház*

[31]Holczer Veronika, "Jegyzetek [Notes]," accessed 21 January 2019, http://holczerveronika.blogspot.com/p/jegyzetek.html.
[32] Gáspár János, "Bemutatkozom - Újra itt a vályogfal ideje! [Introduction - The Time of Earth Walls Is Here Again!]," accessed 28 January 2019, https://valyogfal.hu/bemutatkozom/.
[33] Hungarian Open-Air Museum, "Skanzen - Szabadtéri Néprajzi Múzeum [Hungarian Open-Air Museum]", accessed 28 January 2019, http://skanzen.hu/en.
[34] Belső Udvar Építész Kutató és Szakértő Iroda, "Indításként... [As an Introduction…]," accessed 14 April 2019, http://belsoudvar.hu/.
[35] Környezet és Energiatudatos Építészeti Stúdió, "Környezet És Energiatudatos Építészeti Stúdió [Ecological and Energy Efficient Architect Studio]," accessed 14 April 2019, http://energiatudatoshaz.hu/.
[36] Kozma Zsuzsanna, "Kozma Zsuzsanna építész [Zsuzsanna Kozma Architect]," accessed 14 April 2019, https://www.kozmazsuzsanna.com/.
[37] Bíró Péter, "Rólunk - Biokay vályogvakolatok [About Us - Biokay Earth Plasters]," accessed 14 April 2019, https://valyogvakolat.hu/biobaushop-kft-bemutatkozas/.
[38] Gáspár, "Bemutatkozom - Újra itt a vályogfal ideje!".

> *és Kemence Kft.* [Earth-house and Outside Oven Kft.].[39] Furthermore, expert groups are present in Hungary, such as *Magyar Szalmaépítők Egyesülete* [Hungarian Straw builders' Foundation], [40] *Sárkollektíva Egyesület* [Mudcollective Foundation], [41] the "*Nagyapám Háza*" program ["My Grandfather's House Program],[42] the *Energia és Környezet Alapítvány* [Energy and Environment Foundation],[43] the *Öko Home Expo* [Eco Home Expo][44] and the Regio Earth Festival,[45] which fill a gap teaching, researching and promoting building technologies applying traditional and natural materials." [46]

Furthermore, I highlight the doctoral dissertation of Péter Medgyasszay, on the ecological impact of the earth-straw building structure. He, together with Ádám Bihari and Boldizsár Medvey, works on the legal background of natural building materials.

[39] Vályogház és Kemence, "Kezdőlap [Starting Page]," accessed 14 April 2019, https://www.facebook.com/valyoghaz/.
[40] Magyar Szalmaépítők Egyesülete, "Bemutatkozunk - Magyar Szalmaépítők Egyesülete [Introduction - Hungarian Strawbuilders' Foundation]," accessed 14 April 2019, http://szalmaepitok.hu/bemutatkozunk.
[41] Sárkollektíva, "Kezdőlap [Starting Page]," accessed 14 April 2019, https://www.facebook.com/sarkollektiva/.
[42] Nagyapám Háza, 'Kezdőlap [Starting Page]," accessed 14 April 2019, https://www.facebook.com/Nagyap%C3%A1m-H%C3%A1za-1579901552321023/.
[43] Eneregia és Környezet Alapítvány, "Energia és környezet alapítvány [Energy and Environment Foundation]," accessed 14 April 2019, http://energiaeskornyezet.hu/component/phocadownload/category/1-szalmabala-epiteszeti-anyagok%3Fdownload%3D12:tipusterv.
[44] Öko Home Expo, "Öko Home Expo konferencia és kiállítás [Eco Home Expo Conference and Exhibition]," accessed 14 April 2019, http://xn--kohome-vxa.hu/.
[45] Regio Earth, "Kezdőlap [Starting Page]," accessed 14 April 2019, https://www.facebook.com/regioearth/.
[46] Medgyasszay, Bihari, and Medvey, "Természetes építőanyagok szabályozása," 84–85.

1.4 Ecological impact

Natural building materials – such as earth and straw bale structures – are promoted as environmentally friendly solutions, meaning that they have a low ecological impact. In the next chapter I will examine the ecological impact of traditional building materials. Sustainability has various measures, among which I introduce those, which I use in the next chapter. [47]

The Operating Energy is the "energy used in buildings during their operational phase, as for: heating, cooling, ventilation, hot water, lighting and other electrical appliances".[48] (Table 1) The Embodied Energy is "the sum of all the energy needed to manufacture a good."[49] It has two forms: initial and recurring embodied energy. Life Cycle Assessment "studies the environmental aspects and potential impacts throughout a product's life (i.e. cradle to grave) from raw material acquisition through production, use and disposal."[50] Among the measures, Life Cycle Assessment is the most common, internationally accepted method, in which direct and indirect energy is distinguished.[51] In Table 1, I introduce the stages of the life cycle by relating them to the categories and subcategories of Life Cycle Assessment, Operating Energy and Embodied Energy.

[47] Canadian Architect, "Measure of Sustainability Introduction," accessed 26 January 2019, https://www.canadianarchitect.com/asf/perspectives_sustainibility/measures_of_sustainablity/measures_of_sustainablity_intro.htm.

[48] Igor Sartori and Anne Grete Hestnes, "Energy Use in the Life Cycle of Conventional and Low-Energy Buildings: A Review Article," *Energy and Buildings* 39 (2007): 249.

[49] Ibid., 249.

[50] International Organization for Standardization, "International Standard ISO 14040 - Environmental Management - Life Cycle Assessment - Principles and Framework" (International Organization for Standardization, 1997), iii, https://web.stanford.edu/class/cee214/Readings/ISOLCA.pdf.

[51] Aashish Sharma et al., "Life Cycle Assessment of Buildings: A Review," *Renewable and Sustainable Energy Reviews* 15, no. 1 (2011): 871, file:///C:/Users/User/Downloads/RSER1096.pdf.

Table 1: The stages of the life cycle associated with the categories of Life Cycle Assessment, Embodied Energy and Operating Energy.

<table>
<tr><th colspan="5">Measures of sustainability</th><th>Stages of life cycle</th></tr>
<tr><td rowspan="8">LIFE CYCLE ASSESSMENT (LCA)</td><td rowspan="3">INDIRECT ENERGY (LCA)</td><td rowspan="6">EMBODIED ENERGY</td><td rowspan="5">INITIAL EMBODIED ENERGY</td><td rowspan="3">INDIRECT EMBODIED ENERGY</td><td>acquisition of raw material</td></tr>
<tr><td>transportation of raw material</td></tr>
<tr><td>production of building material</td></tr>
<tr><td rowspan="5">DIRECT ENERGY (LCA)</td><td rowspan="2">DIRECT EMBODIED ENERGY</td><td>transportation of building material</td></tr>
<tr><td>construction</td></tr>
<tr><td>RECURRING EMBODIED ENERGY</td><td colspan="2">maintanance, reparing</td></tr>
<tr><td>OPERATING ENERGY</td><td colspan="3">consumption of energy by the building</td></tr>
<tr><td colspan="4">post-use disposal or recycling</td></tr>
</table>

The relation and importance of these measures are different in the case of each construction, depending on the location, function and usage of the building considered. As the production methods, average transportation methods and distances, types of energy resources are different in each country, using Hungarian data would show me precise result. However, finding Hungarian data is a limitation in my case. According to a research report, a Hungarian construction material and a building structure database has been compiled, but not accessible.[52] I do not have a database that contains all the materials or structures I am dealing with. Therefore, I will examine them according to the available resources in the next chapter.

Life Cycle Assessment can be done in the case of a product, building material, structure or a whole building. In its impact assessment Life Cycle Assessment uses the CML method, which sorts the environmental effect of the product in several characterization factors, focusing on the environmental problems. The most common factors are: Global Warming Potential (GWP), Acidification Potential (AP), Ozone Depletion Potential (ODP), Photochemical Ozone Creation Potential (POCP) and Eutrophication Potential (EP).[53]

In the 35/2011 EU Regulation the aspect of sustainability appears regarding the construction materials.

> „The construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable and in particular ensure the following: (a) reuse or recyclability of the construction works, their materials and parts after demolition; (b) durability of the construction works; (c) use of environmentally compatible raw and secondary materials in the construction works."[54]

This idea appears in the Hungarian regulation as well. Paragraph 50 of 253/1997. (XII.20.) specifies that the building should fit „the basic requirements of sustainable use of natural

[52] Tiderenczl Gábor et al., "Épületszerkezetek építésökológiai és -biológiai értékelő rendszerének összeállítása az építési anyagok hazai gyártási/előállítási adatai alapján [Collection of the Evaluation System of Building Ecology and Biology of Building Structures Based on Hungarian Production Data of Building Materials]" (Független Ökológiai Központ, 2006 2004), 6, http://real.mtak.hu/1364/1/46265_ZJ1.pdf.
[53] Medgyasszay Péter, Szalay Zsuzsa, and V. Horn Valéria, "Környezetbarát építés - Egyetemi jegyzet - Munkaközi változat [Environmentally Friendly Building - University Material - Version in Preparation]" (Budapest University of Technology and Economics, 2019), 17–25.
[54] European Union, "Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 Laying down Harmonised Conditions for the Marketing of Construction Products and Repealing Council Directive 89/106/EEC Text with EEA Relevance" (2011), http://data.europa.eu/eli/reg/2011/305/oj/eng.

resources".[55] This means that the Embodied Energy and the post-use disposal of the materials have to be taken into consideration.[56] However, no measures are given specifying this requirement.

As a result of focusing on Operating Energy, an energy regulation was introduced in 2006, which restricted the amount and type of energy the building needs. It requires a complex calculation of the house, determines the insulation capacity of the structures and specifies the minimum quantity of reusable energy resource as 25 per cent. The requirements of the regulation increased gradually in the recent years, the last modification happened in 2018.

Due to the requirements of the energy policy every new building, – regardless the material it is made of, – ensures a low Operating Energy to the building. Therefore, in the followings I will focus on the Embodied Energy and the post-use disposal of the examined materials. This approach is also useful for the design part of my thesis, as the building I am planning is open-air and has a seasonal use, therefore Operating Energy is not in the focus in this case.

[55] Hungarian Government, "253/1997. (XII. 20.) Korm. rendelet [253/1997. (XII. 20.) Governmental Order]" (1997), https://net.jogtar.hu/jogszabaly?docid=99700253.KOR.
[56] Medgyasszay, Bihari, and Medvey, "Természetes építőanyagok szabályozása," 3–4.

Chapter 2 – Traditional building materials

The aim of this chapter is to summarize the building materials applied in vernacular architecture with a special emphasis on their modern usage in heritage interpretation of Pomáz-Nagykovácsi-puszta site. As my intention in the design of the visitor's facility is to introduce various wall structures, those materials will be discussed that were used in vernacular architecture and that are used in modern walling practice as infilling or loadbearing structures. I will search vernacular practices using these materials that are applicable in modern sustainable building methods. Furthermore, I will look at the ecological impact of the modern products made of these materials, comparing with other modern products made of artificial materials. My aim with this part of the research is to discover "how ecological" the materials and structures of vernacular architecture are today.

2.1 Stone

Stone is the most durable building material; therefore, we have numerous sources that show that it has been used since ancient, even prehistoric times. It has a great compressive strength but its tensile and bending strength is small, therefore mostly walls and vaultings are made of this material. However, the use of stone depends on its type, as there are numerous types with quite different characteristics.[57]

[57] Mednyánszky Miklós, *Kőházak* [Stone Houses] (Budapest: TERC Kiadó, 2017), 8–22.

Applicable practices of vernacular architecture in sustainable building processes

People obtained stones in different ways in the ages of vernacular architecture.

- ‘cultivated stone’ (*termett kő)* is a by-product of agriculture. For the cultivation of lands, especially for vine growing, stones must be removed from the soil. They were usually used for building retaining walls, cellars and houses for vine pressing.
- ‘river stone’ (*patakkő*) could be found on the river bank. It did not belong to anyone and could be taken for free. As it is hard, durable, but difficult to carve, it was usually used in its original forms, without carving, for foundations or in places exposed to natural destruction. After the Second World War because of the lack of brick and cement regulations required that stone – that was river stone in practice – had to be used for foundations.
- ‘gained stone’ (*szerzett kő*) is a reused stone. After wars destroyed and abandoned houses, castles and churches became resources for those who lived around them.
- mined stone is the best-known type. In Hungary besides territories of riverbanks stone mines could be found almost everywhere. In areas where there was a need for stone, small mines were erected often by the inhabitants of the surrounding villages. The mining process depended on geographical features and the type of stone.[58] Mining was industrialized in the twentieth century increasing its scale and at the same time its ecological impact.

The first three methods of obtaining stone have a relatively low ecological impact, as in most cases only transportation requires the use of energy. Today these three methods can be

[58] Mednyánszky, *Kőházak*, 51–53.

considered in small scale constructions depending on local opportunities. The owner of the territory of the Pomáz-Nagykovácsi-puszta site has a small shop a few hundred metres away from the medieval ruins, the footing of which is made of 'river stone'. The opportunity of using 'gained stones' from the excavation can be taken into consideration for the purposes of heritage interpretation.

Sustainability of the modern building practice

In present-day architecture, stone is often used in restorations. In the case of new constructions, it forms only coatings, but wall structures made of stone are not present due to their high cost. The exceptions, including the attempts at building traditional stone walls, are rare. In these cases, usually cultivated, river or gained stones are used. As stone production for erecting walls is not significant, I do not examine the sustainability of this area.

I will examine the sustainability of traditional wall structures, which are present in the contemporary building practice. In case of using locally resourced, not-mined stones, the ecological impact of transportation is minimal. Traditional stone wall techniques require only a minimal amount of technology, such as the building of scaffolding and the use of a mixer. Therefore, the question in the case of these methods is the sustainability of the material of the mortar.

There are three types of mortars distinguished by their binders: cement, lime and earth mortars. In vernacular architecture mostly earth mortar was used, the flexibility of which is advantageous, however its strength is low. For this reason, it is not applied by contemporary building practice. Lime mortar was used by wealthier families in vernacular architecture and this material is still in use today.[59] Considering the sustainability of lime, it is important that its

[59] Mednyánszky, *Kőházak*, 83–84.

production has fundamentally changed since the industrial revolution. Cement is a modern material, not known in vernacular constructions, however, it is a common mortar type today. It is a mistake to use it for soft stone walls because of its inflexibility.[60]

One unit of sand requires similar quantities of binders in the case of cement and in the case of lime mortars. The amount of mortar that is needed for a wall unit is also similar in the two cases. Therefore, answering the question of whether cement or lime mortar is more sustainable we can focus only on the ecological impact of the binders. The general view about the sustainability of binders is that cement has higher ecological impact than lime. This is what Dougles Kent, the technical secretary of the Society for the Protection of Ancient Buildings states in his article.[61]

> "Lime requires less energy to produce than cement because limestone, the basic raw material, can be burned at lower temperatures - 900-1,000C rather than 1,300C or higher. Also, some of the CO_2 created during firing is reabsorbed by lime as it hardens. And lime can be produced locally on a small scale, cutting pollution by limiting transport distances. (…) When buildings reach the end of their lives, lime is soft enough to allow the masonry to be taken apart and reused. Cement will potentially add to landfill problems for generations to come. Last but not least, lime's ability to control moisture means it is compatible with low-energy, sustainable materials, such as water reed, straw, hemp, timber and clay."

[60] Mednyánszky, *Kőházak*, 123.
[61] Douglas Kent, "Response: Lime Is a Much Greener Option than Cement, Says Douglas Kent," *The Guardian*, 22 October 2007, sec. Opinion, accessed 11 May 2019, https://www.theguardian.com/commentisfree/2007/oct/23/comment.comment.

Table 2: UK estimates of embodied primary energy & specific CO_2 emissions of construction materials[62]

Material	Density, g/ml or t/m³	Primary Energy, kJ/g or GJ/t	Carbon, as %CO_2 by mass	Carbon, as kg.CO_2/m³
Aggregate	2.5	0.083	0.5	11
Rammed earth (no cement content)	1.5	0.45	2.3	34
Bricks (common, fired clay)	1.7	3.0	24	400
Cement mortar (1:3)	2.3	1.33	21	480
Structural concrete (excluding steel)	2.4	1.11	16	380
Ordinary concrete blocks (10 MPa)	1.45	0.67	7	105
Aerated lightweight blocks	0.75	3.50	30	225
Limestone block	2.18	0.85	5	110
Marble	2.50	2.00	12	290
Plasterboard	0.8	6.75	38	300
Gypsum plaster	1.12	1.80	12	135
Clay tile	1.90	6.50	45	850
Timber (general - excludes sequestration, i.e. excludes internal carbon content)	0.5 – 0.7	10.0	72	350 - 520
Hardboard	0.6 – 1.0	16.0	105	630 - 1050
Glass	2.50	15.0	85	2100
Steel (general - average recycled content)	7.80	20.1	140	11000
Aluminium (general & incl. 33% recycled)	2.70	155	820	22000
PVC (general)	1.38	77.2	2800	39000

Source: Ellis M. Gartner, "Are There Any Practical Alternatives to the Manufacture of Portland Cement Clinker?," Journal of the Chinese Ceramic Society 40, no. 1 (2011): 2.

Table 2 from Ellis Gartner's article, examining the embodied energy and specific embodied carbon expressed as carbon-dioxide of materials based on UK data, confirms Kent's point.[63] However, a comparative environmental assessment study produced in collaboration with mortar producers from various EU countries on 17 formulations of mortars, came to the conclusion that "there are no significant differences in terms of environmental footprint between cement and lime based mortars."[64] (Table 3) This study used the Life Cycle Assessment method, examining the materials from "cradle to the grave".

[62] Ellis M. Gartner, "Are There Any Practical Alternatives to the Manufacture of Portland Cement Clinker?," *Journal of the Chinese Ceramic Society* 40, no. 1 (2011): 2.
[63]Ibid., 1.
[64] T. Schlegel and A. Shtiza, "Environmental Footprint Study of Mortars, Renders and Plasters Formulations with No, Low or High Hydrated Lime Content" (9th International Masonry Conference at Guimaraes, 2014), 1–7, https://webcache.googleusercontent.com/search?q=cache:Uai1z6TkggwJ:https://www.eula.eu/file/516/download%3Ftoken%3Dz-g_uHSM+&cd=4&hl=hu&ct=clnk&gl=hu.

Table 3: Selected environmental indicators for cement and lime-based mortars

Category	Unit	Average cement based mortar	Average lime based mortar	Δ (LI-CE)/LI
Primary energy consumption	MJ/t	1 989	1 887	-5,40%
Abiotic resource depletion	kg Sb/t	0,676	0,624	-8,30%
Global warming potential **without** inclusion of the long term carbonation	kg eq CO_2/t	180	189	+4,7%
Air acidification	kg eq SO_2/t	0,553	0,550	~0,6%
Photochemical oxidant formatio	kg eq C_2H_2/t	$4{,}47 \times 10^{-2}$	$5{,}00 \times 10^{-2}$	+10,7%
Stratospheric ozone depletion	kg eq R111/t	$8{,}75 \times 10^{-6}$	$8{,}90 \times 10^{-6}$	+1,7%

Source: T. Schlegel and A. Shtiza, "Environmental Footprint Study of Mortars, Renders and Plasters Formulations with No, Low or High Hydrated Lime Content" (9th International Masonry Conference at Guimaraes, 2014), 1–7, https://webcache.googleusercontent.com/search?q=cache:Uai1z6TkggwJ:https://www.eula.eu/file/516/download%3Ftoken%3Dz-g_uHSM+&cd=4&hl=hu&ct=clnk&gl=hu.

A special type of cement is natural cement. "The natural designation indicates that the raw material, a type of limestone known as clayey marl is simply mined and burnt with no further additions" contrary to artificial cements. I have no data about the sustainable criteria of natural cement, therefore its comparison with artificial cement and lime is not possible. The cost of this cement in Hungary is relatively high, therefore it is not widely used in the building practice.[65]

From a practical point of view, those who intend to build with lime mortar or using dry wall technique have to face the challenges of finding an expert on these techniques. In an interview, Szabolcs Herczig, the organizer of a stone walling construction camp using lime mortar technique said that the local mason refused to participate in the camp, because he could not take the responsibility of using anything other than cement mortar.[66] (See Chapter 3)

[65] Vicatprompt, "Termék - Gyorskötő románcement [Product - Fast Curing Time Roman Cement]," accessed 11 May 2019, https://vicatprompt.hu/gyorskoto/.
[66] I have made an interview with Szabolcs Herczig on telephone in March 2019.

2.2 Straw

"Straw is the plant structure between the root crown and the grain head. The internal structure of a single straw is tubular, tough, and efficient. It contains cellulose, hemicelluloses, lignin, and silica with high bending and tensile strength. The tube shape is inherently stable and, with a microscopically waxy coat, slightly hydrophobic."[67] Many kinds of straw are suitable for building purposes, such as barley, wheat, oats, rye or flax. Furthermore, the stem of other plants has been used for making building structures, such as hop, flax and reed.

In Hungarian vernacular architecture straw constituted the fibre needed in the mud for earth walls, daubing and plasters. In territories where the cultivation of cereals was significant, hay roofs were widespread. Besides being an ingredient of earth structures, -which is an important role of straw even today, – its traditional use was not significant in vernacular wall structures. On the other hand, in present-day building practice, the application of straw bales as infilling wall structures is becoming widespread.[68] However, this technique is not traditional, – as straw was not stored in bales in the vernacular past, – it is worth to be examined because of its contribution to sustainability.

Applicable practices of vernacular architecture in sustainable building process

Vernacular farming was a sustainable system that did not produce waste. By-products of agriculture, such as straw, were used for other purposes and, – as the resources were natural materials, – the needless materials degraded fast, in many cases enriching the soil with

[67] Taha Ashour and Wei Wu, "Using Barley Straw as Building Material," *Barley: Production, Cultivation and Uses*, 2011, 273–300.
[68] Eneregia és Környezet Alapítvány, "Összefoglaló a szalmabála hőszigetelés célú felhasználásához [Summary for the Use of Straw Bale for Insulation Purposes]," Table 2, accessed 16 March 2019, http://www.energiaeskornyezet.hu/szalmabala-epiteszet/hirek/47-osszefoglalo-a-szalmabala-hoszigeteles-celu-felhasznalasahoz.

hummus. In the intention of creating and maintaining sustainable building practices the logic of using local and natural materials can be learned from vernacular farming and it is manifested in straw bale architecture.

Figure 14: An example of a straw bale house
Source: Fekécs Edit, "Egyre népszerűbbek a szalmabálából készült házak [The houses made of straw bales are becoming more and more popular]," Sokszínű vidék (blog), 2016, http://sokszinuvidek.24.hu/kertunk-portank/2016/10/27/egyre-nepszerubbek-a-szalmabalabol-keszult-hazak/.

Today straw is gathered, compressed and stored in a straw bale. In Hungary three types of bales exist: round bale, rectangular small bale and large bale. For construction, usually small bale is used as its size and strength is suitable for building, even for load bearing walls. (Figure 14) Small bales are usually 80 to 100-centimetre-long, 50 to 60-centimetre-wide and 30 to 35-centimetre-high. Only a few examples of public buildings exist in Hungary that were made of large bales.[69]

Moisture content of straw as a building material is highly considerable. The raw material should be dry at the stage of the construction, which means that it shall contain 8 to 14 per cent of moisture. The straw structure should be protected from rain and soil moisture, which is a

[69] Eneregia és Környezet Alapítvány, "A szalmabála mint építőanyag tulajdonságai [The Characteristics of Straw as a Building Material]," accessed 16 March 2019, http://www.energiaeskornyezet.hu/szalmabala-epiteszet/1-a-szalmabala-mint-epitoanyag-tulajdonsagai.

question of design: suitable eaves and footings are needed.[70] Straw bales must not be closed by vapor barrier plaster. Therefore, they are usually covered by a three to five-centimetre-thick earth plaster lacking cement stabilization. The earth coating enables the wall to exhale the redundant humidity absorbed from one side of the structure and it also protects the straw bales from fire and animals. Under the suitable circumstances the lifetime of straw walls can be even one hundred years.[71] The bales having a density of 110 to 130 kg/m^3 are stable enough to use them for load bearing walls.[72]

Sustainability of the modern building practice

Considering the ecological impact of the production of straw we can count that it is basically nothing, as it is an agricultural by-product. If the cereals were produced for building purposes, the result would be different, as the impact of planting, growing and producing bales should be taken into account.

> "In Hungary the annual straw production is 4.5 million tons. Only its half is used in livestock production. The remaining quantities are ploughed back to the soil or deteriorates in the field, a smaller quantity is used for energy reasons. This means that if straw building was highly popular, there would not be a lack of base material, as this amount is enough for 80 000 family houses."[73]

Bale production happens on the field, which means that they need to be transported to the building plot. As cereals are produced in all counties of Hungary it can be assumed that in almost each case straw bales can be found locally. (Figure 15) However, I do not have data about which type of straw bales are produced in the different counties.

[70] Eneregia és Környezet Alapítvány, "A szalmabála mint építőanyag tulajdonságai".
[71] Eneregia és Környezet Alapítvány, "Általános ismertető [General Introduction]," accessed 16 March 2019, http://www.energiaeskornyezet.hu/szalmabala-epiteszet/5-altalanos-ismerteto.
[72] Eneregia és Környezet Alapítvány, "A Szalmabála mint építőanyag tulajdonságai".
[73] Eneregia és Környezet Alapítvány, "Költségek, felhasználási terület [Costs, Fields of Application]," accessed 16 March 2019, http://www.energiaeskornyezet.hu/szalmabala-epiteszet/10-koltsegek-felhasznalasi-terulet.

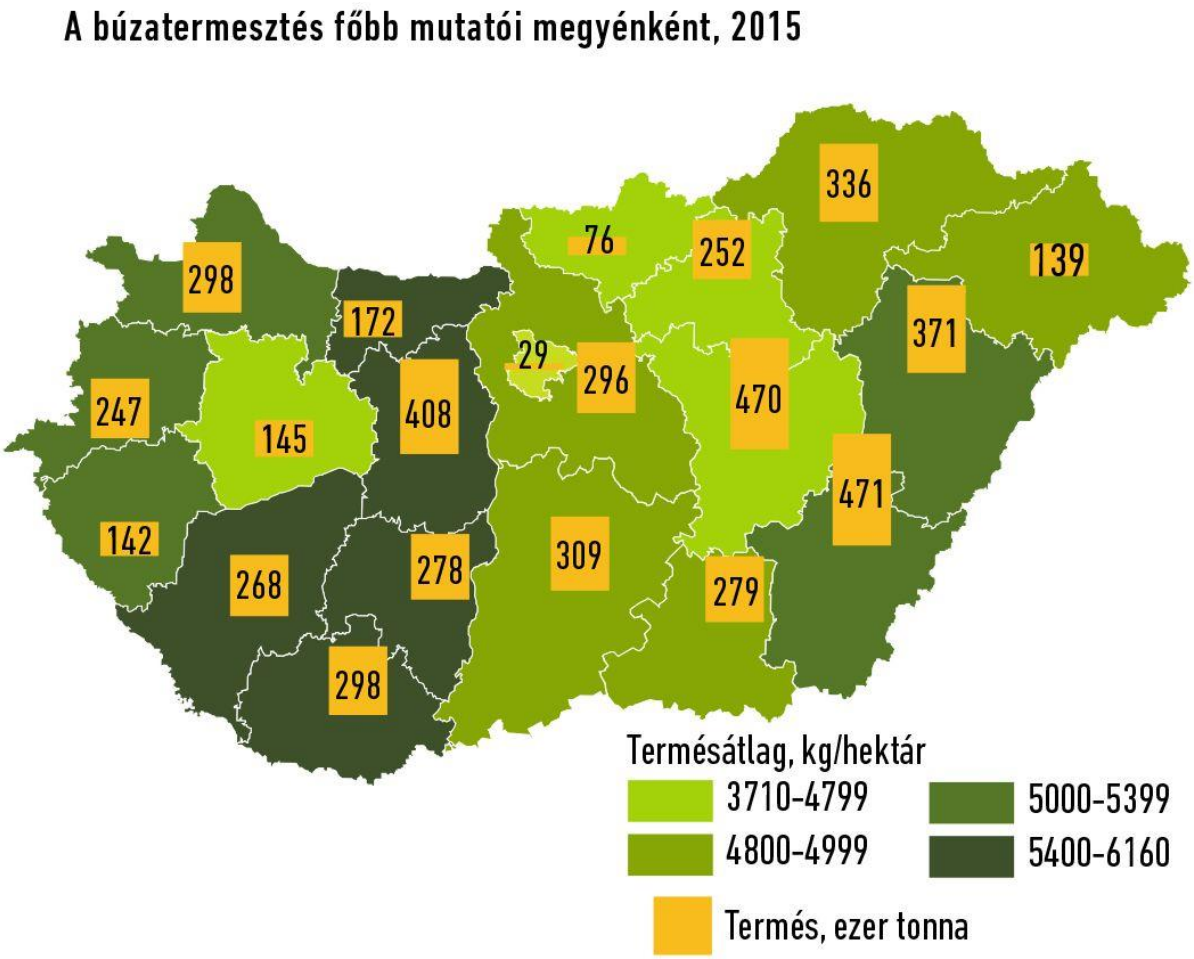

Figure 15: The main indicators of wheat production in the counties of Hungary, 2015
Legend: Green rectangles: average of production, kg/hectares, yellow rectangle: production in thousands of tons.
Source: Agro Napló - A mezőgazdasági hírportál, "A tavalyi gabonahozamok a statisztika tükrében - Terméseredmények [Statistics About the Outputs of Corn - Results of Production]," accessed 16 March 2019, https://www.agronaplo.hu/szakfolyoirat/2016/06/gazdasag/a-tavalyi-gabonahozamok-a-statisztika-tukreben.

The impact of construction of straw bale walls is not significant as no special motorized equipment is needed, what is more, it can be considered as a low-tech technique. Its post-use impact is also very low, because after demolition it deteriorates in one or two years, getting back into the biological cycle by transforming into valuable nutrition. [74]

[74] Eneregia és Környezet Alapítvány, "Költségek, felhasználási terület".

2.3 Earth

"Earth (for earth building) is natural subsoil or manufactured mineral material, comprised of varying amounts of clay, silt, sand and gravel, which has sufficient natural cohesion to ensure satisfactory performance for unfired wall and floor construction."[75]

Earth played a crucial role in the history of Hungarian vernacular architecture and it has a great significance in the present-day sustainable architecture. Therefore, earth will be examined in a detailed way in this section.

Applicable practices of vernacular architecture in sustainable building process

Soil types

In Hungarian vernacular architecture, earth was built in the structure with different kinds of techniques. During this step the earth could be rammed, pressed or dried. The production of the earth differed according to regional traditions and the needs of the technique.[76] The consistency of this mixture depended on the technical needs. For example, rammed earth required a minimum amount of water, while earth brick technology needed more water.

For building purposes, certain types of soils are suitable. Earth structures are made of natural subsoil, – called "earth soil" (*vályogtalaj*), – to which aggregates are added if needed. The original characteristics of the soil is significant as it determines the building techniques. Building with earth today, these local characteristics need to be considered, like in vernacular architecture. As vernacular architecture used local resources, the spread of the certain

[75] Peter Walker, *The Australian Earth Building Handbook* (Sydney: Standards Australia International Ltd, 2001), 17.
[76] Molnár Viktor, "A vályog és a favázas vályogépítészet [The earth and the wooden framed earth architecture]," 2004, 45.

techniques depended on the characteristics of the local earth. Adobe walls were built in territories where earth contains a great amount of clay, rammed earth walls became widespread in the areas where the soil had a medium amount of clay and cob walls were common where earth with less clay content can be found. Other aspects of the techniques also influenced their proliferation. For example, cob wall demands the least tools but the most human resources among these techniques, therefore it became widespread in the territories where the price of labour was low.[77]

Earth soil was evolved during thousands of years under very different circumstances. Therefore, different types of earth soils exist. These are according to Viktor Molnár: hill earth (*hegyi vályog),* earth of the slopes *(lejtők vályoga),* moraine *(moréna),* alluvial earth *(hordalékvályog),* stone-earth mixture *(köves vályogkeverék),* marl *(márga),* flooded earth *(elárasztott vályog),* earth deposited in rivers *(folyóvízben ülepedett vályog),* aeolian earth *(löszvályog),* deposited earth *(leülepedett vályog),* silt-earth mixture *(iszapos vályogkeverék),* tertiary material *(tercier agyag)* and broken earth *(szikes vályog).*

[77] Molnár, "A vályog és a favázas vályogépítészet", 45.

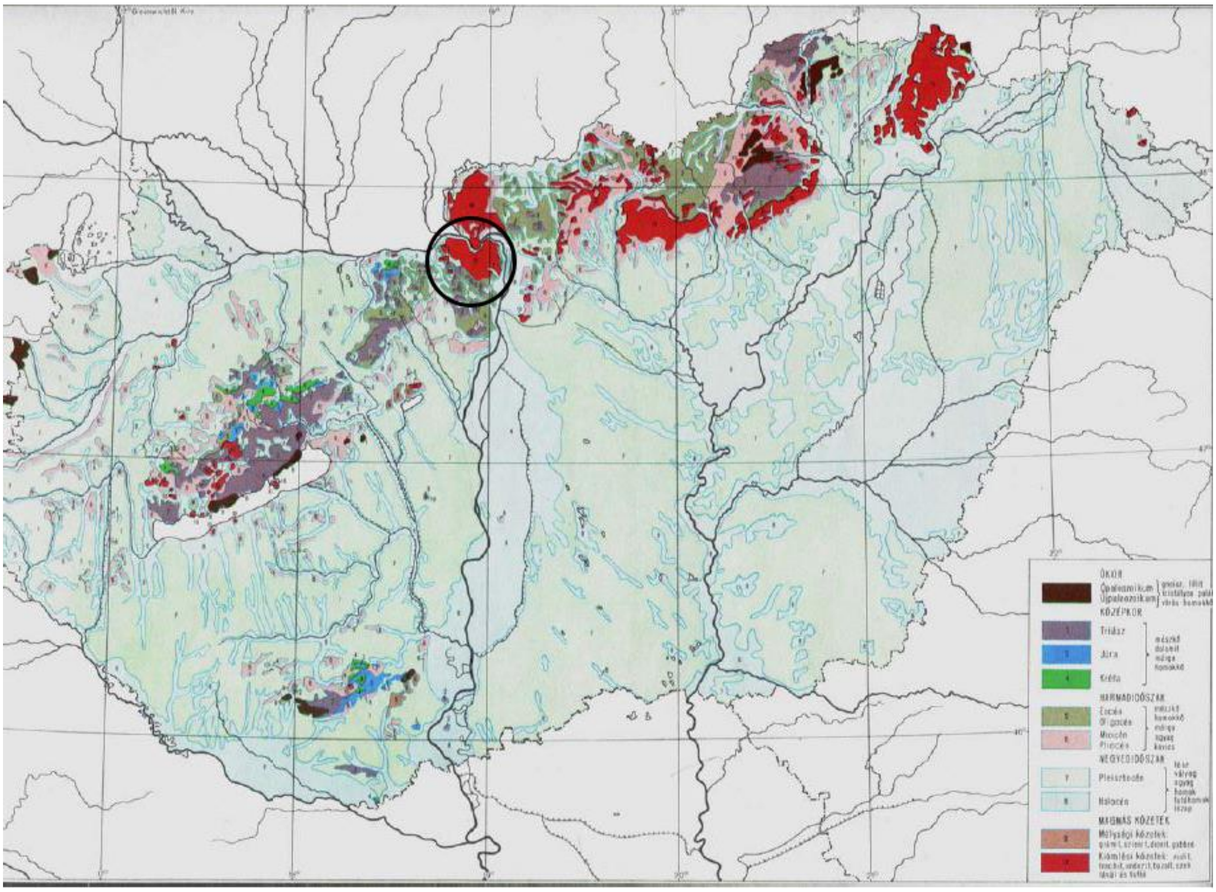

Figure 16: Hungarian earth soils according to the World Atlas
The coloured area shows the territory of present-day Hungary.
Source: Radó Sándor, "Képes politikai világatlasz [Political World Atlas with Pictures]"(Kartográfiai Vállalat, 1979), 28.

In Hungary the most common type of earth is "alluvial earth" (*hordalékvályog*), coloured with light green in Figure 16. "In the river basins and right next to them this type of earth is not suitable for building purposes. […] Although somewhat more far from the rivers – where it contains more clay – […] it can be well used for building."[78] In the Pilis, (circled in Figure 16) as it is a hill, rather the "earth of the slopes" (*lejtők vályoga*) can be found. "This type of earth consists of very different sizes of granules; therefore, its binding strength can be very different. Therefore, every type needs to be carefully examined to see if it is suitable for building."[79] The other type of earth that could be found in the Pilis is marl *(márga),* (dark green in Figure 16)

[78] Molnár, "A vályog és a favázas vályogépítészet", 14.
[79] Ibid., 12.

which is rich in clay and lime. If the lime consistence is 5-30 per cent it is suitable for construction purposes.

Pomáz-Nagykovácsi-puszta is located between the red and dark green areas, which means that before organizing the construction of earth walls in case of the barn, an examination needs to be done on the site to determine the type of the local earth. Knowing the local vernacular earth techniques is also useful as it gives us information about the possible structures that can be applied in the new construction. (Section 3.2)

Sustainable practices in vernacular architecture

In vernacular architecture the extraction of earth happened with manual tools, from local deposits in the case of each building methods. As only small-scale constructions happened, the recultivation of the field did not cause problems. Earth for building purposes needs to contain clay and must not contain hummus, therefore its excavation was not in contrast with the agricultural use of the soil. For these reasons the methods of extraction did not have a significant ecological impact. In present-day practice using small-scale local deposit is an environmentally friendly option, as this choice reduces the ecological impact of transportation.

The techniques adapted to the local characteristics of the raw material, therefore a minimum amount of aggregates was needed, that decreased the input of energy. The form of the houses was adapted to the loadbearing capacity of the earth walls. Mud production, brick production and the building of the structures needed a great amount of human resources, but no motorized tools were used, which is considered as an ecological procedure. Most of the tools were common in farming such as spade and shovel. The special tools that were needed, – such as the mud brick form or the shutters for rammed earth, – were made of wood or durable metal, so they were either made of natural materials or they were durable. For these reasons the production of the structures had a minimum ecological impact.

The orientation, the form and the structures of vernacular houses were adapted to the local climatic and geological circumstances, using hundreds of years of experience. The thick walls and the small rooms ensured an appropriate temperature inside, minimizing the impact of operating energy, which had a very practical reason: heating meant expenses.

Natural earth does not go through chemical changes during the production of the walls, therefore after demolition it can be reused by adding water and mixing. The post-use disposal of these structures does not have ecological impact as they were only made of natural materials, which can get back to the cycle of nature without causing any harm. On the other hand, for the reason of these characteristics, earth walls needed maintenance time to time, to which vernacular lifestyle was adapted.

Vernacular building of earth walls had in general a low ecological impact, which means that the closer we follow these practices the more sustainable we are. On the other hand, the modern requirements of houses and the modern lifestyle demands new solutions in many cases. Furthermore, the resources, tools and the knowledge of the techniques are often not available. These challenges require the builders to make a compromise in many cases.

Sustainability of the modern building practice

The modern use of earth

With the spread of ceramic blocks and other modern, usually artificial materials, traditional techniques were overshadowed. At the end of the twentieth, beginning of the twenty-first century earth building got a special attention, because it can ensure a healthier environment than other materials, it is ecological and centuries of practice in Hungarian tradition proves its stability. Therefore, earth has been examined from different point of views and experiments were done to prove its eligibility as a building material in our modern times.[80] Several modern techniques were invented; monolithic methods and local earth brick production methods exist with the help of motorized tools. These use local earth, but if necessary earth can be also transported to the building site, which requires extra energy. The situation is the same in the case of earth bricks, produced in factories. From an ecological point of view the recultivation of clay mines is highly important. The source of earth should not be far from the building plot to reduce transportation distance.[81] In Hungary there is a brick factory in Tapolcafő, – producing earth bricks as well –, which is 185 kilometres far in public road from the site of Pomáz-Nagykovácsi-puszta.[82]

Not only new techniques, but also new mixtures of earth were invented. Besides the three main components of earth, which are grades (gravel, sand, silt and clay), water and air, other materials can be added to earth to modify its properties. Viktor Molnár distinguishes aggregates and stabilizers. According to him aggregates are fibres such as straw, reed, chip, pine or tree leaves. They increase the insulation capacity and the tensile strength of the earth structures and avoid the appearance of cracks caused by shrinkage.[83] Traditional earth mixture usually contained some kind of aggregates, usually "waste material" of agriculture, mostly straw. Stabilizers are materials like lime, gypsum, cement and synthetic resin.[84] They increase the

[80] O. Csicsey Ágnes, "Analysis of Adobe-Clay as an Environmental-Friendly Structural Material," *Materials Science Forum* 537–538 (2007): 17–24.
[81] O. Csicsey Ágnes, "A Vályogépítés életciklusainak rövid bemutatása [Short Presentation of the Life Cycle of Earth Construction]," *Materials Technology* 63, no. 3–4 (2011): 46.
[82] Google Maps, "Ciszterci kolostorromtól Tapolcafőig [From the Cistercian Monastery Ruins to Tapolcafő]," accessed 28 January 2019, https://www.google.hu/maps/dir/Pom%C3%A1z,+Ciszterci+kolostorrom/P%C3%A1pa,+Tapolcaf%C5%91,+8598/@47.4398454,17.7666673,8.99z/data=!4m14!4m13!1m5!1m1!1s0x476a79168b5bbba3:0xca3c4c33b70682af!2m2!1d18.9461907!2d47.6772819!1m5!1m1!1s0x47696487f8ab8c93:0x1435addca874c09f!2m2!1d17.519386!2d47.2825589!3e0?hl=en.
[83] Molnár, "A vályog és a favázas vályogépítészet", 63.
[84] Ibid., 92.

water resistance, the strength or the reduce shrinkage of earth. In vernacular architecture lime could be added to the mixture, but the other stabilizers were not available at that time.

Today there are two ways of earth development. One of them wants to increase the stability of the material by stabilizing it with cement. The use of cement and synthetic materials is problematic because they reduce the "breathing capacity" of the earth wall, which means that they delay one of its most advantageous characteristics. The other direction of the new developments is to increase the insulation capacity of earth. This can be done by the production of earth blocks that contain holes or by mixing aggregates to earth.[85]

The artificial fibres and aggregates have a higher ecological impact than natural and local ones, which increases the ecological impact of the building product. On the other hand, these modern mixtures of earth were invented to develop certain characteristics of the walls, making in this way this building material more attractive for building industry and for costumers.

Ecological impact of earth-straw structure

A Hungarian research was done and published on building structures by Dr. Tiderenczl and his colleagues,[86] and a PhD dissertation was written by Péter Medgyasszay,[87] based on the same research that shows the differences of the ecological impact of structures in a visually understandable way. In this analysis eight indicators were chosen and illustrated in a pie chart. The performance of the indicators is represented in percentages, according to the highest rates, that occurred during the research.

[85] O. Csicsey, "A vályogépítés életciklusainak rövid bemutatása," 46.
[86] Tiderenczl et al., "Épületszerkezetek építésökológiai és -biológiai értékelő rendszerének összeállítása".
[87] Medgyasszay Péter, "A földépítés optimalizált lehetőségei Magyarországon - különös tekintettel az építésökológia és az energiatudatos épülettervezés szempontjaira [Possibilities of Optimum Usage of Earthbuilding in Hungary, with Special Attention to the Aspects of Building-ecology and Energy-conscious Planning]" (Budapest University of Technology and Economics, 2007), https://repozitorium.omikk.bme.hu/bitstream/handle/10890/768/ertekezes.pdf?sequence=1.

“The rates of the indicators were defined based on the most common and most accurate Ecoinvent Swiss database, referring to 112 construction products and methods. Adapting the data to the Hungarian situation, the Hungarian energy structures and the average transport distance of the different products were considered. Despite the original plans, the environmental impact of the Hungarian factories could be considered in a limited way, due to their lack of interest.”[88]

[88] Tiderenczl et al., “Épületszerkezetek építésökológiai és -biológiai értékelő rendszerének összeállítása,” 2.

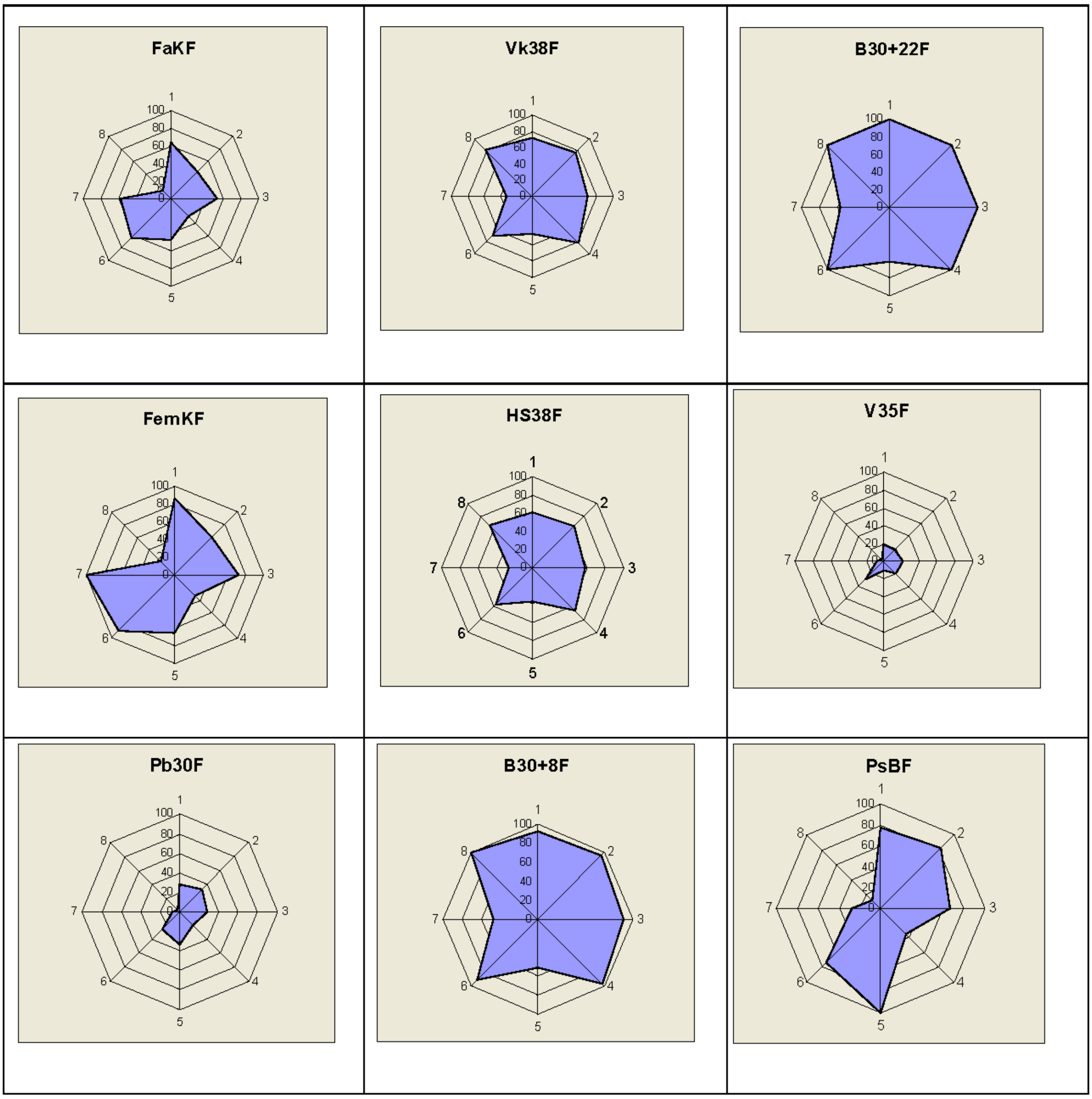

Figure 17: The environmental impact of wall structures considering the production and waste periods. Indicators: 1. Provincial Energy Strategy (PEI, n.r.) 2. Global Warming Potential (GWP) 3. Acidification Potential (AP) 4. Ozone Depletion Potential (ODP) 5. Photochemical Ozone Creation Potential (POCP) 6. Eutrophication Potential (EP) 7. Human Toxicity Potential (HTP) 8. Ecotoxicity Potential (ETP)
Wall structures: ***FaKF****: timber framed lightweight wall structure* ***FemKF****: light metal structure* ***Pb30****: homogenous lightweight concrete wall structure without loadbearing frame* ***Vk38F****: homogenous ceramic block wall structure without loadbearing frame* ***HS38F****: homogenous ceramic block wall structure without loadbearing frame [sit]* ***B30+8F****: ceramic block wall structure without loadbearing frame with 8 centimetres of insulation layer* ***B30+22****: ceramic block wall structure without loadbearing frame with 22 centimetres of insulation layer* ***V35F****: timber frame with earth infilling wall structure with straw bale insulation layer* ***PSBF*** *Concrete wall structure poured between polystyrene shutters*
Source: Medgyasszay Péter, "A földépítés optimalizált lehetőségei Magyarországon - különös tekintettel az építésökológia és az energiatudatos épülettervezés szempontjaira [Possibilities of Optimum Usage of Earthbuilding in Hungary, with Special Attention to the Aspects of Building-ecology and Energy-conscious Planning]" (Budapest University of Technology and Economics, 2007), Figure 9.1.1-1.

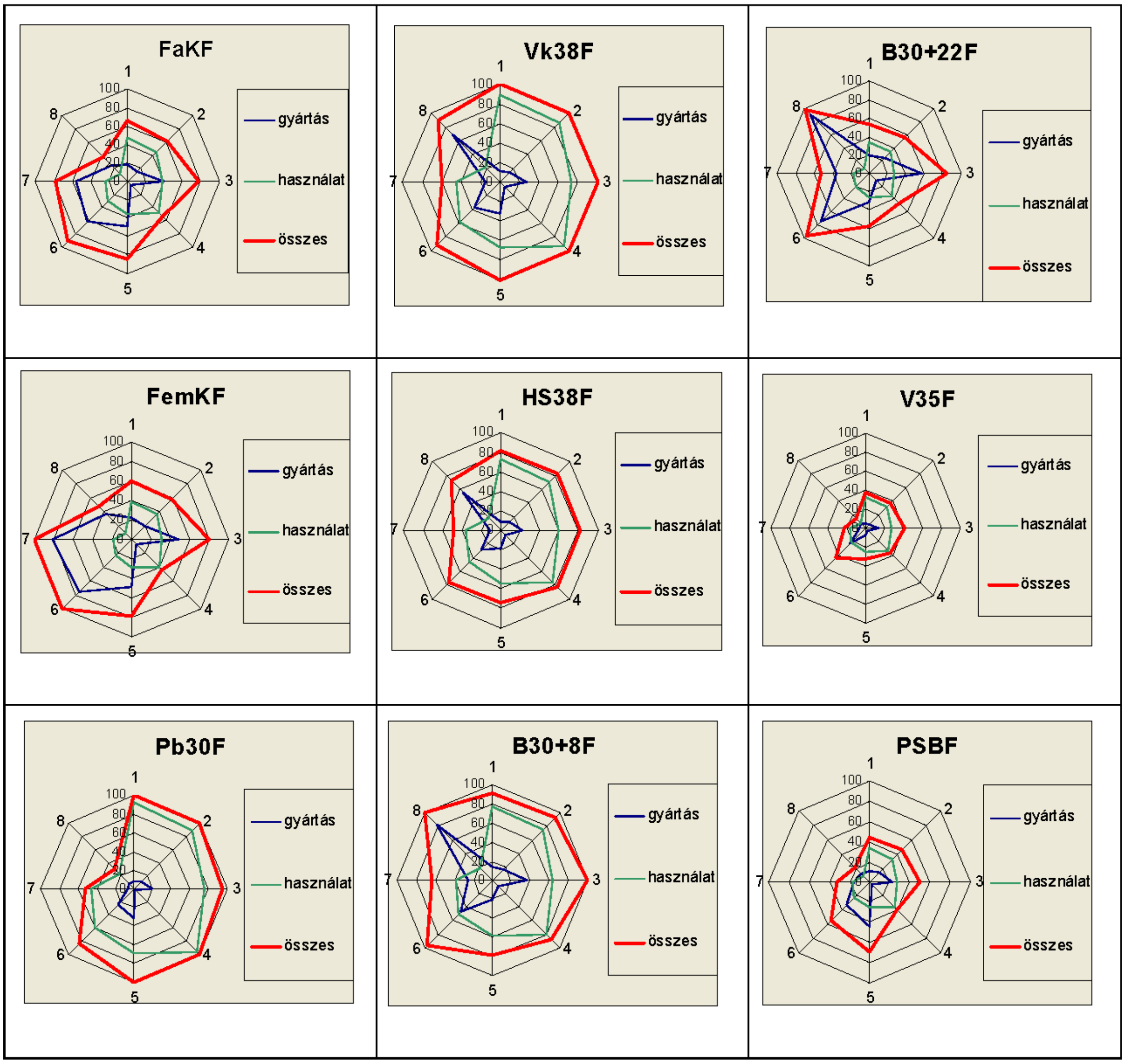

Figure 18: The environmental impact of wall structures considering their life cycle.
Colours: ***blue line:*** *production,* ***green line:*** *operation,* ***red line:*** *both*
Indicators: 1. Provincial Energy Strategy (PEI, n.r.) 2. Global Warming Potential (GWP) 3. Acidification Potential (AP) 4. Ozone Depletion Potential (ODP) 5. Photochemical Ozone Creation Potential (POCP) 6. Eutrophication Potential (EP) 7. Human Toxicity Potential (HTP) 8. Ecotoxicity Potential (ETP)
Wall structures: ***FaKF****: timber framed lightweight wall structure* ***FemKF****: light metal structure* ***Pb30****: homogenous lightweight concrete wall structure without loadbearing frame* ***Vk38F****: homogenous ceramic block wall structure without loadbearing frame* ***HS38F****: homogenous ceramic block wall structure without loadbearing frame [sit]* ***B30+8F****: ceramic block wall structure without loadbearing frame with 8 centimetres of insulation layer* ***B30+22****: ceramic block wall structure without loadbearing frame with 22 centimetres of insulation layer* ***V35F****: timber frame with earth infilling wall structure with straw bale insulation layer* ***PSBF*** *Concrete wall structure poured between polystyrene shutters*
Source: Medgyasszay, "A földépítés optimalizált lehetőségei," Figure 9.1.1-2.

Figure 17 considers the most relevant aspects of building process for this research: the production and the demolition phase of construction materials. It is clearly visible that the earth structure with straw isolation has the least economic impact – as it has the smallest covered area – with witch only light concrete can compete. Examining the red line of Figure 18, – which considers the production and the operating phase of the structures, – the characteristics of earth structure seems to be much better than of light concrete. This data relates to insulation capacity – among others.

The Embodied Energy of earth is low, which is proved by this research. All life stages of earth construction have low energy demand and often can be replaced by human resources even in our modern times.[89] With an ecological insulation layer – for example straw – its Operating Energy can be reduced, while keeping the Embodied Energy and post-use energy demand of the wall structure low.

Brick

Brick is fired earth block. Its material is similar to adobe, although its sand-clay proportion is different and usually does not contain fibres. The production of bricks happened in many ways in vernacular architecture. For own purpose they were produced and burned on the building plot. In meadows temporary and permanent workshops were run by a professional. A more developed method was the production in factories, that was common in the nineteenth-twentieth century. Brick became common in a later stage of vernacular practice, in the nineteenth century. Whole houses were rarely built of brick, only some parts of the walls, as it was an expensive material.[90]

[89] O. Csicsey, "A Vályogépítés Életciklusainak Rövid Bemutatása," 42–47.
[90] Buzás and Sabján, *Hagyományos falak*, 102–7.

For brick firing a great amount of natural resources need to be burned, therefore it is not considered as an ecological building material. Figure 18 shows that the modern production and post-use impact of homogenous ceramic structures, also with (Vk38F, HS38F) and without insulation layer (B30+8F, B30+22F) is high. On the other hand, second-hand bricks that are in a good shape can be used for new constructions. Reuse has low ecological impact, as the energy demand of production is zero, only transportation requires the use of resources. Furthermore, it extends the life of the building product, which saves energy.

2.4 Wood

Wood is a common building material as it has numerous characteristics that make it suitable for construction purposes. "Although its weight is small, it has huge compressive, tensile and bending strength. Its insulation capacity is good, at the same time its thermal expansion is sufficiently low. It is easy to work with and it is reusable if it is worked in an appropriate way."[91] Since ancient times, wood has been an easily accessible material in all of Europe including the Carpathian Basin.

Applicable practices of vernacular architecture in sustainable building process

In Hungarian vernacular architecture the whole amount of the wood lumbered was used, although today thin branches and some parts of the trees deteriorate in the forest, which is a waste of resources.[92] People in the time of vernacular architecture collected switches and branches for building purposes or most commonly for different kinds of basketwork. These tools were produced not only for people's own purpose but for trading as well. Switches were

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[91] Mednyánszky Miklós, "Fachwerk," accessed 4 December 2018, http://fachwerk.uw.hu.
[92] Schiberna E., "Fenntartható (tartamos) erdőgazdálkodás [Sustainable Forest Cultivation]," in *Örök társunk a fa [Wood, Our Eternal Companion]*, ed. Molnár Sándor (Nyugat-magyarországi Egyetem Kiadó, 2011), 12.

needed up to the eighteenth-nineteenth century, when the wattle structure was still common. On other occasions "the switches were donated by the landowner. Usually a village took home the number of switches that was enough for several houses."[93] Today the purpose of non-used switches and branches are not solved, therefore their application for building wattle wall is a sustainable practice. (Section 3.2) On the other hand, finding a way of their supply is a challenge, as it requires extra communication to gain knowledge regarding their local resources.

In the time of vernacular architecture cutting method of trees were different than today. About this topic my sources are going back to the eighteenth-nineteenth century. In that time the building methods had less environmental impact as its tools were not motorized and transportation had a smaller role than today. "It was not the whole amount of the logged wood that left the forest as raw material. A certain percentage of the wood was partly fully manufactured" in the forest.[94] The reason was, that forests were part of a group of different types of lands – grape fields, grain fields, lakes – with one owner. Wood was needed to produce tools that helped in the maintenance of the lands, so in a way its primary purpose was self-sufficiency. Traditionally, logging and the production of wooden tools were not divided. The natural heterogeneity of the forest was used by people and it helped self-sufficiency not only of the land owners but also of the inhabitants of the villages. It also meant that the size of wood was not standardized as it is now.

Wood with uneven forms is not applied by modern building industry, although they commonly formed structures in vernacular building practice. Today this type of wood is often burned for

[93] Mednyánszky, "Fachwerk".
[94] Hegyi Imre, *A népi erdőkiélés történeti formái* [The Historical Forms of Vernacular Use of Forest] (Budapest: Akadémia Kiadó, 1978), 77.

energy purposes, which shortens the life of the material causing energy wasting. In small-scale constructions the non-standard forms of wood could be used despite the saw products.

In vernacular architecture the recycling of wood was a common phenomenon. Especially the thick hardwood beams were precious and durable. Therefore, in case of demolition these beams were often reused in new constructions. From a contemporary point of view this practice is sustainable. Today second-hand wooden elements are not present in trade; therefore, their supply is only possible through the owner, which requires knowledge about the local circumstances. Old wooden products have the advantage of not shearing like the fresh ones. On the other hand, they need special attention, because they might contain pathogens or needles that make the work difficult.

Sustainability of the modern building practice

The environmental impact of modern wood production

Wood industry has various products made in motorized factories today. Wood used for construction has two main types: the sawed products made of natural wood and the wood-based panels containing a high or a low percentage of wood according to their type. In general, the first location of the preparation of wood is the sawmill, products of which are transported to building, furniture and energy plants in great quantities.[95] The operations of factories and the transportation of the material has a heavier environmental impact than the traditional way of wood production had. Due to the lack of data regarding the transportation, I will examine the ecological impact of the present-day production in Hungary.

[95]Pásztory Z., “Fafeldolgozás, fatermék gyártás [Wood Preparation, Wood Production],” in *Örök társunk a fa,* 27–28.

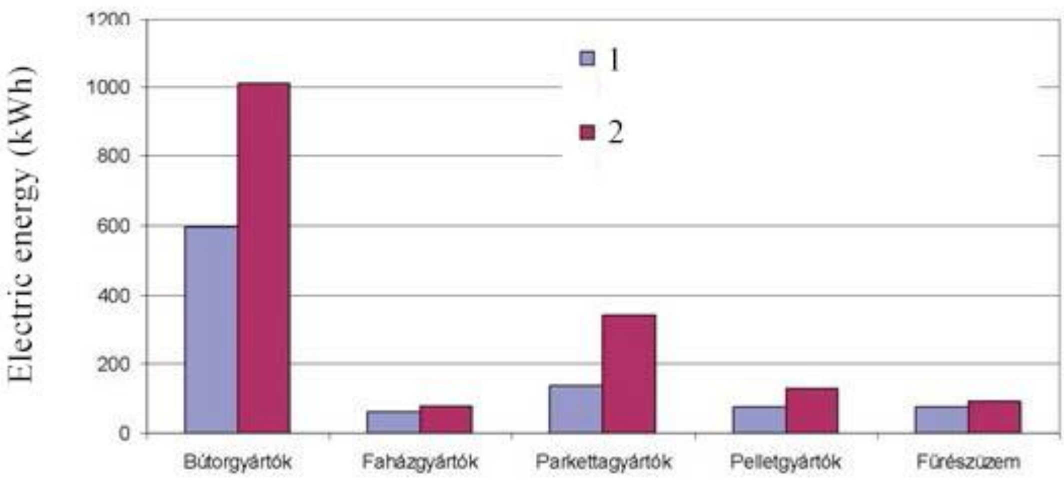

Figure 19: The distribution of electricity demand needed to produce a unit of basic commodity or product Legend: 1. electric energy demand needed for the processing of one cubic metre raw material 2. electric energy demand needed to produce one cubic metre product. All translations are mine, unless otherwise stated. Adapted from: Varga M., Németh G., and Kocsis Z., "A fatermékek gyártási energiaszükséglete [The Production Energy Need of Wood Products]," in Örök társunk a fa [Wood, Our Eternal Companion], ed. Molnár Sándor (Nyugat-magyarországi Egyetem Kiadó, 2011), Figure 7.2.

The environmental impact of raw wood production is small, as forestry operations have low energy demand. The stages of industry however, shows a very diverse picture. Factories need heat energy and electricity, the proportion of which has changed over the last decades. The rate in the 1980's was 80 to 20 per cent, while today in several Hungarian modern factories it is 50 to 50 per cent or even 40 to 60 per cent, which was the intended goal for long from a sustainable point of view.[96] The speciality of wood industry is that it earns its energy from the burning of the waste material of its production method. In Hungary two thirds of the waste material or the by-products are used locally by factories.[97] Varga and his colleagues studied the electricity need of different factories. (Figure 19) According to the results sawmills and the building industry use a relatively low amount of electricity.

[96] Varga M., Németh G., and Kocsis Z., "A fatermékek gyártási energiaszükséglete [The Production Energy Need of Wood Products]," in *Örök társunk a fa*, 35–36.
[97] Varga M., Németh G., and Csitári Cs., "A fa mint megújuló energiaforrás [Wood as a Renewable Energy Source]," in *Örök Társunk a fa*, 43.

Table 4: The energy demand needed to produce different products

Product	Energy demand to produce one-ton product
Wood	580
Brick	2320
Cement	2900
Plastic	3480
Glass	8120
Steel	13920
Aluminium	73080

All translations are mine, unless otherwise stated.
Adapted from: Varga M., Németh G., and Kocsis Z., "A fatermékek gyártási energiaszükséglete," Figure 7.1.

Table 4 shows the energy demand of the production of one-ton product of various building materials. It can be clearly seen that wood has the least demand among the listed materials.[98] However, this table has its limitations, as it does not consider the differences in the amount of material needed for a house regarding the different materials.

Besides energy demand, another aspect of sustainability is carbon footprint. "Carbon footprint is the amount of carbon-dioxide and other greenhouse gases emitted during the whole life cycle of a product or a service expressed in equivalent tons of carbon-dioxide. Figure 20 shows the carbon footprint of different materials. The negative value in the case of sawed products means that the amount of the absorbed carbon-dioxide by the photosynthesis while the tree is growing is more than the total emission of greenhouse gases during the full life cycle of a sawed product."[99] However, it is important to note, that the production of wooden building materials in many cases does not end in sawmills and this data is not based on Hungarian factories.

[98] Varga, Németh, and Kocsis, "A fatermékek gyártási energiaszükséglete," 35.
[99] Schöberl M. and Lakatos Á., "Fatermékek ökológiai mérlegen [Wooden Products under Ecological Examination]," in *Örök társunk a fa*, 45.

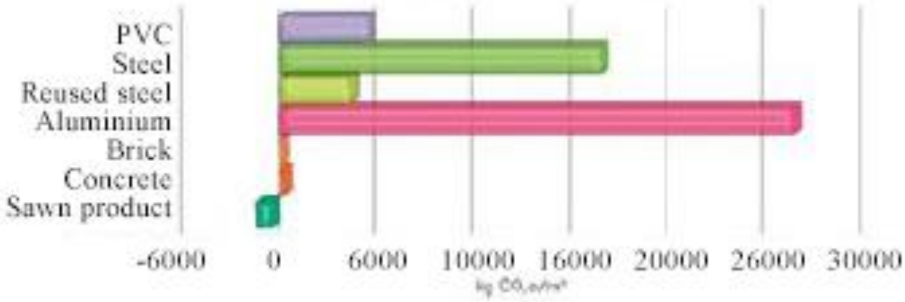

Figure 20: The carbon footprint of different materials
All translations are mine, unless otherwise stated.
Adapted from: Schöberl M. and Lakatos Á., "Fatermékek ökológiai mérlegen [Wooden Products under Ecological Examination]," in Örök társunk a fa, Figure 9.4.

Modern forest cultivation in Hungary and in the Pilis

Figure 21: The increase of the number of trees in Hungary between 1980 and 2009
Source: Schiberna E, "Fenntartható (tartamos) erdőgazdálkodás [Sustainable Forest Cultivation]", in Örök társunk a fa, Figure 2.5. Primary source: MgSzH database

The aim of modern forest cultivation is to serve human demand for wood, while ensuring the sustainable maintenance of forests and considering the ecological factors.[100] In Hungary the territory of forests is increasing, at the same time the amount of logged wood is less than the newly grown wood. (Figure 21) Certification systems inform customers that the wood originates from a sustainable forest by indicating their logos on the suitable material. There are

[100] Schiberna E., "Erdőgazdálkodás az ember szolgálatában [Forest Cultivation in the Serve of People]," in *Örök társunk a fa*, 10.

two types of systems in Hungary: FSC (Forest Stewardship Council) and PEFC (Program of Endorsement of Forest Certification).[101] (Figure 22)

Figure 22: The logos of FSC and PEFC
Source: Molnár S. and Tolvaj L., "A fa a jövő stratégiai nyersanyaga [Wood, the Strategic Raw Material of the Future]," in Örök társunk a fa, 20.

A good example of sustainable forest cultivation is the forests of the Pilis, which are maintained by the *Pilisi Parkerdő Zrt*, a state-owned organization. (Figure 23) The *Pilisi Parkerdő Zrt*. puts emphasis on the relationship of forest cultivation and nature protection as 65 per cent of its forests are under protection. Its basic maintenance principles are based on natural forest cultivation. They preferably renew forests by local seeds and aim to keep the right balance between the commonly used modern and continuous cover forestry.

Continuous cover forestry started to be introduced on big scale in 2002, and the intention was to increase its territory. By 2016 the size of the area maintained by this method grew to 21,902 hectares, which is 38 per cent of the forests of *Pilisi Parkerdő Zrt*. (Table 5) Continuous cover forestry means that the forest area is covered evenly by trees that are of different age. The renewing of the forest happens without clear-cutting, its landscape appearance does not change because of logging. The characteristics of continuous cover forestry are the heterogenic horizontal and vertical forest structure, the mixed aged trees, prioritizing of indigenous species, the mixture of species and the protection of dead trees. Wood production applies gentle

[101] Molnár S. and Tolvaj L., "A fa a jövő stratégiai nyersanyaga [Wood, the Strategic Raw Material of the Future]," in *Örök társunk a fa*, 20.

methods and considers ecological aspects. Among cutting methods, a selection and transformation system is used.[102]

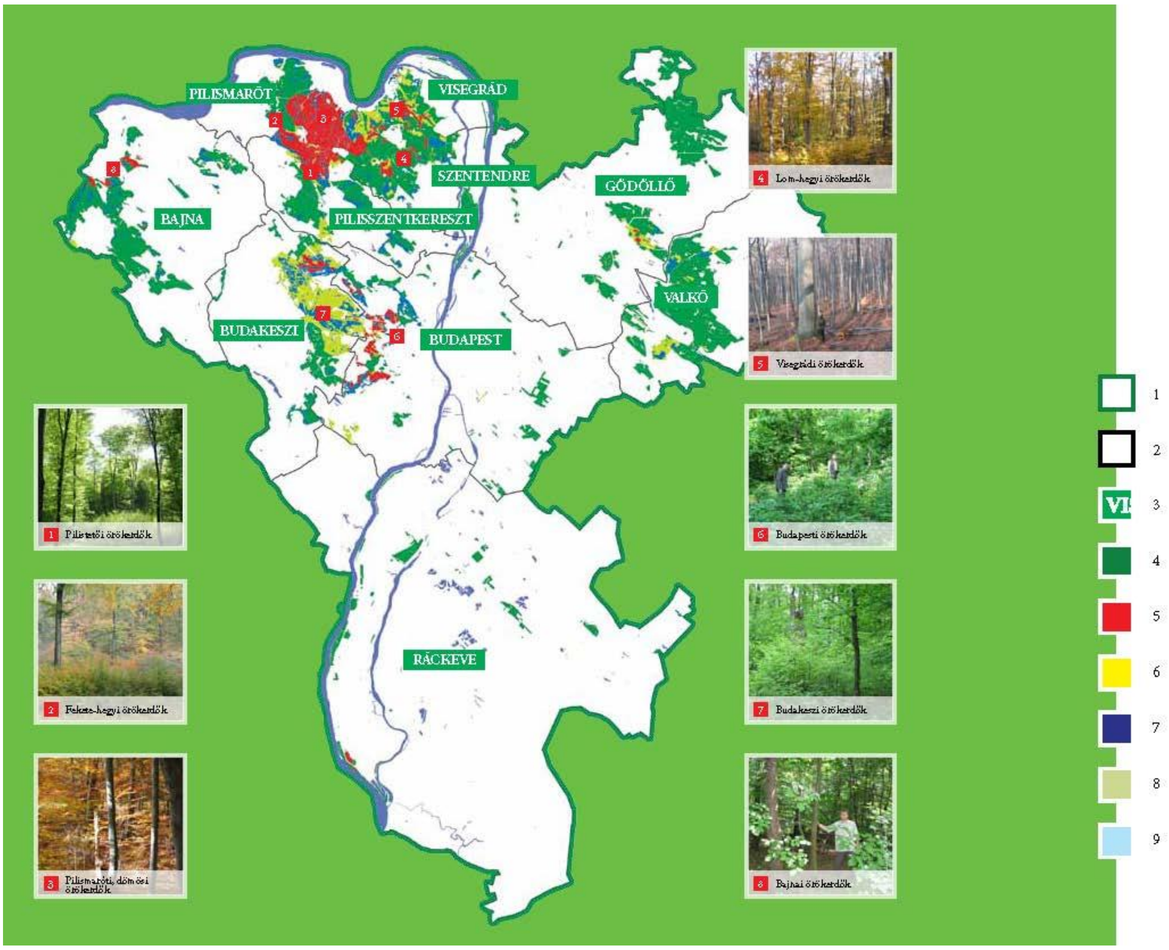

Figure 23: Map about the woodland cultivated by continuous cover forestry by Pilisi Parkerdő Zrt. Legend: 1. the borders of the territories maintained by Pilisi Parkerdő Zrt. 2. the borders of the woodlands of Pilisi Parkerdő Zrt. 3. the capitals of the woodlands 4. territories maintained by clearcutting under the influence of Pilisi Parkerdő Zrt. 5. territories maintained by selection system under the influence of Pilisi Parkerdő Zrt. 6. territories maintained by transformation system under the influence of Pilisi Parkerdő Zrt. 7. territories not serving wood production under the influence of Pilisi Parkerdő Zrt. 8. other woodlands 9. water surfaces. All translations are mine, unless otherwise stated.
Adapted from: Csépányi Péter, "Örökerdők a Pilisi Parkerdőben [Continuous Cover Forestry in the Forests of Pilis]" (Pilisi Parkerdő Zrt., 2016), 27.

The increase of continuous cover forestry happened in two steps. From 2002 to 2012 its territories were chosen, and from 2016 the local types of cultivation were improved, and perfected, furthermore professional analyses and examinations were done.[103] This type of

[102] Csépányi Péter, "Örökerdők a Pilisi Parkerdőben [Continuous Cover Forestry in the Forests of Pilis]" (Pilisi Parkerdő Zrt., 2016), 3–7, https://parkerdo.hu/wp-content/uploads/2018/01/PP_orok_20160831.pdf.
[103] Ibid., 25.

forest cultivation can lead in the future to the appearance and the use of wood with uneven forms in small-scale constructions, which is advantageous from the viewpoint of the ecological impact of wood production.

Table 5: The summary of the areas of different cultivation systems maintained by Pilisi Parkerdő Zrt. at the stage of September 2016

Forestry	**Types of modes under continuous cover forestry**					**Clearcutting mode**		**All modes altogether**
	selection system (hectares)	transformation system (hectares)	not serving wood production (hectares)	altogether (hectares)	prop. (%)	territories (hectares)	prop. (%)	territories (hectares)
Szentendre	277	330	725	1332	23,6	4320	76,4	5652
Visegrád	452	1293	419	2164	55,6	1727	44,4	3891
Pilismarót	3363	94	1004	4461	71,5	1777	28,5	6238
Pilisszentkereszt	1344	540	1103	2987	48,1	3226	51,9	6213
Pilis mountains, Visegrád Mountains altogether	5436	2257	3251	10944	49,8	11050	50,2	21994
Budakeszi	300	350+	1846	5652	71,7	2230	28,3	7882
Budapest	979	594	1192	2765	55,3	2234	44,7	4999
Buda Mountains altogether	1279	4100	3038	8417	65,3	4464	34,7	12881
Gerecse Mountains: Bajna	297	50	863	1210	18,1	5489	81,9	6699
Great-Alföld: Ráckeve	91	8	37	136	7,4	1686	92,6	1822
Gödöllő	54	283	69	406	6,3	6032	93,7	6438
Valkó		477	313	790	9,6	7428	90,4	8218
Gödöllő Hills altogether	54	760	382	1196	8,2	13460	91,8	14656
Pilisi Parkerdő Zrt. altogether	7157	7175	7570	21902	37,7	36149	62,3	58051

All translations are mine, unless otherwise stated.
Adapted from: Csépányi, "Örökerdők a Pilisi Parkerdőben," 27.

Carbon-dioxide absorption

It is important to use the whole amount of wood of a lumbered tree, because “trees absorb carbon-dioxide from the air during their photosynthesis that they store in their “body”. (…) They store carbon, which means that they contribute to the reduction of the carbon-dioxide in the air, which causes the greenhouse effect.”[104] Carbon disengages when the wood deteriorates, or when it is burned. This also means that the longer the wood is used the more it contributes to the reduction of greenhouse effect.[105] The life of the material can be increased with its reuse or recycle.[106] The burning for energy reasons should happen at the end of the life cycle.[107] Alpár T. presented in 2011 a method called sequential use of biomass. He recommends that different types of wooden production lines should work next to each other. In this way the waste material of a factory can be easily used by another one. (Figure 24) This means a huge opportunity to make wood production more sustainable, although I have no data if this recommendation had any practical effect in Hungarian wood production methods.[108]

[104] Schöberl M., Börcsök Z., and Führer E., “Erdő és a faanyag lehetséges szerepe a klímavédelemben [The Possible Role of the Forest and the Wood in the Climate Protection],” in *Örök társunk a fa*, 21.
[105] Schöberl, Börcsök, and Führer, 24.
[106] Schöberl and Lakatos, “Fatermékek ökológiai mérlegen,” 47.
[107] Schöberl, Börcsök, and Führer, “Erdő és a faanyag lehetséges szerepe a klímavédelemben,” 24.
[108] Alpár T., “Újrahasznosítás, hulladékmentesség, a faanyag csodálatos adottsága [Reusable, Waste-Free: The Wonderful Characteristics of Wood],” in *Örök társunk a fa*, 31–33.

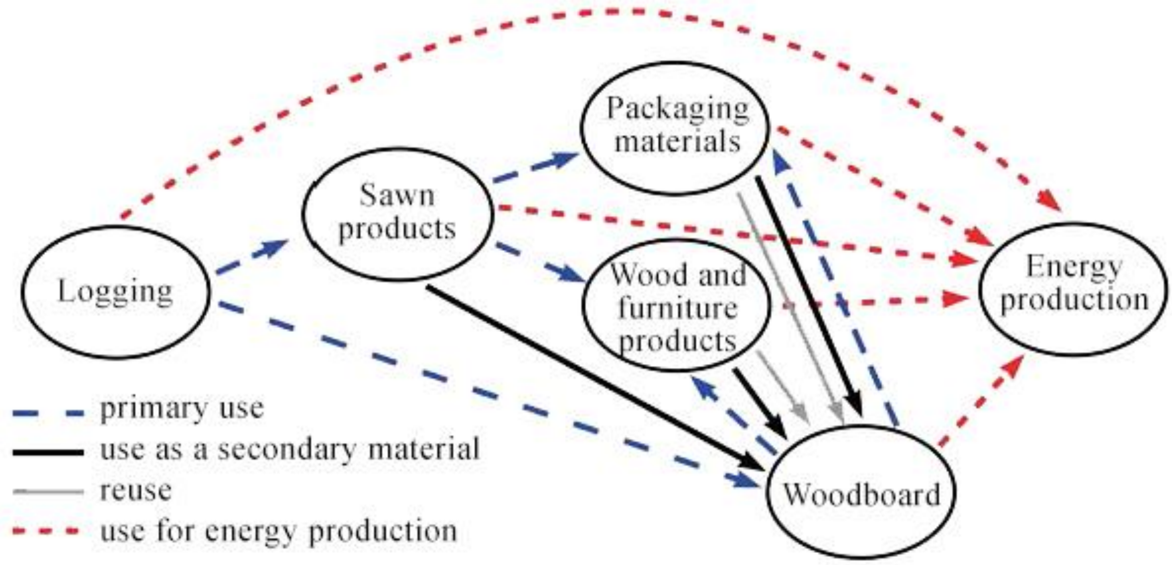

Figure 24: The general flowchart of cascading of biomass regarding the usage of wood
All translations are mine, unless otherwise stated.
Adapted from: Alpár T., "Újrahasznosítás, hulladékmentesség, a faanyag csodálatos adottsága [Reuseable, Waste-Free: The Wonderful Characteristics of Wood]" in Örök társunk a fa, Table 6.1.

Schöberl argues that "the carbon storage capacity (therefore the capacity of decreasing carbon-dioxide in the air) of wood products is significant in the case of heavy products, for example wooden houses, furniture, etc. (Table 6) Regarding Europe, including Hungary, primarily the development of wooden architecture can be beneficial. Therefore CEI-Bois (European Confederation of Woodworking Industries) advertised the motto: Tackle Climate Change: Build with Wood".[109] (Figure 24)

[109] Schöberl, Börcsök, and Führer, "Erdő és a faanyag lehetséges szerepe a klímavédelemben," 26.

Table 6: The amount of carbon stored in a couple of wood products.

	Weight of wood (kg)	Stored coal (kg)	carbon-dioxide decrease (kg)	lifetime (years)
a bed of a child	12	6	22	10-15
sand box	30	15	55	15-20
interior door	10	5	18	30-45
desk	25	12,5	46	30-40
family house (140 m2)	15000	7500	27525	80-120
furniture (flat with 3 rooms)	1400	700	2569	30-50
parquet	126	63	231	10-25
wooden fence (20m)	150	75	275	15-20
garden bench	18	9	33	10-15

All translations are mine, unless otherwise stated.
Adapted from: Schöberl M., Börcsök Z., and Führer E., "Erdő és a faanyag lehetséges szerepe a klímavédelemben [The Possible Role of the Forest and the Wood in the Climate Protection]", in Örök társunk a fa, 21.

Consumption of wood

The use and the production of wood has a great tradition in Hungarian ethnography and vernacular architecture. While the territories of Hungarian forests have grown by 228 thousand hectares in the last twenty years, the primary use of wood – meaning for non-energy purposes – has been reduced by 30 per cent. The growing number of forests, the environmentally friendly forest cultivation, the relatively low environmental impact of wood industry and the advantageous carbon-dioxide storage capacity of wood urges Hungarians to use wood in larger quantities.[110] This means that the use of wood for building purposes is a sustainable solution.

[110] Pásztory, "Fafeldolgozás, fatermék gyártás," 30.

Chapter 3 - Traditional and semi-traditional techniques and structures

In the design of the visitor's facility I use natural materials, vernacular buildings are made of. I intend to provide a basis of my decisions regarding building structures of the visitor's facility. Therefore, in this part of my research I will do two analyses. With the first analysis I intend to snow how Ádám Bihari's approach using the structures of Hungarian vernacular architecture – introduced in his study of The Hungarian Vernacular Architecture as a Sustainable Building Method[111] – works in my case. The second analysis will focus on wall structures made by traditional techniques in present-day practice. Its aim is to have a research which enables me to decide what kind of wall structure to use for my design.

3.1 General structures

In his study Bihari listed the structures of vernacular architecture and analysed them according to current needs. He wrote that 'the building structures used in vernacular constructions fit many contemporary technical requirements, although from many points of view they are needed to be reinterpreted, additional measures are needed to be considered.'[112] I will use Bihari's results to decide which one of the vernacular building structures fit the needs of the visitor's facility that I intend to build.

I design a single-story visitor's facility, where visitors can sit down, eat, have a rest, or listen to a lecture. (See Chapter 4) The house will be in temporary use, which means that it will be open from spring to autumn for occasional events. Visitors will spend here a couple of hours

[111]Bihari Ádám, "A magyar népi építészet mint fenntartható építési eljárás [Hungarian Vernacular Architecture as Sustainable Building Method]" (Budapest University of Technology and Economics, 2013), https://tdk.bme.hu/EPK/Kivitel/Magyar-nepi-epiteszet-mint-fenntarthato.
[112] Ibid., 42.

during daytime. The visitor's facility building is open, therefore heating and insulation is not an issue in my case. Considering public utilities, I intend to design a low-tech building. In the house electricity is needed, while running water is not a requirement, as water will be brought here from the guardhouse.

I will study the requirements of buildings and building structures. A building and its structures are affected by several phenomena, that they need to resist. These phenomena and the function together determine the requirements of a building. I will introduce these requirements in general according to the current Hungarian law[113], in a way listing them and at the same time referring and comparing them to traditional houses and to the building, I design. I will use the idea and the results of Bihari's research.

- Mechanical strength and stability: The minimum requirements of stability must be fulfilled in every case. Usually architects need to design a building of which durability is 50 years. This considers the stability of the structures as the finishes (for example plasters) need maintenance regularly. It is especially true for the buildings of vernacular architecture as they are made of materials that deteriorate easily. On the other hand, in Hungary several buildings are standing even today that were made of traditional materials and structures much more than 50 years ago. This proves that the structural durability of these buildings can be much more than the required.
- Fire protection: every building in Hungary must satisfy the National Fire Protection Policy,[114] which considers the needs of structures according to the function of the building. Bihari stated that 'the fire resistance of the plant derivatives roofs needs to be

[113] European Union, "EUR-Lex - 32011R0305 – HU," accessed 25 November 2018, https://eur-lex.europa.eu/eli/reg/2011/305/oj/?locale=hu.
[114] Ministry of Interior, "54/2014. (XII. 5.) BM rendelet [54/2014. (XII. 5.) BM Order]" (2014), https://net.jogtar.hu/jogszabaly?docid=A1400054.BM.

firmed.'[115] Although, other parts of the buildings like walls, wooden beam and roof structures fit to the current requirements.

- Hygiene, health and environmental protection: One of the advantages of traditional structures is that they are made of natural materials whose ecological footprint[116] is much lower than in the case of artificial materials. They are harmless materials to the nature and human body, they do not contain or absorb any chemicals. The traditional structures are 'breathing structures', which means that they do not block the humidity flow, in this way they ensure a healthy environment inside the house. Although, the moisture protection of traditional houses does not reach today's requirements. As Bihari states 'the moisture protection of walls, foundations and floorings is needed to be increased'[117].
- Safe use and obstacle-free use: This requirement is not connected to the structures and materials of the buildings, it is a question of design.
- Noise protection: Buildings must satisfy three policies[118] regarding noise protection. The performance of vernacular building structures reaches the requirements of the rules. As the building site of the visitor's facility is located quite far from the road, and from the houses of the owner and the workers, it is not affected by noise pollution and the noise that will be caused by the future visitors will not disturb the inhabitants of the farm. Due to the functional needs, the noise protection of façade and interior structures and do not require special measures.

[115] Bihari, "A magyar népi építészet mint fenntartható építési eljárás," 42.
[116] Related terms are defined in Chapter 1.
[117] Bihari, "A magyar népi építészet mint fenntartható építési eljárás," 42.
[118] Ministry of Environment and Water and Ministry of Health, "27/2008. (XII. 3.) KvVM-EüM együttes rendelet a környezeti zaj- és rezgésterhelési határértékek megállapításáról [27/2008. (XII. 3.) KvVM-EüM Order about the Limits of the Environmental Vibration and Noise Pollution]" (2008), https://net.jogtar.hu/jogszabaly?docid=A0800027.KVV.

- Energy saving and thermal protection: Buildings need to satisfy the regulations of Energy Policy. Traditional building structures do not reach the current requirements of insulation capacity, that were raised in the beginning of 2018.[119] This can be solved with extra insulation layers. Considering the function and the use of the visitor's facility, the requirements of the Hungarian energy policy[120] [121] do not have to be fulfilled according to the current building law.[122] The traditional structures entirely meet the requirement of the sustainable use of natural resources, as the building materials are partly reusable or degradable, they are environmentally friendly, and the traditional buildings are permanent (in the cases when the intend of the builders was this). I put a special emphasis in the case of the visitor's facility to fit this requirement.

In the followings, I summarize the performance of vernacular structures, based on the results of Bihari. His research question was if the remaining old buildings can be saved and re-used. However, my question is, if similar structures can be used regarding a new design. He examined the ecological performance and technical performance – such as stability, fire protection, moisture resistance, insulation capacity, noise protection, durability and resistance against chemical and biological impacts. Summarizing the ecological performance of the structures listed below, it is true to all the structures that:

[119] Ministry without Portfolio, "7/2006. (V. 24.) TNM rendelet [7/2006. (V. 24.) TNM Order]" (2006), https://net.jogtar.hu/jogszabaly?docid=A0600007.TNM.
[120] Ministry without Portfolio, "176/2008. (VI. 30.) Korm. rendelet [176/2008. (VI. 30.) Governmental Order]" (2008), https://net.jogtar.hu/jogszabaly?docid=A0800176.KOR.
[121] Ministry without Portfolio, "7/2006. (V. 24.) TNM rendelet".
[122] Medgyasszay Péter and Gáts Andrea, "Áttekintés az energetikai követelmények rendszeréről és a közeljövőben várható változásokról – I. rész [Overview of the System of the Energy Requirements and the Changes of the Near Future]," 2018.

- “for their production and for their maintenance no harmful or unnatural materials are needed”[123]
- “they were produced with the use of human force without any industrial technologies” [124] and “ideally the energy needed for transportation is minimal” [125]
- “they are made of natural materials”[126]

Therefore here, I study only the technical performance of structures. (Appendix 1) The results of this analysis from the viewpoint of the design are the following:

- Foundations: However, foundations are suitable to all needs, – especially stone structures, given to their high performance of stability, the human resources are missing today to build a stone foundation. This aspect has to be considered during the design process. Modern foundation techniques – concrete and reinforced concrete structures – are preferred in architectural practice in the case of a new construction.
- Floorings: Vernacular structures are not suitable for the current needs of moisture resistance. However, as the visitor’s facility is an open building, its requirements of floorings differ from residential houses. Therefore, I do not consider using vernacular flooring techniques.
- Walls: In general, vernacular walls are suitable for modern needs if insulation and soil moisture problems are solved. I put a special emphasis on wall structures regarding my design, as this structure means opportunities for experiment.
- Ceilings: Vernacular structures are suitable for current needs, except for insulation requirements, which can be solved with extra insulation. The lack of need for

[123] Bihari, “A magyar népi építészet mint fenntartható építési eljárás,” 15–38.
[124] Ibid.
[125] Ibid.
[126] Ibid.

maintenance in the case of vernacular ceilings is advantageous. My design does not have any ceilings.

- Roof structures: Vernacular wooden structures are perfectly suitable for modern requirements. The most suitable roof structures are in present-day use in architecture practice. However, the vernacular method to connect wooden elements requires specially trained joiners and more time than modern methods. As the roof of the visitor's facility is not a typical vernacular form, I need to apply modern structures.
- Roof coverings: Straw and reed structures are not fireproof, which excludes their use. The construction of wooden roof cover is expensive and requires special knowledge. Therefore, I apply ceramic tiles for roof cover, which is the most common practice in the reconstruction of roofs of vernacular houses.

3.2 Wall structures

Among Hungarian vernacular structures, walls have the widest varieties of techniques. There are a small number of traditional or semi-traditional techniques that are present in Hungarian building practice. My intention in the case of the visitor's facility is to present various techniques, in different parts of the building.

I decided to use loadbearing wooden frame for the loadbearing structure for the visitor's facility, as the use of wood for building purposes is ecological (Section 2.4), has a sound legal basis, – fulfilling the modern requirements of stability, – and wood is easily available in Hungary. Furthermore, the timber-frame structure makes the presentation of different wall techniques possible, as even traditional walls, which do not fulfil stability requirements, can be built in between the frames as infilling walls.

The timber-framed structure was present in Hungarian vernacular architecture in two forms. (Figure 26 and Figure 25) The earthbound post structure consists of a row of earthbound posts, placed in back-filled post-holes, with an about three-metre distance between them. The posts of the timber-framed structure are wedged in a bottom plate, making a closed frame together with the top-plate. I use a modern form of the earthbound post structure in the reconstruction of the barn in Pomáz-Nagykovácsi-puszta. (See Chapter 4)

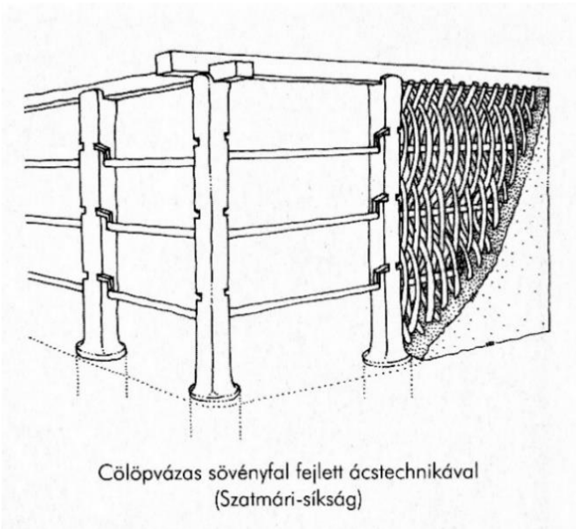

Figure 26:: Earthbound post structure with wattle wall, with developed joiner technique (Szatmári-síkság)

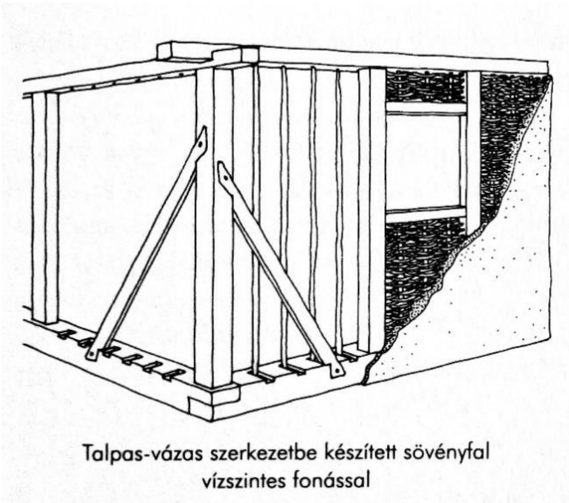

Figure 25: Timber-framed structure with bottom plate with vertical infilling of wattle

I study wall types, which exist in present-day Hungarian building practice and which are traditional walls or use the traditional logic of building with by-products of agriculture. The managers of the site intend to involve volunteers in the construction of the visitor's facility, to raise awareness of the values Pomáz-Nagykovácsi-puszta represents and to bring people close to the site itself. Therefore, besides introducing the history of the structures and their relevance to the Pilis, I analyse them from the viewpoint of their feasibility during a construction camp.

(Table 7) I intend to collect the characteristics of the possible structures that can be applied in the visitor's facility, to confirm my choices of wall techniques, I used in the design.

(See Chapter 4)

I need to note here, that I regard the territory of the Pilis as it was used in the Middle Ages. Today the area is divided into two geographically different parts, the Pilis and the Visegrád Mountains. However, in the Middle Ages both was called Pilis.[127]

Regarding the past of the Pilis area my main source is The Vernacular Architecture of Pilisszentlászló[128] by Rudolf Franyó, which has been the only available publication about vernacular architecture in this region. Pilisszentlászló is a small village in the heart of the Pilis Mountains. (Figure 27) In terms of wood and stone sources it is a typical village of the Pilis, but its accessibility to water is worse than in the other settlements. About the quality of earth found here I have no data to tell whether it is similar to other parts of the Pilis. Regarding the presence of earth, wood, stone and straw, I will examine "how local" these construction materials are in the case of the site in Pomáz-Nagykovácsi-puszta.

[127] Szabó, "Woodland and Forests in Medieval Hungary," 152.

[128] Franyó Rudolf, *Pilisszentlászló népi építészete* [The Vernacular Architecture of Pilisszentlászló] (Pilisszentlászló: published by the author, 2005).

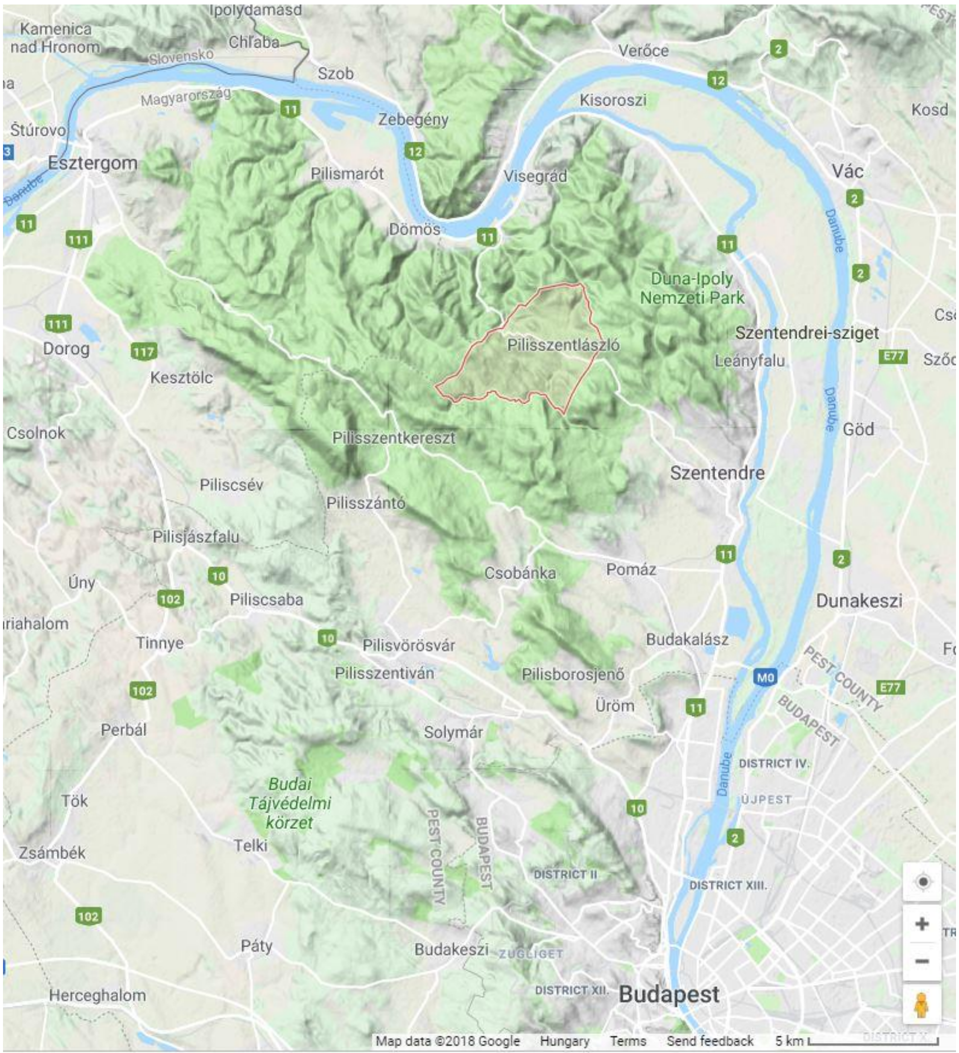

Figure 27: The location of Pilisszentlászló
Source: Google Maps, "Pilisszentlászló," accessed 29 December 2018, https://www.google.com/maps/place/Pilisszentl%C3%A1szl%C3%B3,+2009/@47.6722966,18.5969303,11z/data=!4m5!3m4!1s0x476a7e93871eae19:0x400c4290c1e79b0!8m2!3d47.7240115!4d18.9877803!5m1!1e4?hl=en.

The most important written sources of this analysis are three books:

- Traditional Walls[129] by Miklós Buzás,
- Construction and Renovation of Earth and Adobe Walled Houses[130] by Miklós Szűcs
- and Vernacular architecture of Pilisszentlászló by Rudolf Franyó.[131]

[129] Buzás and Sabján, *Hagyományos falak*.
[130] Dr. Szűcs Miklós, *Föld- és vályogfalú házak építése és felújítása* [Construction and Renovation of Earth and Adobe Walled Houses] (Budapest: Építésügyi Tájékoztatási Központ Kft., 2008).
[131] Franyó, *Pilisszentlászló népi építészete*.

The figures of this section are taken from the book by Buzás and Sabján, unless otherwise stated. Although, Szűcs provides the description of the building methods of 2008, regarding most of the wall techniques I analyse, I intend to provide up-do-date information with my special focus on construction camps. Therefore, I have made interviews personally, on telephone and via email with experts on the wall techniques concerned. The analysis is based on the interviews; information from different sources are footnoted.

Cob wall (Rakott sárfal)

- General description: The wall is made of mud, in a way mud proportions are placed on the top of each other. Several techniques existed in Hungarian vernacular architecture, the so-called 'swallow heap wall' is in present-day architectural practice.[132] (Figure 28, Figure 29 and Figure 30) My interviewee is an expert on this technique.
- History and geographical relevance: Cob walls have an early history in plain lands, namely in the Great Alföld and the Little Alföld, but it was known in all areas where Hungarians lived. In regions rich in wood, it became widespread only in the eighteenth-nineteenth century, but in some territories – for example in the Mezőség – it became common at the beginning of the twentieth century.[133] According to Franyó, in Pisszentlászló cob walls were not present because of lack of straw, – that this technique requires, – and for the reason of the time and energy consuming nature of this building method.[134]

[132] Buzás and Sabján, *Hagyományos falak*, 69–78.
[133] Ibid., 75–77.
[134] Franyó, *Pilisszentlászló népi építészete*, 21–22.

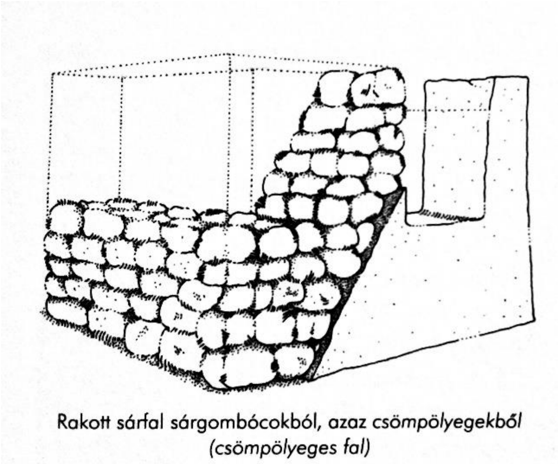

Figure 29: Cob wall made of 'mud dumplings'

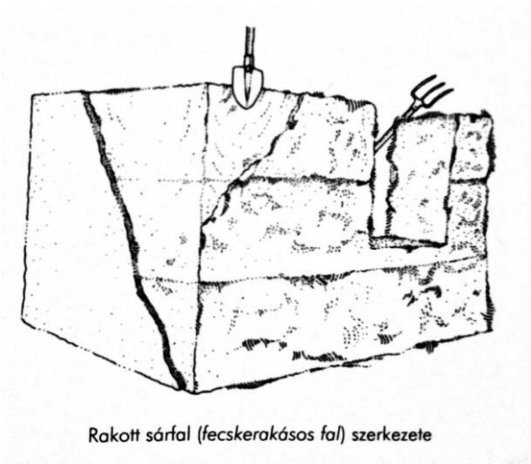

Figure 28: Cob wall ('Swallow heap wall')

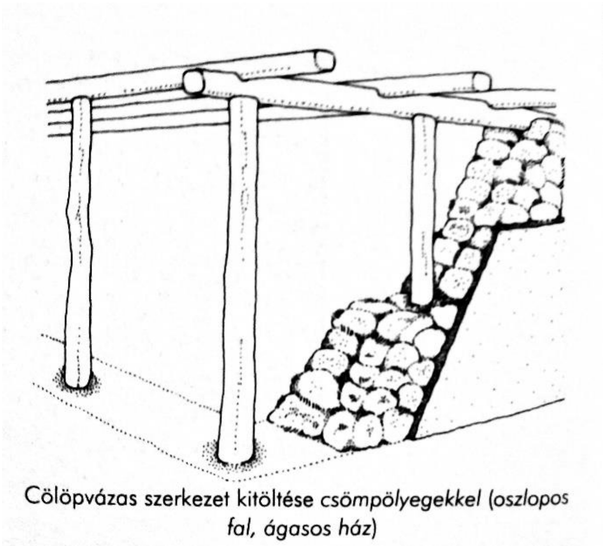

Figure 30: Pine frame structure filled with mud dumplings

- Interviewee:[135] János Gáspár is a cob-wall builder by profession, with decades of experience, working with his own team of constructors.[136]
- Required equipment: Only such tools are needed, that are available on an average farm, such as a hoe, shovel, pitchfork and spade. A pitchfork with a short handle was used in

[135] I have made an interview with János Gáspár by telephone in March 2019.
[136] Gáspár, "Bemutatkozom - Újra itt a vályogfal ideje!".

the vernacular practice, and the same tool is used today, as it is lighter than long-handled pitchforks.

- Required materials: earth, straw, water
- Building method: The mud has to be prepared by mixing earth and straw, adding water and trampling it continuously. Then a one-metre-high wall is built going around the perimeter of the house. After waiting for two weeks, the surface of the wall is evened by a spade, which is followed by a week of drying. Then the work begins again with building another metre of wall. (Figure 31) Szűcs states that the construction of a cob wall is easier, on the other hand, there is more shrinkage than in case of other earth wall techniques. [137]
- Team of builders: People making the mud, work in pairs. The wall is also built by pairs: one gives the mud to the person who places it on the wall. (Figure 32) At least the former needs to be an expert, as it is important to always give the same amount of mud, which means that the number of experts and volunteers involved needs to be the same. Gáspár has his own professional team, he regularly works with. He says the work is hard, therefore volunteers are able to work only for one hour at a time. Thus, when organising a construction camp, the possibility that volunteers are able to work only a few hours a day, has to be taken into consideration.
- Required time for building: five workers, – with two of them working in pairs, and one helping them, – build 20-22 metres of one-metre-high wall in one day. According to Gáspár, it is a fast and easy technique, although between two building phases builders need to take a break of a week. The walls of an average residential house take about two months to build from the foundation to the top, depending on the weather.

[137] Dr. Szűcs, *Föld- és vályogfalú házak építése és felújítása*, 83–84.

Therefore, Szűcs describes cob wall technique as a relatively slow building method. [138] In case of construction camps, three camps have to be organized for the construction of a three-metre-high wall.

- Price: According to Gáspár the cost of cob walls is in medium category, similar to the ceramic block wall, which is a widespread technique in Hungary.

Figure 31: Cob walls after the third building stage Source: Gáspár János, "Hogyan készül a vályogfal? Bemutatkozom - Újra itt a vályogfal ideje! [How Earth Wall Is Made? - The Time of Earth Walls Is Here Again!]," accessed 5 May 2019, https://valyogfal.hu/hogyan-keszul-a-valyogfal/.

Figure 32: Building cob walls: working in pairs Source: Gáspár János, "Képgaléria - újra itt a vályogfal ideje! [Gallery- The Time of Earth Walls Is Here Again!]," accessed 5 May 2019, https://valyogfal.hu/kepgaleria/.

Rammed earth wall (Vert fal)

- General description: The wall is made of soil, without extra amount of water added and rammed with the use of shutters. It must not contain hummus, but it should contain a small amount of clay.[139]
- History and geographical relevance: Two building methods existed in Hungary, the so-called "yoke shutter" and the "column shutter". (Figure 33 and Figure 34) The early history of this technique is not known, but we know that from the middle of the eighteenth century it was used in Hungary. The "yoke shutter" rammed walls were

[138] Dr. Szűcs, *Föld- és vályogfalú házak építése és felújítása*, 83–84.
[139] Ibid., 99–100.

common in Transdanubia and the southern part of the Great Alföld. The "column shutter" was known in the Little Alföld, in some parts of Transdanubia, in the Great Alföld, in the valleys of the Northern Mountains and in the middle areas of Transylvania.[140] According to Franyó rammed earth wall technique was used also in Pilisszentlászló.[141]

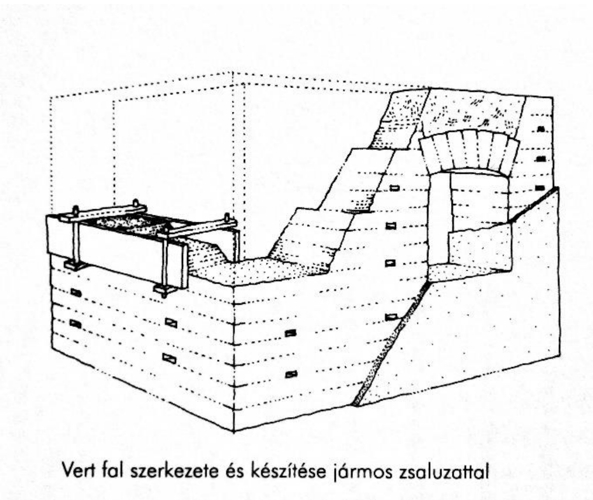

Figure 33: Rammed earth wall with "yoke shutter"

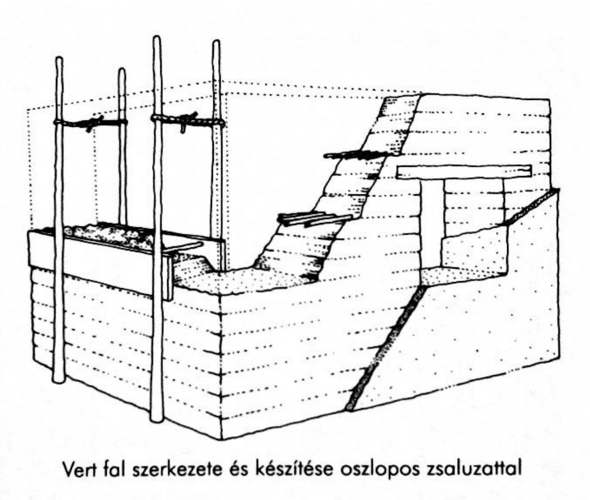

Figure 34: Rammed earth wall with "column shutter"

- Interviewees: I have made three interviews regarding this technique, with János Gáspár,[142] Ádám Bihari[143], and Sándor Nagy.[144] Gáspár and Bihari did not construct a house made of rammed earth, although they have made test walls. Ádám Bihari is an architect designing and constructing houses made of natural materials. He studied earth

[140] Buzás and Sabján, *Hagyományos falak*, 79–90.
[141] Franyó, *Pilisszentlászló népi építészete*, 20–21.
[142] I have made an interview with János Gáspár on telephone in March 2019.
[143] I have made an interview with Ádám Bihari personally in March 2019. He forwarded me the documentation of the rammed earth wall of Nagyvázsony and allowed me to use the data and pictures of the document.
[144] I have made ai interview with Sándor Nagy on telephone in May 2019.

building at the *Université Grenoble Alpes*, an institute that researches earth as a building material. [145] In 2018 he constructed an experimental rammed earth wall in Nagyvázsony. Nagy was a designer, constructer and a technical manager in charge, now he is a pensioner. He built a small number of rammed earth walls in the '70s with "column shutter" technique.

- Required equipment: According to Gáspár, besides the ramming stick only simple tools are needed that are available on an average farm, such as a shovel, hoe, spade and boards, sticks for the shutter. On the other hand, in Nagyvázsony a special shutter was used, that was prepared before the construction.
- Required materials: earth, water, a small amount of straw and aggregates, such as sand and clay if needed
- Building method: In the case of the Nagyvázsony wall, besides the construction of the foundation and the footing a special shutter was made, – similar to the "yoke shutter", – in the preparation phase of the work. The edges of the shutter, that was placed on the wall was filled with straw-earth, that was prepared after the excavation of the local earth. (Figure 35) The ramming was conducted by traditional ramming sticks in ten-centimetre-thick layers. (Figure 36) After reaching the top of the boards, the shutter was removed and placed on the wall again, enabling to continue the work with filling its edges by straw-earth. According to the experience of Nagy, the work can be continuous, there is no need to wait between ramming phases. His team placed a small amount of straw between earth layers, to absorb moisture. Nagy said that deep cracks often

[145] Université Grenoble Alpes, "Université Grenoble Alpes - Physics, Engineering, Earth and Environmental Sciences and Mechanics Teaching and Research Department," accessed 6 May 2019, https%3A%2F%2Fwww.univ-grenoble-alpes.fr%2Fabout-us%2Forganisation%2Fdepartments-schools-and-institutes%2Fphysics-engineering-earth-and-environmental-sciences-and-mechanics-teaching-and-research-department-1249.kjsp%3FRH%3D1481038554444.

appear, especially on the facades with windows. It is possible to avoid them by placing reed or switches between earth layers around windows and in corners.

- Team of builders: In Nagyvázsony, five people worked on a six-metre-long wall at a time. Gáspár explains, that besides conducting the task of placing the shutter, inexperienced workers are able to work on the wall. Most of the constructors of the Nagyvázsony wall also had little experience in ramming. At the same time Szűcs emphasises that for the construction of rammed earth wall a special knowledge is needed.[146] Therefore, in a construction camp an expert is necessary, but the rest of the group can be volunteers.
- Required time for building: Gáspár states that the stability and insulation capacity of rammed earth walls are poorer than that of cob walls. On the other hand, Szűcs and all my interviewees agree, that its building time is less, – as earth contains less moisture, and there is no need to prepare mud.[147] In Nagyvázsony, five people built thirty-centimetre-high wall in ninety minutes, which is a 4.2 hours/square metre average.
- Price: According to Gáspár, the rammed earth wall is not cheaper than the ceramic block wall, because it requires a great amount of human resources. However, the price can be lowered by replacing the workers with volunteers.

[146] Dr. Szűcs, *Föld- és vályogfalú házak építése és felújítása*, 100.
[147] Ibid., 99–100.

Figure 35: Shutters on rammed earth wall, straw-earth placed on the edges Source: Photo made by Ádám Bihari, in Nagyvázsony, 2018

Figure 36: Ramming earth wall in Nagyvázsony Source: Photo made by Ádám Bihari, in Nagyvázsony, 2018

Mud brick wall (Vályogfal)

- General description: Mud bricks, – also known as adobe, – are produced and dried in the sun and built in the wall with common masonry technique. Traditionally, reed was often placed in between the rows of mudbricks.
- History and geographical relevance: The first source about mud brick walls is from the seventeenth century, but this structure is considered to be older. In the nineteenth century it became widespread in many areas: in the Northern Mountains, in the Upper-Tisza region, in Moldova, in Transdanubia – instead of wooden structures – and in some parts of the Little Alföld and Partium. In Transylvania it is only known in the Mezőség.[148] In Pilisszentlászó the mud brick structure was known, but it is a later technique than rammed earth. However, walls only made of bricks are rare, as their production is energy consuming. They were mostly used for mixed walls, most commonly together with stone.[149]

[148] Buzás and Sabján, *Hagyományos falak*, 90–99.
[149] Franyó, *Pilisszentlászló népi építészete*, 22–24.

- Interviewee:[150] Zoltán Vass, an adobe expert, runs a business with his son. It is called *Vályogház és kemence* (Mud brick house and outside oven), reconstructing and building mud brick walls.[151]
- Required materials: earth, straw, water, (reed)
- Required equipment: To produce mud bricks hoes, spades, bowls, molds and wheelbarrows are needed. For building the wall rakes, hoes and shovels are necessary, which can be replaced in case of mechanical mixing by an agitator and shovel.
- Building method: After the excavation of earth, the mud needs to be prepared with adding water, straw and if necessary, clay or sand. The mud is placed in the mold, which is removed and put into water for a second. Afterwards, the mold can be filled with mud again. Next day the bricks are turned on their back side for drying, the following day they are stacked in pyramids. They need to be dry when they are built in the wall. Building adobe walls requires the same, commonly known technique as brick walls. However, instead of cement mortar, earth mortar is prepared on the building site, which has the same technique as the preparation of mud for mud bricks.
- Team of workers: To produce mud bricks people work in pairs. Wall building requires minimum four people: two masons, working on the edges and two laborers working in between. The Csoma's Room Foundation leads mud brick construction works every summer in Zangla (India), that I took part in, in 2017.[152] Producing mud bricks by hand requires time and human resources, but in my experience an expert can easily teach and train people. In this case it has to be taken into consideration that inexperienced volunteers produce a smaller amount of bricks than practiced laborers.

[150] I have made an interview with Zoltán Vass by telephone in March 2019.
[151] Vályogház és Kemence, "Névjegy [Introduction]," accessed 5 May 2019, https://www.facebook.com/pg/valyoghaz/about/?ref=page_internal.
[152] Csoma's Room Foundation, "Csoma's Room Foundation," accessed 8 May 2019, http://csomasroom.org/en/.

- Required time for building: A pair of experienced workers can produce 700-750 pieces of mud bricks in one day. For a house, which is one hundred square metres in size, sixteen-seventeen thousand bricks are needed. Four workers can build eight-ten metres of a sixty-centimetre-thick wall in one metre height.
- Price: According to Vass, adobe walls are not cheaper than the commonly used ceramic block walls, what is more, they are usually more expensive as a large amount of human resources is needed. Mud bricks are also produced by companies. The cost of one square metre of thirty-centimetre-thick ceramic block wall (7670 HUF) and the same size adobe wall (7520 HUF), are similar. In the comparison I used the prices of Porotherm, a well-known company, producing ceramic blocks,[153] and the prices of *Tapolcafői Téglaipari Kft.* (a brick production company in Tapolcafő), producing mud bricks.[154]

Wattle wall (Sövényfal)

- General description: Wattle wall consists of several elements: the timber frame, the thicker sticks and thinner switches and branches, that are woven in between them. This structure is plastered by earth from both sides. There were vertically and horizontally woven walls in practice of Hungarian vernacular architecture. (Figure 37 and Figure 38)
- History and geographical relevance: The wattle wall is one of the earliest building techniques in Hungarian vernacular architecture. It was commonly used from the early ages until the nineteenth century especially in flat areas. Due to the requirements of the eighteenth century – that wanted to reduce the use of wood – their construction stopped

[153] Épker 2000 Kft., "Akciós termékek - Épker 2000 Kft. [Discounted Prodcuct - Épker 2000 Kft.]," accessed 5 May 2019, http://epker2000.hu/termekek/akcios-termekek?gclid=CjwKCAjwk7rmBRAaEiwAhDGhxG-VXtvfvGvOV3KEmSCHCYUX0U1G7AKBDq2YH-pl5xZvujWvMcghMBoCDJMQAvD_BwE.
[154] Forrástégla, "Árlista [Price List]", accessed 5 May 2019, http://www.forrastegla.hu/?id=arlista.

in some regions, but in others, – where timber-framed houses were common, – it became more popular. In the nineteenth century they were common in the villages of the Little Alföld, in the Transdanubia, alongside the Danube, in Kiskunság, in the Upper-Tisza region, in some counties of Northern Hungary, in Transylvania and in Moldova. They were used for residential and agricultural purposes.[155] According to Franyó, in Pilisszentlászló there were still standing houses with this structure in the turn of the eighteenth and nineteenth century.[156]

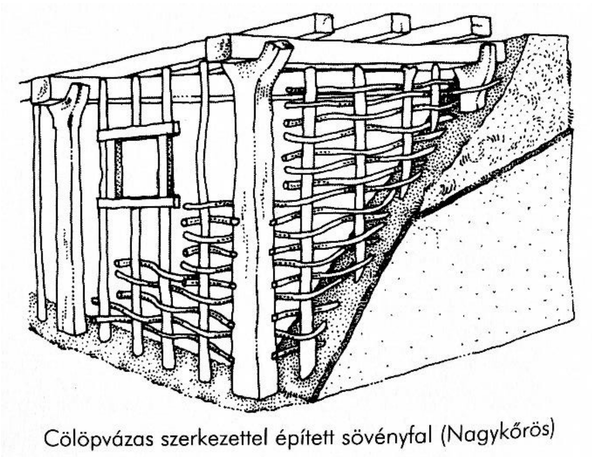

Figure 38: Wattle wall built with earthbound-post structure

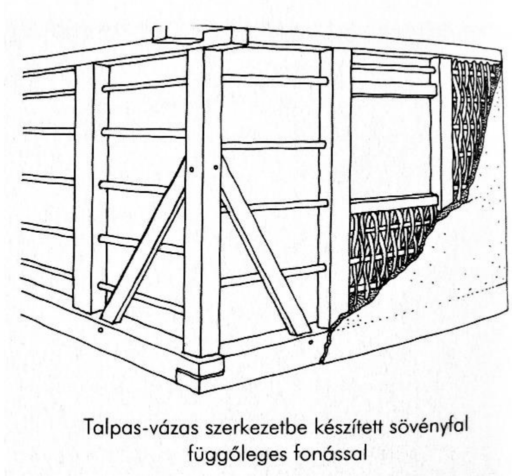

Figure 37: Wattle wall built with timber-frame structure with bottom plate

- Interviewee:[157] Ádám Bihari lead a construction camp about making wattle walls.
- Required equipment: For the preparation of the wooden structure: saw, bard, hatchet and clippers are needed. These are authentic tools, difficult to supply in good quality. On the other hand, they can be replaced by modern tools such as chainsaw and bolt cutter. For waving: clippers, for daubing shovel, hoe, spade and wheelbarrow are necessary.

[155] Buzás and Sabján, *Hagyományos falak*, 39–46.
[156] Franyó, *Pilisszentlászló népi építészete*, 20.
[157] I made an interview with Ádám Bihari personally, in March 2019.

- Required materials: timbers and wooden sticks, for the wood structure, switches for the waving and earth, straw and water for the daubing. The sticks can be many type of woods, natural branches, thick branches slashed into pieces, or battens from the sawmill. The thinner switches can be freshly cut willow, hazel, birch or straw rope. Bihari said, that in his construction camp the supply of the switches caused problems, as it is difficult to forecast the necessary amount, which he underestimated. The supply of switches depends on local circumstances in general, which might be a challenge also in other construction camps. In Pomáz-Nagykovácsi-puszta the ways of supply have not been found yet, therefore, I would consider this structure to be used primarily for relatively short walls.
- Building method: This technique has three stages: building of the wooden frame, wattle making and daubing. The first phase requires carpentry work, which means the construction of the loadbearing frame and the placement of wooden sticks between the timber frame. Daubing begins with the preparing of the proper mixture of mud, containing earth, straw and necessary aggregates if needed, likely to cob and adobe walls. However, this type of mud differs in consistency from the material of other earth techniques, as it contains more water. The mud is placed on the wall by hand or by hand tools. In Pomáz-Nagykovácsi-puszta the carpentry work, that is described here, is done when the wooden loadbearing structure is constructed.
- Team of workers: For the carpentry work one carpenter and two laborers are needed. Waving and daubing can be constructed by volunteers after a short teaching period, although, the supervision of an expert is needed. These techniques can be easily learned, and a construction camp can be organized with the supervision of a few experts, depending on the number of the team.

- Required amount of time for building: A five times five metre big, two-metre-high unit requires two days for making the carpentry work, two days for the waving and one week for daubing, working with tree people.
- Price: The cost of the materials is lower than the cost of ceramic blocks, but it requires a higher amount of human resources, which raises the cost of the construction.

Straw bale wall

- General description: Straw bale wall has two types: loadbearing wall and infilling wall within a timber frame. In Hungary, infilling structure is used, which is the possible type in the case of the visitor's facility.[158] In architectural practice straw bale structure is often used as an insulation layer in front of a brick or adobe wall. This wall structure has a better thermal storage capacity than straw bale structure and has a better insulation capacity than brick or adobe walls. As the visitor's facility does not require thermal quality, I examine only straw bale structure, which have a simpler construction method than brick or adobe wall with straw bale insulation layer.

[158] Novák Ágnes, "Építés szalmabála felhasználásával [Building with the Use of Straw Bale]" (thesis), (Szent István University, 2002), 14–15.

- History and geographical relevance: In Hungary this technique is not present in vernacular architecture. The first Hungarian straw bale house was built between 2000 and 2002. Since then the number of straw constructions has been rising.[159] (Figure 39)

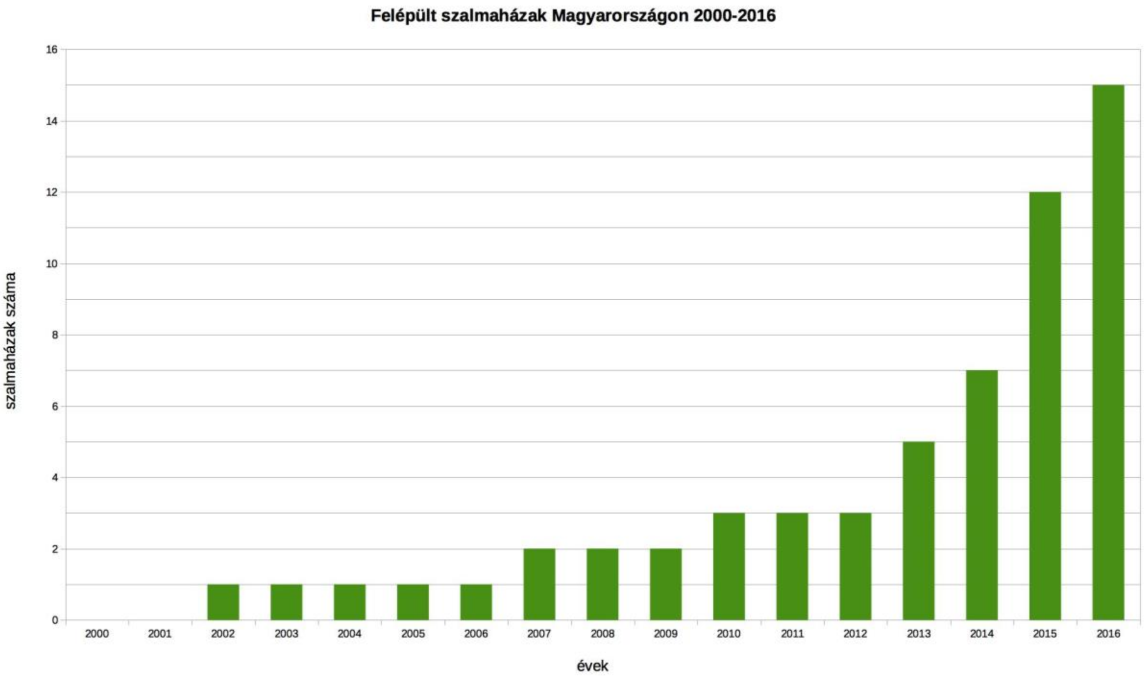

Figure 39: The number of ready straw houses in Hungary 2000-2016
Legend: horizontal data: years, vertical data: number of straw houses
Source: Eneregia és Környezet Alapítvány, "Szalmabála építészet hazai története: valami elindult [The History of Hungarian Staw Bale Architecture: Something Got Started]," accessed 6 May 2019, http://www.energiaeskornyezet.hu/szalmabala-epiteszet/hirek/39-szalmabala-epiteszet-hazai-tortenete-valami-elindult.

- Interviewee: Márton Révész has been dealing with straw architecture for almost fifteen years. In the Environment and Energy Foundation he raises the popularity of straw building technique by giving presentations and trainings. He participated in the construction of more than fifteen houses as a consultant. He has been a running his own business for three years, in which he has already built six houses made of straw.

[159] Eneregia és Környezet Alapítvány, "Szalmabála építészet hazai története: valami elindult [The History of Hungarian Staw Bale Architecture: Something Got Started]," accessed 6 May 2019, http://www.energiaeskornyezet.hu/szalmabala-epiteszet/hirek/39-szalmabala-epiteszet-hazai-tortenete-valami-elindult.

- Required equipment: For the carpentry work: hand-held circular saw, chain saw, cordless impact driver, jigsaw, chisel, spirit level and chalk line are needed. For placing the straw, straw bale needles, wooden mallet, strappings, chain saw, and hedge trimmer are necessary.
- Required materials: Timbers, battles and boards for the wooden frame and straw bales are needed.
- Building method: For the frame the joints are needed to be done. Regarding windows and doors, the lintels are needed to be built in, which is followed by the construction of the outside wooden frame. When the carpentry work is ready, the frame can be filled with the bales, which are cut or sewed in case of the pieces where the measures of the straw bales are needed to be changed. The straw is pressed by a wooden mallet or by trampling. In Pomáz-Nagykovácsi-puszta the carpentry work described here, should be done in the building phase of the construction of the wooden loadbearing structure. This means, extra work in the case of the straw bale wall, as the outside wooden frame is needed to be placed.
- Team of workers: The carpentry work requires a minimum number of three people. A carpenter needs to work continuously in the construction, as this phase necessitates a trained person. After the preparation of the sample pieces, the cutting, and the joints can be conducted by the laborers. For placing the bales minimum two people are necessary. A straw expert needs to lead the construction, which can be conducted by volunteers.
- Required amount of time for building: Regarding the carpentry work three people can build around twenty square metre of wall structures in one day. Two people can place fifty square metre of straw bales a day. The speed of construction is relatively high,

which is advantageous. On the other hand, plastering is required on both sides of the wall, if possible, the same year of construction to avoid the deterioration of straw bales.

- Price: The straw bale wall requires a great amount of human resources, which means a higher construction price than ceramic block wall has.

Stone wall (Kőfal)

- General description: Stone walls were built in various building techniques in vernacular architecture. Today they are presently used for buttresses or fences.
- History and geographical relevance: Buzás and Sabján describe two main territories of stone architecture: the Bakony Mountains with the hills of the northern part of Lake Balaton - and the Northern Mountains.
  - In the Bakony area, a special structure is common: first, the two sides of the wall are built with a gap in between, which is filled with stone and earth later. These walls are at least 60 centimetres thick. Stones were built in many cases with a dry technology, without mortar, although the stones of the vaultings were always placed in earth. From the 19th century lime mortar was used, first only in churches, later in residential houses, too. In this region stone dust was mixed in the plaster, although stone walls without plastering were also common.
  - In Northern Hungary, earth or lime mortar was always used; stone walls built with dry technology were unknown. In this territory, the stonework industry was developed, which contributed to the appearance of stone window and door frames and stone porch columns.[160]

Stone became a widespread building material in Hungarian vernacular architecture much later than earth and wood. It was an important material in urban, royal and

[160] Mednyánszky, *Kőházak*, 109–13.

military architecture, especially after the Mongol invasion (1241-42). In the eighteenth century, during the rebuilding of the country after the Ottoman invasion, stone was widely used, which also meant that mines were established. In vernacular architecture in the Middle Ages wood replaced stone, as it was accessible, cheaper and easily workable.[161] However, in the eighteenth century the shortage of wood and the official regulations[162] – that narrowed the accessibility of wood for peasants – made them use other materials, such as earth and stone.

- Interviewee: This structure is exceptional regarding the source of information, as I did not find an expert, who constructs traditional stone walls. Traditional stone wall technique does not use cement mortar, which I find it important for the reason of sustainability, as the production of cement has a high ecological impact. I have conducted an interview with Szabolcs Herczig, who organized a construction camp to build a buttress in Vértesszőlős.[163] This subsection presents his experiences.
- Supply of the material: In Vértesszőlős, the construction of stone walls was widespread in the past, but today it is not a common building material. Two types of building stones can be found in the region: second-hand stone from demolitions, and stone produced for the reconstruction of monuments, which is sold in a high price. Therefore, Herczig asked the owners of the houses under demolition to take the stones, that they do not need.
- Finding an expert: A friend of Herczig knew a mason who could construct stone walls. First, the mason agreed to work in the construction camp, but his conflict with Herczig made him to change his mind. Herczig intended to build with lime mortar, but he

[161] Buzás and Sabján, *Hagyományos falak*, 115.
[162] Zentai Tünde, "A hatósági előírások és a faépítkezés hanyatlása [Regulations of the Authorities and Decline of Using Wood in Building]," in *Az Arany János Múzeum Közleményei* [Publications of Arany János Museum] (Arany János Múzeum, 1989).
[163] I have made an interview with Szabolcs Herczig on telephone in March 2019.

adhered to use cement mortar. According his opinion stone can be placed only into cement mortar.

- Preparation: Herczig conducted the construction camp without an expert. He did a research on internet before, to gain knowledge. He has found a video about an English stone wall construction, but characteristics of that stone and the stone they had, was very different.
- Results: The work went very slowly. They used lime mortar, the binding strength of which is lower than of cement mortar. Therefore, they intended to build as precisely as dry walls are constructed. The limestone they applied, had an uneven shape and was difficult to cut or carve. Furthermore, they had to remove thick roots from the soil, which was time consuming. The frequent change of volunteers was another reason of the slow work. In five days, with an average of three-four volunteers, they did not manage to finish a five-metre-long wall.
- Construction camp: In Pomáz-Nagykovácsi-puszta there is a limited number of stones from the excavation, which are possible to be used, according to József Laszlovszky, the leading manager of the site. On the other hand, for a construction camp about stone walls an expert is required, which neither me, nor Herczig have managed to find.

I have prepared a table to summarize the data, I collected through interviews and written sources. (Table 7) Regarding wattle wall and straw bale structure I did not count with carpentry work, as I consider that all the extra carpentry work, these structure needs will be done in the building phase of the timber-frame of the visitor's facility. For the reason of not finding an expert, I do not consider stone wall technique as a possible structure in my design. Furthermore, I regard cob wall structure as the less advantageous one, as the contribution of volunteers is questionable due to the hard physical work, and the wall has to dry one week after each metre, therefore, its building time is longer than of other walls.

Table 7: Analysis of the wall structures

walling technique	**cob wall**	**rammed earth wall**	**mud brick wall**		**wattle wall**		**straw bale wall**		**stone wall**
working phase	-	-	brick production	wall building	wattle making	daubing	placing straw bales	daubing	
Is it a traditional Hungarian technique?	yes	yes	yes		yes		no		yes
Is this technique traditional in Pilis-szentlászló?	no	yes	yes (part of mixed walls)		yes		no		yes
Are there any special equipment needed?	no	shutter and ramming stick	frame	no	no		straw bale needle, wooden mallet	no	?
Team of builders	in pairs	5 - depends on the lenght of the wall	in pairs	4 people: 2 at the corners, 2 in between	around 3 people		minimum 2 people are needed to place the straw bales	around 3 people	?
Experts	in each pair one is required to be an experienced person	an expert is needed to teach and lead the constr.	an expert is needed to teach and lead the constr.	experts need to make the corners (about 2 experts needed)	an expert is needed to teach and lead the construction		an expert is needed to teach and lead the construction		I did not find.
Volunteers	hard work for volunteers	volunteers can do the ramming	volunteers can be teached	volunteers can be teached	volunteers can be teached		volunteers can be teached		?
Time - 10 people - 1 day (8 hours)	40-44 m2 (experts)	67 m2 (volunteers)	3500-3750 pieces (experts)	20-25 m2 (experts and laborers)	67 m2 (volunteers)	19 m2 (volunteers)	250 m2 (volunteers)	19 m2 (volunteers)	?
Notes	after one metre height one week is needed for drying								

Chapter 4 – Plan for the visitor's facility

In this chapter I introduce the architectural plans of the transformation of the barn, located next to the medieval ruins of Pomáz-Nagykovácsi-puszta into a visitor's facility building. I have done this project in consultation with the managers of the site, József Laszlovszky and Dóra Mérai. Their aim is to run the site according to the aims of the Cooperative Heritage Lab. (Introduction) Therefore they intend to involve volunteers in some construction phases of the barn, that I took into consideration.

The building structures of the design are based on my research (See Chapter 1-3) and my practical knowledge about the contemporary architectural use of natural materials, I gained during my work experience at NaturArch Studio, an architect office lead by Ádám Bihari. The drawings and the photos of this chapter are my work.

The site of the present-day farm is a mixture of man-made buildings and natural landmarks. The forestry area surrounds a stream, a lake and temporary water surfaces, that are former medieval fishponds. The buildings on the site date from different ages and are in different conditions. There are medieval ruins, pharmaceutical depositories and other constructions built before the fall of communism, and post-1990 agricultural buildings. Over the past twenty years the present-day owner constructed several buildings, such as the cheese shop and other houses in the near of the entrance. (Figure 40)

Next to the medieval ruins stands the barn, that my plans have transformed. This building is a part of a pattern, – indicated in purple in Figure 40, – houses which have a similar shape and orientation, influenced by the geographical circumstances of the territory. The barn has a mixed static structure: its south-west wall is made of bricks, infilling a reinforced concrete frame, but its other walls are loadbearing brick walls infilled by dross. (Figure 41) The outside walls are in good condition, but the roof is damaged in several places. (Figure 42-44)

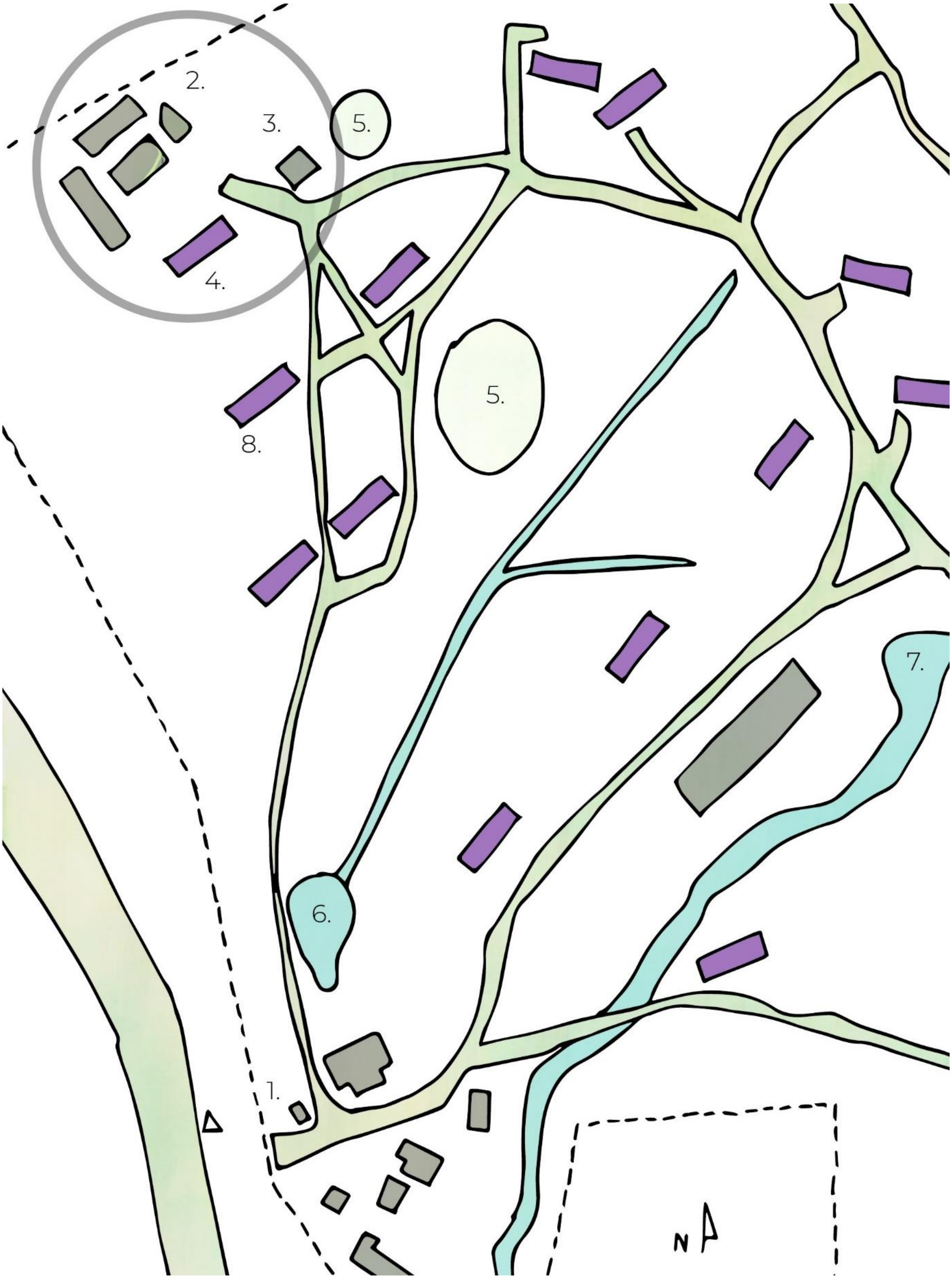

Figure 40: General layout, scale 1:2000
This figure is based on a map, made by Aleksandar Pantic. Source: Mérai, Source: Mérai, "Pomáz-Nagykovácsi-puszta Cooperative Heritage Lab", 23.
Legend: 1. Entrance, cheese shop, 2. Medieval ruins, 3. Guardhouse, 4. Barn, the topic of the design, 5. Medieval fishponds, temporary water surfaces 6. Lake, 7. Stream, 8. Barns built in the '90s

Figure 41: The wall structure of the barn

Figure 42: Inside view of the barn

Figure 43: The south-east wall of the barn

Figure 44: The south-west wall of the barn

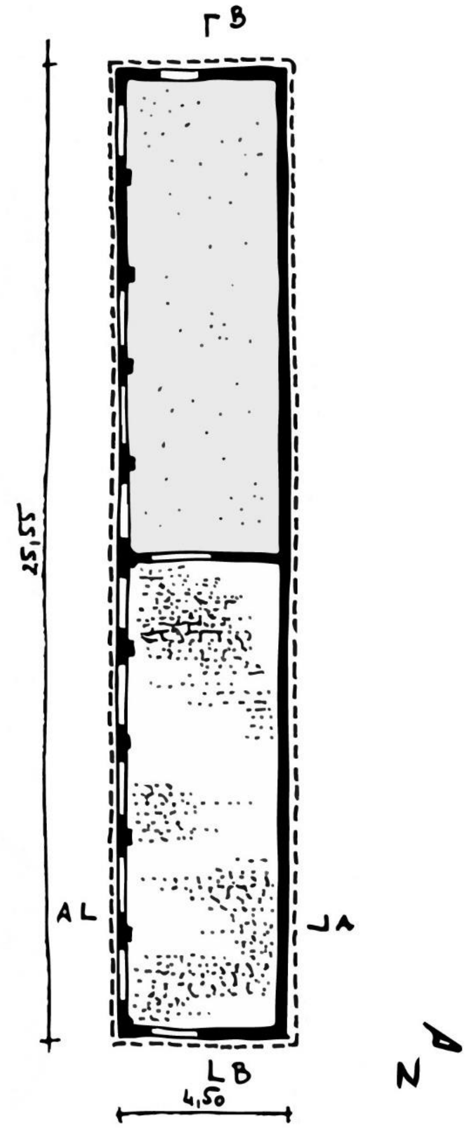

Figure 45: The layout of the present barn, scale 1:200

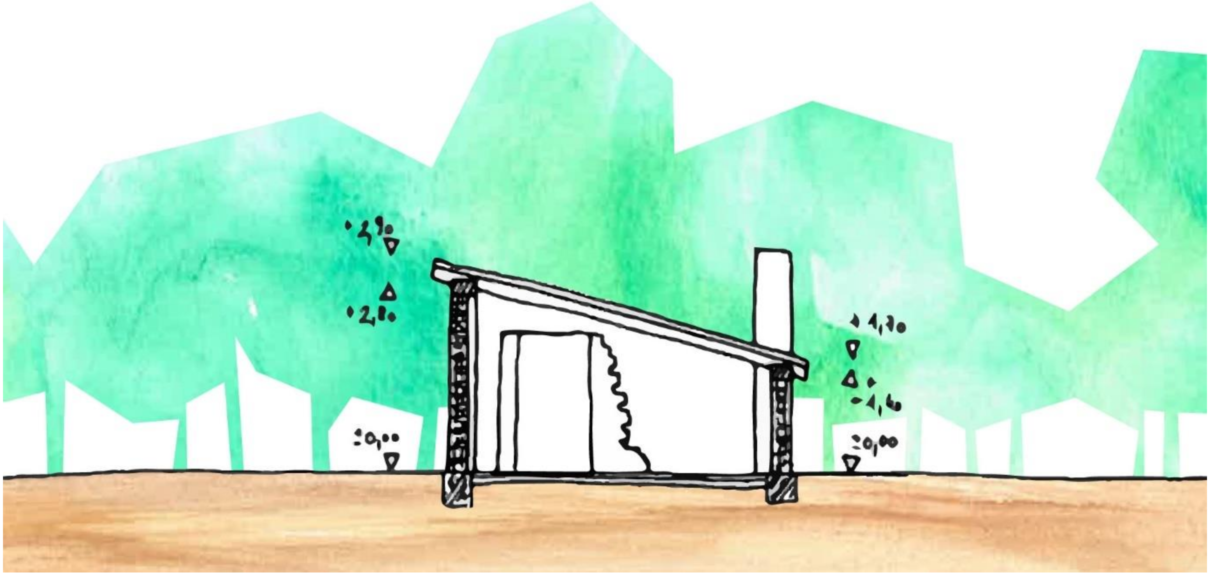

Figure 46: Section A of the present barn, scale 1:100

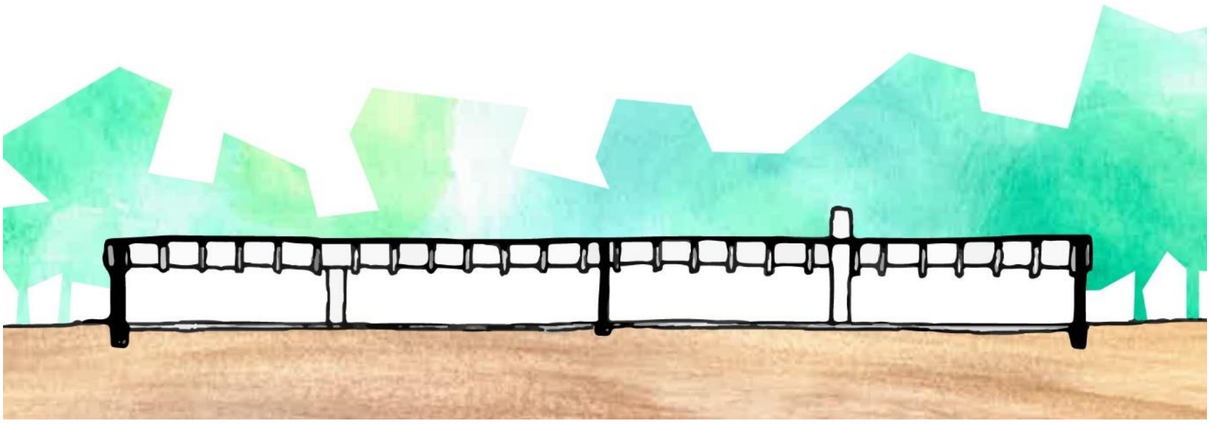

Figure 47: Section B of the present barn, scale 1:200

Figure 48: South-east façade of the present barn, scale 1:200

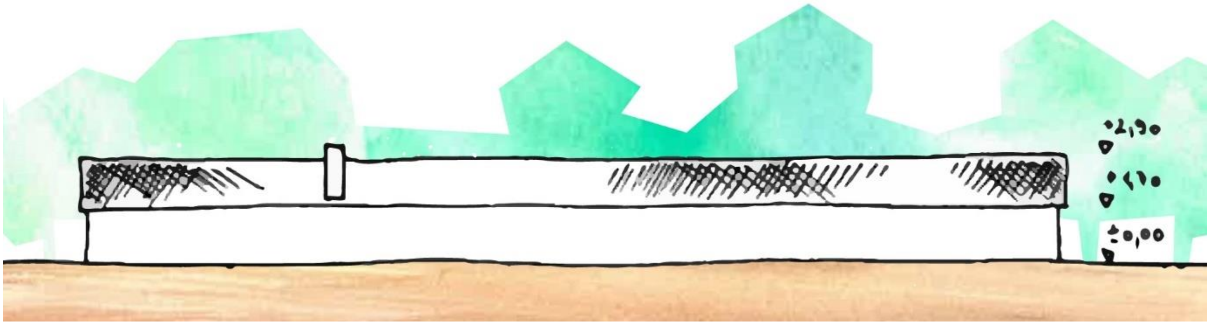

Figure 49: North-west façade of the present barn, scale 1:200

Figure 50: North-east façade of the present barn, scale 1:200

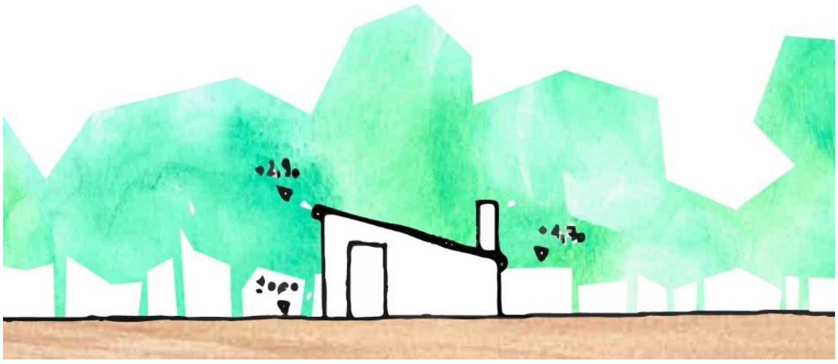

Figure 51: South-west façade of the present barn, scale 1:200

The single-pitch roof of the barn has a minimum interior height of 1.50 metres, which is not suitable for human use. (Figure 46-51) Furthermore, the roof is covered by asbestos slate that is a presently banned, toxic building product. Therefore, the roof must be removed and replaced, thus giving a new form to the visitor’s facility building, suitable for its new function.

The site of the medieval ruins can be reached on foot using a stone road. (Figure 52) Before entering the area of the monastic remains the visitor walks a few metres between the barn and the guardhouse, – which includes an exhibition room. Therefore, the visitor’s facility building needs to have a connection towards this direction. On the other hand, a more important connection needs to be ensured with the medieval ruins. Therefore, the necessary extension of the barn, required by the new function is added to the part, which is between the guardhouse and the ruins. (Figure 53)

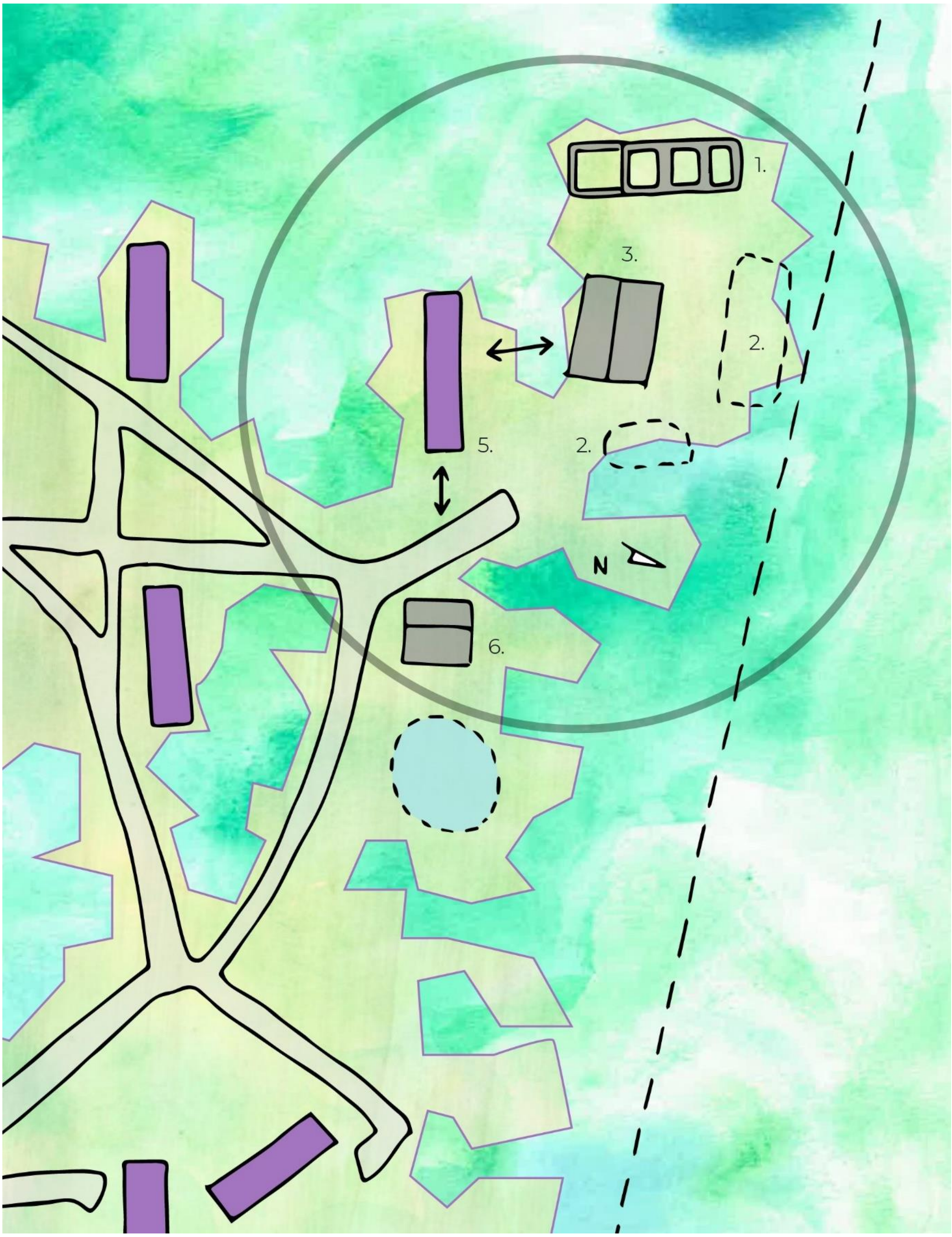

Figure 52: General layout of the present barn, conceptional connections, scale 1:1000
Legend: 1. Excavated wing of the monastery, restored medieval walls 2. Unexcavated wings of the monastery, traces of medieval walls 3. Remains of the medieval church under a temporary metal roof 5. The barn 6. The guardhouse

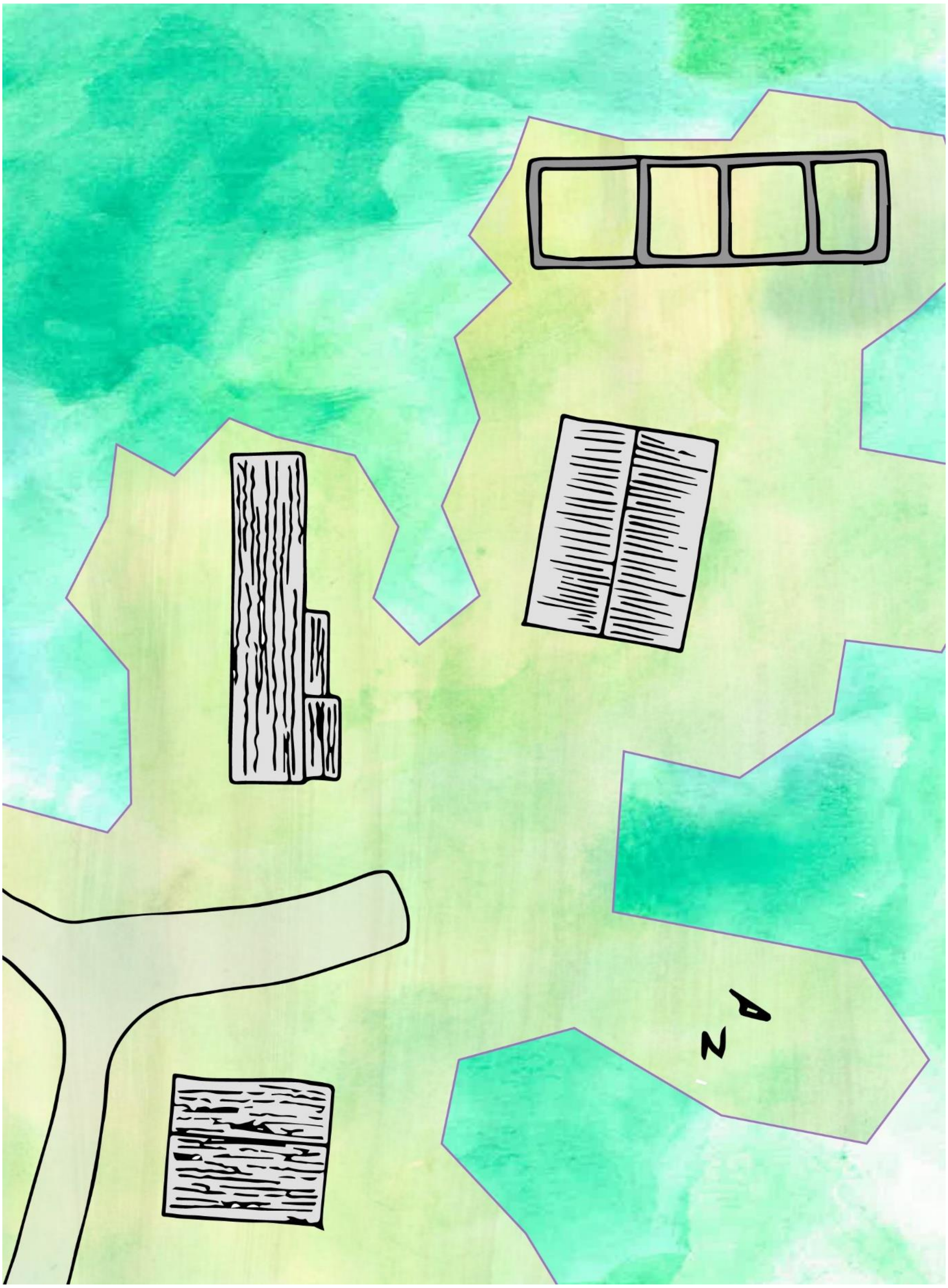

Figure 53: General layout of the visitor's facility, scale 1:500

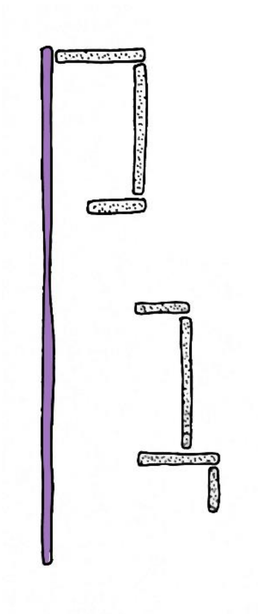

Figure 54: Concept of the plan, wall system

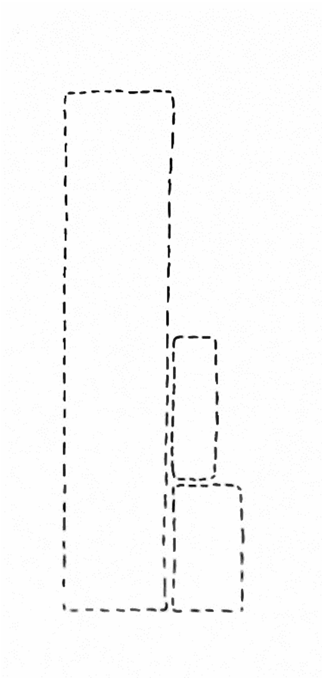

Figure 55: Concept of the plan: additive character of the expansion

The concept of my design focuses on the two main values of the site: heritage and sustainability. Adaptive heritage reuse, – which is the management concept of Pomáz-Nagykovácsi-puszta – intends to add layers of values and functions to a heritage site without erasing earlier layers.[164] The barn belongs to the history of the site, furthermore as an existing building, it contains inbuilt energy. Therefore, its revitalization with keeping some parts, is recommended, because it represents the values of adaptive heritage reuse and because it is a sustainable solution. The barn is part of a group of buildings, facing towards south-east, and the south-eastern wall of the building is in proper condition, is high enough for human use, and with its wooden windows is a characteristic element of the house. Therefore, I intend to keep this wall. (See purple wall in Figure 54.) I also keep two shorter walls, – the north-west façade and a part of the interior wall, – to show the original form and to support the enclosure of different functional spaces. (Figure 59 and Figure 64)

[164] Clark, Lardner, and Wolkenberg, "Adaptive Reuse," 4.

In my plan, other walls are made with different techniques with the use of traditional materials. (Walls with dotted infill in Figure 54.) This gesture, representing the new function of the building, refers to the fact that the monastic site was a grange, built with less elaborated structures, probably with a mixture of monastic and vernacular techniques. Furthermore, building with local and natural materials supports the idea of sustainability.

The form of the visitor's facility echoes that of the barn, although its main purpose is to give a suitable answer to the new functional needs of the building. (Figure 56) The additive character of the extension emphasizes the original longitudinal outline, separating the additional parts in form and height, which fits the idea of adaptive reuse, adding an extra layer to the existing ones.[165] (Figure 55)

Figure 56: View of the visitor's facility

[165] Clark, Lardner, and Wolkenberg, "Adaptive Reuse," 4.

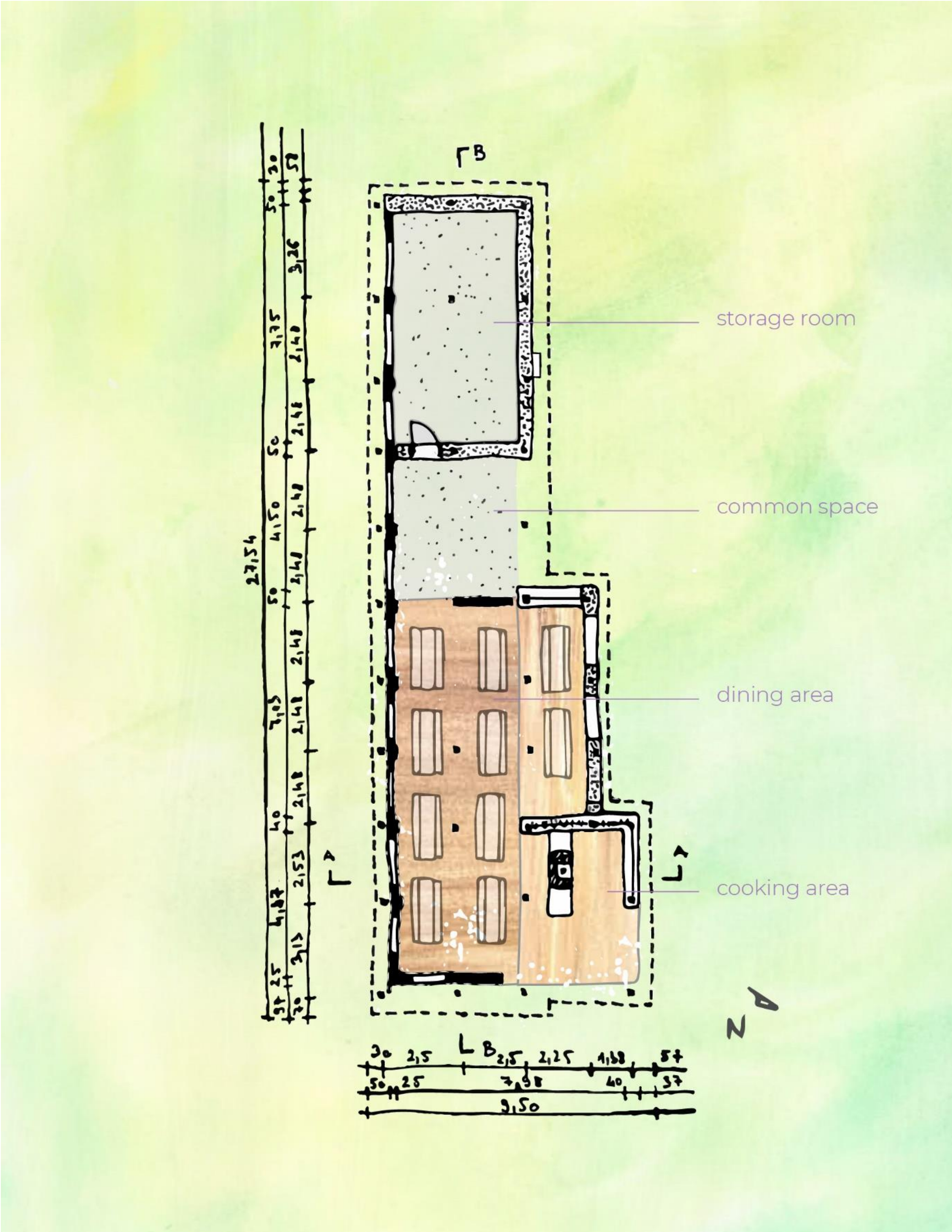

Figure 57: Layout of the visitor's facility, scale 1:200

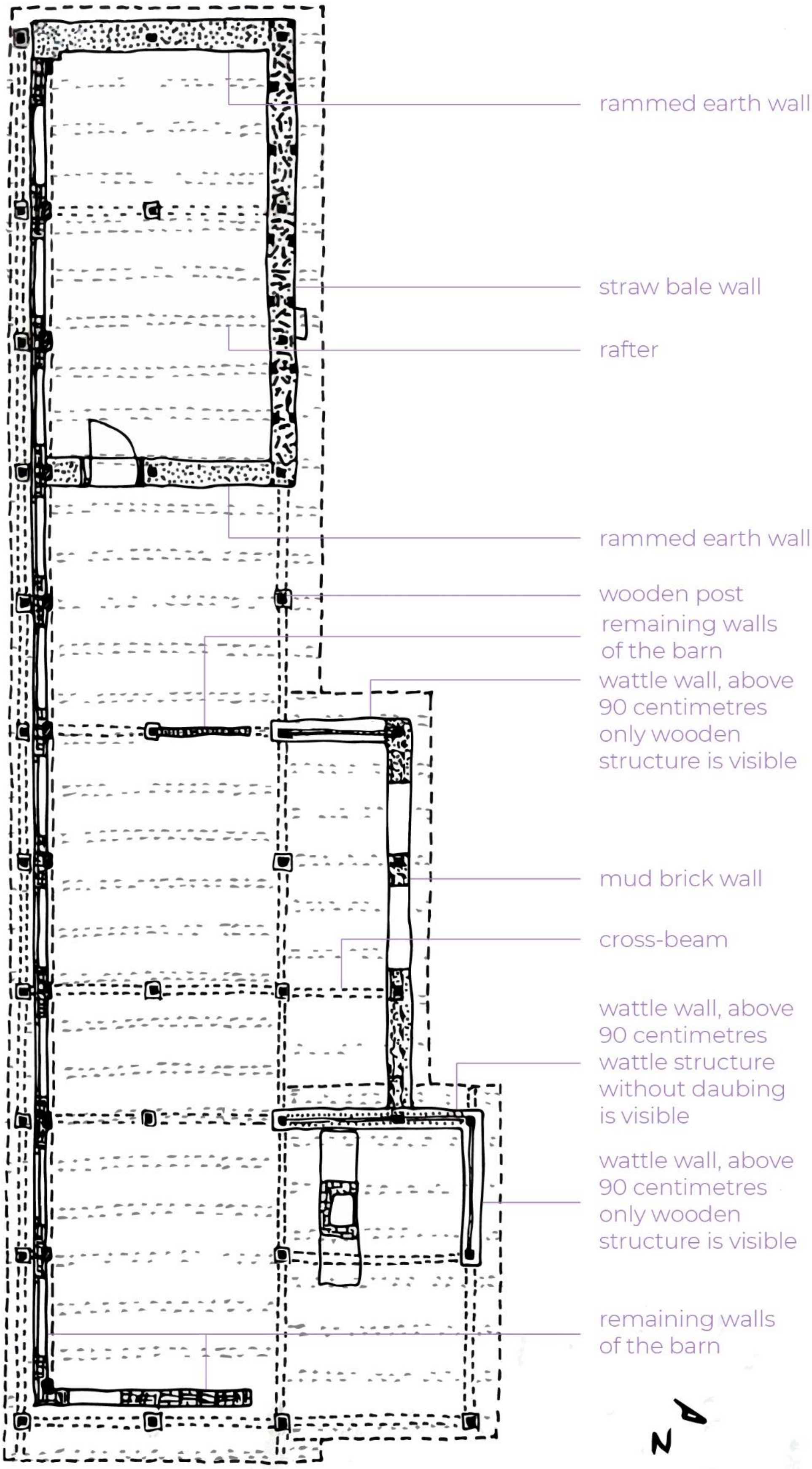

Figure 58: Layout of the visitor's facility, scale 1:120

The function of the visitor's facility was determined in consultation with the managers of the site. (Figure 57) The building will be used from spring to autumn and needs to provide shelter against rain and heavy sun. A large space for relatively big groups and a storage room are needed. I was asked to add an outside oven with measures given, that will serve the additional activities of baking and cooking. It will be built in a construction camp this summer, led by a master oven builder. I have placed the oven fitting to the longitudinal direction of the building, semi-separating the cooking and dining spaces, giving enough room for about ten people to be able to see the fire from the inside, while more people can have a proper view of the oven from the outside.

The visitor's facility has its own static structure: the beams and rafters are placed on wooden posts surrounding the former barn. (Figure 58) All walls are only infilling structures. The wooden elements, besides the rafters of the longitudinal body of the barn can be made of available second-hand wood, as they are relatively short elements. As it is unlikely to find second-hand wooden rafters, that have suitable size for the longitudinal body, I recommend supplying sawed product for this purpose. The wooden posts stand on concrete point foundations and the walls on concrete barn bases, which are the only contemporary solution for making the foundation suitable for present-day stability needs. The footings of the walls are 30-centimetre-high brick rows, protecting the wall structure from moisture and rain. The original floor is partly brick, partly concrete. (Figure 45) The extension has a brick floor, placed in another direction to emphasize its additive character. (Figure 57)

The built walls apply different techniques and traditional materials to present various wall structures. The north-east part of the visitor's facility, which is close to the stone road, needs semi-open structures to separate the functional spaces, at the same time enabling the view towards the ruins and the guard house. This is ensured by the empty, rare battens and undaubed rare-woven wattle wall, that show what the wall structure is made of. Furthermore, there are two windows looking in the direction of the ruins.

The closed storage room is in the south-west end of the building, where the movable tables, benches and other equipment can be stored. These are solid walls, that the visitors see only from the outside. The straw bale, the structure is made of, is shown in a small surface of the wall. This undaubed part is protected by a thick wooden frame against heavy rain. The structure of the rammed earth wall is visible in the case of the north-eastern wall, as its surface is not daubed. (Figure 59)

Figure 59: Section A of the visitor's facility, scale 1:100

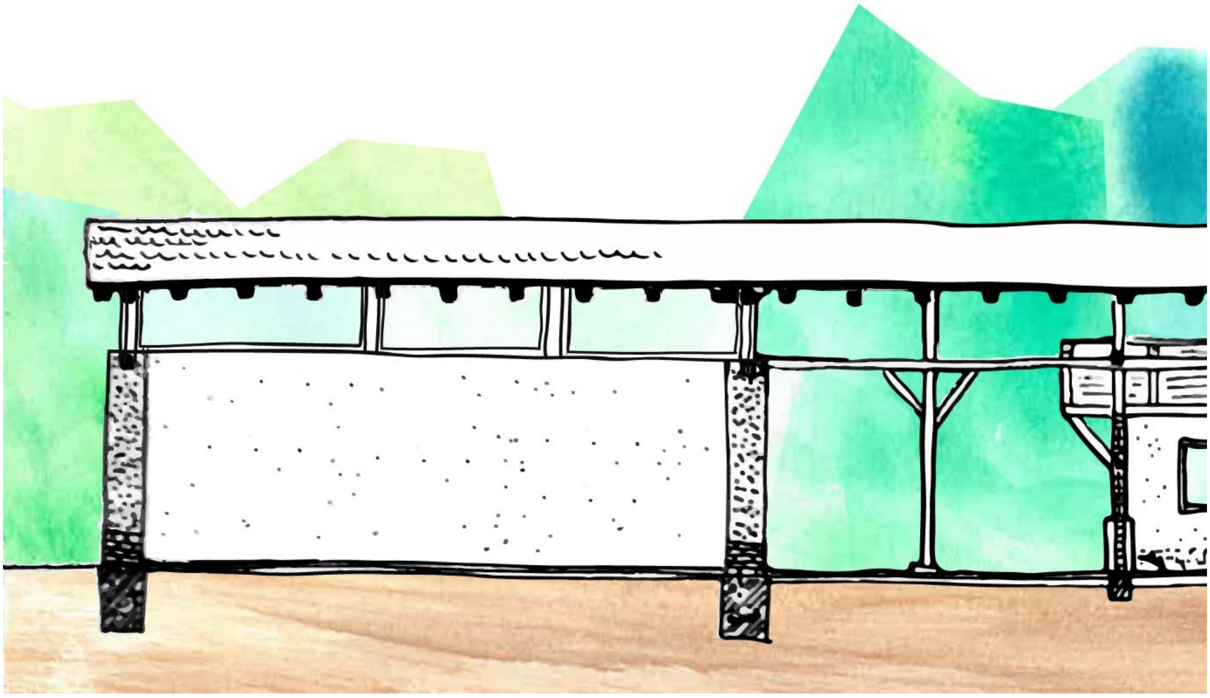

Figure 60: Section B of the visitor's facility, Part 1, scale 1:100

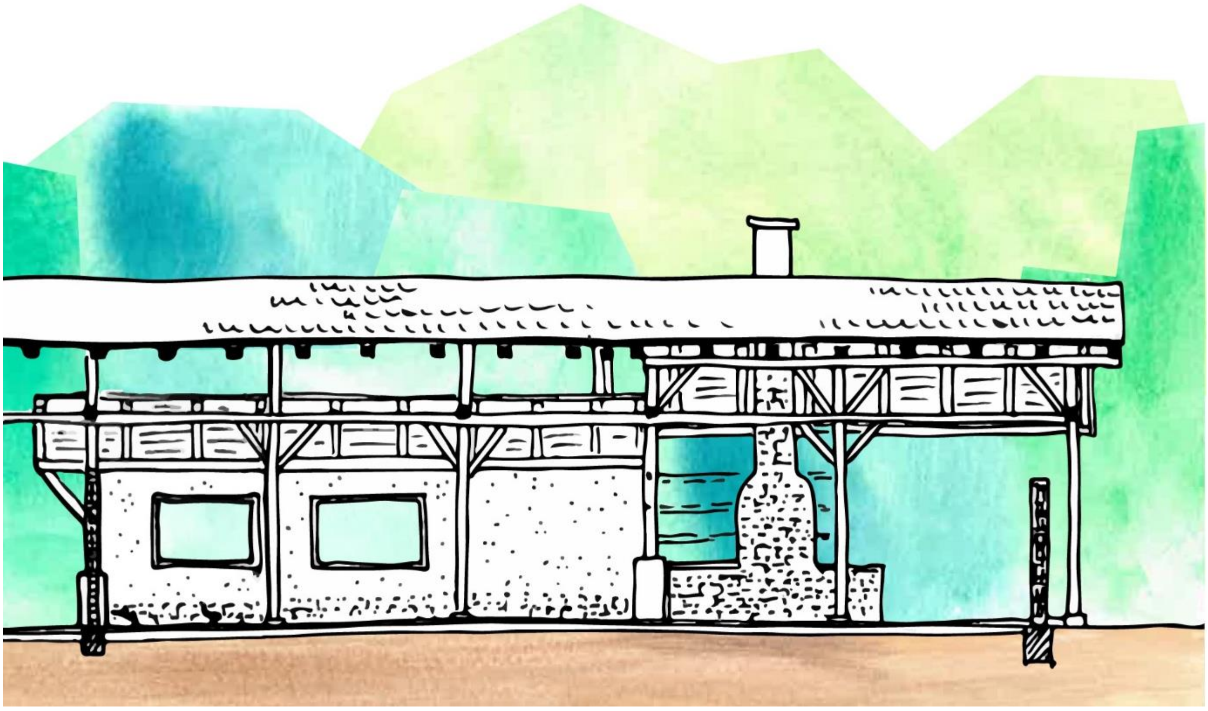

Figure 61: Section B of the visitor's facility, Part 2, scale 1:100

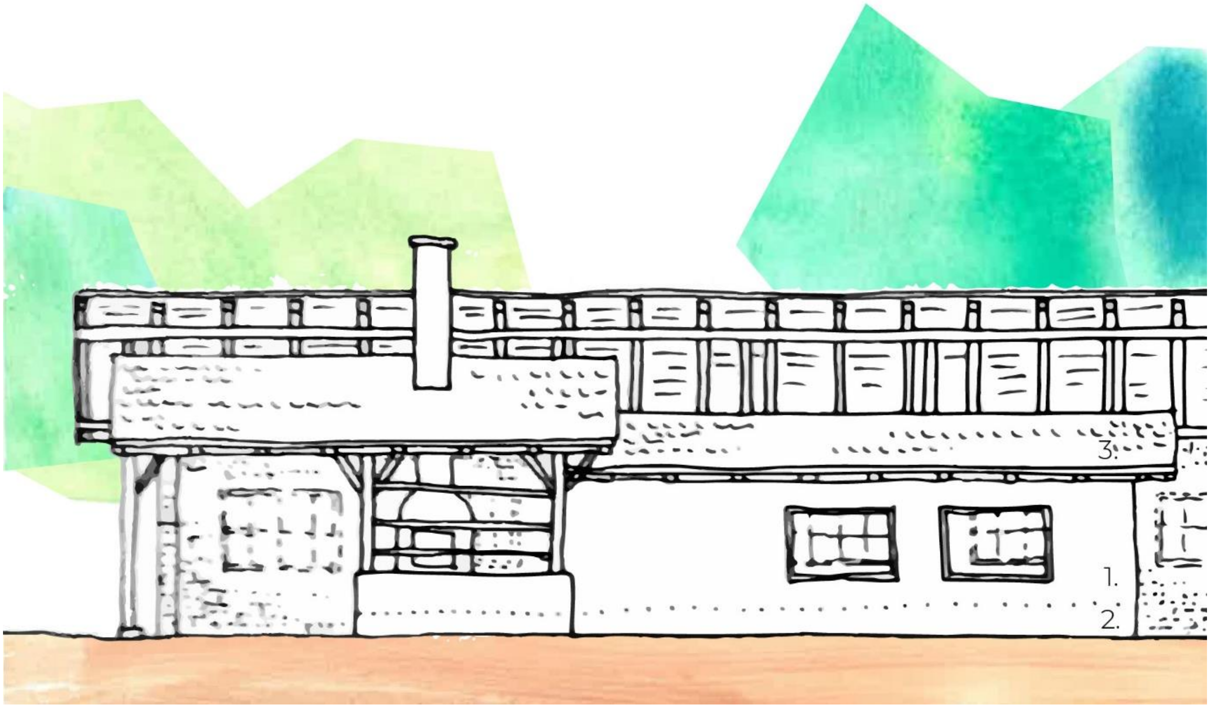

Figure 62: North-west façade of the visitor's facility, Part 1, scale 1:100

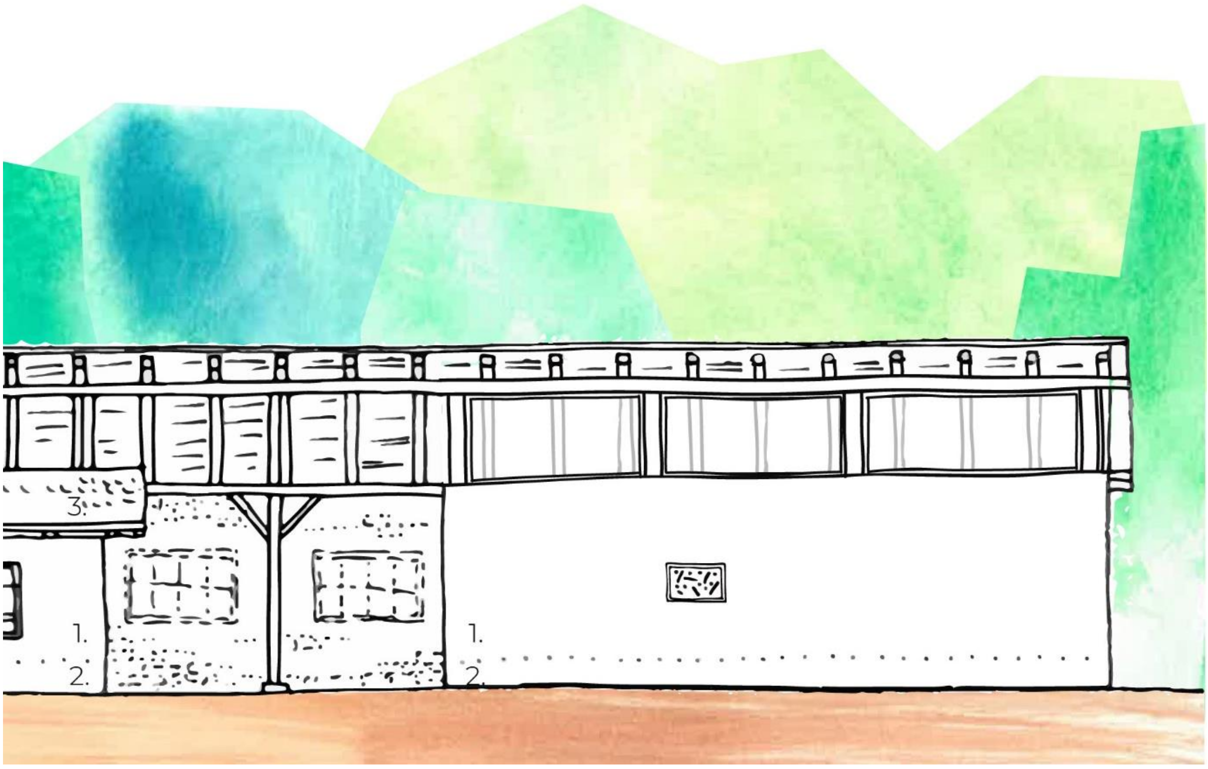

Figure 63: North-west façade of the visitor's facility, Part 2, scale 1:100

Figure 64: North-east façade of the visitor's facility, scale 1:100
Legend of the facades: 1. Lime plaster, white, 2. Cement plaster, white, 3. Second-hand roof tiles 4. Original brick wall, 5. Earth plaster, 6. Brick footing, 7. Unplastered earth wall, 8. Wattle structure

The outside surfaces of the daubed walls, appearing on façades, are covered by lime plaster and whitewashed. The footings are covered by cement plaster from the outside, also whitewashed. Lime plastering is a traditional technique for wall surfaces, while cement plaster is a modern material, but its use avoids damage caused by rain and moisture. Whitewashing is a traditional technique, that lacks chemicals. The concept is that the outside outline of the building is finished and white, while the inside parts of the building show the original colour and texture of earth plasters and daub. (Figure 59-68)

Figure 65: South-east façade of the visitor's facility, Part 1, scale 1:100

Figure 66: South-east façade of the visitor's facility, Part 2, scale 1:100

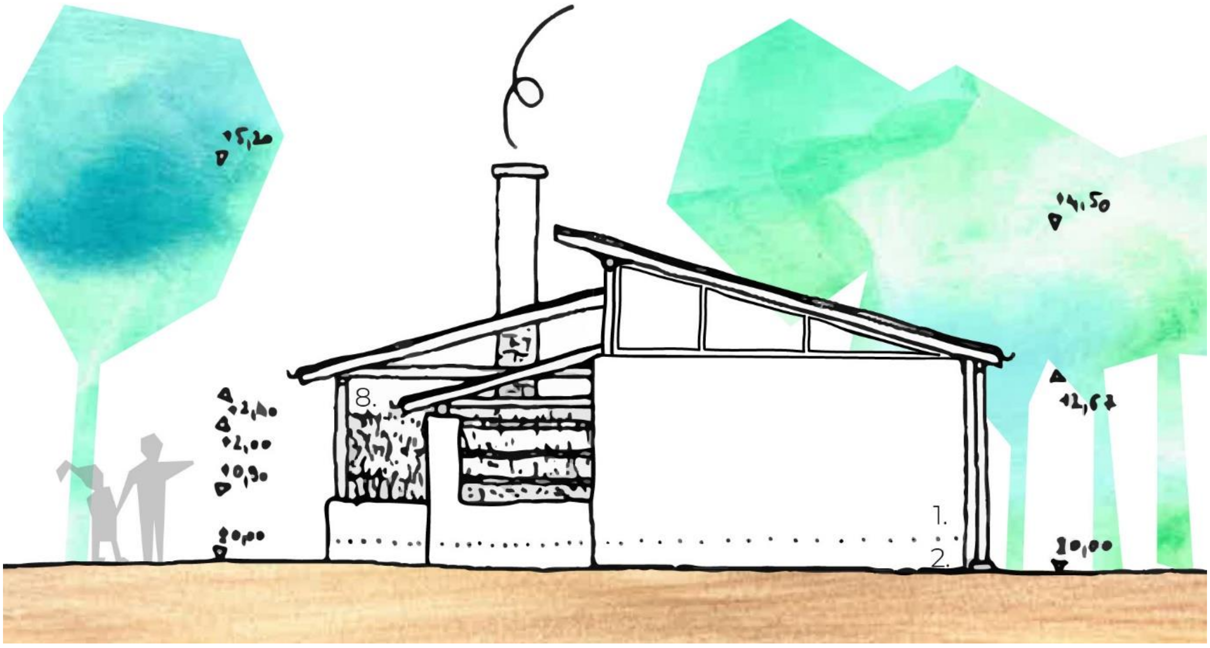

Figure 67: South-west façade of the visitor's facility, scale 1:100

Figure 68: Interior of the visitor's facility, looking towards north-east

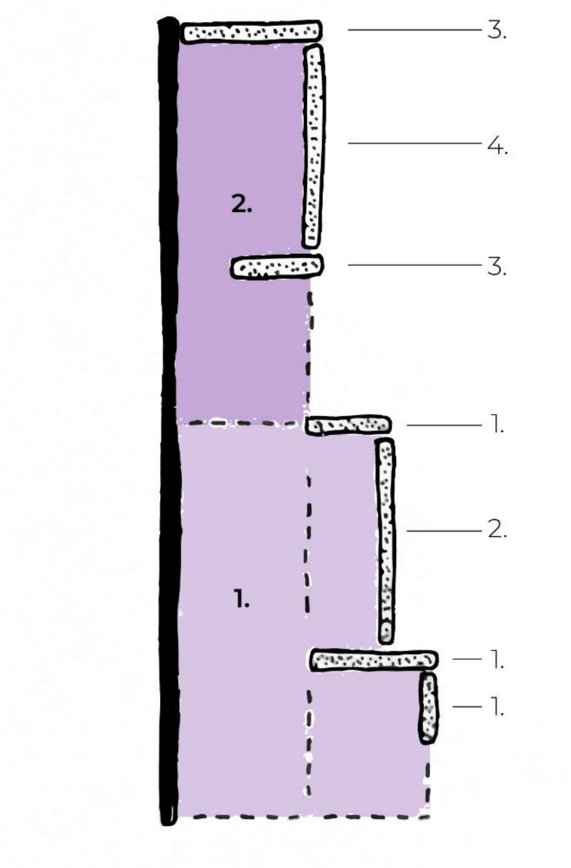

Figure 69: Construction phases
Legend: bold numbers show the construction phases of the wooden loadbearing structure and the roof, regular numbers show the construction phases of the infilling walls

The implementation of the building happens in several stages. (Figure 69) I recommend dividing the construction of the loadbearing wooden structure and the roof into maximum two stages, as the division increases some of the related costs and the energy needed for the organization of the construction. The structure needs to be overseen by a static engineer before construction and a more detailed plan must be made. The wooden structure needs to be made by professional carpenters, however involving volunteers in the process is possible.

The four types of infilling walls are made during four workshops. I have chosen these wall structures from the ones that I have analysed in the interviews presented in Chapter 3: rammed earth wall, mud brick wall, wattle wall and straw bale wall. (Figure 58) These are the most suitable structures regarding their implementation in construction camps.

In the design I intended to take into consideration the limited finances available. The major costs are the demolition and the wooden structure. The costs of the workshops, the material and the human resources are relatively low. I have separated the wall surfaces in a way that all of them could be constructed in a few days with a reasonable number of volunteers.

The loadbearing wood structure and the roof, that is covered by second-hand ceramic tile, is durable without regular maintenance, while the built walls need maintenance every two or three years. The managers of Pomáz-Nagykovácsi-puszta intend to build a community around the site involving schools and local people. The maintenance of the earth plasters is an opportunity for locals, school children or people interested in natural building materials to obtain some experience of traditional building techniques.

Conclusion

Building with local and natural construction materials have a low ecological impact. Due to the small number of people, who build traditional or semi-traditional structures using these materials, the suitable techniques are available even today. The popularity of these low-tech structures has raised in Hungary in the last decade. Furthermore, not only the use of building materials, but also the present-day traditional and semi-traditional techniques can be regarded as relatively sustainable building solutions, as they require the use of motorized tools in a low quantity.

The characteristics, the suitability to the functional needs, the required time, human and financial resources of these structures need examination in each building process. I have studied the possibility of using local and natural materials, traditional and semi-traditional structures in the heritage site of Pomáz-Nagykovácsi-puszta, considering the fact that the fact that the walls will be constructed with the help of volunteers. I have found five wall structures eligible for this purpose: cob wall, rammed earth wall, mud brick wall, wattle wall and straw bale wall, out of which I have chosen four for my design.

Involving volunteers in this project will most probably contribute to a minor decrease in the costs of the building process. On the other hand, organising a construction camp requires extra time, human and financial resources. The contribution of volunteers is a part of the management concept of the site, as adaptive heritage reuse intends to involve people in the development phase of the site.

I believe that in every building process the issues of sustainability and the ecological impact of the construction have to be taken into consideration. In each relevant cases the use of local and natural materials and low-tech structures should be examined instead of the instant use of materials and structures which are easily available but have high ecological impact. To raise the popularity of natural building solutions a growing number of examples are needed. In this thesis I have intended to show an example, where using traditional and semi-traditional building materials serves the function of the building and fit the values of the location. I believe that other small-scale heritage projects should also consider the use of traditional building materials and techniques.

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Glossary

The Glossary is applied from Peter Walker: The Australian Earth Building Handbook. [166] It is completed by words of other authors and my own definitions. (See citations.)

ADDITIVE - material used to improve characteristics of earth for construction, including chemical agents, waterproofing agents and vegetable binders such as straw.

ADOBE - sun-dried earth blocks, formed with wet mud placed into molds; material may contain a binding agent to limit cracking and improve strength (see MUD BRICK).

AGGREGATES - fibre added to earth to increase the insulation capacity and the tensile strength of the earth structures[167]

BINDER - material added to improve mechanical properties of earth, including strength, durability and handling, and reduce cracking due to shrinkage.

BINDING STRENGTH - the capacity of material that shows its strength and durability.[168]

BRICK - burned block made of earth, that has customized size.[169]

CLAY - very fine-grained mineral less than 0.002 mm in size, consisting mainly of hydrated silicate of aluminium.

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166 Walker, *The Australian Earth Building Handbook*, 16–20.
167 Own definition.
168 Own definition.
169 Own definition

COB - method of monolithic earth wall construction in which wet lumps (cobs) of earth are progressively stacked in courses without the use of mortar and shaped by hand *or other tools* without using formwork.

COHESION OF SOIL - stickiness characteristic of clay and silt, which is absent from sand and gravel.

EARTH (for earth building) - natural subsoil or manufactured mineral material, comprised of varying amounts of clay, silt, sand and gravel, which has sufficient natural cohesion to ensure satisfactory performance for unfired wall and floor construction.

EAVES - the edge of the roof, which projects beyond the external walls.

EARTH SOIL - Natural subsoil that is used for earth building.[170]

FOOTING - construction that transfers the load from the building to the foundation.

FOUNDATION - ground that supports the building.

GRANGE - outlying landholdings held by monasteries independent of the manorial system.[171]

GRAVEL - natural or manufactured granular mineral material greater than 2 mm in size.

INFILLING WALL - wall, placed in between a loadbearing structure, supporting only its self-weight[172]

LINTEL - small beam or another member that supports the wall over a door or window opening.

[170] Own definition.
[171] Wikipedia, 'Monastic Grange', accessed 11 May 2019, https://en.wikipedia.org/wiki/Monastic_grange.
[172] Own definition

LOADBEARING STRUCTURE - structure supporting any vertical load in addition to its own self-weight.

MUD BRICK - sun-dried earth blocks, formed with wet mud placed into molds; material may contain a binding agent to limit cracking and improve strength.

NATURAL EARTH/SOIL WALLED HOUSES - houses that were either entirely or partly under the surface, in this case their "walls" were entirely or partly the terrain.[173]

NATURAL BUILDING MATERIAL - building material that during its production phase does not go through chemical changes[174]

RAMMED EARTH - monolithic earthen material compacted in situ between temporary formwork; earth often stabilized with binders such as cement.

SAND - cohesionless granular material, comprised mainly of quartz, between 0.06 and 2 mm in size.

SHUTTER - temporary support used in rammed and poured earth construction and kept in place until material has attained sufficient strength to be self-supporting.[175]

SILT - granular material finer than sand but coarser than clay (0.002- 0.06 mm in size).

STABTLISATION - process to improve properties of earth for construction by densification (compaction), binder addition, or addition of a waterproofing agent.

[173] Own definition
[174] Own definition
[175] Replaced the word formwork in the original text

STABILISER - material that is added to earth to increase its water resistance, strength or reduce its shrinkage[176]

WATTLE WALL - a composite wall technique, in between wooden structure switches and branches are woven and daubed by earth.[177]

WORKED EARTH WALL - built up earth wall[178]

[176] Own definition
[177] Own definition
[178] Own definition

Appendices

Appendix 1: Technical performance of vernacular structures[179]

[179] Bihari, 'A magyar népi építészet mint fenntartható építési eljárás [Hungarian Vernacular Architecture as Sustainable Building Method]'.

Structure	Stability	Fire protection	Moisture resistance	The capacity to absorb humidity	Insulation capacity	Noise protection	Durability	Resistance against chemical and biological effects
Foundations	Eligible in case of single-story residential houses. The proofs are the existing peasant houses.	Big performance as all of the used materials are fireproof.	Poor performance in case of moisture and humidity of soil and the break of water pipes.	No need for performance.	No need for performance.	No need for performance.	Long term usage.	Not resistant against the effects coming from the soil (roots and impurities).
Floorings	No need for performance	Big performance as all of the used materials are fireproof, with one exception, which is the wooden floor.	Poor performance in case of moisture and humidity of soil and the break of water pipes.	No data from Bihari. Floorings do not block moisture and humidity either. This concludes, they have high performance in absorbing humidity.	Poor performance. Extra insulation is needed.	No need for performance.	Long term usage. In case of eligible maintenance floorings are usable for decades.	Not resistant against the effects coming from the soil (roots and impurities). With regular maintenance they are resistant against the interior effects.
Walls	Eligible in case of single-story residential houses. The stability of frame structures is exceptionally high, but loadbearing earth walls are eligible as well. (The reason: in case moisture gets in the structure, earthen walls loose from their stability, while frame structures still preserve their stability.)	Eligible. The earth building materials, which fibrous plants were added to, and which have density larger then 1700 kg/m3, are in non-combustible category. The elements of framed structures are covered by five-ten centimetres of earth plaster, therefore they belong to the same category.	Poor performance in case of moisture and humidity coming from soil and the break of water pipes. Perfect protection is ensured in the interior against rain.	High performance. (Important for healthy living environment and for the durability of structures.)	Not eligible for current energy policies. Extra insulation is needed.	High performance. Attention is needed in the construction of windows and doors.	High performance in case of regular maintenance. (Renovation in every two-three years, for example renewing the lime coating. Durable even for a hundred years.)	Eligible in case of regular renewing of lime coating and the right construction of structures attached to walls.

Ceilings	Eligible in case of good quality of wood. (A traditional structure with the right size of wooden beams is capable to cover a 6 meter wide room.)	Eligible. The earth building materials, which fibrous plants were added to, and which have density larger then 1700 kg/m3, are in non-combustible category. The earth-straw mixture is in hardly combustible category if it has a density larger then 600 kg/m3. The ceilings covered by straw or reed are covered by five-ten centimetres of earth plaster, therefore they have a high performance on fire resistance. Wood have a good performance on fire resistance itself.	No need for performance.	High performance.	Not eligible for current energy policies. Extra insulation is needed. (Not even the structure that has the highest insulation capacity - straw-earth laid in soft wooden boarding - are eligible for the energy policy.)	High performance.	High performance in case it is protected by the roof. No maintenance needed.	Wood has to be protected from mouldiness and fungousness with ventilation and the avoiding of moisture.
Roof wooden structures	Developed structures are eligible. Depends on the quality of wood and the connections. Some structures are used today.	Eligible. Wood have a good performance on fire resistance itself.	No need for performance.	No need for performance.	No need for performance.	No need for performance.	High performance. Durable even for hundred years.	Wood has to be protected from mouldiness and fungousness with ventilation and the avoiding of moisture.
Roof coverings	Well-prepared straw and reed roofs are eligible. Important to resist the forces of wind.	No data in Bihari. Wooden cover is eligible, straw and reed covers are not eligible.	No data in Bihari. Well-prepared vernacular structures are eligible.	No need for performance.	No data in Bihari. In case of need these structures are not eligible. Extra insulation is needed.	No data in Bihari. Not eligible.	Straw and reed covers are needed to be repaired in every two-three years. Straw is durable for 30, reed is for 40 years. No data about wooden covers.	No data in Bihari. See durability.