⊙ From Excavation

to

In June 2023, kuidas.works opened the exhibition FROM EXCAVATION TO ELEVATION. The exhibition explored the valorization of clay and soil into construction and finishing materials from the excavation site of a residential development on Sõpruse Boulevard in Tallinn. The displayed materials included rammed earth, raw brick, stabilized brick, plaster, mortar, and clay paint. The prototype series of construction and finishing materials was named MUSTAMÄE GREY after the location of excavation.

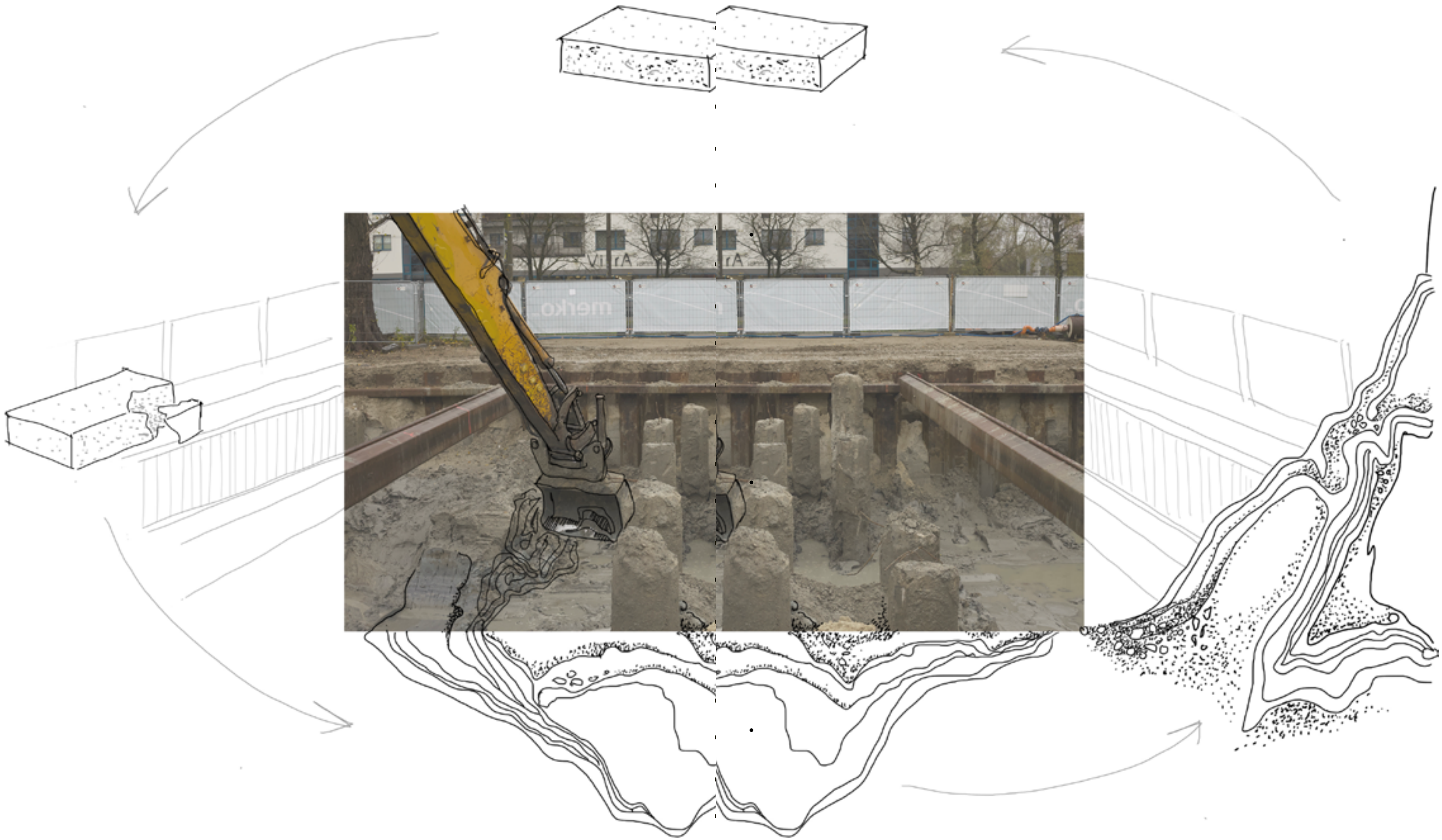
This publication documents the development process of FROM EXCAVATION TO ELEVATION and provides insights into the background and stages of the process.

Studio kuidas.works, established in 2021, focuses on clay and earth-based construction materials to modernize traditional and sustainable building methods and promote their use in architectural design. Kuidas.works operates as an open platform, allowing interested parties to join on a project basis to gain both theoretical and practical knowledge. In the fall of 2022, the kuidas.works team began researching the valorization of soil residues, bringing 15 tons of Cambrian soil rich in blue clay to their workshop yard.

Materials from local clay-based soil are one of the possible solutions towards a more sustainable construction sector. From clay-based soil, by combining different materials, one can make, for example, load-bearing exterior walls, interior walls, partitions, wall fillers, and interior finishing materials like (acoustic) plaster and paint.

The concept of valorizing excavation waste is based on the principle that the clay-based soil extracted from the excavation pit of a building's foundation is a local construction material that can be extensively used in the building under construction. The positive aspects of local material production include site-specific material use, which significantly reduces the transportation and processing footprint, replacing new factory-produced materials, and a better indoor climate due to the thermal, porous, and hygroscopic properties of clay.

Elevation



Elevation

Mart Raud's poem
"From the Language Border" (1978)
begins with the following verse:

Two banks has the Raudna river
As does every other.
Indeed, two banks has the Raudna river
*Just like every other.**

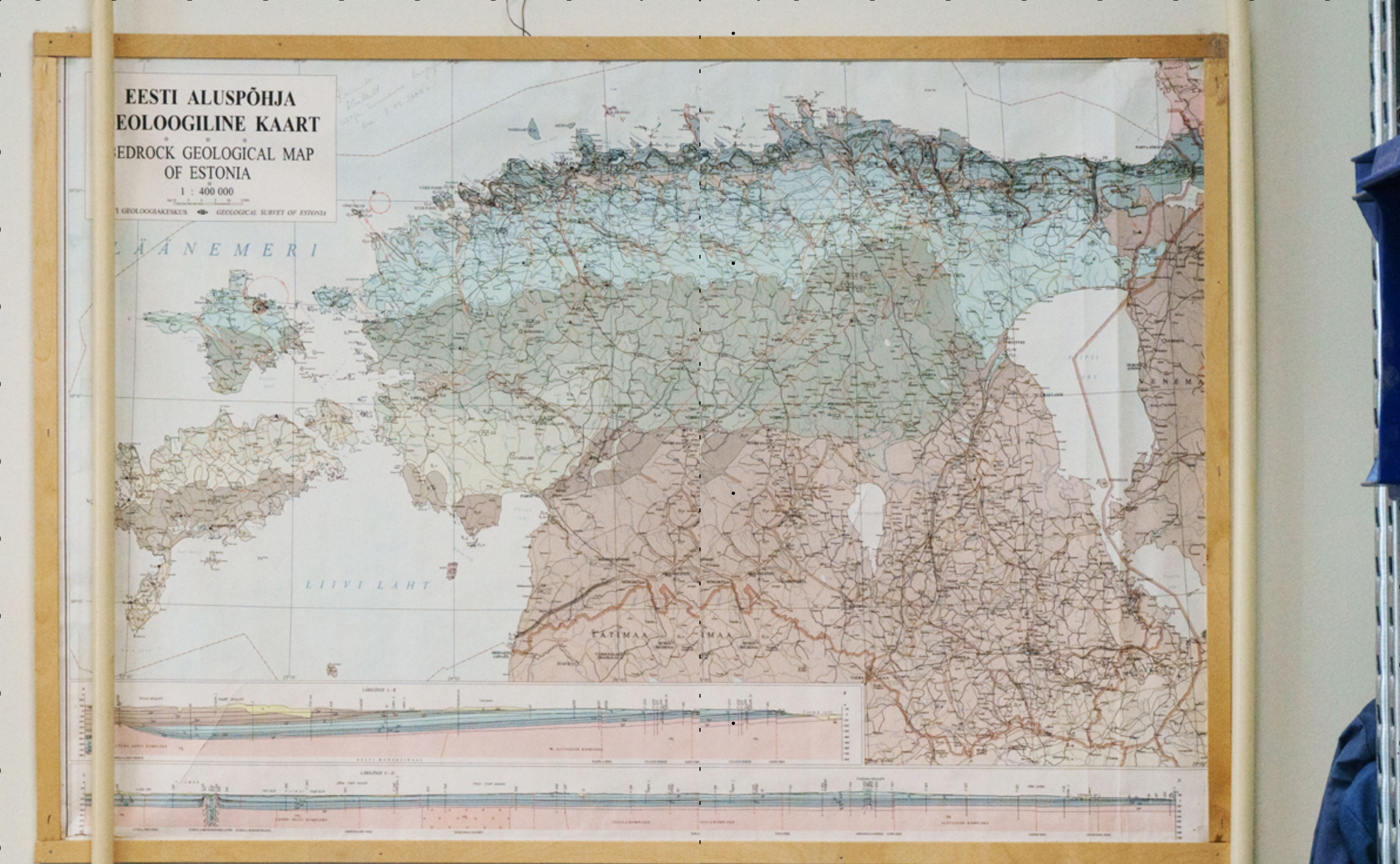
Both the beginning and end of the verse assert the same, yet after the second line, the literary language shifts to the Mulgi dialect* (the dialect is difficult to convey and is lost in translation). The poem speaks of a landscape peculiarity visibly shaped by climatic changes over geological time — the ancient gorge of the Raudna river formed as the Ice Age receded. The gorge created by the melting of a two-kilometer-thick ice block, which was once a linguistic border, has become somewhat impassable due to drainage ditches. However, another boundary runs parallel to the Raudna riverbed to the north.

Elevation

This border is visible on the geological foundation map of Estonia, where the Lower Silurian and Middle Devonian sediments meet. From the Raudna river onwards, the Devonian sediments come so close to the surface that it manifests in the landscape as a difference in soil color and the choice of materials in vernacular architecture. The first preserved clay buildings appear in Viljandimaa, ten kilometers south of the Raudna river. Moving further south, the number of buildings increases significantly. At the exhibition “Tales From the Soil” opened in Milan in 2022, South African artist Dineo Seshee Bopape questions how we are influenced by the mineralogical composition of the soil, which we also ingest daily through the plants grown in it. Although tribal boundaries are hopelessly confused in today’s era of globalized movement and transport, we may still agree that there is a distinction between southern and northern Estonians. In the context of architecture, we might ask whether the local mineral found in local vegetables also has value in local construction? Perhaps it is appropriate to look towards local technologies and resources to connect the sense of home with the sense of touch through tangible local materials?

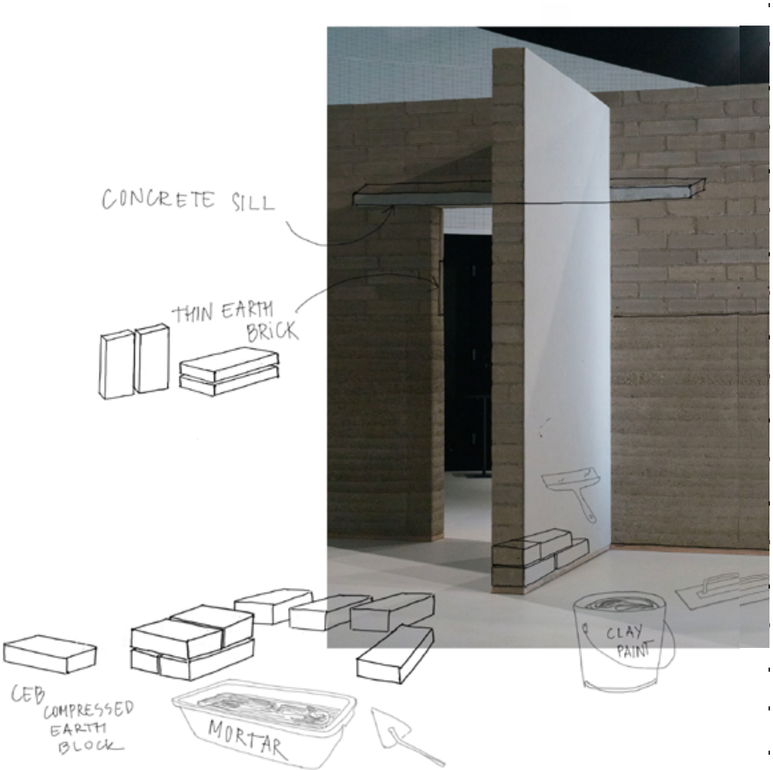
Konrad Mägi
“On the Road from Viljandi to Tartu”
1915–1916
Oil on canvas
94 × 102 cm
Art Museum of Estonia

Elevation

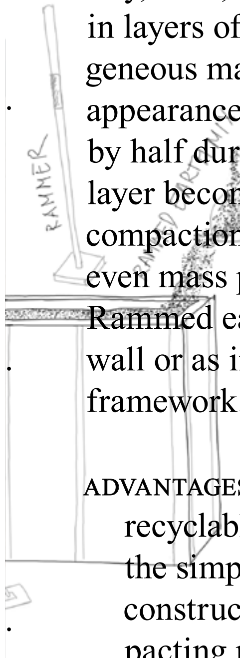

EESTI ALUSPÕHJA
EOLOOGILINE KAART
EDROCK GEOLOGICAL MAP
OF ESTONIA
1 : 400 000
GEOLOGICAL SURVEY OF ESTONIA
LIIVI LAHT

Elevation

1. What common materials can clay-based soil produce?



1. Rammed Earth



Rammed earth is a material consisting of clay, sand, and coarser gravel. It is compacted in layers of 14 cm thickness into a homogeneous mass, which also gives it a layered appearance. The compacted layer reduces by half during the process, meaning a 14 cm layer becomes 7 cm. Alternatives to manual compaction include pneumatic tampers and even mass production of panels in factories. Rammed earth can be used as a load-bearing wall or as infill within for example a wooden framework.

ADVANTAGES Rammed earth is an infinitely recyclable clay-based load-bearing material, the simplest to execute among soil-based construction materials. Mixing and compacting rammed earth require minimal specialized technology: a mixer, tamper, and formwork are needed.

Elevation

CHALLENGES Unstabilized rammed earth is not water or moisture-resistant. It can be stabilized with lime or cement, making it resistant to moisture and increasing its compressive strength, but this reduces its recyclability. Moreover, manual construction of rammed earth can be time- and labor-intensive.

2. Compressed Earth Block and Stabilized Compressed Earth Block

While the traditional fired clay brick is highly durable and a well-known construction material, it is non-recyclable and its production process is highly energy-intensive. Clay can also be used to make "raw brick" (CEB or compressed earth block) and stabilized compressed earth block. CEB consists of clay, sand, and finer gravel. The moist mixture is compressed into a brick shape using water and significant mechanical force. The blocks must then dry for at least two weeks to achieve the necessary compressive strength, typically between 3–5 MPa. The difference from fired bricks lies in the energy-intensive firing process, which significantly increases CO_2 emissions. Also, clay bricks lose their porosity, hygroscopicity, and recyclability when fired.

ADVANTAGES CEB is infinitely recyclable, meaning that the blocks can be crushed and re-pressed into new blocks an unlimited number of times.

CHALLENGE CEB is not water-resistant and is best suited for interior walls or as wall filler.

Stabilized CEB is made using the same technology, with the addition of lime, for example, which hardens through a chemical reaction. Stabilized brick is an intermediate variant between compressed and fired brick, with 5–10% lime or up to 7% cement added to the

Elevation

mixture, making the brick more resistant to moisture and compressive forces. Stabilized CEB is nearly waterproof, with a compressive strength between 5–8 MPa.

ADVANTAGES Stabilized CEB is more moisture-resistant and stronger than unstabilized CEB, with a compressive strength of 5–8 MPa.

CHALLENGES Stabilized CEB cannot be re-pressed into new bricks. However, the production of a stabilized CEB has a significantly smaller footprint than that of fired brick.

3. Clay Plaster

Clay, sand, and binding fibers can be used to make base and finishing plaster of varying coarseness. The plaster's color and properties are determined by the mineral composition of the clay used.

ADVANTAGES The thicker the plaster layer, the more the positive properties of clay benefit the indoor climate. Depending on the coarseness of the finish, the plaster can also positively affect room acoustics. Damaged clay-plastered surfaces can be easily repaired, smoothed, or patched. The plaster can be removed from the wall and reapplied, making clay plaster fully recyclable and reusable.

CHALLENGES Clay-plastered surfaces are less durable than, for example, cement plaster or latex paint and are more susceptible to moisture, so clay plaster should only be used in dry spaces.

Elevation

4. Clay Mortar

Clay and sand of the right fraction can be used to make mortar for laying the aforementioned building bricks, achieving a consistent result in color and materiality.

ADVANTAGES Using clay mortar allows for the dismantling of the wall at the end of its use, as clay mortar does not harden as much as cement mortar, and also allows for faster bricklaying.

CHALLENGES Clay mortar is weaker than cement mortar.

5. Clay Paint

Clay, (quartz) sand, and binders like cellulose fiber can be used to make local tone clay paint.

ADVANTAGES Clay paint is a natural finish that contains no chemicals or harmful volatile compounds. It can be removed from the surface with a pressure washer.

CHALLENGES Surfaces coated with clay paint are not washable; the paint comes off with water.

2. What are the characteristics and properties of clay-based construction materials?

Like all materials, clay-based construction materials have their pros and cons aka suitable and unsuitable uses. It is important to understand the potential and limitations of each material and find the optimal ratio of materials in the structure. Clay's positive properties include thermal mass (1), hygroscopicity (2), antibacterial properties and odor neutralization (3), acoustic absorbency (4), and infinite recyclability in its unburnt/unstabilized form (5).

1. Thermal mass refers to a material's ability to absorb, store, and release heat. For example, a material with high thermal mass can store heat from heating and release it during non-heating periods, contributing to a more energy-efficient microclimate. The opposite also occurs, where a material with thermal mass cools down at night and helps to lower indoor temperatures on a hot summer day.

2. Hygroscopicity is the ability of a material to regulate humidity. Clay-based raw materials keep humidity within the ideal range for humans, which is 40–60%. If humidity falls below 40%, clay releases stored moisture; if it rises above 60%, excess moisture is stored in the material's pores.

3. Due to its porosity, clay-based material helps neutralize odors in a space, such as those from cooking or smoking. Clay minerals like illite and smectite have been observed to have effective antibacterial properties.

4. Clay-based materials generally have a rougher texture, which contributes to better room acoustics by reducing excessive sound reflection and echo.

5. As long as clay-based material is not fired or stabilized, it is infinitely recyclable* and can be molded into various shapes, from construction to finishing materials.

* Infinite recyclability means that the material’s quality does not degrade or depend on how many times it is recycled. Earth-based materials are infinitely recyclable if the mixture is not thermally processed or mixed with cement, lime, or other chemically stabilizing agents.

CHALLENGES IN BUILDING WITH EARTH-BASED MATERIALS

The advantages of earth-based materials for the living environment are most evident in interior spaces and finishing materials, but they also have significant benefits in structural elements, as they can replace a large volume of new construction materials. It should be noted that the load-bearing qualities of raw earth cannot be compared to those of concrete, and raw earth is susceptible to moisture or precipitation. This can be addressed by combining earth-based material with wood or concrete and properly designing the eave and plinth details.

3. Material Sourcing

The geographical location of clay, its content in the soil, and its depth from the surface vary by location. It is advisable to start with a visual inspection at the construction site or conduct soil studies before excavation. The simplest way to understand soil content is through laboratory analysis, which provides a precise composition of the soil. It is also necessary to perform contamination and radon tests before recycling the soil.

4. Tools and Material Preparation

Processing soil is characterized by being time-consuming and labor-intensive, which is not necessarily a negative attribute. Working with the material takes time, from preparation to the process of drying. It is essential to plan the work process well in advance, preferably according to the seasons, as working with soil in winter can be challenging in Estonia's climate. Work should be ideally scheduled for the spring-summer period.

PREPARATORY STEPS

1. Excavating, collecting, and transporting the material.

2. If possible, laboratory analysis of the soil, which can also be done before excavation in the form of soil samples.

3. Initial mixture tests: It is beneficial to start practical material tests early to predict the final mixture composition and observe drying and shrinkage, considering the desired material (raw brick, rammed earth, plaster, etc.).

4. Drying and crushing the soil: The soil should be dried and finely crushed before mixing.

5. Sieving the soil and crushed concrete (for bricks and rammed earth): A proper fraction sieve is needed to filter out debris, stones, and uncrushed material clusters. Concrete sieving can be done through a reform bed for larger fractions up to 10 mm. Larger fractions of stone and gravel are suitable for rammed earth, and smaller ones for CEB.

6. Mixing the mixture: The final step involves mixing the prepared materials according to the results of the initial mixture tests and the desired material.

FORMING THE MATERIAL INTO BUILDING MATERIALS

7. Pressing raw bricks requires a mixing station/mixer and a brick press. It’s crucial to store the bricks in a warm, dry, and well-ventilated room for at least two weeks to dry and achieve the necessarycompressive strength.

8. For rammed earth, the necessary tools include a mixer, formwork, and tampers.

9. For plaster and paint, the wall surface must be prepared before application.

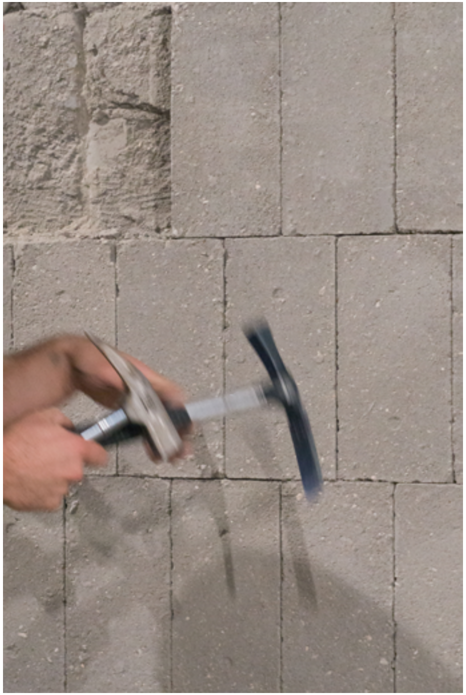
10. Brick production is the most resource-intensive, requiring a brick press and a mixing line where the mixture is blended and transported to the press. The general recipe for bricks is 1 part clay, 2 parts sand, and 1 part finer gravel* (0–8 mm). The simplest but most labor-intensive technique is rammed earth, where the material can be manually processed and tamped. The general recipe for rammed earth is 1 part clay, 2 parts sand, and 1 part coarser gravel (0–15 mm).

* For the FROM EXCAVATION TO ELEVATION exhibition, gravel was replaced with construction waste, i.e., crushed concrete. It's advisable to wash the crushed concrete to reduce the amount of dust and ensure the proper ratio of components (clay, sand, gravel) is maintained.

11. If needed, the surface of an earth-based material can be covered with a coat of finishing mixtures to ensure better lasting. For example a coat of linseed oil can be used on rammed earth and CEB for better surface durability.

5. Material Afterlife

After the exhibition, the used materials were either recycled or reused. The brick wall was dismantled brick by brick and stacked on pallets, while the mortar and rammed earth were crushed and stored in big bags for the next project.



6. Material Use Possibilities and Limitations

Understanding the properties of construction materials, such as strength, moisture susceptibility, and indoor climate properties like acoustics, is crucial. Strength tests were conducted by Ando Pärtel, a laboratory engineer at TTK University of Applied Sciences. Raw brick test specimens measuring 150×150 mm were tested under laboratory conditions, yielding a very positive strength range of 5–6 MPa. We tested the exact recipe of raw bricks produced for the FROM EXCAVATION TO ELEVATION exhibition in the lab, but the test specimens had to be recreated in the correct size.

Due to the variability of soil and raw materials, tests should be repeated for each project, especially if raw brick or rammed earth is designed for load-bearing structures.

Acknowledgements

UKU Pure Earth & Marko Kikas
NGO Eestimaaehitus & Mikk Luht
Helari Sirelpuu (Wuni)
Malvo Tominga (Wanawiisi ehitus)
University of Tartu – Department of Geology
TTK University of Applied Sciences –
Institute of Civil Engineering
Peri AS
Floorin AS
Viimsi Artium & Kristiina Reidolv
Kalev Ramjalg
Tiit Roots
Jaan Škerin

Author: kuidas.works
Editor: Maria Helena Luiga
Photos: Maria Helena Luiga, Hannes Praks,
Henri Papson, Tõnu Tunnel
Illustrations: Andrea Tamm
Graphic design: Aimur Takk
Support: Cultural Endowment of Estonia

kuidas.works 2023