YRKESHÖGSKOLAN NOVIA

HANDBOOK FOR BUILDING A ROOT CELLAR
Sustainable Heritage Report No. 8

Traditional Wooden and Masonry Structures in the Baltic Sea Region
Sustainable Heritage reports, 1/2016

KIRSTI HORN, editor

SERIE R: RAPPORTER, 4/2016

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SUMMARY

The need and technique of storing foodstuffs varied traditionally from one climate to another - but today we are free from the natural limits of seasons and harvesting times thanks to all the modern electric appliances in every standard kitchen. However, the desire to live in harmony with nature and to eat healthy has reawakened the interest in traditions not only by the stove but also in the vegetable garden and in storage buildings of the good old times. There is also a growing worldwide trend to make new root cellars according to traditional principles. A perfectly good way of keeping the harvest edible through the winter is thus put into practice without electricity.

In the following a specification for building a vaulted root cellar runs parallel with the description of work and experiences on the Sustainable Heritage intensive course at Novia University of Applied Sciences in September 2014.

SVENSK SAMMANFATTNING (SUMMARY IN SWEDISH)

Behovet och sättet att lagra livsmedel har traditionellt varierat beroende på klimatet, men idag är vi fria från de naturliga begränsningarna som väderleken och skördetider ställer tack vare de moderna elektriska apparater som är standardutrustning i dagens kök. Önskan att få leva i harmoni med naturen och äta hälsosamt har åter väckt intresse för traditioner vid spisen, för grönsaksodling samt för att lagra produkterna i lagerbyggnader enligt gammal sed. Det finns även en världsomfattande trend att bygga nya jordkällare enligt beprövade traditionella principer. Detta är ett perfekt sätt att hålla skörden ätbar hela vinterhalvåret, helt utan elektricitet.

Denna rapport, den åttonde i serien Sustainable Heritage Reports, beskriver byggandet av en välvd jordkällare parallellt med en berättelse om det arbete som utfördes och erfarenheter som erhölls under den Sustainable Heritage intensivkurs som hölls på yrkeshögskolan Novia i Raseborg i september 2014.

A joint project between Novia University of Applied Sciences, Uppsala University, Campus Gotland and Estonian Academy of Arts.

www.sustainableheritage.eu

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TABLE OF CONTENTS

PREFACE

Students and teachers from Estonian Academy of Arts in Estonia, Novia University of Applied Sciences in Finland and Campus Gotland at Uppsala University gathered in Ekenäs, Finland for the fifth intensive course within the project **Traditional Wooden and Masonry Structures in the Baltic Sea Region** in September 2014. For more details about this project, its predecessor Sustainable Heritage and past and future courses, please visit its site on the Internet at the address www.sustainableheritage.eu.

The international cooperation within the field of building conservation was established many years ago and has already resulted in eleven successful intensive weeks during these years thanks to a motivated group of teachers and thanks to the Nordic Council of Ministers, who have supported the projects financially through Nordplus grants. So far some 150 students of architectural conservation, conservation of artefacts, structural engineering and site management from the three universities in Estonia, Sweden and Finland have taken part in the Sustainable Heritage courses, and most of them have contributed to the 8 published reports with text, drawings and photographs.

Every course has had a different theme and they have been hosted by the three universities in turns. Students have been taught by expert craftsmen and given an academic background to each topic by teachers of the involved institutions. In addition to the pedagogical goals we cherish an idealistic wish that the performed hands-on work should contribute to the rescue and maintenance of our built heritage. This time the traditions were tested by constructing a brick vault on a new root cellar. The understanding and experience of vaulting technique should come handy in many restoration jobs.

We thank **Mr. and Mrs. Rancken**, in whose garden the vaulted cellar was built, for all the patience they had with the slowly advancing project. The foundations were built by first year students of Construction Engineering and Construction Management at Novia University of Applied Sciences. The walls were then laid of concrete blocks instead of traditional red bricks to speed up the project. Finally the international group of 18 students completed the building project with vault, damp proofing, doors and finishes of the interior.

Niklas Nyman, lecturer at Novia was primus motor of the cellar and vault project. The masonry technique was taught by master mason **Krister Lindroos** in situ. **Joosep Metslang** from the Estonian Open Air Museum was active in the wood working studio where the doors were built. **Kristin Balksten** from Uppsala University, Campus Gotland, contributed with her expert knowledge in lime mortars. **Ulrika Grönvik** of Västankvarn experimental farm[1], Novia, and **Ann-Louise Erlund** of, Novia[2], introduced participants of the intensive course to the traditions of storing fresh foodstuffs in root cellars.

Many thanks to all of these experts - each of a different field - for sharing their know-how with the participants of the course!

Kirsti Horn
Senior lecturer, Architect AA Dipl.

1 Project: Västankvarn - en västnyländsk matkälla
2 Project: Bra Mat i Västnyland

1. DESIGNING A ROOT CELLAR

Students at the Department of Construction Engineering at Novia designed the model cellar, which is presented here through drawings and photographs, under supervision of their teacher in construction technique Niklas Nyman. The dimensions of the storage space were determined by the client.

1.1 INTRODUCTION

Well planned is half done is a Finnish saying which applies to a root cellar as well as any building project.

Building permit
In general, a building permit is not required for a small root cellar of the kind that is presented in this report - at least not in Finland. Yet, it is advisable to inform the local authorities about your plans, and in densely built areas the plans should, of course, also be discussed with neighbours whose view might be disturbed by the construction.

Functional requirements for cold storages depend on the foodstuffs
In the northern parts of Europe root cellars are built for storing vegetables, primarily potatoes and carrots, but of course, also for less common root crop in our diet, cabbage, onions, leeks, fruits etc. Very often the cellar is built underneath the dwelling house if the site conditions are favourable. But there is also a tradition for several free standing cellars per farm where roots, vegetables, fruits, conserves, milk or ice were stored in larger amounts in suitable conditions for each foodstuff. Because fruits emit ethylene which makes other plants perish, they must be stored in separate cellars; ice needs to be stored in well insulated rooms; bottles and jars do better in dryer conditions while roots must be kept moist. Milk products on the other hand, have different standards. As a rule the hygiene of any food storage should be easy to maintain and monitor.

This report is about free standing root cellars in particular. The art of arranging the root crop in wooden boxes is beyond the limits of this report. Also the landscaping which gives the final touches to a root cellar scheme has been left out.

The indoor climate of a root cellar
It is essential to create a very cool and humid indoor climate with adequate ventilation to keep the vegetables edible throughout the winter months from October till mid-June. Vegetables consist mainly of water: 65-95% of their weight is water. A loss of 5-10% of their water content will cause wizening and spoil. This is why the relative humidity must be 90-100% inside a root cellar.

The temperature in a root cellar should be just a few degrees above freezing point but it must never sink below 0°C. Immediately after harvesting the temperature ought to be kept low and the humidity should be increased. The building materials must not emit smells or harmful gases and they should adapt well to the damp conditions and balance out the inevitable slight seasonal changes of temperature and humidity.

Old and new root cellars
The technique of making a functional root cellar in the northern climate was developed to its perfection over the centuries. There is a lot to be learned by studying historic buildings, their construction technique and arrangements for heating, cooling and ventilation. Modern root cellars are generally small scale interpretations of the reawakened vernacular traditions that make use of the climate and landscape. The large scale refrigerators that are built by modern growers of potatoes and carrots create similar indoor conditions with the help of cooling and air conditioning machinery.

Requirements

Whatever building project you plan to embark on, it is advisable to start by writing down your own wishes and requirements for it. In the case of a root cellar the following matters are worth considering:

- site: quality of earth, terrain, landscape and distance from kitchen
- function: the foodstuffs that are going to be stored, realistic quantities, special conditions these require
- size: estimations of the needed storage space, the linear meters of shelving, the height of the space, the floor area for storage boxes etc.
- arrangement and building materials of the above
- lighting
- aesthetics of the parts that are above ground: building materials, colour scheme, height and width landscaping and planting

FIGURE 1.1. The historic root cellar of a grand scale built of granite at Västankvarn experimental farm, Finland, was presented by Ulrika Grönvik to the authors of this report. Note the thickness of the double skin masonry in the entrance. Photograph by Towe Andersson.

FIGURE 1.2. The interior of the big root cellar at Västankvarn. Photograph by Towe Andersson.

FIGURE 1.3. Small disused root cellars next to a workers´ block of flats at Dragsfjärd industrial estate, Kemiö, Finland. Photograph by Towe Andersson.

FIGURE 1.4. Model root cellar (before damp proofing) built by students at Novia and participants to the intensive course in Ekenäs, Finland in the autumn of 2014. Photograph by Towe Andersson.

1.2 CHOOSING THE SITE FOR A ROOT CELLAR

The names for a root cellar in Swedish: *jordkällare*, Estonian: *maakelder*, and Finnish: *maakellari* explain what is special about a traditional storage like this: it is for the most part in the ground (i.e. jord or maa). The coolness and dampness of the earth is made use of in a natural and ecological way.

Ideal location

Traditionally root cellars were built on sloping ground so that only the front wall and the door remained visible while the rest of the construction was underground. In this way changes in the terrain are minimized and the construction will literally sink into the landscape. If your site is very flat there is no need to worry because you can build the cellar above ground just as well, and then pile a mound of earth around and on top of it to give insulation from sun and frost. To make it look nice you can plant grass and flowers on top of it and camouflage it with other vegetation. Make sure the roots of the planting do not penetrate the structures and crack them! It is also possible to dig half the cellar together with some stairs into the ground on a flat site. The hollow for the stairs will, however, cause problems when there is heavy rain, frost or snowfall.

Ground conditions

The site for a root cellar needs to be damp enough so that the inside climate of the storage space will be humid. The ideal humidity for keeping fruits and vegetables fresh is around RH 95 %. This is why choosing too dry a spot is not a good option. At the same time it is essential to stay above the ground water level. It is worth noting that the ground water level changes with the seasons and during heavy rain and there is always a risk of flooding and consequent spoil of materials, frost action and cracking in the construction if the cellar is built too deep in the ground. To prevent

FIGURE 1.5. An old disused root cellar built into a slope. Photograph by Towe Andersson.

FIGURE 1.6, 7. The back and front of a root cellar built on flat ground, Hiiumaa in Estonia. Photographs by Kirsti Horn.

all this from happening you need to survey the site carefully and then, in any case, install adequate drainage of the surrounding earth. Sand or gravel is the best choice of soil around and under your root cellar.

The best way to place the cellar is in the shadow of adjacent buildings or terrain so as to avoid excess heat gain in the summer. For the same reason the best way of placing the door is making it face north. This will guarantee a cool airflow when the door is opened and through the vents in the door while it is closed. If we consider the daily use of the cellar it would be practical to place it rather close to the kitchen quarters of the dwelling house.

1.3 DRAWINGS FOR A ROOT CELLAR

Below we present sketches for the cellar, the building of which, is presented through photographs in this report.

Site plan
The best position for a root cellar on this particular site is in the slope in the northeast corner close to the back entrance of the main building. The soil is sandy.

Plan
The size of the storage room corresponds to the requirements of the owner. Not only ecologically homegrown root vegetables but also conserves will be stored in this cellar. The double doors and the front lobby prevent outdoor air from flooding into the storage space: it is important not to disturb the indoor climate (humidity and temperature) in any way.

Section
The height of the rooms was determined by the owner. The top of the vault is 2000mm from floor level while the lower side walls are still quite adequate for shelving. A ventilation shaft is installed through the roof near the back wall. Fresh air is taken in through vents at the bottom of the doors. The section shows the thickness of the concrete block walls and the vault that was laid with red brick. There was not much space for earth on top of the cellar. This is why some thermal insulation was laid underneath the soil. Only small plants and grass can be grown on the top in order not to disturb the neighbour on top of the slope.

Elevations
The side elevations show the mass of the covered up cellar in relation to the levels of the terrain.

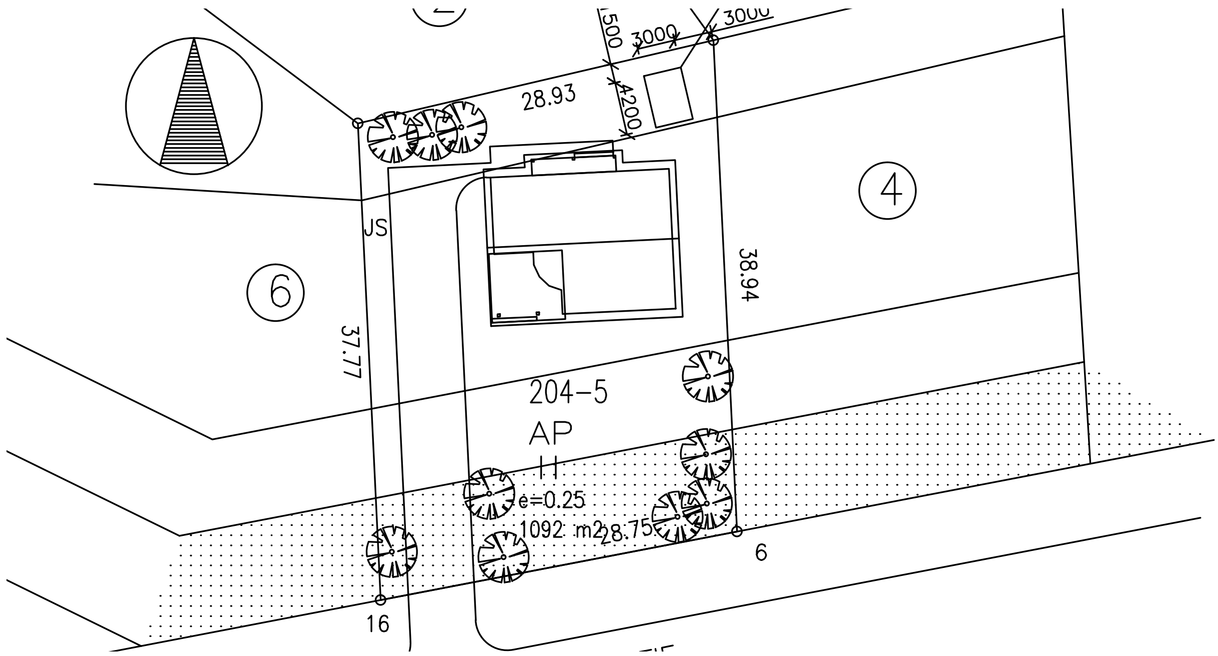


FIGURE 1.8. Site plan. Drawing by Iiro Vainikainen and Christoffer Sundholm.

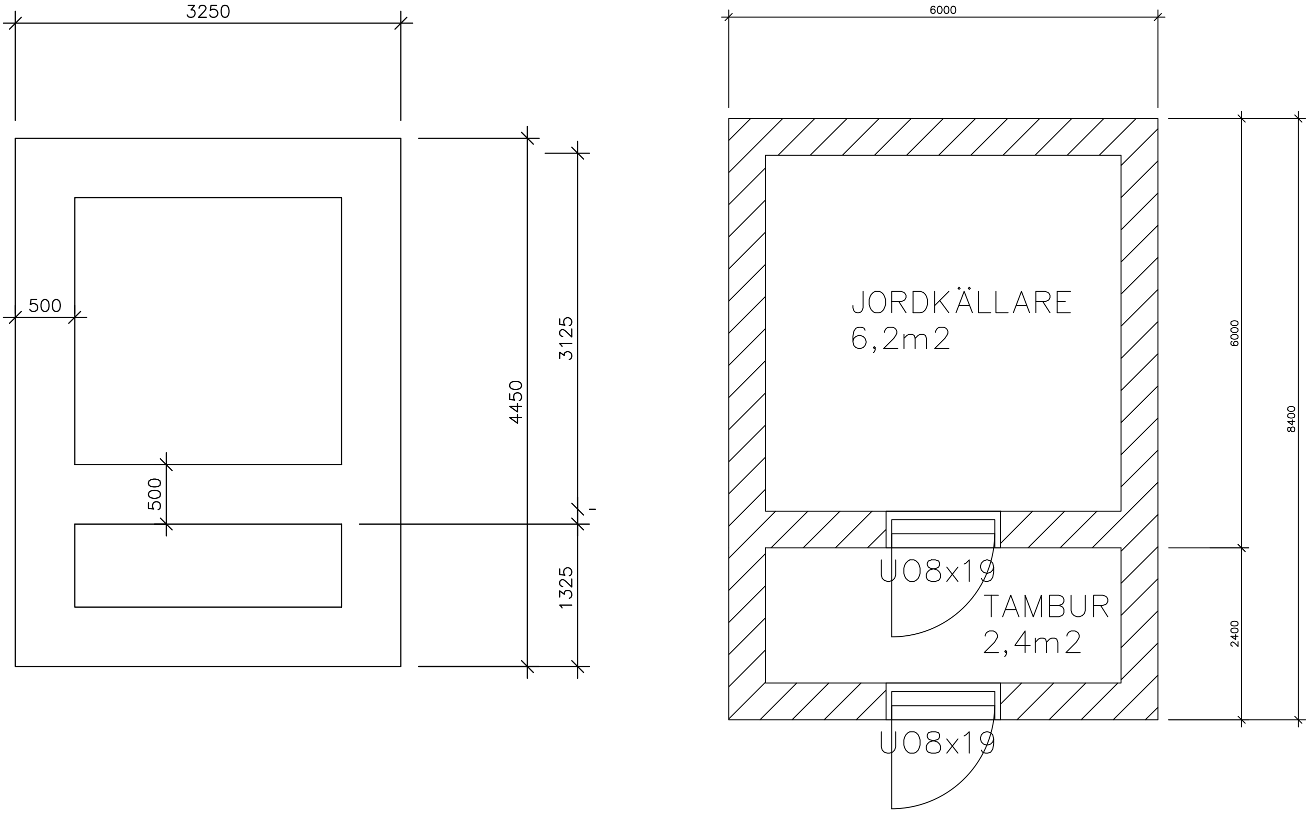


FIGURE 1.9. Plan of plinth (to the left) and the rooms (to the right). Drawings by Daniel Karlsson and Filip Åberg.

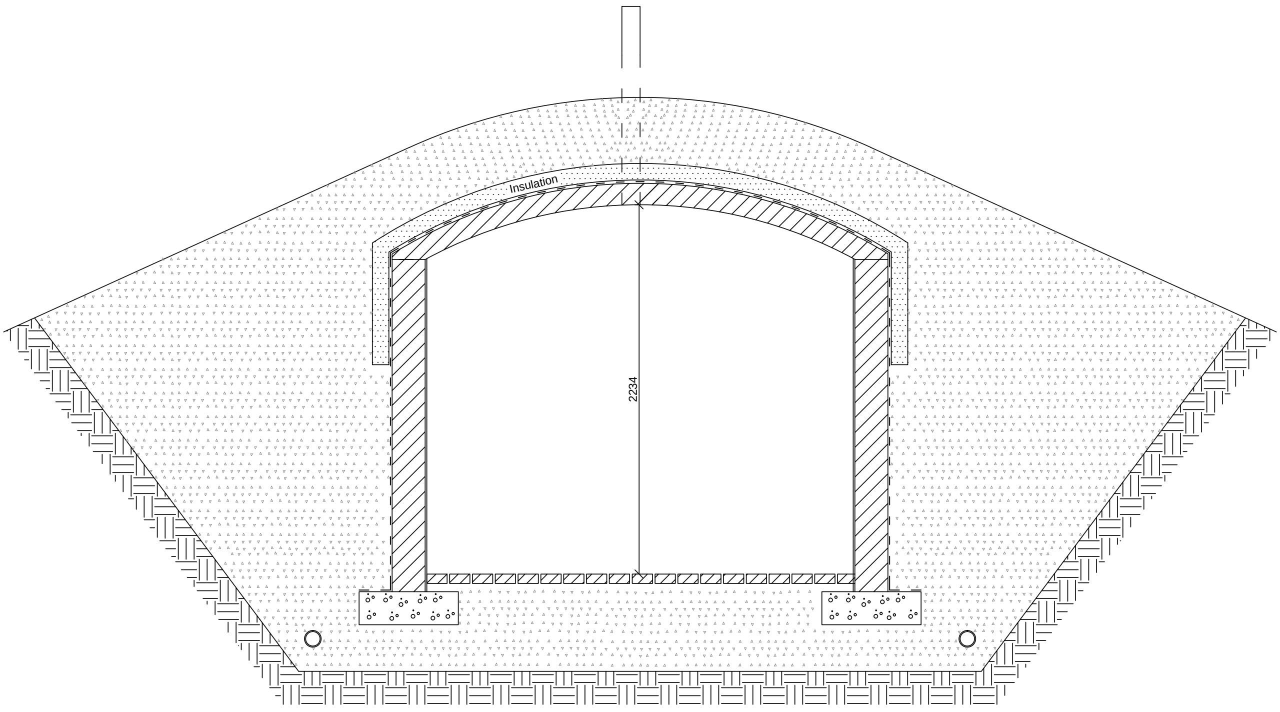


FIGURE 1.10. Section. Drawing by Christoffer Lindholm and Rasmus Karlqvist

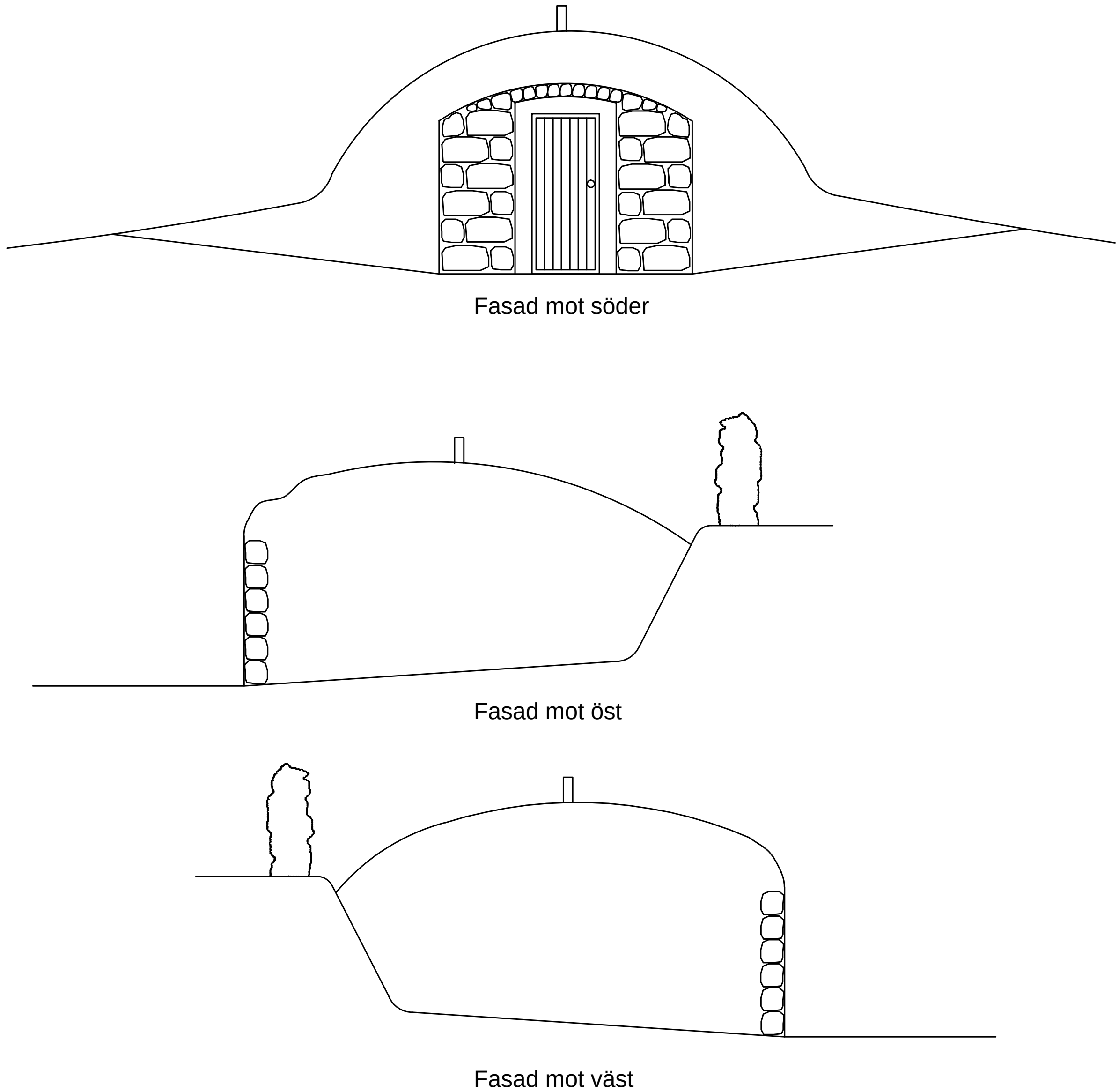


FIGURE 1.11. Elevations. Drawing by Patricia Lönnqvist, Ellinor Eklund and Magdalena Pomrén.

2. MASONRY WORK

In the following there are detailed descriptions for how to go about the building of a root cellar. This should help the reader to choose the most suitable material for his particular cellar. The choice is between stone, brick and concrete.

2.1 FOUNDATIONS AND DRAINAGE

After the topsoil has been removed and the earth underneath the cellar has been evened out the next step will be the building of the plinth. The plinth is the part of the foundations which will transfer the whole load of the masonry structure from above to the ground underneath. It should always be wider than the wall which is built on top of it. Historic foundations are usually made of stone while concrete is the standard modern solution.

The concrete must be reinforced with steel rods to make it strong enough to withstand the stresses it will be subjected to. The dimensions and placing of the reinforcement depends on the dimensions of the plinth, the actual loads and ground conditions. A structural engineer or an experienced builder should be asked for calculations and details. The plinth for the model cellar described in this report was cast 200mm high and 600mm wide with two reinforcement rods along the base of the plinth. A standard plastic drainage pipe was laid along the outside of the plinth and joined to the existing drainage system of the site.

The formwork for the casting of a low plinth is usually made of rough boarding or plywood. It needs to be secured against the pressure of the concrete by e.g. boards or poles that are driven into the ground. When the concrete has set the boarding can be dismantled and the building of the walls can be started.

FIGURE 2.1. The sandy slope between two houses is an ideal spot for the model root cellar. Photograph by Niklas Nyman.

FIGURE 2.2. The surface of the plot is levelled to the depth of the plinths and the drainage pipe. Photograph by Niklas Nyman.

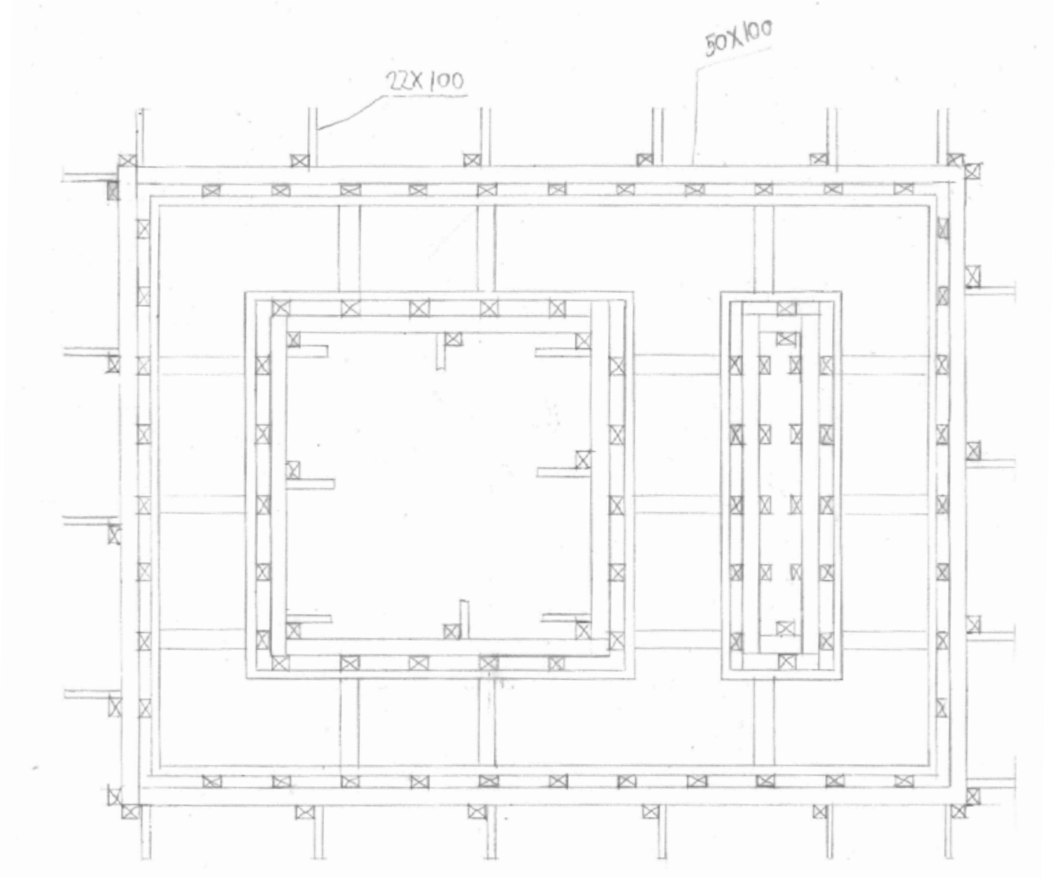


FIGURE 2.3. Design for the formwork. Engineering students plan more complicated than they build… compare with figure 2.6.

FIGURE 2.4. The formwork for the plinth was built of boards. Photograph by Niklas Nyman.
FIGURE 2.5. The concrete for the plinth is being mixed and then carted to the site. Photograph by Niklas Nyman.

FIGURE 2.6. The casting is almost done here. Time for a creative pause. Photograph by Niklas Nyman.

2.2 CONSTRUCTING THE WALLS

Five different ways of building the walls of a root cellar are presented below. The materials are stone, brick and concrete.

Structural design

The walls of a root cellar are always **retaining walls**. It is important to calculate the thrusting horizontal forces the surrounding earth transfers onto these and design them accordingly. Two matters need to be calculated: the thickness of the wall (which depends also on the chosen building material) and the reinforcement which is to be placed in the structure. Again a structural engineer should be consulted! Five different ways of building walls for a root cellar are presented in the following.

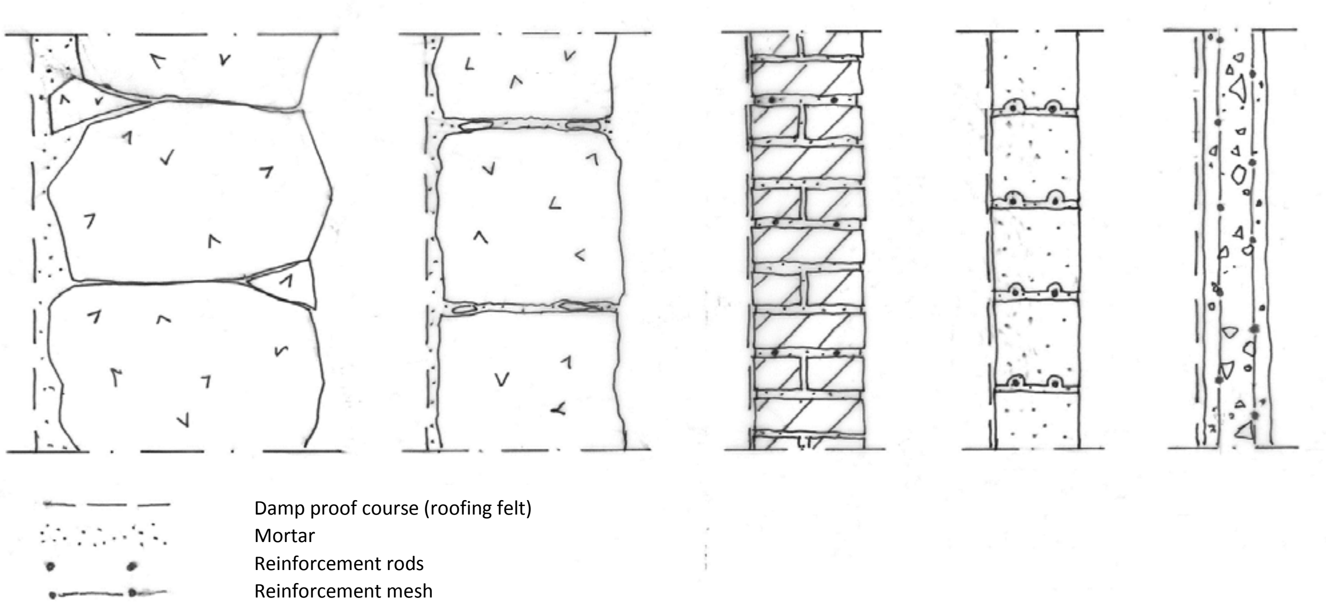
Figure 2.7. Random stone

Figure 2.8. Dressed stone

Figure 2.9. Brick

Figure 2.10. Concrete blocks

Figure 2.11. concrete



FIGURES 2.7- 2.11. Retaining walls can be built of various materials in many ways. The damp proofing is presented on the left surface of each structure.

WALLS OF RANDOM STONE

The plinth for a wall of random stone would traditionally have been made of big flat stones laid on a bed of gravel. Concrete might be a good option today. A traditional dry laid stone wall would seem natural in a root cellar but this is definitely the most difficult wall to construct. (figure 2.8) The joints between the stones can be finished with lime mortar or clay on the inner face to keep the wall smooth and easier to clean. The overall appearance of a stone wall depends on the available material and the craftsmanship of the mason. Stone and walls made of stone are discussed in the *Sustainable Heritage report no 4. Handbook for building and repair of stone walls* http://www.sustainableheritage.eu/publications/.

Material

- Stone from the site or nearby

Tools

- The stone mason´s selection of tools depends entirely on the available stone.

Instructions

- Follow local traditions in the way you use the local material!
- Remember that a stone wall construction relies entirely on gravity: each stone must lay balanced on the previous. Stones cannot be glued together with mortar or concrete however strong this is!
- Build the wall by using the big stones at the bottom and proceed with reduced sizes the further up you go.
- Secure the stones into position by inserting wedge shaped small stones in between them.
- The thrust of the surrounding earth can be counterbalanced by building buttresses on the opposite side of the wall, i.e. inside in the case of a cellar.
- Dress the joints.

WALLS OF DRESSED STONE

The same design principles apply here as in the case of walls of random stone. (figure 2.9)

Material

- Stone; if recycled stones are available this material might be a good option for a root cellar. Recycled foundation walls, curb stones, discarded pieces from a stone mason´s yard etc. might make a beautiful cellar!
- Lime mortar.

Tools

- Mortar mixer
- Shovel
- Trowel
- Joint filler
- Bricklayer´s hammer
- Hawk
- Spirit level
- Line and poles
- The stone mason´s selection of tools depends entirely on the available stone.

Instructions

- First of all, a line must be stretched between two poles to guide the laying of the stones.
- Keep the courses straight and level.
- The mortar should always be weaker (more perishable) than the stone.
- Small flat stone splinters should be inserted in the joints to keep them uniform.
- The pressure from the surrounding earth can be counteracted by building buttresses on the opposite side of the wall, i.e. inside in the case of a cellar.
- The bond can be chosen according to taste, available material and craftsmanship.

WALLS OF BRICK

This is a traditional well-tried and beautiful material to be recommended in a root cellar. (figure 2.10) Recycled bricks might be a good option!

Material

- Bricks
- Mortar (sand, lime and water)
- Reinforcement rods

Tools

- Mortar mixer
- Shovel
- Trowel
- Joint filler
- Bricklayer´s hammer
- Hawk
- Spirit level
- Line and poles
- 2 pairs of plyers for bending the reinforcement rods

Instructions

- First of all, a line must be stretched between two poles to guide the laying of the blocks.
- Keep the courses straight and level.
- The mortar should always be weaker (more perishable) than the bricks.
- Insert reinforcement rods in every third horizontal joint.
- The bond depends on the thickness of the wall.

WALLS OF CONCRETE BLOCKS

Of all the presented materials concrete block walls are easiest and fastest to build. (figure 2.11) A coat of plaster will give a pleasant hygienic surface.

Material

- Concrete blocks
- Mortar (sand, cement and water)

Tools

- Mortar mixer
- Shovel
- Trowel
- Joint filler
- Bricklayer´s hammer
- Hawk
- Spirit level
- Line and poles
- 2 pairs of plyers for bending the reinforcement rods

Instructions

- First of all, a line must be stretched between two poles to guide the laying of the blocks.
- Keep the courses straight and level.
- The mortar should be compatible with the blocks.
- Follow the manufacturer´s recommendations.
- Insert reinforcement rods in every horizontal joint.
- A simple stretcher bond should be used. (i.e. the blocks in each successive course is staggered by half a stretcher i.e. long side of the block).

WALLS OF CONCRETE

The appearance of a concrete wall is dependent on the quality of the formwork it is cast in. (figure 2.1)

Material

- Boards or plywood
- Posts
- Nails, screws
- Reinforcement mesh
- Concrete mix
- Water

Tools

- Saw
- Hammer
- Screwdriver
- Level
- Measuring tape
- Shovel
- Concrete mixer
- Wheel barrow

Instructions

- Formwork for concrete walls is constructed of either boarding or sheets of plywood.
- The mould must be sturdy enough to hold the concrete in shape and not move during casting.
- The reinforcement is placed inside the mould before pouring the concrete in it.

- Make sure the reinforcement stays in its correct position while the casting is done.
- Make sure none of the reinforcement rods come closer than 30mm to the surface of the finished wall.
- For a small job it is advisable to use a standard ready mix of concrete.
- Remove the formwork when the concrete is mature. (rule of thumb: one week per 10mm thickness)

2.3 BUILDING A SMALL BARREL VAULT

The stability of a vaulted structure is created by an immovable support at the base of the vault. All arches (excluding the ideal arch) together with the loads on top of them cause an outward thrust at their base. The flatter the arch is the more intense the thrust. The supporting walls must be solid enough to counterbalance this horizontal force. The vault itself can take a great deal of pressure but point loads should be avoided. In the structure the bricks press sideways against one another while their wedge shaped joints meet the pressure at a right angle.

BUILDING THE CENTERING FOR A SMALL BARREL VAULT

Building centering is an essential part in the process of building vaults of any kind. The purpose of this is to build a removable support out of wood upon which the subsequent vault of stone or bricks can be laid. The centering ensures the correct shape of the vault.

The instructions given here describe a very basic type of centering. Larger formwork may require trusses and buttresses to secure the stability of the construction. Regarding the choice of material, any material could be used in creating the centering, as long as the material has the durability and strength to support the vault that is laid on top of it. It can be made by any desired measurements, as long as the vault on top of it is secured at its base and has the strength to support itself once the formwork has been removed.

Materials

- Plywood
- Wood: boards and posts
- Screws
- Nails

Tools

- Saw
- Level
- Measuring tape
- Screwdriver
- Hammer

Instructions

- Measure and saw the wooden posts. The height of these should be the same as the height of the side wall of the cellar.
- Measure the length of the horizontal beams.
- Cut out a slot at the top of each post for the wooden beams. These make a simple timber framework.
- Place the posts evenly distributed along the inside wall of the cellar, using a level and a measuring tape. Make sure these are in level, both horizontally and vertically. In the model cellar we used nine posts to support the brick vault. Place them about 10 centimetres from the walls of the cellar for the sake of

strength and to facilitate the removal of the construction.

- Place the wooden beams lengthwise in the slots in the posts. This will be the base on which to place the half circular sheets of plywood later. Secure these by screwing them together, alternatively using hammer and nails. Screwdriver is preferable, seeing as screws can be easily removed when the centering has served its purpose.
- Measure and saw the half circular supports of plywood. These should be as wide as the inside width of the cellar and have the intended shape of the vault. The number of supports depends on the length of the construction. Appropriately placed, there should be about 50 centimetres between each sheet of plywood.
- Place the sheets of plywood evenly along the beams. Fasten with screws in the underlying beams.
- Measure and cut wooden boards according to the inside measurements of the cellar's length.
- Fix one board lengthwise on the top of the plywood moulds, making sure it is levelled and centered between the side walls. This will ensure that the following boards will be parallel with the walls as well. Also make sure the plywood supports are vertical.
- Place the rest of the wooden boards lengthwise on top of the plywood sheets and secure these using a screwdriver and screws, alternatively hammer and nails. These will serve as a base on which the vault will be laid.
- After the vault has been laid and given sufficient time to set, the centering can be safely removed. Note that the vault has to be completed entirely before the centering can be removed, as the vault cannot support itself until it is completed.

FIGURES 2.12. The centering rests on a structure of beams and posts which matches the height of the room. Photograph by Sanna Svensson.

FIGURE 2.13. The rounded sheets of plywood must stay straight to give a perfect, symmetrical shape. Photograph by Sanna Svensson.

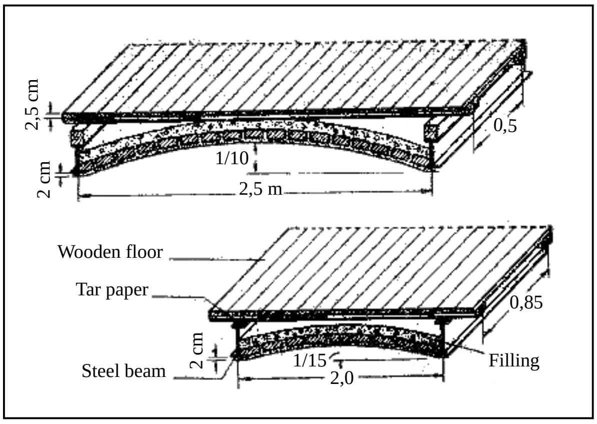
FIGURE 2.14. The centering for the storage room vault is completed by boards nailed onto the plywood sheets. Photograph by Sanna Svensson.

LAYING THE BARREL VAULT

As described above, the crucial point of a vault or arch is the stability of its base. Usually the tops of the supporting walls are built with a suitable tilt, or some heavy member (e.g. an I-beam of steel) is placed on top of the wall and secured in its position to counterbalance the thrust.

When a round form is built of rectangular blocks the joints become wedge shaped. After the mortar has set they keep the bricks from sliding out of position when the arch or vault is put under pressure but they do not need to glue the bricks together. If the bricks or stones are made wedge shaped archers and vaults can be built of them even without mortar, as described later.

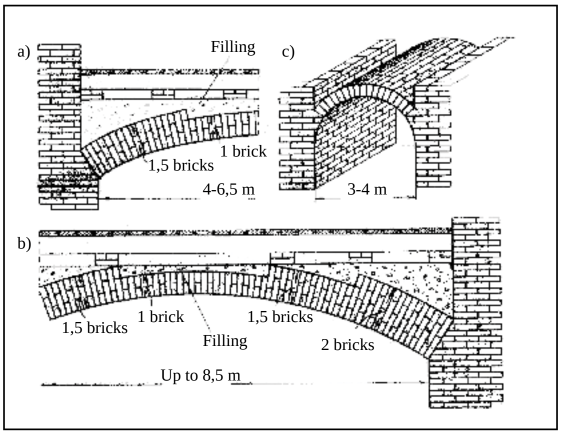
Illustration 6. A vault supported by steel beams.



Veski, Arvo 1948. Müüritööd. Tallinn: Pedagoogiline kirjastus, p 184.

FIGURE 2.15. Masonry details for vaults - according to Arvo Veski´s illustration for his book Muuritööd.

Illustration 5. Brick vaults in the case of different span distances:
a – a span of 4…6,5 m; b – a span up to 8,5 m; c – a span of 3…4 m.



Veski, Arvo 1948. Müüritööd. Tallinn: Pedagoogilina kirjandus, p 183.

FIGURE 2.16. An intermediate floor built with flat vaults which are supported by steel beams - according to Arvo Veski´s illustration for his book Muuritööd.

Materials

- Concrete
- Mortar

Tools

- Trowel
- Pencil
- Measuring tape

Instructions

- Use concrete to shape the top of the wall (alternatively: cut the top rows of the masonry) so that its angle will point to the central point of the arch.
- Lay the bricks in straight rows following the markings simultaneously from both sides.
- Leave to set for at least 24 hours (the less cement in the mortar, the longer the setting time).
- Remove the centering.

FIGURE 2.17. Positions for the brick courses are being marked on the centering. It is important that joints are uniform. Photograph by Kirsti Horn.

FIGURE 2.18. Bricks are laid from both sides of the barrel shaped centering. Photograph by Kirsti Horn.

FIGURE 2.19. The completed vault. When the formwork was removed we could see that we had used too much mortar in some places and too little in others. Photograph by Kirsti Horn.

FIGURE 2.20. The biggest cavities were filled. Photograph by Kirsti Horn.

LAYING A FLAT ROOF OR INTERMEDIATE FLOOR OF BRICKS

Another common traditional method of making a roof or an intermediate floor of bricks was experimented with during the course. Here the thrusting sideway forces are counterbalanced by steel beams. Traditionally these were often reused tram rails. This kind of structure[1] can be found most often in cellars, but also underneath stoves, in balconies and landings of stairways in the blocks of flats from a hundred years ago. In a big ceiling a series of vaults make a beautiful wavy surface. It is easy to build and gives a relatively fireproof structure. A typical historic flat vault structure has 900mm-1000mm wide vaults laid in a stretcher bond of red brick and lime mortar. (figure 2.16.) In case of fire the weakest part is of course the steel.

The following series of photographs shows how such a structure could be built without mortar. After the bricks are cut to the correct shape they make a strong and stable flat vault. Even a hole can be made without compromising the stability!

FIGURE 2.21. The shape of each brick was carefully measured and cut to make a flat vault. Photograph by Kirsti Horn.

1 kappaholvi in Finnish; kappvalv in Swedish

FIGURE 2.22. Cutting bricks with a circular saw is dusty and hazardous work; not a job for inexperienced people! It could be done with a brick guillotine or a mason´s hammer as well but the cut would not be precise. Photograph by Kirsti Horn.

FIGURE 2.23. A vent is being constructed with some temporary support. Photograph by Kirsti Horn.

FIGURE 2.24. Note how the two back rows are made with waste pieces from the bricks of the front rows at the ends. Alternating the two types would give a stretcher bond. Photograph by Kirsti Horn.

2.4 DAMP PROOFING THE VAULT

As a root cellar is situated partly or completely underground it is really important to seal its roof and walls from excess dampness. Note that none of the structural materials that are discussed in this report are water tight!

The best way of keeping the moisture that will appear through capillary action, diffusion and rain, from entering the cellar is to lay bitumen roofing felt on the vault and side walls. The felt should not be laid on the masonry before it has set because you need to climb on top of the structure to do this job properly and because the water from the building materials needs to evaporate before you start. Follow the roofing felt manufacturer´s specification!

- Measure the distance from one foundation plinth to the other over the vault and cut the sheets from the roll accordingly.
- Make the sheets overlap by the width of the bitumen glue along the edge (or some 100mm).
- Heat the whole length of each sheet, one at a time, with a blow torch so that the edges stick together and the sheet sticks to the underlying surface at least partially. (Alternatively use bitumen glue.)
- Press the warm felt tight onto its substructure as you proceed.

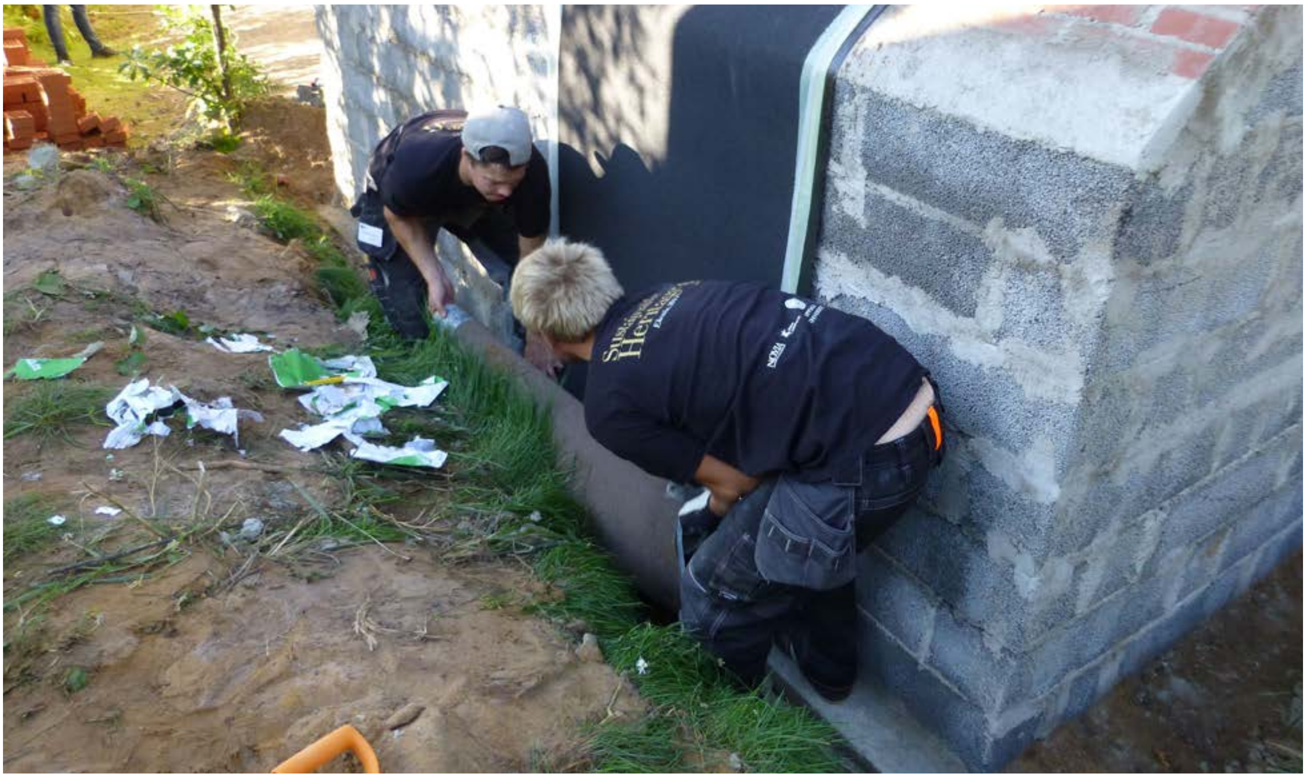


FIGURE 2.25. The felt is being measured long enough to protect vault, walls and the top of the plinth from rainwater. Photograph by Kirsti Horn.

FIGURE 2.26. The finished damp proofing gives mainly protection from rain. A French drain was placed along the plinth around the whole building to lead excess water away from the masonry. Note how the felt has been bent over the joint between brick vault and concrete blocks at both ends. The back of the cellar will be hidden by sand which will allow some necessary humidity through the wall into the cellar. Photograph by Kirsti Horn.

3. INTERIOR FINISHES

In humid conditions such as in a root cellar the walls should allow some diffusion through the materials. This will balance the seasonal variations in the indoor climate. A pure lime mortar applied on brick or stone is beneficial due to the high grade of permeability within the material which allows moisture to travel through the material. A root cellar is always susceptible to frost damages in its plaster due to the fact that it remains unheated during the whole year. This is why it is important to install drainage and ventilation.

A cellar is also prone to biological degradation due to the high relative humidity especially during periods of a higher temperature in summer. The surface treatment should not be oil based because the oil is a favourable breeding ground for algae and moulds. It should also not be impermeable (i.e. contain alkyd or plastic binders) because then it would not allow the necessary diffusion. This is the reason why a lime or cement based treatment – if any – is recommended on the walls. This is odourless and will not affect the foodstuffs.

3.1 PLASTERING THE WALLS

Lime-cement plaster was used for the finishing of the light concrete blocks because the mixture between cement and lime offers a strong yet agile facade due to the elasticity of the lime. A standard tinted mix was used according to the recommendation by the manufacturer of the concrete blocks. The cement in this kind of plaster makes it harden in just a few hours.

Material

- Hydraulic plaster mix
- Water

Tools

- Big bucket
- Hand mixer
- Edging trowel
- Plaster trowel
- Brush
- Hawk

Instructions

- Use an edging trowel to fill any eventual holes in the joints and uneven surfaces with mortar, in order to create an even base for the plaster.
- When the mortar has dried appropriately, wet the surface with the brush to help the plaster stick to the wall.
- Mix the plaster according to the instructions on the bag. Mixing ratio depends on the brand.
- Now, apply the plaster with the plaster trowel. Start from the floor and work your way up towards the ceiling. To create an even, smooth surface use long strokes. Always make sure the tool is relatively free of excess plaster, as this helps create a clean surface.
- Fill the hawk with plaster to avoid interrupting the job on the wall too often.

FIGURE 3.1. Students are mixing the plaster with an electric plaster mixer. Photograph by Kirsti Horn.

FIGURE 3.2. Plastering a wall takes a lot of practise. These students obviously knew the trade. Photograph by Kirsti Horn.

FIGURE 3.3. Plastering almost completed. Photograph by Sanna Svensson.

3.2 FLOOR

In order to create the desired humidity inside a root cellar the floor should allow diffusion and capillary action through its materials. It is important to use clean materials and make sure there are no organic pieces e.g. sawdust, shavings of wood or parts of vegetation among them or in the ground underneath.

Materials

- Fine sand
- Airbricks
- Water

Tools

- Wheelbarrow
- Shovel
- Straight wooden board

- Brush
- Hose

Instructions

- Spread a layer of fine sand on the ground at the far end of the cellar on an area some 1meter x the width of the floor. Keep filling until you reach the level some 30mm above the top of the plinth.
- Even it out and level it using the edge of a board. (take the plinth as a guideline)
- Water the sand in order to pack it.
- Lay the bricks on the bed of sand starting from the middle of the back wall.
- Use a stretcher bond and lay the rows parallel to the walls to minimize the inevitable cutting of bricks along the walls.
- Choose the width of the joints so that you meet the side walls with full bricks.
- Repeat until the whole floor area is covered.
- Bring in more sand and fill the joints and the holes using a brush.
- Water the floor so as to pack the sand densely.
- Repeat filling and watering and finally brush the floor clean from excess sand.

FIGURE 3.4. Many wheelbarrows full of fine clean sand were brought in. Photograph by Sanna Svensson.

FIGURE 3.5. The bed of sand is being watered. Photograph by Kirsti Horn.

FIGURE 3.6. Air bricks are being laid on the bed of sand. Photograph by Kirsti Horn.

FIGURE 3.7. The finished floor is both functional and beautiful. Photograph by Kirsti Horn.

4. DOORS

Choosing good timber is especially important when building a door. The material must not be warped in any way because this would cause the whole door to warp. A crooked door will not fit into its frame, it will not close tightly and its lock and hinges will be difficult to mount properly. A few easy guidelines to go by when choosing material at a lumberyard are:

- Straightness: no bending or warping is allowed
- As few knots as possible
- No cracks
- The growth rings must be tightly spaced
- Make sure the heartwood is turned outwards

The surface treatment which was applied only on the outside of this particular door was mixed of boiled linseed oil tar and turpentine. Paints with plastic or alkyd binders should not be used on porous and organic surfaces out of doors since the impervious coating tends to trap the moisture inside the undelaying material. This will inevitably lead to structural problems and failure of the surface treatment. Inside a root cellar the wooden surfaces should not be treated with anything at all. Instead, make sure the material is not in close contact with the damp floor or walls.

The tar paper or roofing felt which is placed under the threshold is of utter importance in a cellar. It prevents capillary ground moisture from entering the wood which would in time cause the frame to rot. Untreated wooden surfaces attract moisture but find a healthy balance with the surrounding air as long as we provide adequate ventilation and keep it from direct contact with damp surfaces. Untreated timber emits no harmful odours or gases.

Materials:
Door

- Sheets of plywood
- Wood and panelling from coniferous trees
- Sheets of polystyrene (preferably same thickness as the framework)
- Screws
- Nails
- Wood glue
- Stainless steel screen
- Door handle
- Door hinges

Surface treatment

- Boiled linseed oil
- Tar
- Turpentine
- Tools:
- Hammer
- Handsaw
- Jigsaw
- Drill
- Measuring tape

- Sandpaper
- Clamps
- Chisel
- Rubber hammer
- Set square
- Pencil
- Paintbrush
- Table saw or circular saw
- Level

Instructions:

- Constructing the door and frame
- Measure the size of the doorway in order to determine the dimension of the door. The width of the opening in the wall should be measured in several places to find the narrowest point. Keep in mind that there must be min. 15mm slits around the doorframe so that it can be installed and adjusted straight.
- Depending on the measurements, proceed by sawing out the four parts needed for the frame using a handsaw.
- Join the pieces at right angles with screws and glue to form the frame and leave it to rest overnight.
- Measure the size of the door. The door should be a half a centimetre smaller than the frame to allow for swelling and shrinking according to the relative humidity in the air.
- Saw out the framework for the door using the timber with a handsaw. The framework should be reinforced with diagonal braces.
- Make an opening for an air vent in the bottom part of the door using the jigsaw and surround it with a frame of wooden rails. A durable mesh against insects and mice should be attached in the opening.
- Make a ventilation hatch of plywood. Use a jigsaw or a handsaw and insert the piece into the grooves of its frame.
- Make a little handle of wood by sawing and sandpapering its form. Attach this to the hatch.
- Make two covers of plywood for each side of the door using a table saw or a circular saw.
- Attach one plywood cover using wood glue and clamps. Use a piece of wood between the clamp and the door to avoid the inevitable marks from the clamps.
- Let the glue dry overnight under pressure from the clamps.
- Cut out suitable pieces of polystyrene and fit these in between the reinforced frame, braces and the ventilation shaft.
- Attach the second plywood sheet on top of the insulation using the same technique as before. Use wood glue and clamps and leave it to dry overnight.
- Cut the panelling to desirable length. Make openings for the air vent in the panelling before attaching the boards with a hammer and nails to the structural frame of the door. Sandpaper all ends before mounting. (Only straight pieces should be used because any warping in the panelling will cause tension in the door itself and cause it to warp as well!)
- Attach a desirable handle to the door at a suitable height.
- Measure and mark where the door hinges should be on the door and chisel out the marked area and the depth of the hinges so that the frame is flush with the hinges. Keep in mind that there should be a half a centimetre between the door and the frame on all sides.
- Measure and mark where the door hinges should be on the door frame according to where they are marked on the door.
- Pre drill the holes and then attach the door to its frame using the drill and screws.

Mounting the door and frame

- Insert the frame in the opening of the wall and level the top by using wooden wedges.
- Place tar paper or roofing felt underneath the threshold.
- Use a level to make sure the frame is straight and rectangular.
- Screw the frame to the wall using a drill and screw plugs.
- Insulate the space between the frame and the opening with a durable and flexible material which allows for diffusion, e.g. coarse flax fibres.

Surface treatment

- Mix one part boiled linseed oil, one part tar and one (smaller) part turpentine.
- Brush a thin layer of the mix on the outside of the outer door, one board at the time.

FIGURE 4.1. The parts of the frame have been joined. Photograph by Aulden Carter.

FIGURE 4.2. The air vent is being built at the bottom part of the door. Photograph by Aulden Carter.

FIGURE 4.3. The sliding air vent hatch. Photograph by Kirsti Horn.

FIGURE 4.4. The plywood is being glued onto the framework of the door. Photograph by Sanna Svensson.

FIGURE 4.5. Polystyrene insulation in place; glue for the inner sheet of plywood is being spread onto the framework. Photograph by Aulden Carter.

FIGURE 4.6. Doors are being mounted. Photograph by Sanna Svensson.

FIGURE 4.7. A mixture of tar, boiled linseed oil and turpentine was applied on the outside of the front door. Photograph by Kirsti Horn.

5. VENTILATION

The inner climate – temperature and relative humidity – of a root cellar is controlled through proper ventilation. The vents should be adjustable because the climate on the outside is reflected directly on the inside.

In the model cellar the air flow passes through the vents in doors, through the spaces and out through a pipe in the roof. A round poppet valve must be installed in the opening of the pipe in the ceiling. A durable mesh against insects and mice must be installed on top of the pipe together with a cap against rainwater. The same applies to the vents in the doors as described above. Adjustable hatches at each vent make it easy to regulate the air flow.

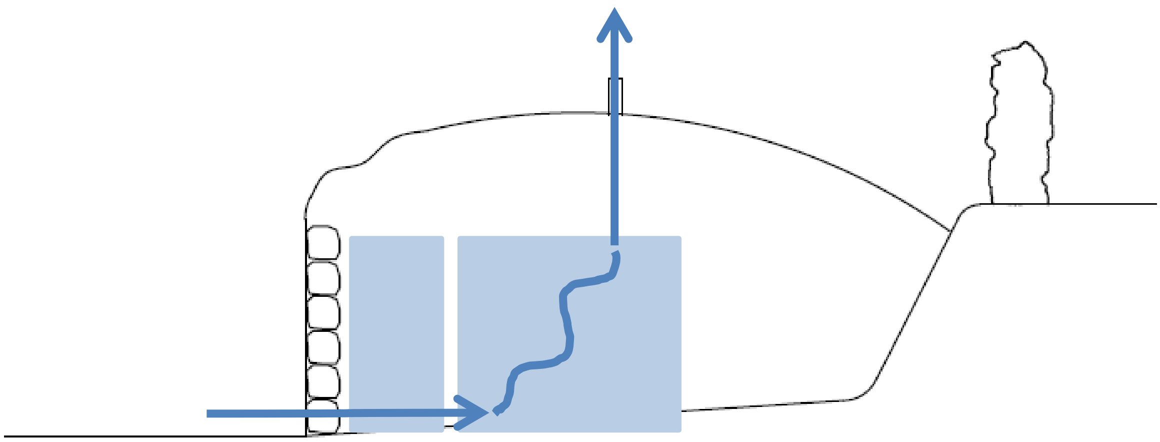


FIGURE 5.1. The air flow through the cellar follows the chimney principle: the warm indoor air rises out through the pipe in the back of the storage room ceiling. Favourable winds accelerate the flow.

6. CONCLUSIONS

A root cellar looks like a relatively simple building but there are many tricks the builder needs to be aware of. The moisture of the earth ought to be made use of in the inner climate remembering at the same time that excess dampness will harm both the building materials and the foodstuffs. For a successful result the following aspects should be taken into account:

- Check the ground water level. Keep your root cellar well above that!
- Make use of the existing terrain.
- Drain the earth around the structure.
- Use only such building materials that can withstand humid conditions.
- Count for the thrusting forces of the earth and snow against the walls and roof. Consult experts.
- Protect those parts of the structure which are exposed to rainwater.
- Choose harmless materials for the surfaces and furnishings inside the cellar.
- Provide for adequate and adjustable ventilation!

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REFERENCES

Balksten Kristin, 2005: *Kalkputs – Porstrukturens betydelse för beständighet*, avhandling Chalmers Tekniska Högskola, Göteborg
Sjöström Alfred, 1891: *Landtmannabyggnader*
Urpo Nurmisto, *Maakellari, Rakennusalan kustantajat* RAK. ISBN 978-952-254-058-4
Arvo Veski, 1948: *Muuritööd*, Pedagoogiline kirjastus.

LINKS

- useful links concerning food:
  www.motherearthnews.com/real-food/fundamentals-of –root-cellaring
  www.eldrimner.com
- about building Mexican vaults :
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ABOUT TRADITIONAL WOODEN AND MASONRY STRUCTURES IN THE BALTIC SEA REGION

The project Traditional Wooden and Masonry Structures in the Baltic Sea Region is a partner project in the field of Building Conservation involving Uppsala University, Campus Gotland in Sweden, Estonian Academy of Arts in Tallinn, Estonia and Novia University of Applied Sciences in Ekenäs, Raseborg, Finland. This is a follow up of an earlier, very successful project called Sustainable Heritage during which both publication series and an online project site were established.

There have been one or two courses annually so far – and this will go on for years to come. The course programme consists of a wide range of themes which are always associated with the most common building materials in the Baltic Sea Region: wood and masonry. The aim is to learn how these are to be preserved in the best manner and how traditional building and decorating techniques can be applied in modern buildings.
The intensive courses are tailored for students of Construction Engineering and Construction Management at Novia UAS, Building Conservation and Objects Antiquarian Programmes at Uppsala University, and Architectural Conservation and Conservation of Artefacts at Estonian Academy of Arts. These courses are hosted by the three partner universities in turns and they are designed to widen the scope of the standard curriculum at each university.
The Nordic-Baltic Network has so far been financed by the Nordic Council of ministers through Nordplus funds and its cooperation is run by Novia UAS.

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YRKESHÖGSKOLAN

NOVIA

This report is about the art of building of a vaulted root cellar.

The project Traditional Wooden and Masonry Structures in the Baltic Sea Region is designed for students of architectural conservation, conservation of artefacts, structural engineering and site management from three universities in Sweden, Estonia and Finland in order to give them the opportunity to learn about the traditional materials in different parts of buildings. From the conservation point of view they learn how constructions and surfaces made of these materials are to be preserved in the best manner.

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