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Wood. Construction. Austria. Norway

MASTER'S THESIS

to achieve the university degree of

Diplom-Ingenieur

Master's degree programme: Architecture

submitted to

Graz University of Technology

Supervisor

Dipl.-Des. BDA Univ.-Prof., Wolfgang Tom Kaden

Institute of Architecture Technology

Graz, January 2019

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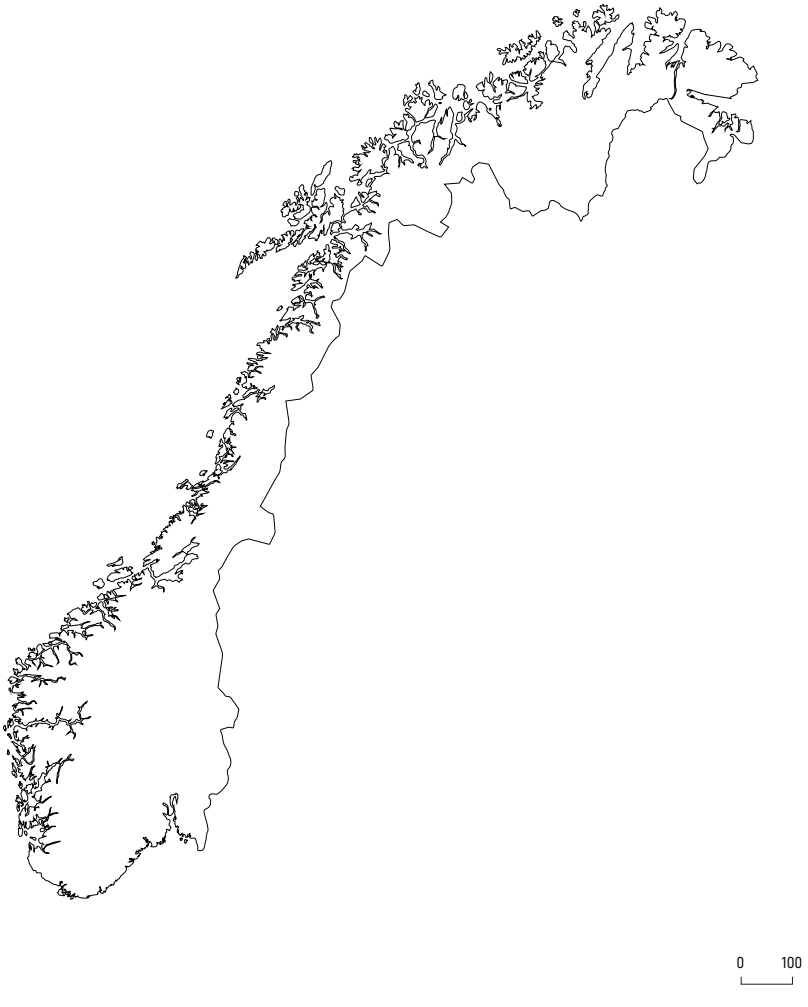
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Contents

"Where can we find greater structural clarity than in the wooden buildings of old?
Where else can we find such unity of material, construction and form?
What warmth and beauty they have! They seem to be echoes of old songs.
What better examples could there be for young architects?"
Mies van der Rohe

Prologue

The paths leading to this book are tightly connected to significant milestones of my personal life. An important factor was education. Attending a Higher Technical School specialised on timber industries, generated broad interest and a deep understanding of wood, in all its facets.
Another step manifested in studying Architecture at the University of Technology in Graz, understanding our built environment and the variety of challenges coming along it.
A parallel path led to the interest in Norway. Several journeys to different parts of the country created a persistent impression and kept me fascinated. Those two ways merged while studying at NTNU in Trondheim for the second half of my master's degree and are resulting in this thesis.

Therefore this book covers traditional wooden constructions in Austria and Norway and the advanced techniques and knowledge necessary to erect such sophisticated structures.
Beginning with the single tree itself and the variety of different types of wood, each with unique properties, to our forests and the way this natural material is sourced in sometimes challenging conditions, providing the sustainable foundation of wooden constructions.
Covering the history of both countries' building traditions, from the first, primitive use cases to advanced carpentry. Austria and Norway share a common tradition utilising timber as a key component of all kinds of constructions. While large parts of that knowledge disappeared through time and the introduction of other materials such as concrete and brick, several remarkable examples remained and provide interesting insights.
A large part of the book focuses on those details in construction and execution. How do wooden buildings withstand harsh climate conditions over centuries and what can be learned from it?
Where are the similarities and differences between Northern and Central European buildings? The focus is on structures of the Middle Ages onwards, where timber construction techniques peaked, and structures were entirely wooden.
By choosing three representative examples, regarding construction, use case and appearance and putting them side by side to their counterpart from the other country, one can see how different or similar wooden building traditions can be — every building unique in its way, but connected by the same material, wood.

Ill.1 Hoddevik, Norway, 2018

Vorwort

Die Wege, welche zu diesem Buch führen, sind eng mit wichtigen Abschnitten meines persönlichen Lebens verbunden. Ein wichtiger Faktor ist dabei meine Ausbildung. Das Besuchen einer Höheren Technischen Lehranstalt, mit einem Fokus auf die Holzindustrie, erzeugte ein breites Interesse und umfassendes Wissen von Holz, in all seinen Facetten. Ein weiterer Schritt stellte das Studium der Architektur an der Technischen Universität Graz dar, um unsere gebaute Umwelt und die dadurch entstehenden Herausforderungen zu verstehen. Ein paralleler Weg führte zum Interesse an Norwegen. Einige Reisen in unterschiedliche Regionen des Landes faszinierten mich und hinterließen einen bleibenden Eindruck. Diese beiden Wege kreuzten sich mit dem Studium an der NTNU in Trondheim, wo ich die zweite Hälfte meines Masterstudiums absolvierte und in das Thema dieser Arbeit resultierten.

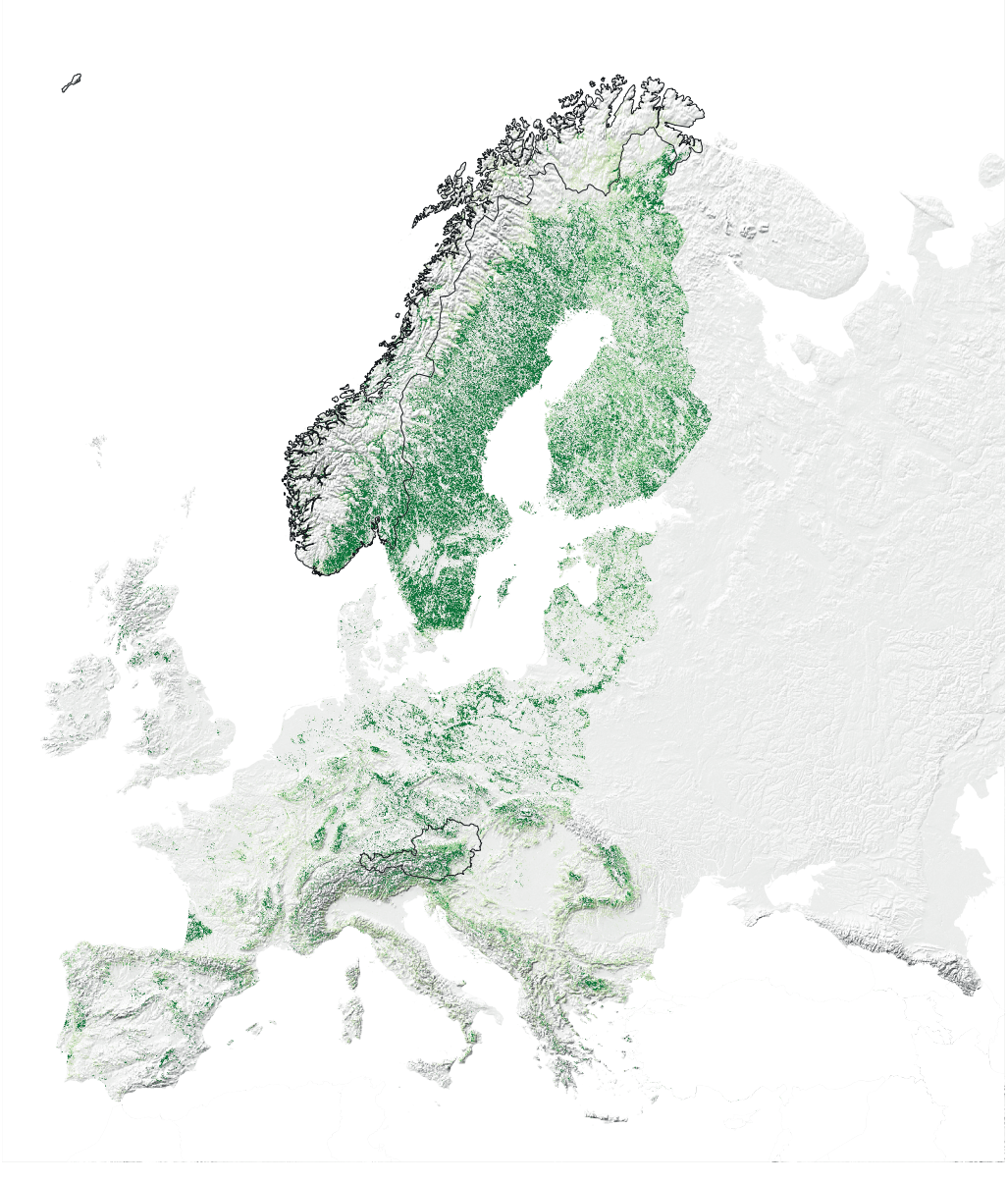
Aus diesem Grund befasst sich dieses Buch mit traditionellem Holzbau in Österreich und Norwegen, den ausgereiften Techniken und dem Wissen welches notwendig ist um solche durchdachten Konstruktionen zu errichten. Beginnend bei dem einzelnen Baum und den unterschiedlichen Holzarten und ihren einzigartigen Eigenschaften, zu unseren Wäldern und den Methoden wie dieses natürliche Material beschafft wird, in manchmal schwierigen Bedingungen, um damit das Fundament einer nachhaltigen Konstruktion zu schaffen.
Die Geschichte der Holzbautraditionen beider Länder umfassen. Von den einfachsten Anwendungsfällen bis hin zu fortgeschrittener Zimmermannsarbeit. Österreich und Norwegen teilen eine gemeinsame Tradition in der Verwendung von Holz in den verschiedensten Konstruktionen. Während große Teile dieses Wissens mit der Zeit verschwanden und neue Materialien wie Beton und Ziegel zur Anwendung kommen, verbleiben einige eindrucksvolle Beispiele und bieten einen interessanten Einblick.
Große Teile des Buches fokussieren sich auf die Details der Konstruktionen und deren Ausführung. Wie können Gebäude aus Holz den harschen Klimabedingungen über Jahrhunderte überstehen und was können wir daraus lernen? Wo sind die Gemeinsamkeiten und Unterschiede zwischen Nord- und Zentraleuropäischen Bauweisen?
Mit der Auswahl von drei repräsentativen Exemplaren, in Hinsicht auf Konstruktion, Verwendungszweck und Aussehen, und der Gegenüberstellung zu den jeweiligen Gegenstücken des anderen Landes, können Unterschiede und etwaige Gemeinsamkeiten klar aufgezeigt werden. Jedes Gebäude ist einzigartig, jedoch verbindet alle das gemeinsame Material, Holz.

Ill.2 Weißgrubenkopf, Austria

Acknowledgements

Before starting with the content, it is time to mention and thank those who were involved in creating this thesis.
First and foremost my most profound appreciation concerns my parents. Not only supporting me during the work on this thesis but enabling and smoothing the path leading up to this point.
Thank you!
Another contributor represents the University of Technology Graz, providing the architectural foundations and academical education over the past years. In particular, professor Tom Kaden, who followed and mentored this work.
The initial idea of comparing Austrian and Norwegian wooden building traditions dates back to the exchange year at the Norwegian University of Science and Technology in Trondheim.
Due to the university environment, open minded professors and not least fellow students, this time marks the start of the project.
Furthermore, thanks to the staff members of the Byarkiv in Trondheim and the Salzburger Freilichtmuseum, who provided access to research material, drawings, maps and texts.
Especially to Monika Brunner-Gaurek for her time, discussion and inspiring insights into Austrian building traditions.
Again, thanks to everyone who had a direct or indirect influence on the outcome of this thesis.

Ill.3 Sommarøy, Norway



Coniferous forest
Deciduous forest

Ill.4 Forest Europe

The architecture of a tree.

If we talk about the architecture of a tree, the forest is the equivalent of urbanism. A single tree is just a small part of a larger, functioning ecosystem. Forests cover large portions of the earth's land surface. While the numbers were decreasing worldwide to around 30% in 2015, Austrian forests are continuing to grow and cover 47% of the whole country. Data of Norway shows a very stable situation as well, but due to different topography and climate, forests make only for a third of the land mass.[1] Four main functions define the value of those areas. First of all, the production function. Wood as a natural resource plays an essential role in the economy of Austria. Around 250.000 people are employed in forest- and timber industries and supply a natural material for a wide variety of use cases.
Another function is especially important in mountainous regions. Trees are protecting settlements from avalanches, keeping the soil from erosion and are preventing floods and rock falls. Some parts of Austria and Norway would not be inhabitable without forests.
In addition to the productive and protective functions, forests do have positive effects on air quality, climate and water. Trees are regulating the climate, cleaning the air, producing oxygen, while sequestrating carbon dioxide. A cubic metre of wood is storing one ton of carbon dioxide.
Lastly, forests are accessible to everyone and are serving humans as a place to relax and spend their free time.
Foresters started to cultivate sustainably in Germany over 200 years ago, to maintain those functions. Sustainability even originates from forestry and implies the rule of taking less wood out than can grow back, securing a functioning ecosystem for generations to come.[2] Which means in respect of Austria that the annual growth exceeds the harvested amount and every second a cubic metre of wood regrows.
What type of tree depends on each location. Different species prefer different environments and adapt to climate, soil and altitude. A rule of thumb assigns deciduous trees to milder weather and coniferous trees to colder climates and higher elevations, with a few exceptions. Larger regions of deciduous forests occur in the lower parts of Austria and the

southern part of Norway, the rest is dominated by conifers. Towards the polar circle dense forests disappear, and the remaining trees are not suitable for constructional use. Both countries show a similar distribution of deciduous and coniferous forests. While the spruce is the dominant species in Austria, pines and birch are very common in Norway.
Per definition a tree has to be lignified, perennial, show a dominant trunk and an annual growth in length and diameter. The stem has a conical appearance and adds a new layer of material every year, hence the name, annual ring. In temperate zones with its distinct seasons, each growth ring consists of late and early wood. Latewood is responsible for the stability of the tree while earlywood transports water and nutrient from the roots to the crown. The faster the growth, the more extensive are those rings. Dendroecological examinations take a look at those patterns and match them with results from different trees and climate data to determine the age of the wood. Constructors prefer slowly grown coniferous wood because the annual rings are closer together, resulting in a stronger material. The opposite applies for deciduous trees.
The structure of a tree is comparable to a pack of straws. These straws are called tracheids (conifers). Some having thicker walls than others (late-, earlywood) and all are connected in the radial direction by pits.
Wood is an inhomogeneous material with a distinct anisotropy. Due to that anisotropic setup, wood behaves differently in each direction (longitudinal, radial, tangential). Most mechanical properties differentiate in along and across the grain. Along the grain, high tension and compression stresses can be received. An essential fact worth considering for wooden constructions. Therefore the fibres should stay intact if possible. Another characteristic of timber is also based on the properties of grain.
The porosity plus the chemical features of cellulose make the material hygroscopic. That means the moisture level of wood adapts to the environment, absorbing and releasing water. The structure of the cells reacts to those differences with dimensional changes. Taking up moisture results in swelling, drying is followed by shrinking.
Longitudinal shrinkage is ten times lower than in radial direction, a critical factor to consider in all wooden buildings but especially log constructions. A change of the moisture level of the wood correlates directly to a change in dimensions. This phenomenon occurs below saturation of 30% when water from the cell walls starts to evaporate. Thus, wood is technically dried to a moisture level according to the humidity at the later use.
Another property of some trees shows in differentiation in heart and sapwood. The heartwood is the dead part of the trunk. With the incorporation of phenols, it stops supplying water and function solely as a mechanical stabilisation. These substances not only colour the wood but increase the natural resistance against fungi and insects. Typical examples are the larch with its red and the oak the natural brown coloured core. Sapwood is the conducting part of the trunks cross-section and serves as the water supply from root to crown. It consists of living cells, always has a light colour and is vulnerable to fungi and insects. Hence it is often removed to increase the durability.[3]
As a natural material, trees can show several growth anomalies — tapering, sweeping or sweeping being the most common. Depending on the

severity, they complicate or hinder the use for building purposes. While tapering is particularly troublesome at notched log constructions, the conical shape became a design element in stave churches. The tapering columns appear to be even higher to the viewer's eyes. Some anomalies, however, find application due to their abnormal shape. Bends and forks develop to hooks or hold eave battens.[4]

The primary goal of every wooden construction is to reach the highest possible durability. Wood has to be protected first and foremost against water, to accomplish that. Over time, carpenters found various ways to solve this problem constructively. How these methods are implemented, will be shown in a later chapter. But even before felling the tree, Norwegians modified the wood to make it more durable. Certain species like spruce, larch or pine are resinous. A tree uses resin to cure injuries and damages. The pitch is also hydrophobic and therefore a natural wood preservative. To take advantage of this property, people cut off the top of pines and removed pieces of bark at the bottom of the trunk. The trees remained standing and impregnated themselves throughout years, resulting in increased durability. This process is called girdling.
Another reason why wood is a popular building material is its workability. Simple tools are sufficient to process timber, making it possible for almost everybody to build. In the beginning, mostly axes, drills and saws are favourable tools of the carpenter. Additionally, forests provide a constant supply. Adequate dimensions, the ease of transport and a low price contribute to the popularity, especially in former times.[5] Flammability led to many fires and eventually to the rethinking of city planning and a ban on wooden houses. An organic material, such as wood, comes with natural downsides. Cracking, crumping and potential rotting have to be taken into account. Knowledgeable carpenters could deal with all those situations and extract the best out of the material.[6]

Ill.5 Topography Europe

We, humans, make use of wood ever since. Even primates value its universal properties as tools in their daily lives. From the Palaeolithic Age, people collected wood as fuel and developed useful tools. Because wood was easily processable and tools got more sophisticated elaborated timber construction evolved. While the sapiens settled during Neolithic period and began to cultivate land, timber was the preferred building material. Especially in forest covered regions, people gained a broad knowledge of tree species and wood. Early palisade or buried stave constructions superseded tent-like structures. Wattle and daub walls close up the spaces. The German word "Wand" (wall) actually originates from the process of making wattle and daub structures (Ger. winden).[7]
Windowless longhouses with hipped or saddle roofs accommodated gatherings of whole tribes. The following dwelling houses were very similar, and people lived together with their livestock under one roof. Not until the transition to smaller family groups, houses became smaller and eventually divided into dwelling and outbuildings.[8]
Wooden constructions were common in major empires, such as Persian, Egyptian, Chinese, Greek and Roman. Athens was made entirely of wood until the 6th century B.C. Even the Greek temple has its origins in timber constructions. The shape of Doric columns traces back to tapered wooden trunks.[9]
While stone buildings superseded timber construction in most cities, due to the immense fire hazard, typologies in rural areas kept wood as a preferred building material. Both Austria and Norway have various examples of great architecture executed in timber.

In addition to the general overview of each country, it is necessary to explain the development of a city as well. While the rural areas of Austria and Norway appear very similar, the evolvement of urban regions is vastly different. Salzburg and Trondheim will showcase the process of urban settlements in both countries. Both cities have nowadays a population of over 100.000 inhabitants, are not the capital of their respective countries and additionally are the seat of an archbishopric.
As Salzburg was under the Roman influence and developed stone architecture early on, Trondheim kept building wooden buildings almost throughout history. Despite several town fires and laws prohibiting the erection of timber houses, one can find many wooden buildings even in the city centre in Trondheim.

Nature and mountainous topography shaped the architecture of both countries. Harsh climate demanded robust housing and people found the answer in the wooded areas.
Although superseded by stone architecture, from the Middle Ages throughout the 19th century, wooden construction predominant in farm and bourgeois houses.[10]
The historical development gives insight into the backgrounds of wooden buildings traditions; from early settlements to the Golden Age. Why Austria and Norway heavily relied on wood as a construction material and the inevitable end.

Ill.6 Austria

Austria lies in the centre of Europe. The Alps are dominating the country, hence the nickname “Alpenrepublik”. Austria shares borders with both western and eastern European countries. Nowadays, Austria is a landlocked state, bordering to Italy and Slovenia in the south, littoral states of the Mediterranean Sea. The central position made for a turbulent history, inhabited and ruled by many different people and empires, some examples being Celtics, Romans or the Habsburg dynasty. Those influences can be traced back also to the building style.

First post constructions have been found close to Linz and date back to the Neolithic period. During that time the building size decreased, and the gabled roof became common. Several pile dwellings were found in alpine lakes, such as Lake Constance, Mondsee and Attersee. Although the remains are now underwater, they might have been on shore back then.

The transition to the Hallstatt period brought first homesteads, and an early example of a notched corner joint was found in Hallstatt. The piece dates back 3500 years and is on display at the Natural History Museum in Vienna.

An open hearth was the centre of every dwelling. Humans, livestock and crop shared a common space. Smoke was not controlled in any way and escaped the room through gaps in the roof. Later smokehouses and kitchens were found all along the north side of the Alps, from the Vienna Woods to Lake Geneva, and were in use until the previous century.

In addition to the dwelling house, people built storehouses for seed, clothing and other appliances. The main reason was probably fire-safety, but the robust design protected against raids and robberies as well. Gradually more outbuildings appeared and got individual functions such as a barn, shed and workshop.

Celtic, Germanic, Bavarian and Slavic tribes which settled in the area of Austria and the feudal system of the Middle Ages led to distinct characteristics of buildings and settlements, because of their different building traditions and mentality. Regions with solely wooden constructions were Carinthia, Styria, the Northern parts of Upper- and Lower Austria, the mountainous areas of Salzburg and the Bregenz forest. Notched log constructions became dominant around 1000 A.D., but simultaneously the Babenberg dynasty started to build castles, churches and mansions of stone. While cities switched to stone constructions, rural areas kept building in wood for centuries, and carpenter stayed to most important craftsmen.

In lower areas, villages and larger settlements formed, whereas, in mountain regions with harsher climate and isolated location, people lived in self-sufficient farms. The focus was more towards the production of goods than the living situation. Hence the separation of certain parts of the farmstead into independent buildings.[11]

Ill.7 Fence, Salzburger Freilichtmuseum

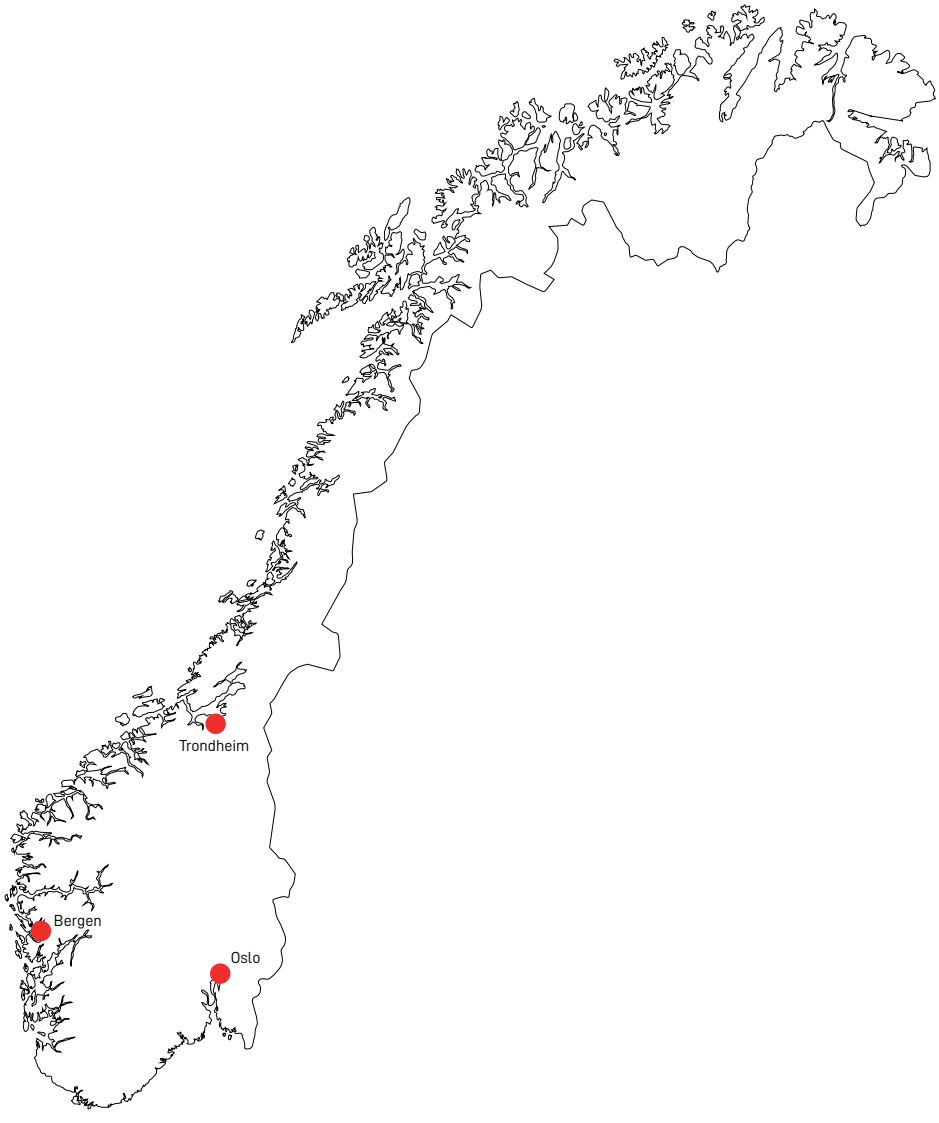
Salzburg lies embedded into the mountain ranges of the northern Alps, where the Salzach valley opens up to the Alpine foothills. The environment defines significantly the cityscape of Salzburg. The city centre is right in the middle of the Salzburg basin, 420 metres above sea level.
Being at the northern rim of the Alps provides the city with an oceanic climate with four well-defined seasons and make for a high amount of precipitation, peaking in July. Temperature can fluctuate quite drastically between summer and winter.
Coming from the mountains, the Salzach is running through the basin to the North. A bit outside the city borders it merges with another river, the Saalach. Several inselbergs rise from the valley ground. Those inselbergs are also responsible for the ideal scenery to settle. In combination with the river, they form a natural protection against intruders. Therefor Salzburg did not need a city wall until the 13th century. The half-moon shaped Mönchsberg is wrapping around the old town and reaches on both sides the river. Leaving just a narrow passage to enter the town. The existing building stock of Salzburg consists of profane monuments only back to the 14th century and sacral ones back to the 12th century. Nevertheless, is the old town heavily influenced by the medieval development.
First traces of people in the area of Salzburg date back to Palaeolithic Age (800.000-18000 B.C). People were still hunters and gatherers because of the widespread glaciers at that time. For this reason, not much evidence exists. But several findings of bones and tools were found in caves near Salzburg. First archaeological evidence of human activity within the current city borders are from the Middle Stone Age (18.000 – 4500 B.C). With the end of the last Ice Age, people started to settle down and practise agriculture. Humans were no longer totally dependent on nature. Simple tools enabled people to construct simple wooden houses. Bigger settlements emerged on the inselbergs like Rainberg, Mönchsberg or Kapuzinerberg. Salzach and Saalach being the most important transport routes. With the possibility of processing metal came a cultural and

social shift. First forms of cult and religion can be found, mostly burial object. Mitterberg, close to Bischofshofen, was a significant mining area for copper. Another major step was the extraction and processing of iron. The late Iron Age, also known as the Hallstatt period, brought the exploitation of salt and with it the preserving of meat. Mining areas were in Hallstatt at first, but after landslides and mining disasters, the Dürrnberg close to Hallein became the new exploitation ground. The production of salt was dominated and organised by the first known ethnical group, the Celts. Around 600 B.C. marks another cultural shift. A noble class emerged. Importing luxurious wines from Italy, as well as clothes and arms. Burial chambers and grave mounds were set up in a distance to the graveyards of the common population. After the Golden Age of the Celtic, salt production on the Dürrnberg around 500 B.C. the Celts lost influence. The kingdom Noricum was a loose bond of Celtic tribes in the eastern Alps. Romans from the South and Teutons from the North put pressure on the empire. Following an early defeat against Roman troops, the rest of Noricum accepted to new leadership. The Celtic settlements featured wooden houses but with the Roman influence, stone architecture was introduced in Salzburg in the end of the 1st century A.D.[12] Imperator Claudius made Noricum a province of the Roman empire.[13] At that time the Roman settlement of Iuvavum got town privileges. Iuvavum was to the Roman name of Salzburg and set the foundation for the medieval town structure later. Additionally to the favourable, natural circumstances, the town was also on a crossing of Roman roads. One leading over the mountains to Carinthia and a pre-alpine road from Ovilava (Wels, Upper Austria) to Augusta Vindilicorum (Augsburg, Germany).
In 488 A.D the Roman elites left Noricum due to an order of Odoaker. As a result, the activity in the city came to a complete stop. The town decayed but due to the roads and bridge fell not into oblivion. Up until today several streets are following the ancient path.
A new impulse to refound the city was made by the Bavarian duke Theodo. He instructed Rupert of Worms to missionize the region. Under his order many churches were found. Back in those days the Bavarians were a tribe of free farmers in rural areas. Their houses resemble the Germanic longhouses. About 20 metres long, wattle and daub walls and steep roof, over 10 metres high covered with either reed, straw or bark. Beside Rupert, a second bishop significantly influenced the city of Salzburg and sacral activity in particular. Virgil came from Ireland and led the way of Salzburg becoming archbishopric.[14]
To date the archbishop has his residence in Salzburg.

Devastating town fires happened regularly, destroying vast parts of the medieval city. For this reason, building regulations for cities were put in place already in the Middle Ages. In the 17th century the archbishop of Salzburg, Paris Lodron, gave out orders to his subjects to prevent dangerous fires. Some points of this order from 1648 were: sweep the chimney 4 times a year, no hay, straw or wood next to the fireplace, keep tubs of water in the attic (only during non-freezing times), establish fire-fighting pons.
But the rural population was doubtful about those innovations and regulations. Since 1548 it was illegal to build a house without permission

of the court chamber. In 1697 and 1711 people got sentenced if building or rebuilding without allowance of the archbishop.[15]

Archbishop Hiernoymus Colloredo (1772-1803) dictated the use of natural stone or brick in the 18th century. Only people who could not afford the new building material were allowed to continue using wood. These exceptions became the rule and a general use of brick only started in the middle of the 19th century. Reasons for this transition were the removal of the servitude for farmers in the forests of the authority, the increase in the prices of wood and the higher insurance costs for wooden buildings. But no important brick industry evolved, due to a lack of clay deposit and its poor quality in the area of Salzburg. Building material were hard to get and the collection took often several years. Hence the use of regional material, which were easier to obtain. The archbishop even gave guidelines for the building process. Apart from rules for how to store and transport materials, the guidelines contained regulations for dwelling and outbuildings. Buildings should be erected economically and as fire save as possible. Hay and threshed grain should be stored in a separate building, to avoid damage to seeds and food supply in case of a fire. The granaries also stored cloth and cured meat. Although building regulations were in place, the remoteness of some villages and farmsteads hindered the establishment. Some areas probably never heard of the restrictions. Hiernoymus Colloredo set many regulations into place to improve fire safety, resource savings and hygiene. Aesthetics and style intentions were completely missing. The real change came with an economical change, industrialization and a change in social demands. Fire proof building materials got cheaper and everyone was able to afford them.[16]



Ill.8 Norway

A wild landscape, dominated by rough mountains, high plateaus and deep fjords, shapes Norway. The country consists of three main parts. In Western Norway, glaciers carved out steep valleys which later filled up with seawater and particularly the area between Stavanger and Ålesund embodies the picturesque Norway. High plateaus mark the transition between east and west. Towards the border of Sweden, hilly landscape with extensive forests defines Eastern Norway. Trondheim marks the beginning of Northern Norway. Arctic climate starts to influence the scene, and coniferous forests give way to birch trees. Although having mainly a harsh and cold environment, the Gulf stream keeps the Atlantic harbours ice-free.

First settlers came to Norway via two diverging routes. One being from the Kola peninsula in the north (Komsa culture) and the other from the south (Fosna culture).[17] Evidence suggests that happened in a period from 9000 to 6000 BC. People lived on hunting, fishing and gathering. During this period, the climate was 3-5°C warmer than today. The Norwegian coast was rich in fish, seals and the deciduous forests were full of life as well. Round, tent-like structures were used for housing. Later superseded by pit houses with an open hearth in the middle and elevated sleeping spots.

In the Neolithic period agriculture was introduced and longhouses embodied the new dwelling situation. Everything happened under one roof. Livestock was kept on one end, while people lived on the other. Usually, a hearth was at the centre.

The longhouses of the Bronze Age were up to 25 metres long, and two rows of poles were bearing the roof. Wattle and daub filled out the space between the staves and created an enclosure.

Climate conditions got colder in the Iron Age and were 1-2°C colder than today. Pine and birch trees suppressed deciduous forests. Vast spruce forests expanded in Eastern Norway, and beech tree spread in the south. Agricultural yield decreased. With only one harvest a year, people had to store goods to survive. Due to climate change, the buil-

ding style had to change as well. Wattle and daub walls weren't insulating enough. Post and plank constructions, palisade or stone and earth walls were the alternatives.
The age of the Vikings started with their raid of a monastery Lindisfarne, in Northumberland England. While the Vikings were well known for their attacks and explorations to foreign countries, their architecture and crafts were equally impressive. An example of a longhouse was reconstructed in Bøstad, Lofoten and is 85 metres long and 9,5 metres wide. And capabilities of constructing boats was later used in stave constructions.[18]
Starting around 1000 AD missionaries tried to introduce Christianity in Norway.
During the Middle Ages, 13 larger settlements spread over Norway. Except for Hamar, all of them were along the coastline. Those early cities consisted almost entirely built out of wood. Only some churches used stone as a building material. The development included different types of constructions. Logged structures were used for houses, lattices, foundations, quays, wells etc.
Furthermore, various types of frame constructions were in use houses. For example, stave, wattle or palisade walls. Those types can be found in other European regions as well. Hence wooden constructions were a typical building style in Middle Age Europe.
While the cities were still relatively small, the buildings of cities and rural areas differed just slightly.
In 1349 the Black Death reached Norway and wiped out about half of the population. The life stood still, and large areas decayed. No constructions meant no consumption of wood, resulting in increased timber resources. Buildings after this period feature logs with larger dimensions.

Ill.9 Geirangerfjord, Norway

Ill.10 Historic city plan, Trondheim Byarkiv

Trondheim is the third largest Norwegian city and lies by the sea. The Trondheimfjord meanders through peninsulas towards the town. Those landmasses shelter Trondheim from the open Atlantic Ocean. Hilly landscape, covered with forest, surrounds the centre. The river Nidelva runs through the old town. Trondheim is part of Trøndelag county, seemingly the last region not considered northern Norway. The climate of coastal areas depends on the Gulf stream and is substantially milder than the backcountry. Atlantic influence makes for reasonable precipitation, although noticeably lower than Bergen or Stavanger.

Excavations between 1973 and 1985, while building a new library in Trondheim, suggest due to dendrochronological examinations that first settlements date as far back as the first half of the 10th century. Non-permanent structures like fireplaces, tents and sheds were built on the northeast corner of Nidernes (region of Nideros, one of the former names of Trondheim) to house first inhabitants. The development of those settlements in the Middle Ages can be categorised into five chapters. Part 1 lasted from around 900 A.D. to 970/980 A.D. and informal and non-permanent buildings shaped this period.

During the second part from around 980 A.D. to 1050 A.D the transition to permanent buildings was made. Excavations close to the crossing of Søndre Gate and Kongensgate show development around a small bay with terraces which could have been landings for smaller boats. Around the turn of the century, the settlements stretched wider along the river Nidelva. On those terraces small, one-room log houses were built, with the short side of the house facing the water. During this part the transition of non-permanent to permanent housing structures took place. King Olav Tryggvason was mainly responsible for the city's development.

From 1050 A.D. to 1150 A.D. the level of activities within the city rose. For example, the first dwellings were tenements. Due to land rising and filling up some bays the harbour activities were moved to the riverbanks. In this period Trondheim developed to a transregional centre. After 1150 A.D. the archdiocese gained a lot of influence and affected the city's development, both spiritually and economically. The town got divided by three streets running north. Along those streets, townhouses had been built. If a plot was shared or split, row houses occurred or townhouses with shared courtyards. Stave and palisade constructions formed At the beginning of the 15th century the growth stagnated, and in combination with the Black Death, the population decreased by 50-75%.
In addition to the threat of the plague, the town was destroyed by sev-

Ill.11 Historic city plan, Trondheim Byarkiv

eral fires throughout the years. Eight big fires occurred until 1681 A.D. After each town fire the buildings were re-erected almost identical to their predecessors. The remains were torn down and buried in place. Hence several traces of different houses can be found on one site.

In the aftermath of the fire of 1681, a new city plan was elaborated. Responsible for the development was Johan Caspar Cicignons. Therefore the masterplan is known as the Cicignons Plan. Born in Luxemburg, he came to Norway in 1674.
The big problem during the previous fires was the fast rate of which they were spreading. Reason being the proximity of the buildings because of the ancient, narrow street network.
Cicignons concept divides the city in four quarters by 40-metre-wide streets. Located in the centre is a generous square with a side length of over a hundred metres. Instead of using just perpendicular streets, Cicignon uses the cathedral as a starting point for rays running through the city. Munkegata, as the main street, connects the Nideros cathedral, the main square (Torget) and the Fjord. Aim on the sea is the island of Munkholmen. Another important connection is Kjøpmannsgata, being parallel to the River and separating city life and Bryggen. These two streets opening towards the fjord are forming a triangle.
Main parts of the plan remain the same until the present time; even most street names are unchanged.
A major weak point of the new plan was the big size of each quarter. Within the districts, the old street network remained the same and with it the danger of fire. Some of these parts stayed unchanged and are still visible today.
The plan was not popular among the people of Trondheim, because it did not consider old property borders. Hence it took quite a while until

it became a reality. 1685 A.D. half of the city was rebuilt, and a new bridge “bybrua” was almost finalised.
In the beginning of the next century not only the eastern part of the city was restored but also new buildings emerged west of Prinsens Gate.

The next big town fire took place in 1708 A.D. and destroyed large parts of the city again. Within the triangle, all buildings were affected, but Bryggen survived. In parts confirming Cicignons plan. As a next step Wibe and Stockhoff, a general and a conductor, were commissioned to widen all remaining, narrow passages.
Johan Wibe had to work out a building regulation for the king in 1709 with the goal to satisfy the burghers while setting a high standard for fire safety. An example being Kjøpmannsgata, where the width of the street should stay the same but the building along it should be made out of masonry or stone and should have the same height. While Stockholm and Oslo had similar regulations in place at that time, the people of Trondheim didn’t except the change. Instead of switching to stone they erected new, higher buildings along Kjøpmannsgata in wood.
Possible was this partly because of the municipalities’ lack of supervision.
Starting in the 17th century, a new type of buildings began to appear in Trondheim. Large townhouses, all with log timbered constructions and a vertical board cladding outside. First, the interior was raw; later the wooden walls were painted and equipped with additional panels or canvas. But the decoration was not found before 1760.
The areas of early development, close to Kjøpmannsgata, were still divided into smaller plots, whereas further west the properties were much more extensive.
General Wibe bought some of the land between 1684 and 1688 and built

a magnificent house on the spot of the later Stiftsgården. The ensemble was u-shaped and had two side arms towards Munkegata, almost like pavilions. All wooden houses had hipped roofs, pilasters structured the facade and were influenced by the Dutch style, while the floor plan followed French examples. For a long time, Stiftsgården remained the largest wooden building in Europe. But Wibe moved to Lade around 1700, and the town fire of 1708 destroyed the complex. Another example in the city was a house on Olav Tryggvasons gate which was later moved to the open-air museum Sverresborg in Trondheim and is still on display today.
During the 18th century a wealthy group of people, traders, ship-, land- and mine owners shaped to the social upper class. Those men often had foreign names and with them came foreign workers to Trondheim. Therefore, different styles were imported, such as an example in Kjøpmannsgata were a Danish homeowner built a Copenhagen styled house. From 1750 to 1800 building after building was constructed. The competitiveness of the wealthy citizen partly created that boom, but new capabilities in craft and art were equally responsible.
A typical house at that time had two storeys, either a hipped, mansard or manorial roof and a Dutch-inspired facade organised by pilasters. But the board clad facade and "strekkefisk" stayed because of the log timbered construction.
Also, the floor plans involved away from long know central corridor plans, to more complex, French-inspired multiroom plans. In 1769 Trondheim had 7578 inhabitants.
Besides the homes of the rich, some much simpler houses had been built as well. Those had still the central corridor plan or even the traditional three-room plan.

Earlier it was prevalent to build dwelling houses right behind the storage house (Bryggen) along the river, but the Cicignons plan stopped that. While those regulations counted for the west side of Nidelva, those rules excluded Bakklandet. Traders lived and had their offices right behind the storage houses, having a direct connection to the people loading the ships.
During the first decades of the 19th century the city grew towards the harbour but could not stretch further west, and the densest part was within the triangle of Prisensgate, Erling Skakkes gate and the river. Bakklandet grew into a continuous line of buildings and was passing the church on the east. The population increased from 8840 in 1801 to almost 13000 in 1835, and the fortification wasn't relevant anymore. In the second half of the 19th-century war and an economic crisis stopped most building activities and the few buildings constructed were much simpler built.

A new development boom started around 1900, and due to new regulations, stone and concrete constructions replaced a lot of the buildings. Two big projects of that era are the E.C. Dahls Stiftelse and the NTH University Building.[19]

Bergen is the second biggest city in Norway. Situated at a natural harbour and surrounded by mountains, in the middle of the fjordland of Western Norway. The proximity to both Hardanger and Sognefjorden made Bergen the ideal spot for trading. Farmer and fisherman came from the surrounding areas to exchange their goods. Olav Kyrre founded the city in 1070 as a merchant's town. The medieval part of Bryggen, where the merchants and their tenants lived, worked and the goods were stored, has still its original layout. With the gables facing the sea and separated just by a narrow passage the buildings string together up a slight hill. While the first floor was projecting over the ground floor in the rear buildings, there is no projection at the front.

Even the German merchants of the Hanseatic league, which dominated the city in the late Middle Ages kept the building tradition. Partly because they want to blend in and not break with the existing conditions. Although the town act of 1276 required more open streets and a standardised projection of the houses, Bryggen wasn't affected by that regulation. The area has an individual character because the buildings vary in height and depth and the wood-boarded passages are winding through the narrow gap between each row.

Internally the organisation was as interesting as externally. Owner and tenants formed a community, partly because of the structure of the house and the disposition of the site. One could say it was a co-operative system. Some houses were common property, others individually owned. A row of buildings always had the same organisation. The very last structure of the row was called "firehouse", had only one storey and was used for cooking. Followed by a two-storeyed building called "Schødtstue". Both places were common property, and the first floor of the "Schødtstue" served as a social space, a meeting place for people of all classes. The ground floor was divided into storage rooms of various sizes. In front, the houses were usually three storeys high and accommodated office, living and storage spaces. Because the ownership also varied throughout one row, the buildings were reconstructed almost identically after each fire. Minor changes included the change to tiled roofs instead of turf and from the Rococo period in the 18th century onwards wooden panelling of exterior walls, which gave Bryggen its today's appearance.[20]

Ill.12 Bundwerk joint, Salzburger Freilichtmuseum

After examining the way how building traditions evolved alongside human history, the following chapter focuses on the technical development of those constructions — differences in execution, handling of loads and the protection against decay. Starting at the early post and palisade constructions, to stave-, timber frame and notched log structures. Primarily the methods of joining large pieces of wood to sophisticated structures. From the foundation to the roof. Every kind of construction solves those critical components in fundamentally different ways, but the goal is always to create permanent protection against environmental influences. As technology and handcraft progressed, new ways of solving this challenge emerged. Where palisade structures were still buried in the soil, notched log work (and stave constructions) were lifted above ground to hinder moisture from damaging the logs.
While dwelling buildings usually adopted the newest technology, some typologies tie closely to a specific construction. Stave churches feature almost exclusively stave constructions. Only parts of the traditional loft show a similar construction method. The transition to notched log work was responsible for the reduction of building sizes, spreading out single functions to individual buildings. The length of a trunk became the decisive factor. Building sizes could not exceed those natural boundaries.

As a natural material, wood is prone to mould, fungi and insects. Infestation of such drastically reduces the life expectancy of a building. Exposure to water or contact to soil catalyses that process. Therefore one is keen to minimise the risk factors. On the one hand, constructional solutions can prevent the connection between water and wood or at least ensure a rapid dry out process. Projecting roofs or minimising soil contact are favourable methods. On the other hand, chemical enhancements of the material can increase its durability, such as taring or painting.
Constructional solutions prevent water contact, which is preferable then reducing the consequences.
Mostly farmers were responsible for building their houses. Those with more experience helped others and passed on their knowledge.
A variety of axes were the preferred tools of the carpenter. From felling a tree, and hewing the logs, to splitting up boards, an axe could do everything.[21]
During most of history, farmers were responsible for constructing their buildings. Generations passed on their knowledge, and while farmers kept building in rural areas, guilds formed in cities and carpenter became one of the most prestigious jobs.

Verticality and horizontality are imminent in the architectural discourse — two opposite things, independent and intertwined at the same time. Often referred to as symbols of earth and sky, but in the context of traditional wooden construction, the two terms are pointing towards the orientation of the load bearing elements. Each traditional construction type falls into at least one of the two.

Vertical

Verticality reaching the sky. God like, up to heaven, therefore people fascinated
Verticality, in wooden constructions, means an upright position of load bearing elements. Palisade, stave or frame structures all fall into that category. The orientation of studs, posts and columns aligns with the fibre direction of the material and wood copes bigger stresses parallel to the fibre. Because the vertical elements guide the main loads directly from top to bottom, those elements fulfil the primary constructional function. Secondary, horizontal elements reinforce the structure and form a self-supporting structural skeleton. Bracing is necessary, because the upright orientation is naturally unstable, working against gravity. This type of construction demands a minimal material input and is completely independent of the wall setup.
Depending on the actual construction type the walls are executed in a certain way, either inserted horizontal planks (Post-plank construction), vertical planks (stave construction) or board cladding (Timber frame construction).
Verticality becomes most notable in stave churches, where columns and staves are meant to create the impression of reaching the sky.

Ill.13 Aurora borealis, Målsnes, Norway

Ill.14 Gol Stavkirke, Bygdøy, Oslo

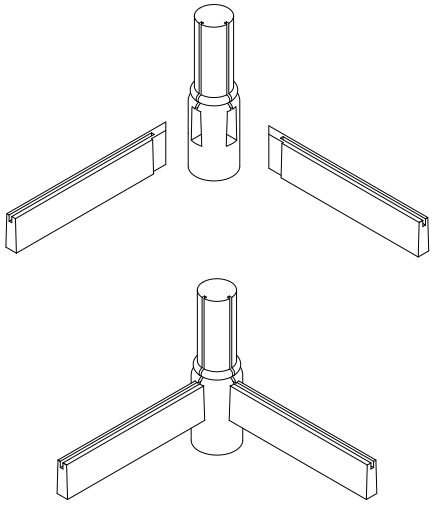
From Viking ships to stave churches

As soon as wood was used a building material post, palisade constructions came to use. Germanic longhouses called "Hallen" is the archetype for following settlements. A rectangular floor plan with a fireplace in the middle or at the gable wall, those houses were entirely out of wood. Posts were buried in the ground for stability, walls consisted of wattle and daub, and the roof had turf or straw covering. People and animals lived under one roof.
From Stone Age to Middle Age not a lot changed, except regions which were influenced by the Roman Empire, those adapted stone constructions.
Today's timber frame houses are nothing but a development of those types. While wattle and daub walls were widespread in Europe, they weren't as dominant in Norway and on Islands in the Atlantic Ocean. Harsh weather conditions and cold climate prevented an adoption.
Outer walls consisted of stone and turf or wooden planks while the roof bearing structure was still wood. Although these differences the style of the buildings wasn't too different than the European one. Up until 1000 A.D where Denmark and southern Sweden adapted European frame constructions and Norway, and northern Sweden began building in massive wood.[22]
While palisade walls and first stave constructions used the ground to stabilise itself, in a remarkable breakthrough, carpenters lifted the structure off the moist soil. The building had to self-support itself, to maintain structural integrity. Massive sill beams formed the foundation for the significant accomplishments which carpenters would create in following centuries.
The knowledge, how to timber self-supporting structures might come from the mighty Viking ships. Light and elastic, yet strong are these boats known for their extremely high quality and seaworthiness. Men sailed the Oceans successfully, partly powered by wind and partly by

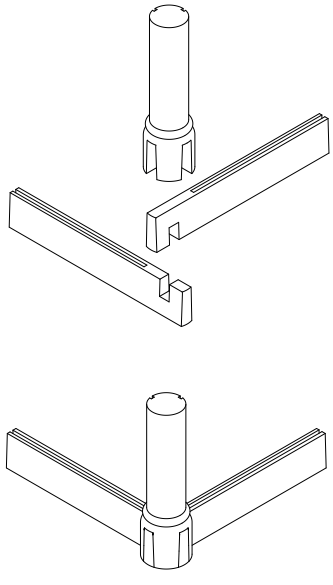
hand. Two spectacular examples of naval architecture were found as burial objects, both almost entirely preserved. Although smaller than those crossing the oceans, the Oseberg and Gokstad ship represent the peak of the Viking ship development. Few different kinds of wooden materials were used to construct the vessel. The keel was usually made of oak, but the other parts were mostly of pine. Only the carvings were of beech. An immediate characteristic which identified Viking boats were the high stems, often adorned with rich ornaments. Therefore the stems were regularly transferred to new ships. The tips often had animal heads fastened to them, typically dragon heads with gaping mouths. Hence the name "Dragon ships". Besides the ornamentation and carvings, the construction of such a vessel is highly interesting and relevant for other wooden structures, for example, stave churches. The way ribs, keel and planks are joined together to create a self-supporting ship, requires the same skillset as the erection of stave walls.[23] Keel and ribs form the skeleton of a Viking ship, like beams and posts of the stave construction. The keel translates to the sill beam, equipped with a groove where planks can slide into. Even the planks closing up the structure have the same purpose at both examples.

By far the most remarkable use case of stave constructions were the brilliant stave churches, scattered all over Norway. Those churches are also the last existing buildings entirely out of stave construction. A less famous but not less striking application of this building method can be found in parts of Norwegian storage buildings. The loft usually has a log timbered core and a projecting second floor of stave construction. Especially impressive is the joining of both construction methods — a blend of vertical and horizontal.[24]

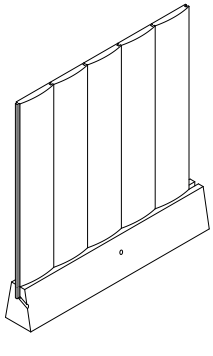
The elementary principle of the stave construction is based on the palisade wall. Vertical elements are combined to a solid wall. The fundamentally different idea of the now known stave construction is to lift the whole structure above the ground. No longer are earth-fast staves responsible for the stability, the entire construction supports itself. Therefor pillars, earlier necessary to bear to the roof, are moved outwards to the corners of the building. Four elements together create a stave wall. Firstly, the staves themselves, which are responsible for bearing loads of the roof and leading it towards the foundation. They are placed on top of intersecting sill beams. Those sill beams rest on the foundation and are one of the horizontal elements of the construction. Grooves on the upper side of the beams accommodate the vertical planks. A cross-beam on the top of the pole is the counterpart to the sill beam and concludes the wall setup.
If necessary, a wall is divided by inferior staves to support the structure additionally. The three-dimensionality of the construction provides stability. The stave church of Haltdalen, now at the Folkemuseet in Trondheim, is an early, simple case, showing the pure form of the stave construction.[25]



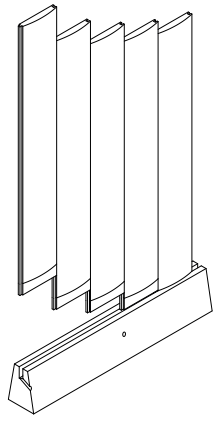
Corner stave joint A



Corner stave joint B

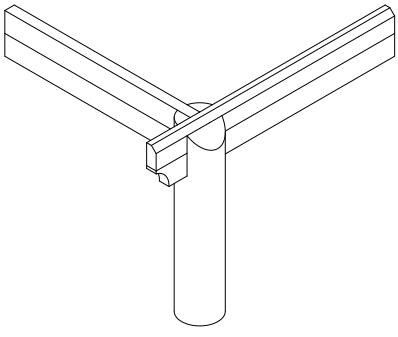


Sill beam

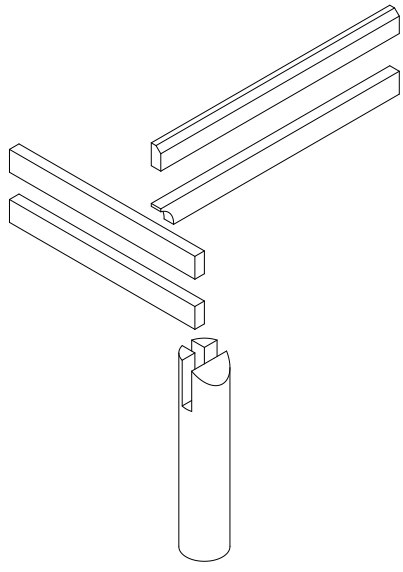


Wall planks

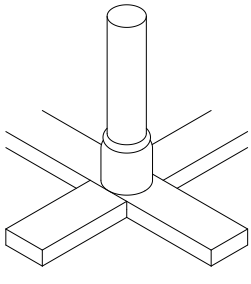
Ill.15 Stave construction principles



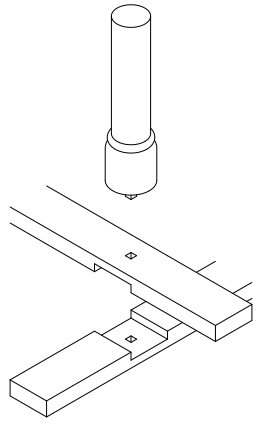
Top corner stave



Cross beam connection



Centre stave



Sill beam connection

Ill.16 Stave construction principles

Parallel to the stave construction emerged several other types of vertical structures, originating from the longhouse archetype. Post-and-beam, half-timbered or post-and-plank constructions all fall into the same category. Timber framing collects all those types under one expression. Most structures found application in outbuildings, which did not require heating as the primary challenge of all frame constructions is insulation. Half-timbered houses solved this problem filling up the intermediate spaces with bricks or clay. Although very popular in Western Europe, Norway and Austria have only scattered examples. Due to fire regulation, half-timbered houses replaced notched-log buildings in part of Oslo.

Timber-framed buildings combine horizontal beams and posts with diagonals, forming rigid structures. Boards clad the frame and close the wall.
A unique Norwegian version is the trestle frame, a direct descendant of the longhouse construction. It is mostly in use along the coast of Western Norway. A transverse beam connects two posts. The ends rest in notches on the stave crown. Diagonal braces at the corner of post and beam stiffen the frame. The number of frames depends on the length of the building. Broader structures have additional aisles made of post-and-beam construction.[26]
In Norway and Austria, mostly outbuildings feature post-and-beam constructions, particularly barns and stables are often built this way.
An advantage of frame constructions is a lower timber input.
Post-and-plank structures are alternating frameworks, which use horizontal planks to fill out the space between studs.
The Bundwerk is a unique form of timber framing, occurring in parts of Austria, Bavaria and South Tyrol. Beams arrange partly in a lattice and cross-shaped pattern, artistically forming the load-bearing elements. The board cladding is placed on the inside, to show the elaborate construction.

Ill.17 Notched-log corner, Sverresborg

Horizontal

Horizontality is an essential conception of architecture. In contrast to the vertical, stretching to the sky, the horizontal is down to earth, quite literally. The horizon marks the border of earth and sky. For this reason, people identify more with horizontality than verticality.
Translated to wooden structures does it mark a turn of the loadbearing elements horizontally.
Stacking single elements to create a wall can also be found in masonry. But the joining of wooden trunks is immensely more complicated. The corner joint becomes the defining part. The execution of the connection substantially influences the appearance of a building, at the same time the logs form the entire enclosure of the built space. One single element is responsible for construction, stability and appearance.
The monumental impression of using entire debarked trees affects the use of the material. Not only the loadbearing posts have to have sufficient dimensions, but every single element is oversized. Openings are created by subtracting from the entirety, instead of leaving out.
All these properties add up to the appearance of massive wooden buildings, using horizontal elements.












Smoking kitchens and east European influence

A next step in the development of wooden constructions throughout Europe and a fundamental change in the construction technique was the transition to horizontally stacked canes, in contrast to the known stave and palisade walls which had vertical load-bearing elements.
Due to the use of whole debarked logs, the buildings became smaller and the original hall transformed into individual buildings with different functions. This change was taking place in several regions throughout Europe. One common factor of those regions was the existence of vast areas of coniferous forests. Log houses were common from Scandinavia, large parts of Russia, the Carpathian Mountains, over alpine regions of Austria and Switzerland, to Northern Spain.
First traces of log timbered structures were discovered in Switzerland and Northern Italy and date back to the Younger Stone Age. In Hallstatt, Austria, notched-log constructions were used in a salt mine. But the first known example of a log house was found in Buchau, Germany close to Lake Constance, from 1100-800 B.C.
Notched log houses have no earth-fast elements and leave unfortunately hardly any archeologic traces. For this reason, the evidence of the historical development is sparse, in contrast to stave and palisade houses, where remains stay in the soil and can be excavated long time after the actual building is gone. One theory focuses on the construction method being specific to different tribes. Germanic tribes in western Europe lived in longhouses, whereas Slavic tribes in eastern Europe preferred log timbered houses. The fact that the Norwegian stua has an identical twin in Russia (izba) and the connections between Norwegian kings and the Russian leaders support that theory.[27] No matter where the first notched log houses had a simple rectangular shape and a single room. A separate chapter explains the evolvement of the typology. From the 10th century onwards the notched log construction is the dominating building method. Many well-documented examples are known from

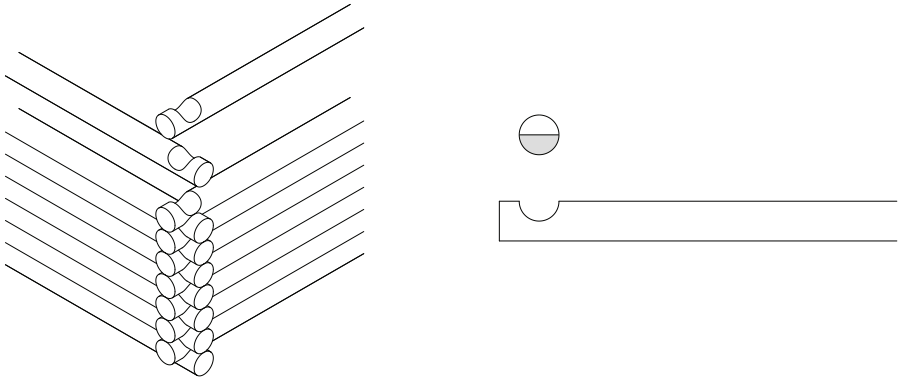
Ill.18 Notched-log corners

Russia and parts of Poland around 800-1000 A.D. The oldest existing examples in Austria are few smokehouses and granaries from the Middle Ages. Buildings in Norway date back to a similar time, like the Rauland stua from 1250. Another reason why regions with particularly harsh climate adopted notched log construction was the great insulation value of solid wooden walls.

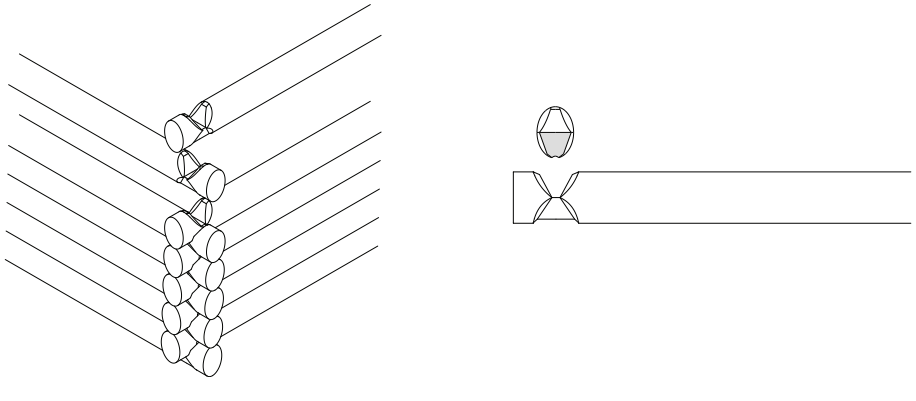
The construction process of any building is a major undertaking. Especially hundreds of years ago it was a multi-year enterprise. Even the gathering of materials could take several years. Carpenter, home or forest owner selected the right trees for each building. The right tree was completely straight and preferably not tapered. Depending on the region the selected tree species was different. Spruce was predominant in Austria, whereas Norwegians preferred pine. A unique method made pine wood extra durable. All branches and the top of the tree were cut off, and each tree remained standing for several years. The trees reacted with producing more pitch and storing it throughout the cross-section. The sourced material was heavier, harder and more durable, thanks to the natural impregnation process.[28] Other wood species played minor roles. Oak, known for its durability, was employed as a sill beam.
Another production step was debarking the logs. Earlier and minor buildings used round logs. In a later development, the trunks were hewn, either to have an oval or a rectangular cross-section.

During the period of the black death, logs had varying diameters because people had to use what was available.
The fundamental principle of notched log construction is the interlacing of horizontally stacked trunks. Precisely made notches tightly join logs of two meeting walls. The purest form of a joint is a round cutout, following the shape of the next log, on the upper side of the trunk. The notch is half the logs diameter deep, creating an offset and the typical construction pattern. Like the fingers of two hands intertwining. Also, the joints evolved, to make for an even tighter fit.
If the timbers are not hewn, every other log has to be turned to compensate for the tapered shape of the tree. The bottom row often differs from the rest of the construction. Often the sill beams have larger dimensions or a different cross-section. A trapezoid shape is very common among Norwegian houses. Another variation can be the wood species. In this case, oak is a great substitute. All those measures increase the stability and durability of this essential component. The sill beam at the transition of foundation to wooden construction is in constant contact with the ground. Hence it is the first element which must be changed due to rot or fungi.
Each round wall log has a groove on the bottom, to create more contact area to the piece underneath. The joints at the corners are preventing the woods from moving but are not sufficient to keep the trunk aligned along the whole length. Therefore, additional, recessed dowels help to keep the log in place. Particularly necessary are those at the gable wall, where the trunks are not connected to the long side wall.
Gaps between individual logs can occur even when the structure is perfectly executed. Inserting moss seals the opening. Wealthier building owners used coloured cloth instead.

Inner walls are connected to the exterior using the same principles. Sometimes projecting, sometimes dovetailed or even artfully formed.[29]
After completion of the building, it stayed untouched for at least another year. Giving it time to settle. The shrinkage of the wood and the weight of the construction led to settling of several centimetres. Only then doors and windows were cut into the walls. The opening had to be as small as possible not to weaken the bound. Windows stretched over only two half logs to remain strong enough. If more light was needed, it was easier to widen the opening. The connection between wall and window frame had to be moveable to allow further settling. Doors were obviously bigger but followed the same principle, leaving the sill beam intact.[30]
The drying process has other side effects as well. Every tree grows with a slight rotation. While drying wood not only shrinks but twists as well. If logs of different rotation are stacked, the twisting can open unwanted gaps in the wall. Another phenomenon is the appearance of cracks. Despite not influencing the strength of the wood directly, water can soak into the cracks and catalyse the rotting process. An anticipating measure is adding an artificial crack on the bottom or top of the trunk, protected from water.
Proper built Norwegian houses have a slight curvature, most notable at the ridge. The central part is ever so slightly higher than the end. This characteristic has similarities to the Greek temples and is especially visible at longer houses. Curved trees are chosen explicitly as purlins to retain the curvature even after settling. Furthermore, buildings before 1770-80 were broader at the eave than the perimeter.[31]
The building process demanded enormous amounts of resources, knowledge and time. Buildings were not designed to last a particular time. They were intended to last infinite. A 700-year-old house which is still standing will survive another 700 years if properly maintained. The logs are oversized to reach such incredible durability. Notched log houses demand a small amount of service. The solid wood decreases the flammability, particularly compared to half-timbered or frame constructions.
Over time, wind and weather give the exterior walls a darkish grey, brown colour. In combination with the turf roof, those buildings blend in perfectly with the surrounding Norwegian nature.



Saddle notch
nor. vagenov



Findal notch

ILL.19 Corner joints

The art of connecting single logs to robust walls requires a firm connection on each corner. Every material has its natural boundaries and to exceed those a variety of joints has been developed. The notching techniques arose with the emergence of iron tools. Axes were the essential tool for creating the corner joint.[32] With improvements of tools and knowledge, the notches evolved, like the buildings themselves; from very primitive to highly technical ones. Each part of the joint has a particular name, often regional specific. Generally, the end of the trunk is called head (ger. Kopf, Schrotkopf, Kopfstrick | nor. hodet, laftehovud, novhovud), while the butted section is called a neck (ger. Hals | nor. hogget, halsen).

Early examples of notched log constructions had a simple semicircular cutout, either on top or bottom. The ends of the stems were projecting up to 25 centimetres from the joint. By merely stacking the logs were locked into place. In Norway, this method was called vagenov. Vaga being a sleigh used for towing logs.

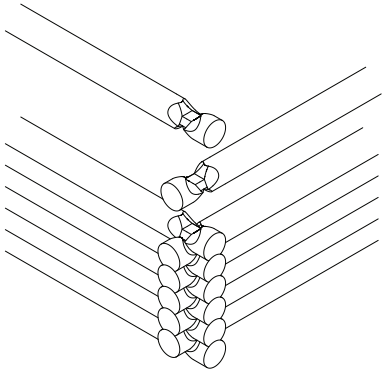
Fortifications in Eastern Europe and foundations filled with stones as found in Bergen were built using this notching technique. In Austria, findings in Hallstatt showed this kind of connection already around 3000 years ago. Although the principle of joining stays the same, each region and almost every carpenter developed its unique style. The vagenov or saddle-notch was later used for secondary structures and outbuildings.

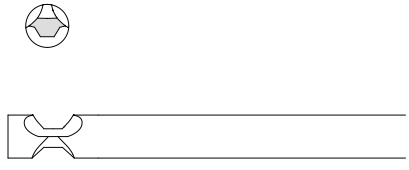
Up until the Middle Ages, two main types were in use in Norway, from which others evolved. Those two being the Findal and Rauland notch.

An evolutionary step of notches was the Findal notch (no. findalslaft). Originating from the word “fyrndar”, meaning old-fashioned. Carpenters using this term suggests that they knew it was old. This technique wasn’t found in any buildings after 1350 A.D. The most common shape of the neck had a trapezoid cross-section, preventing the log from twisting and having a tighter fit than the vagenov. The closer connection meant a significant improvement, shielding the interior from wind and rain. A weak point was the off-centre location of the neck, which made the head vulnerable to breaking off. In its original form, the upper

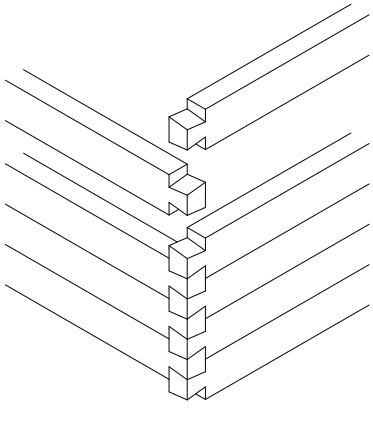
edge in the neck was straight. Over time several iterations of the notch developed. Traces of this technique were also found in burial chambers in Siberia.[33]
The second main type of log timbering techniques was the Rauland notch (nor. raulandslaft). First found in a building in Nore og Uvdal on the Rauland farm was probably the first example ever made and is now in the Norsk Folkemuseum in Oslo. In contrast to the Findal notch, the neck was centred in the log, making it more robust.
Other notching techniques found in Norway were alterations of the same type. All share a similar setup but feature altering cross-sections. A widespread characteristic of Scandinavian joints is kinning. Right before and after the notch the log is additionally hewn to taper towards the joint. This measure could be only cosmetic or help the trunks to interlace more easily.
All the mentioned joints were used with round or oval shaped logs. For hewn trunks with a rectangular cross-section, other types arose. The kuntnov emerged in Trøndelag and is much simpler to create. Because of straight cuts, the connection tightens worse, requiring additional sealing.[34] The dovetail joint was found in Sweden in the 12th century but appears in Switzerland around the 15-16th century.[35] Although already familiar in Central Europe, the dovetail connection spread in Norway as late as the 18th century, with a wider adoption in the 19th century.
In contrast to the notches explained earlier, the dovetail notch as no projecting end. Either following the even corners of masonry buildings or due to a more straightforward application of shingles. The bearing areas are tilted to hinder movement, reassembling a dovetail, hence the name. This kind of joint can also be found in furniture design, where the dovetail pattern is sawn in a board.
Similar to the older joints, the dovetail joint was improved as well. Adding grooves and edges to the connecting area increase the seal tightness. In the case of the Klingschrot, an Austrian iteration, the intention was beauty and elegance. The carpenter showed off his skill. It found implementation in Carinthian granaries and storage buildings. Dowels at the connection further increase the stability of the joint.[36]

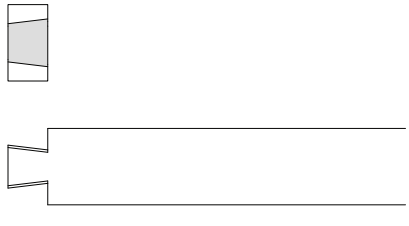
Besides the main notch-types, regional specialities appear in both countries. But particularly in Norway, log shapes and joints alternate immensely. Occasionally, each corner shows another method, when teams of different descent work on a building.





Rauland joint





Dovetail joint

Ill.20 Corner joints

Ill.21 Lifted foundation

Ill.22 Padstone foundation

The foundation connects the building to the earth. Although essential for every construction, wooden structure heavily rely on a properly executed base. Moisture of the soil can damage the timber rather easily. Nevertheless stood early buildings on the bare ground. Depending on the sub-surface rainwater could drain better or worse. Palisade or even first stave constructions had earth-fast walls. The posts gained stability through burying but were unprotected to rot. Longhouses and their columns had similar problems.[37]

First log houses also stood directly on the ground. Decaying trunks were replaced and changed to larger dimensions as we know. A broader contact face to the ground prevented the building from sinking into softer soil. Switching to more durable wood species further increased the lifespan.

First padstone foundations out a large stone under every corner of the construction and created distance to the ground. But inevitably, a single layer of stones beneath the sill beam showed first attempts of building a solid foundation. Broad, flat rocks separated the construction and the earth. Norwegians added layers of birch bark to keep moisture away.[38] Although the stones distributed the weight of the building, they sank in, and separation did not exist anymore.

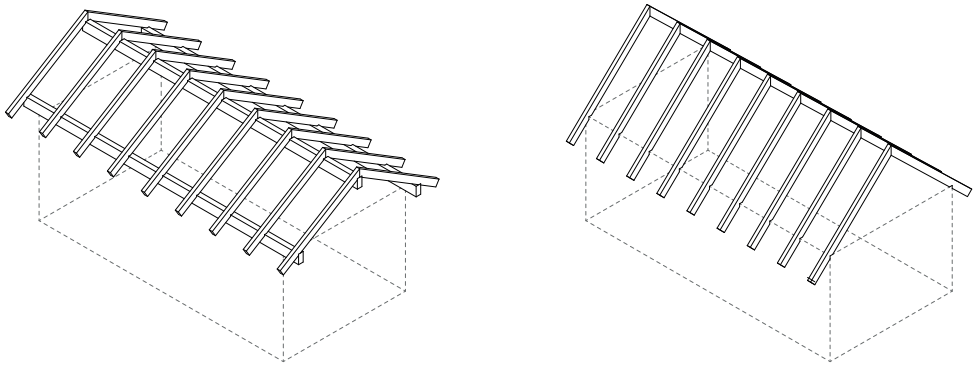
Another purpose of the foundation is to level the ground. Houses on hillsides needed the support, and low walls of dry stone did the job. In a further development, all four sides became a stone foundation. Dry stone walls became the norm during the Middle Ages. In an attempt to increase the distance to the ground, the storehouses in Norway were put on wooden stumps in the 18th century.

Stave churches had a different base. The weight of the posts had to be evenly distributed to the terrain. A wooden grating consisting of massive beams received the loads of the structure. The main columns stood on the crossings of those beams, and even the sills of the exterior walls rested on the ends of the foundation.

Along the coastline, a sort of log timbered construction filled with gravel and stones, ensured that the houses could stand securely close to the water. Those grillage foundations extended the land area and made it possible to live close to the harbour.

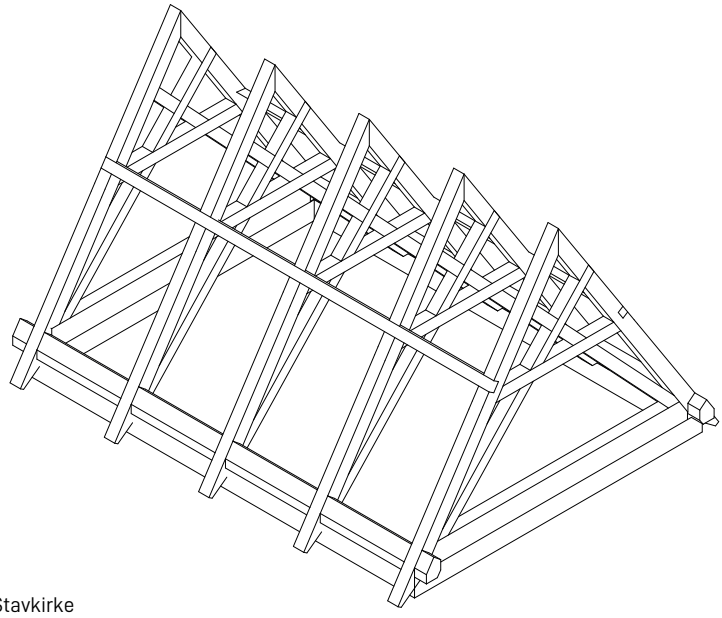
Another type of grounding was also in use next to and on the water. On Alpine lakes and in Norwegian harbours buildings stood on piles. The logs were rammed into the soil and protruded out of the water surface. Underwater, no oxygen can reach the wood, and the moisture level stays above 100%. Hence the timber can't rot. It is the transition zone on the water surface, which is critical to the durability of the posts

Roof construction



Ill.23 Roof construction principle

A roof gives the building closure. There is no shelter without a roof.
For this reason is the cover an essential part of every building, protecting people, animals and goods from the weather. During summer, rain and wind are the most challenging factors for building coverings, while the winter brought snow and coldness.
Climatic and geographical differences influenced the execution of the roof and the cladding. Some regions had to deal with heavy winters and large amounts of snow, while milder areas tuned the roof towards rainfall and winds. Nevertheless, the construction needs to convey the loads towards the bearing wall.
Of all shapes roofs occur to today, the gabled roof is by far the most spread in Austria and Norway. Although hipped and pent roofs existed on the side and found application in several objects.
Two fundamental construction methods established and were the basis for numerous variations. The purlin roof consists of beams (purlins) spanning in the longitudinal orientation, usually one at the ridge and on each load-bearing wall. Depending on the size of the building, additional purlins sit in between to decrease the span width. Notched-log houses use the top trunk as purlins. Because the weight distributes to all four walls and the main load-bearing elements are horizontal, no forces point outwards. Hence no additional measures in a horizontal direction are needed.
The other primary type is the rafter roof. Load-bearing elements are spanning from eave to ridge and are of much smaller dimension than the purlins. In general, rafter roofs find application in steeper structures. The construction rests only on two walls and needs an additional



Ill.24 Scissor truss, Gol Stavkirke

joist to brace both sides.
In Norway, carpenters followed fixed rules to calculate the pitch of the purlin and rafter roofs.
The gavel height was a fixed proportion of the width of the building. Those rules were different in each region. In Telemark, Trøndelag and the eastern parts of Norway, the gavel height was a fourth of the building's width (27°). In Gudbrandsdalen and Østerdalen it was usually a fifth (22°). Even steeper roofs were used in regions with harsher weather, gavel height of one-third of the building width (34°).
The calculation for rafter constructions is similar, but instead of calculating the proportion of height and width, the length of the rafter correlates with the width of the building. In western and southern Norway, the distance from the wall to the ridge was 3/5 of the house width (33°).[39]
In the case of log houses, the roof has to acknowledge the settling of the structure. Either at the ridge or the eave, the beams need to be slidable to react to the movement.
Norwegian houses with open-hearth had openings at the ridge for ventilation, and as a light source, a centred purlin would obstruct the hole. For this reason, a hybrid form evolved, lacking the main purlin, but having additional ones on either side.
Stave churches feature an improved form of rafter roof, called scissors truss. Instead of the horizontal brace, a second pair of rafters is added to the truss at a slightly lower angle. The ends overlap and create a rigid unity. The principle truss of every stave church shows a gabled roof. Extensions and arcade have pent roofs.

Ill.25 Turf roof, Sverresborg

Besides the structural component of the roof, the cladding is just as crucial. This final layer protects the construction and the inhabitants from the outside conditions. Both parts share dependencies; primarily the roof pitch influences the covering considerably. Especially without today's range of materials, keeping the roof tight was an enormous challenge. People experimented with diverse material, combined with differences in climate and precipitation it led to various types and shapes.

Thatch

Thatched roofs are one of the oldest cladding techniques and a popular cladding method of the Germanic longhouses, used in many parts of Europe. While no examples still exist in Norway, south-eastern parts of Austria show several (Burgenland, Styria, Carinthia). The straw is mounted on a wooden construction and held in place either by tying together or holding down by additional sticks.

Tightness comes from many layers, increasing the thickness of the covering and a steep tilt. Thatched roof should not be flatter than 45°. The cladding is very sensitive to moisture, decreasing the durability. If the straw becomes moss-grown, the life expectancy increases because the moss absorbs water.[40] The simplicity of manipulation and broad availability of raw material contributed to the wide application. Thatch appears to be vulnerable to snow and is therefore not utilised in those areas.

Turf

One of the oldest forms of roofing is the turf roof, which was widely adopted. For a long time, it was the only possibility to achieve an insulated and tight shelter.

As the underlying construction, boards are placed edge to edge to provide a plane surface.

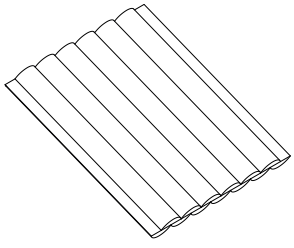
Layers of dried birch bark were sealing the roof. Therefore at least six layers were stacked up, overlapping each other, with the outside up, at the ends ten centimetres overhanging.

The more layers, the longer the roof lasted. Up to 15 sheets were not unusual. Periodically maintaining the roof was common on farms. On

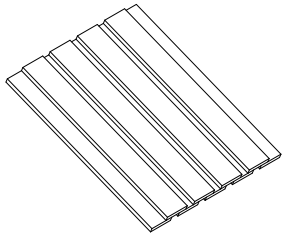
top of the bark came two layers of turf. The first one, grass downwards facing, the second one upwards and at least 15 centimetres thick. As the grass grew it stabilised the turf but was in danger to dry out in more extended periods without precipitation. To prevent that from happening, more robust plants were employed, such as Welsh Onion (Allium fistulosum) and Arctic Root (Rhodiola rosea).
Depending on the craft, climate and amount of bark layers, turf roofs can last 30 to 100 years.[41] Not only was a turf roof insulating the house, but the weight also ensured that the log timbered walls settled evenly.[42]

Boards

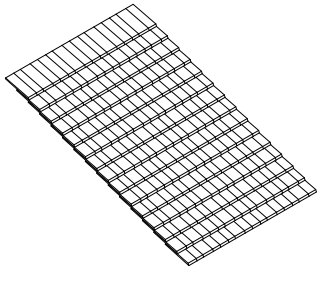
Boards or planks as roofing origin from old shelters, where the entire structure consisted of the roof. Early examples used two layers of logs, split in half, offset to cover the gaps. The hewn sides faced each other. Birch bark helped to seal the cover, similar to sod roofs.
Depending on the roof construction the boards are either placed parallel or perpendicular to the ridge. Rafter roofs principally require parallel running boards, overlapping each other and projecting beyond the gable wall. This method can just be found on several medieval churches throughout Norway, except the most eastern parts. Until today churches in Troms, Trøndelag and Sogn are covered this way.
In Sweden, the boards were laid edge to edge and clad with shingles from the first day onwards. It is not known for how long the roofs in Norway were kept free of shingles, but they show traces of tarring.
Purlin roofs, on the other hand, use boards running from the ridge to the eave and extend over the eave joist, to guide the water coming from the roof and keeping it off the facade.[43]
The board on board cladding came into use in the 17th century in regions with a large amount of wood, such as Agder, Oslofjorden, Telemark and Trøndelag. These roofs were later equipped with tiles as well. Most of the board clad roofs are the underlying construction for tiles. For those kinds of structures, the requirements are less strict.
Regional differences lead to a varied use of wood species and differences in detailing, like a herringbone pattern in the lower boards for advanced water guidance.
Large pieces of wood tend to crack and warp over time, damaging the protective function. A trend to smaller boards and panels led to the development of shingles.[44]



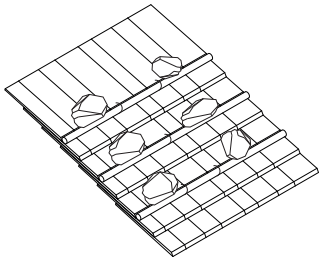
Halved logs



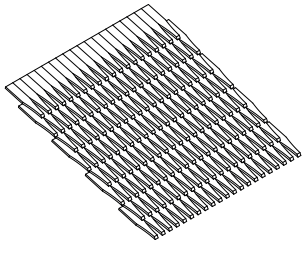
Board cladding



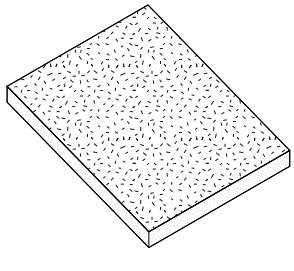
Nailed shingles



Laid shingles



Nor. kirkespon

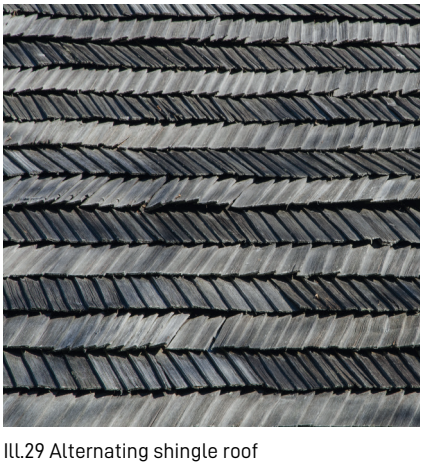


turf roof

Ill.26 Roof cladding

Ill.27 Laid shingle roof, Stübing

Ill.28 Larch shingles, Kolomanskirche



Ill.29 Alternating shingle roof

Shingles are in Austria as well as Norway a traditional cladding technique. Principally they reassemble of small boards, between 8 and 25 centimetres wide and 25-100 centimetres long, laid in scalelike sheets. Shingle describes the sawn version, while shakes are cleaved. For simplification, "shingle" is in this text also refers to the hewn version, unless specifically written otherwise. Shakes are usually manufactured using an axe, a special knife or a wood plane. Splitting instead of sawing keeps the wood fibres intact, and water can drip off more easily. Therefore wood species need to be cleavable. Spruce, pine, larch and fire are very suitable for making shingles. Additionally are oak, beech, elder and ash acceptable alternatives. Oak is the most durable, reaching a lifespan of 100 years, followed by the larch.

Carpenters demand high standards of timber quality. It needs to be knotless, slowly grown and as straight as possible. The diameter of the trunks has to be at least double the shingle's width. Shakes are entirely out of heartwood to increase durability.

There are two ways of applying the shingles to the roof. The first method uses loads to weigh down the cladding. The other one makes use of nails to attach the elements.

The Legschindeldach relies on weight and friction to fixate the cladding. Individual shingles are large, up to a metre long, and overlap to ensure at least two layers throughout the section. Every other row offsets to the previous one by half a shingle width. No gaps should remain open. The underlayment consists either of battens, slabs or boards. Quarry stones and poles secure the position. Those timbers either run parallel to the ridge in a regular distance or diagonally across the slope. This roofing technique requires rather flat pitched roofs, between 18° and 25°. An old rule suggests ridge height to have a sixth of the gable width.

Different measures help to secure the poles. Hooks, wooden nails or the use of special windboards can fixate the sticks.

The ridge is the most weathered part and needs special protection — shakes of one side project over the others. A necessary consideration for the execution is the prevailing wind direction.

This cladding technique makes it quickly possible to turn around all shingles after several decades to expand the durability. A disadvantage of the flatter roof shows when the snow melts on the sunnier side faster than in the shadow damaging the wood more quickly. Although having snow cover helps to insulate the house.[45]
Nailing the shingles on the roof broadens the possibilities. The pitch can be steeper, helping the precipitation to flow off more easily. Truss and cladding are lighter and more versatile, hips, dormers and valleys become feasible. There are several methods to lay the shakes, but all are based on the overlapping, scale like principle.
-each item overlaps its neighbour
-butt-joint shingles
-double-layer, offset and butt-joint
-joined by grooving
Scattered examples indicate up to five layers, but three are more common for roofing.
Medieval stave churches feature shingle clad roofs. The kirkespon got its name from the application on churches up until the 17th century. Made out of pine or oak, the single itself has a distinct shape. A hewn tip, which gives the roof a recognisable pattern. Around 30 to 50 centimetres long and 15 centimetres wide. Formerly those shingles were fixed with one nail on its central axis, causing to be not covered by the next layer. Exposed nails corrode faster and might lead to a shorter lasting roof. Therefore the position of the pins is shifted off-axis later.[46]
Another kind is called “Brede”, cleaved out of a larger piece of wood it is thicker around 20 to 25 millimetres and up to 110 centimetres long (usually approximately 70cm). In contrast to the Kirkespon, this type has no hewn tip and uses either pine or spruce. While the width varies between 10 and 30 centimetres. This type can be preferably found in Numedal, but also other regions like Østfold, Hedmark og Nordmøre.
Stikker or just Spon (shingle) are thin, smaller shingles at 3 to 6 millimetres thick. Because of their smaller size vastly more were needed to cover the roof, therefor Stikker became popular when nails got cheaper in the middle of the 19th century. Spruce was the primary wood species used, but different regions had other preferred types. For example, pine was used in Nordmøre and aspen in Akershus and Østfold. Another regional difference was the underlying construction. In the area of Trøndelag roof boards served as a base, whereas on the west coast at Austlandet battens supported the shingle layers.[47]
A Norwegian speciality was the tarring of shingles to make them even longer lasting, particularly for sawn pieces. [48]

Most vulnerable component is once again the ridge. In addition to the protruding method, two other techniques try to protect this area. Firstly, an extra row of shakes supports the ridge portion, but instead of the usual orientation, the shingles point along the edge. Both rows of those unique items overlap slightly sideways, creating a small further cover for the ridge.
Another method places either a cover of a single piece of wood or connected boards on top of the ridge. The techniques apply in both countries, but stave churches show the ridge cover boards prominently.

Ill.30 Ridge detail, Stübing

Ill.31 Apse Gol Stavkirke

Tiles

Cladding the roof with tiles was known as far back as the Middle Ages, but until the 18th century reserved for wealthy homeowners. One reason being, that tiles needed to be imported from the Netherlands and Denmark. Between 1600 and 1800 the transition to tile roofs led to a separation of building styles. Along the coast, small houses with flatter roofs kept their turf covering. Whereas bigger houses with steeper roofs from 35 to 45 degrees had tile roofs already during the 17th century. In Oslo, it was common to put the tile directly on the scantling without any underlay (boards). At the gavel, rafter and ridge the roof shingles were additionally fixed with mortar, preventing to be blown off the roof by strong winds. In the western parts of Norway, boards were laid towards the ridge, providing a simple underlying construction. In the rest of the country board on board cladding was underneath the tiles. A remaining weak point were gaps between each element. Sparkes from fires can be blown through the openings and lighten the roof construction. Newer, interlocking roof tiles should solve that problem.[49]

Stone

Stone as a roofing material appears mainly in regions where the material is sourced. To be able to clad a roof in stone, the material has to occur in sheets. Two types of rock which meet this requirement are shale and slate.

Shale can be laid either in the natural shape and in an irregular pattern or hewn and in a regular pattern. Especially in Western Norway, it is widespread. A shale roof is robust and bulky and therefore needs a solid roof construction underneath.

Slate, on the other hand, comes in various sizes and shapes and has a comparable weight to roof tiles. It is sourced in a few quarries throughout the country or imported from Wales, France or Germany. Unique characteristics of slate are an extreme vigorousness against weather and lower hygroscopic properties than standard tile; leading to fewer damages from freezing.[50]

Both types are held in place by nails or hooks on a similar underlying construction as a tiled roof. Stone as a cladding material is very durable and can last over 100 years.

Ill.32 Slate roof, Hoddevik

Ill.33 Board clad shed, Trondheim

The facade is the most prominent, exterior feature of a building. People usually describe a house the same way as a person, by its look. This standing gives the facade a powerful position. Decisions made to face of a building change to the whole appearance. Whether it is hiding or explaining something, nevertheless the cladding is also responsible for a more practical reason, protecting the load bearing elements from environmental influences.

Before an additional layer was added to cover the exterior wall, the bare construction served as the facade from wattle closed up the walls of ancient huts to log houses and stave churches of medieval times.

A careful selection of wood, large dimensions of structural elements and projecting roofs ensured a long-lasting building. Throughout the Middle Ages buildings had mostly no additional cladding, leaving the wood exposed to weather.

While log buildings close up their walls already due to the construction method, stave and timber frame constructions are in need of additional coverage.

Through the development of sawmills and a change of building style, the facade gained importance, is not only a protective but an optical layer. Depending on regional differences, the palette of wooden claddings reached from shingles in the Alps to the coloured weatherboarding in Norway. The more importance a building had, the more emphasis was on the facade.

Board cladding in various forms and a range of different shingles represent the most applied types.

Tarring was a popular method in Norway to enhance the strength of the wood. Sometimes only the end grain at corner joints, in case of stave churches the entire exterior was covered.[51]

Board cladding

Board cladding is a simple yet popular method to cover exterior walls. The material is available in various sizes and length resulted in multiple shapes. Similar to the division of loadbearing elements can the weather boarding be classified into vertical and horizontal.
Interestingly, each type had clear regional boundaries in Norway. While horizontal weatherboarding is widespread in the Western parts, such as Bergen, the upright cladding is more common in areas like Trondheim. In Norwegian, the horizontal boarding is even called vestlandspanel, referencing its origin. The more common version is the vertical cladding. In this case, the name is also more general, tømmermanskledding (carpenter cladding).[52]
The different orientations influence the appearance of the buildings. Each direction

Another reason for the region distinction is due to the weather. The Western part of Norway is known for the high amount of precipitation. Especially Bergen renown for heavy rainfall. The horizontal boards overlap and make the facade more suitable for this kind of weather.
The tradition of wooden boarding in Austria is less distinct. Only outhouses and stable feature board cladding. Hence the less attention to detail.
In the beginning, wooden nails fastened the boards. The production process of these was time-consuming and added a weak point to the facade.

The introduction of wood panelling also brought colour to the facade. A majority of houses with wall cladding were painted. While the main reason was to increase the life expectancy, colour had representative functions as well. Nowadays not possible to imagine without, the typical colour scheme of Norwegian houses developed after 1700 A.D. The colour choice was not a choice of style but more of availability and social status. Rare colours such as white and blue were more expensive and therefore only affordable for wealthier part of the population — less fortunate used more widely available colours like red, made of iron ore, or ochre.[53] In the setting of a farm, it was normal to paint the dwelling house in a more exclusive colour than the rest of the buildings. The richer the farmer, the more buildings he painted in a specific colour.

Shingle

Shingle facades build on the same principle as their roof counterparts. Overlapping layers achieve the necessary tightness. Interestingly, the application spreads not as far. Mostly in Alpine regions, buildings feature shingle facade. Due to its wide existence, the larch is the dominant material. The characteristic red colour turns grey after exposure to sun and rain. While three layers are usual for roofs, a double overlap is enough for this use.
The Bregenzerwald region, in Vorarlberg, features especially artistic examples with round bottom edges and enormously detailed patterns.

Ill.34 Board cladding and wooden nails, Salzburger Freilichtmuseum

Ill.35 Portal, Bygdøy

Doors developed earlier than windows, as any opening disrupted the structure delicately. The critical factor is the transition between the walls and the door frame. Any added construction needs to take the settling of the logs into account.
Three main methods emerged, solving the task differently. Although having distinct origins, executions spread all over Europe.
The first technique is the Nordic style. Grooves along the ends of the trunks receive the tongue of the door frame. There is also enough space on the top for the frame to slide when the construction settles. Secondly, the Celtic or Celtic-Germanic type represents the opposite of the Nordic door frame. Not the wall hosts the groove but the door frame itself. Therefore the trunks need to taper to fit into the slot. This method originates from stave constructions and can be found in log-timbered houses in Western Norway.[54]
For the Bavarian version, the structure needs to settle first. Then the vertical frame elements are fitted in the opening and held in place by wooden dowels.[55]
Norwegian portals often feature rich adornments. The carvings date back to the Viking Age, where the stems of ships had dragon motives. Early stave churches show similar ornaments. Under European and Christian influence the carvings changed to floral decorations. The Romanesque style brought elements from stone architecture to the stave church, such as acanthus tendrils and palm leaves, resulting in different but not less impressive ornaments.

Floor

Medieval houses had often just an earth floor. Sometimes stones clad the antechamber, but inevitably wooden floors evolved. Different methods were known to put in such floors. The first one let floor beams into the sill beam on one side and had mortises on the other side sill beam. In the Middle Ages, this method appeared in at least ten lofts or storehouses.
A more commonly used method was that the beams placed on their stone foundation.
Both of these executions were installed after the sill beams were in place. Another two methods required an immediate installation at the same time as the sill beams and were less conventional. The planks of the floor were self-supporting and mortised in the sill beam or laid on shelves in the sill beam. All four types had the same floorboards, which consisted of logs hewn half-round.
Dwelling houses sometimes had alternating constructions, similar to those in stave churches where floor planks were laid in rabbets of the floor beams.[56]

Ceiling

Medieval lofts were the first multi-story building and had, therefore, floor beams also above the ground floor. Instead of half-round logs, those beams were square-hewn.
Because dwelling houses in the Middle Ages were mostly single-story buildings, they had beams just above the entrance room and bedroom.
In lofts, the floor beams had a second purpose. They are cantilevering to support the gallery on the second floor. Several design variations of the floor beams are known. The simplest one is having just a central truss supporting the floor and gallery.
Covered were those beams by floor planks, approx. 20 centimetres wide and 6-8 centimetres thick. The boards were either put together edge to edge, with a simple rabbet or had a tongue and groove connection. The last emerged after the Middle Ages. Both surfaces were often splash-whittled, which is a carved pattern with an axe.
Floors in granaries had to be extra tight, to keep the crop.[57]

Furniture

A single furniture item stands out in Austria and Norway because it is fundamentally different and is a consequence of the respective floor plan. This piece is the main table.

In Norway, the table sits at the end of the room and stretches along the gable wall. Its appearance is long and narrow. In contrast, the Austrian version has a square shape and is placed in the corner of the parlour, opposite the oven. Each example is the result of its environment. While the Austrian table could not be larger, without interfering with the life in the room, the long table occupies only the end of the *stua*.

Fireplace

In central as well as northern Europe, a fireplace was a necessity to make a house inhabitable. Besides heating the building or at least one room, it warmed water, was used for cooking and as a light source.

A typical setup for an Austrian farmhouse was a combination of open fireplace, baking- and heating oven. Often accessible from the antechamber, the back part was facing the parlour. Cooking happened over the open fire, and the smoke escaped freely to the roof. Only a hood stopped sparked from inflaming the building. The whole ensemble was stone, not flammable and storing the heat.

Norwegian stoves remained in the main room but moved away from their original centre position to the corner. The fireplace looked very similar to the Austrian oven, but without the baking and heating part. This setup stayed to same over a long period, until cast-iron stoves become widespread.

Painting

A simple method to enhance the entirely wooden appearance of the interior was painting. Both countries show examples of coloured ceilings or walls. Particularly in Norway, the colour should convey warmth and brightness during the long and dark winters. But also in the border region of Bavaria and Salzburg, the inside walls of farms show coloured ornamentation. The preparation of the surface is rudimental, only larger gaps are filled with clay and a base layer of whitewash is applied.[58]

After examining construction methods and details, the following chapter devotes to typologies, which developed alongside the evolvement of wooden constructions.
Typologies are always the product of particular circumstances. A significant part plays the context the building exists in. Climate, topography and environment build the frameworks for the architecture.
Changes in environmental, technological and cultural factors lead to the emergence of new forms. Therefore they are continually developing throughout human history. Tribes splitting up into individual families meant a fundamental change in lifestyle. Inevitably the buildings changed with it, from longhouses into smaller huts. The more humanity evolved, the more differentiated people's needs became. A single space was not enough to house all functions in people's lives. At first, rooms were split up to serve different purposes. Later outbuildings and stables increased the size of a farm. The production of goods became the centrepiece of human existence. The early longhouses, being a universal space where everything happened, changed into a specialised building for each purpose. Carefully adapted to a particular use case. This transition led to individual buildings for living, cooking, storing goods and livestock.
The less humans had to concentrate solely on survival, the more effort they can put into new areas. Places of cultural exchange and worship emerged increasingly. At the latest when Christianity spread even to the most northern regions, enormous amounts of resources were invested in the erection of churches. While the European continent used stone for building cathedrals, Norwegian took their knowledge of wooden construction and created some of the most magnificent wooden buildings, known as Stave churches.
Not only cultural changes are responsible for the emergence of new typologies. Continuous, technological improvements of tools and craft brought new building materials and joints.

All typologies fall into one of two categories. Buildings serve either a secular or sacral purpose. While sacral structures narrow down to stave churches in Norway and a single wooden church in Austria, secular architecture appears in more diverging shapes.

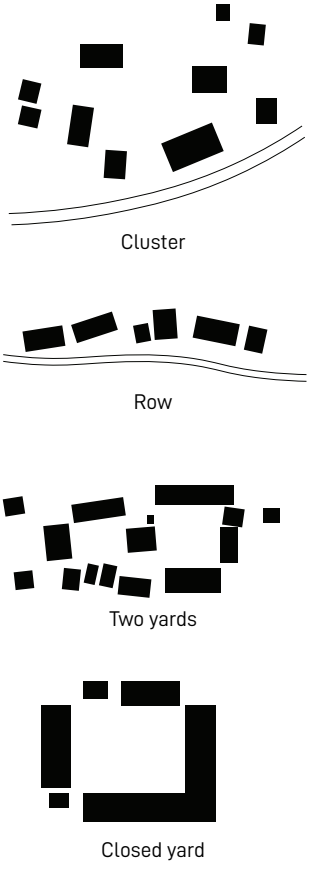
Ill.36 Linesøya, Norway

Ill.37 Cottage, Sverresborg

Secular buildings

Secular architecture involves all buildings without a religious background. The spectrum reaches from farmsteads to townhouses. In Norway, every typology has wooden samples. Whereas in Austria only farms, outbuildings and individual houses have been of timber. Palaces and townhouses are typical examples of stone architecture.

Ill.38 Farmstead Gaustafjeld, Norway, Riksantikvaren



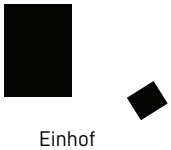
Ill.39 Farmstead arrangement

The development of farmsteads associates with the transition from longhouses to individual buildings. First, known farmsteads occurred during the Hallstatt period. The oldest known arrangement embodies the cluster farm. A not fixed amount of buildings forms an irregular structure. [59] This type predominates in mountainous regions, such as in Tyrolean and Carinthian side valleys. In a further development, the outbuildings are gathered under a single roof and placed parallel to the dwelling house (Ger. Paarhof). Pinzgau, Pongau, Lungau, parts of Tyrol show this kind of development. From the 14th century onwards the agricultural part and dwelling house are joined under one roof, forming the Einhof. Examples of this farm type existed in lower areas of the Tyrol, Salzburg and regions of Upper Austria. Today most of the farms have brick walls, but the floor plans are still identical. It is wrong to assume that the farm only consisted of a single building. At least a granary complemented the arrangement, to store seeds and crops in a safe distance to the farmhouse.

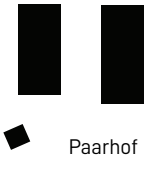
While farms in the mountains needed to be self-sufficient, larger settlements and villages emerged in the lowlands. Distances between each other or to bigger town were relatively short. If a specific thing was needed, the neighbour or another villager could help out. Hence, a single farmstead did not require to have an own smithery, for example.[60]

Topographical differences made the situation in Norway more severe. The large size of the country and sparse population increased distances between individual farms. Towns or cities were days of travel away. Hence the unit had to be self-sufficient. Forges and mills were common elements of the homestead. The traditional Norwegian farm consisted

Ill.40 Farmstead arrangement



Einhof



Paarhof

of several small houses, and large families managed them. Eventually, the farms were split up into smaller units. The buildings remained at the same location around the courtyard of the original farm, although owned by different farmers.

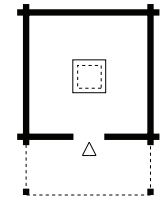
For this reason, the clustering of buildings seems like a village ensemble. There are still examples of such groups in Western Norway. The landscape did not allow for more regular forms. Other regions, like Telemark or Setesdal, gather the structures in two rows. Dwelling and outbuildings are lined up on the opposite side of a road. In Gudbrandsdal, where more space allowed to spread, the farmstead aligned around two, separate courtyards; dwelling houses around an inner and outbuildings around on outer one.

This method is probably the most common one in Norway, up to this day. Whereas both groups are usually placed together, and a road is running diagonally through the courtyards, entering at a corner.[61] Eastern Norway used an open square and in Trøndelag was the closed one prevalent.

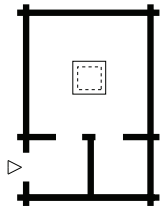
The homestead was the centre of Norwegian life during the centuries. The ensemble appeared clearly defined in the landscape. Within the setting, each house serves a specific purpose. The cottage has an introverted character. Heavy logs block off the outside world in contrast to the interior with painted walls and rich carvings. The decoration should appear warm and fertile, during long and cold winter.

As the granary in Austria, the store-house or loft appears as the treasury of the farm. Often built with a notched-log core and a projecting, second floor in stave construction.[62]

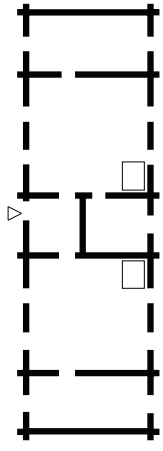
Ill.41 Bauernpeter house, Salzburger Freilichtmuseum



One-room plan



Three-room plan



Ill.42 Norwegian dwelling houses

The dwelling house is the product of the development towards smaller, individual buildings. The introduction of log constructions supported this transition.

Dwelling houses started as single room spaces. Like in the longhouses an open hearth occupied the centre of the room. At least in Norway, a Slavic influence can be assumed. Early one-room plans must be very similar in Austria and Norway. The Norwegian cottage had no windows, only on opening above the fireplace for ventilation and as a light source. In the beginning, the entrance was at the gable wall. The projecting roof protected the entry and together with an extension of the lateral walls formed a porch. In a further development, the porch got included in the structure, and the two-room plan emerged. First, notched-log houses date back to the King's court, assuming the change started in the town and was then adopted by farms in rural areas.

The entrance moved to the long side, leading to the new antechamber. Also, an indication for the use in townships, because the buildings were standing in a row, gable to gable.[64] Later this room was divided in half. First found around 1250, the three-room plan was widely adopted and kept around until the 20th century. The newly added room became a small bedchamber. Often the space above the two, separate rooms was used as well. The living room had no ceiling and was open to the roof. A smoke oven superseded this method, a stone laid oven in the corner of the room, usually next to the closet but the smoke was still not controlled and had to escape at the ridge.

A significant change of the three-room plan marks the introduction of the chimney. The corner position freed up space in the centre of the living room, and the flue made it also possible to build another storey. Although placed in the corner, the chimney was freestanding to allow the log construction to settle. This transition happened during the 17th and 18th century. The newly added second floor needed access. To not waste precious floor area, coastal areas added exterior galleries to solve the problem. The roof opening was no longer necessary, and windows became the natural source of light. Some farms kept the open hearth, hinting towards the longer existence of the longhouse in rural areas, thus becoming a tradition.

During the 18th century, some examples show another main room on the other side of the entrance. This symmetrical type was particularly popular in Trøndelag, making it a signature feature of the region.

At the same time, it was the predecessor to the following townhouses. Beginning around 1750 a baroque-inspired type with a symmetrical plan and central corridor was the primary type of townhouses. First found in houses of the upper class, it became adopted by regular citizens

and was in use up until modern times.
While larger houses kept the central-corridor plan, smaller buildings switched to a cross plan. The chimney sat in the centre of the house and the rooms arranged around it.[65]

Smoke houses

A common typology in Austria and Norway was the smokehouse (Nor. røkstue, Ger. Rauchhaus). Starting in medieval times, people lived in those houses until the last century. The connecting element was the smoke oven, a stone-built stove, with a hood above the fireplace. Without a chimney, the smoke escaped through holes in the roof. Examples of such houses spread from Slavic countries to the Alps and through Finland to Scandinavia. In Austria, only a few smokehouses still exist. Apart from museums, one example can be seen in Hof, close to Salzburg. A family lived in that house until the mid of the 20th century. The floor plan of the Austrian smokehouse differed from its Norwegian counterpart. The entry was mostly at the gable wall, and the antechamber separates the parlour from the chamber. The stove of the Austrian smokehouse stood in the antechamber, sharing a wall with the living room. Therefore the smoke stayed outside, but the heat could come through.
Apart from smokehouses, also individual rooms can have smoke ovens too. Rauchstuben or Rauchküchen are common in the Austrian farmhouse.[66]
The combination of open flames and wooden construction always entails the risk of fire. In order to decrease the danger, separate buildings emerged, just for cooking. Such houses are known in Norway and Austria.

Unlike Norway, the development past the single room house is incomparably more difficult in Austria, nowhere near as many examples are preserved.
As the cities switched to stone architecture very early, mostly farms exist today. Open-air museums show selected examples and give insight to the Austrian dwelling situation. Apart from two main types, many alterations and regional specialities define the position in Austria. Firstly, the Eastern type has a slender appearance with the main entrance along the long wall. Buildings in Burgenland and parts of Styria feature this form. Due to its shape, there is only space for a single room at the gable end. The floor plan has similarities to the farms in Trøndelag.
Further west, the houses increase in width and the entry switches to the gable wall. A central corridor divides the house and in the case of an Einhof leads to the barn. The more extensive floor space leaves space for a parlour and a chamber on either side of the antechamber. If the building has a second floor, the staircase usually sits in the corridor as well. The Stube was often the only heated room of the house. A typical setup has an oven next to the door and a square table in the opposite corner.

Ill.43 Smokehouse, Ederbauer, Salzburger Freilichtmuseum

Ill.44 Berdal loft, Bygdøy

Right behind the dwelling house of old farms, is the storehouse an essential part of the homestead. A fire was a constant danger. To keep crops and seeds safe, farmers erected additional buildings in a safe distance to the main house. Because of the valuable goods, the structure stored, the storehouse had high significance to the farmer. It was known as the treasury of the farmstead. The quality of the construction was accordingly, with tightly timbered walls and joints. The extraordinary strength protected even against robberies.[67]
Both countries impose nearly identical requirements on this typology, making it the easiest to compare among all wooden buildings. The final execution, although based on the same principles, differs in significant ways.
Austrian versions are mostly granaries, storing seeds and grain primarily. The German expression Getreidekasten or its Austrian counterpart Troadkasten mean precisely that. Besides, one regularly finds cured meat and clothing items.
A granary consists of two storeys, either connected internally or via an external staircase. Especially artistic examples stand in Styria, Carinthia and Salzburg. Carpenters carefully crafted the unique corner notches.

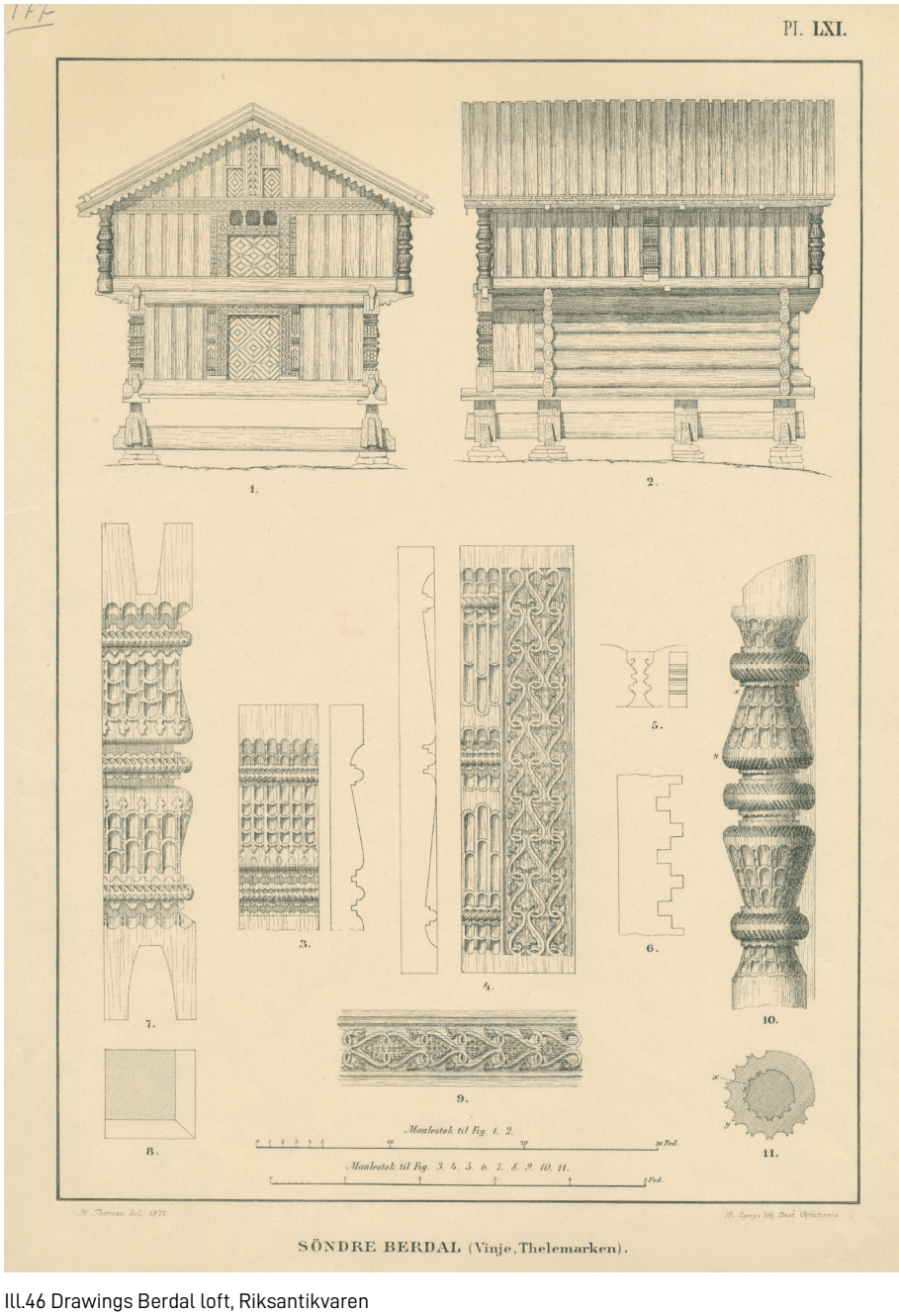
Norwegian lofts are the pendant to the Austrian granary, artistically and constructively not less impressive. The two storey buildings were fully developed already in the Middle Ages and served as storehouses for food as well as clothes. The typical loft has a log-timbered core, but a cantilevered gallery surrounds the second floor. In summer, some farms used the second floor for sleeping. Projecting logs carry the stave construction of the gallery. The combination of the stave and notched-log construction shows incredible skill and knowledge of the craftsmen. The different behaviours of both construction types while shrinking require careful joining; otherwise, staves can suspend, and gaps can open.
Like the storehouses in Austria, regional executions vary. Galleries can-

Ill.45 Carinthian granary, Stübing

tilever on all four sides in Setesdal and the western Telemark county. Eastern regions have log-timbered gables and the projecting second floor only on two edges. Up until the 18th century, the loft stood directly on a low stone wall, from then on stumps lifted the construction off the ground, protecting against moisture and mice. Around the same time, some storehouses got porches closing up the front facade. Not every region adopted this trend. Throughout history, the basic structure of the loft stayed the same, although stylistic changes show a continental European influence.

Medieval examples feature medium-sized logs with a round section. The staves of the gallery are slim and have Romanesque or Gothic adornments. After a period without further development following the Black Death, the Golden Age of loft architecture started. The logs are much larger and have an oval section, but the general shape is simpler and not particularly articulated. The corner posts moved into focus. Baroque influence led to a rich and plastic character, simultaneously differentiating from the other construction elements. Other changes concerned the front porch. Some regions adopted rich floral ornamentation along the vertical and horizontal members of the construction. (Kviteseid) In other areas, structural elements emphasise the level of technical-formal articulation. (Vinje, Rauland, Åmotsdal)

Beside the famous stave churches, the loft represents the pinnacle of wooden architecture in Norway.[68]



Ill.46 Drawings Berdal loft, Riksantikvaren

Ill.47 Barn, Stübing

Ill.48 Storehouse, Sverresborg

Ill.49 Storehouse, Bygdøy

Outbuildings are additional members of a homestead should not stay unmentioned. Several functions became separate buildings to sustain a self-sufficient farm, especially in remote areas. In comparison to the dwelling houses and storage buildings, outbuildings are less significant. Hence the structures are not as unique and sophisticated. Nevertheless, Norway and Austria feature noteworthy models. Besides the usual log construction, timber frame structures are perfectly suitable for these purposes.
Sheds and hay-barns are frequent additions to the homestead. Stables in different shapes host a variety of livestock. Less common, but particularly necessary in remote places are mills and sawmills. The fireplace also moved in some cases to an external building, to decrease the danger. Even separate bath houses emerged, rare examples in Austria due to a ban but numerous in Norway. Comparably to saunas nowadays, hot stones heated steam and people sat on platforms as measures of increased hygiene.

Ill.50 Barn, Stübing

Ill.51 Cross, Gol Stavkirke, Bygdøy

Sacral buildings

Believe, and spirituality gave hope in troublesome times.
The harsh everyday world required compensation.
Religions, in European circumstances Christianity provided people with a place to worship in the form of churches. Cathedral and basilicas are primarily magnificent examples of stone architecture. While churches all over Europe, even in Norwegian cities, are stone, it is again the rural areas where incredible wooden architecture occurred. In Austria wooden churches are rare. Only two relatively small churches exist, and the countless chapels are not worth mentioning in contrast to Norway, where the impressive stave churches give insight to the spiritual life in the Middle Ages. One can only imagine the mystical atmosphere of former times.

Ill.52 Borgund Stavkirke, Riksantikvaren

As Christianity came to Norway, the Stave church as a typology emerged. Håkon the Good tried to establish Christianity and built three stave churches in Møre, Trøndelag. But his idea was faced with the residence of the people, and the churches were burnt down.
While stone churches occurred in the cities, stave churches developed in rural areas. The first examples in the 11th century had earth fast walls and rotted pretty quickly. From the 12th century onwards the walls were set on sill beams, increasing the durability.
Some churches are 700-800 years old and still standing. At one point around 800 stave churches were spread all over the country, most of them south of Trondheim and mainly concentrated in valleys between Oslo and Bergen. Not more than 30 still exist. Most churches built before the Black Death in Norway were stave churches (1350 AD). As a consequence of the plague, wide ranges of the country were abandoned and a majority of stave churches decayed and vanished eventually.
Iconic features are the corner post (stave) and the standing planks, which rest on the sill and gave the name, stave church. All churches fall into a few different types, which vary in size, decoration and construction. Like most churches, Haltdalen, built around 1170, was realised in the simple form. Characteristics being the basic construction and the sparse decoration. Those churches were usually rather small. The nave consists of four walls in stave construction, the choir is shorter and narrower but using the same methods. Haltdalen has a wall height of just 3,5 metres, but the roof is steep and is open up to the ridge, making the impression of a much higher room on the inside. While the corner posts are often cylindrical, staves with a rectangular cross-section divide the walls into sections. Tongue and grooved planks filled those panel and closed the sides. No matter how big the churches were, arcades ran along all exterior walls. Some examples had half-cylindrical attachments on the eastern side, called apse.
The Haltdalen church was moved to Sverresborg, an open-air museum in Trondheim. Not more than a handful of the simple type are remai-

Ill.53 Urnes Stavkirke, Riksantikvaren

Ill.54 Urnes Stavkirke, Riksantikvaren

ning, most of them being demolished or extended.
A further development, far less common, was longer churches. The principle of the floor plan and construction are the same, but the choir broadens to the width of the nave. Although several churches were extended to feature the new choir, only Reinli in Valdres and Rinde in Sogn had it from the beginning. Until then, the walls carried the roof, but this changed with the mid-post churches. A single column stands in the centre of the nave and bears parts of the roof. The sill construction also connects to the central post, making it an indispensable element of the whole structure. Today only three examples of this type still exist, namely the Nore og Uvdal church in Numedal, Høyjord church in Vestfold and Nes og Flå church in Hallingdal.
Probably the shape everybody associates with stave churches are to ones with raised centre naves. Borgund is the most famous of all and simultaneously the best preserved, although not the biggest nor best executed. The characteristics of the "Borgund-type" are the raised roof of the nave and choir, looming over the lower aisles. The gabled roof rests on free-standing staves, approximately one metre within the exterior walls. A scissor truss creates the steep slope and an open space towards the ceiling without interfering cross beams.
Flanking aisles running all around the nave are circa half the height and the pent roofs slope towards the edges. An enclosed walk following the perimeter is again half the height of the aisle and has pent roofs as well.[69]
Essential elements of the construction are the ground sills. Each corner column sits on an intersection, the other posts in between. The beams have projecting end, supporting the exterior construction elements. Two secondary members fixate the posts in a horizontal direction at half their height. Intersecting diagonals, called St. Andrew's crosses, further brace the structure.
The entirety of all elements shapes the recognisable silhouette. A multitude of crosses and dragon heads adorn the ridges. All exterior elements, including the shingles, are tarred to increase durability.
Besides the stave church of Borgund are the ones in Heddal and Gol the most famous examples. The latter is part of the open-air museum on Bygdøy and was moved there in the late 19th century.

Ill.55 Balcony, Stübing

The following chapter showcases with six examples the actual application of Austrian and Norwegian building traditions. The critical part of the process was carefully selecting fitting cases. Each case needs to represent a unique or typical aspect of the country or typology. The list covers the ordinary farmhouse as well as the highly artistical stave church. Some requirements of the selection process were the accessibility of the objects, the amount of available information and the comparability to the opponent.

Additionally, the buildings had to be entirely of wood. Open-air museums concentrate traditional constructions and research material in a single place. Therefore, five out of six cases are items in museums. The Folkemuseum in Oslo displays objects from all parts of Norway, while the Freilichtmuseum in Großgmain focuses on examples from Salzburg.

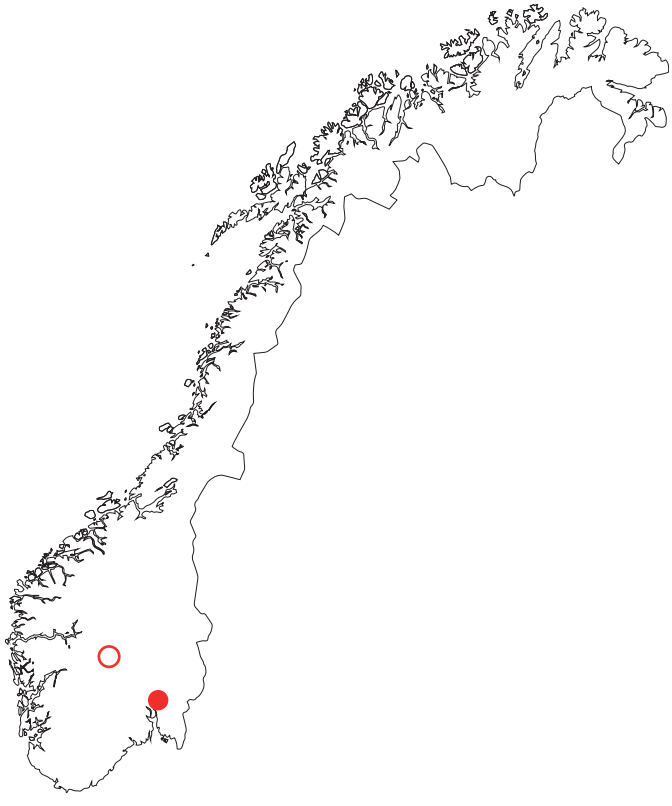
While no urban typologies are timber in Austria, the farms stayed with the material much longer. For this reason, the farm- and storehouse are useful study-objects. The three-room dwelling building is the archetype of most Norwegian houses, and the Raulandstua is probably the oldest version remaining. Homesteads look different in Austria, and the Einhof represents a product of those circumstances. Although built in the 17th century, hence younger than its Norwegian counterpart, the Rauchhaus Ederbauer still features a typical medieval setting.

The typology of the storage buildings is the easiest to compare across countries because the use case is identical and clearly defined.

Lastly, no work of traditional wooden constructions would be complete without stave churches. The magnificence of those structures is unmatched, but the Kolomanskirche, as the oldest wooden church in Austria, will serve as a counterpart.

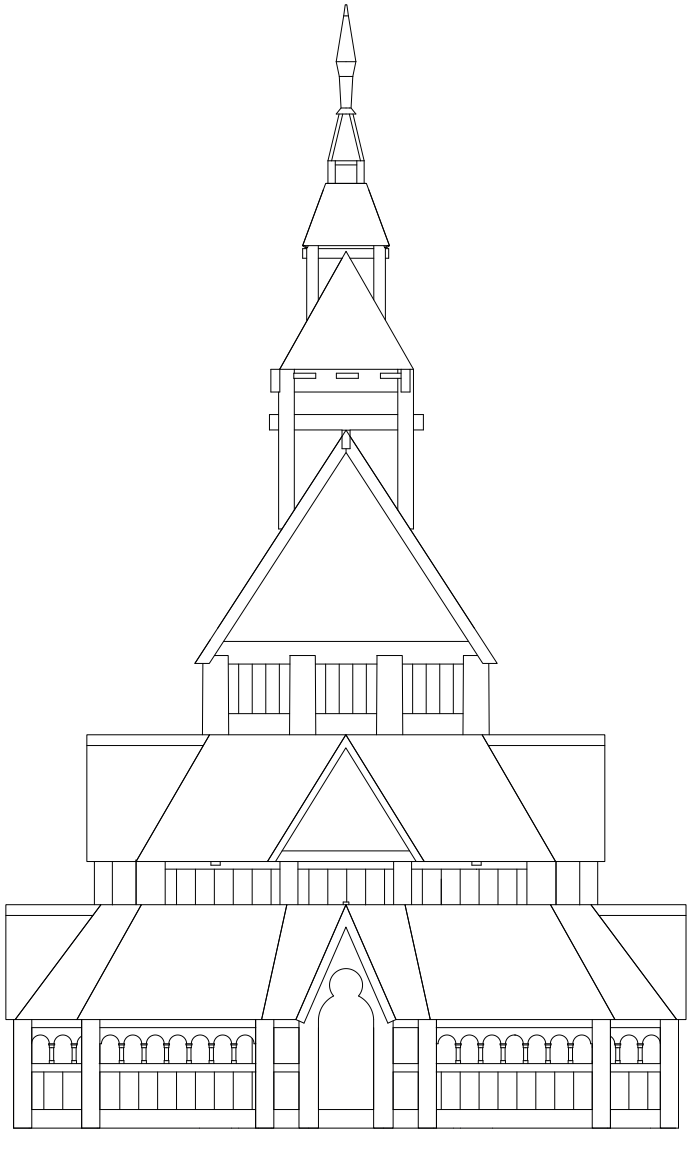
The methodological approach consists of a site visit and photographic documentation of the object. If no archive material was available, the building was additionally measured manually.

Text, pictures and drawings explain the architecture of every example and the craft and knowledge necessary to erect those structures.



○ Original location
● Current location

Ill.56 Map Norway



Ill.57 Front elevation, Gol Stavkirke

Stavkirke Gol

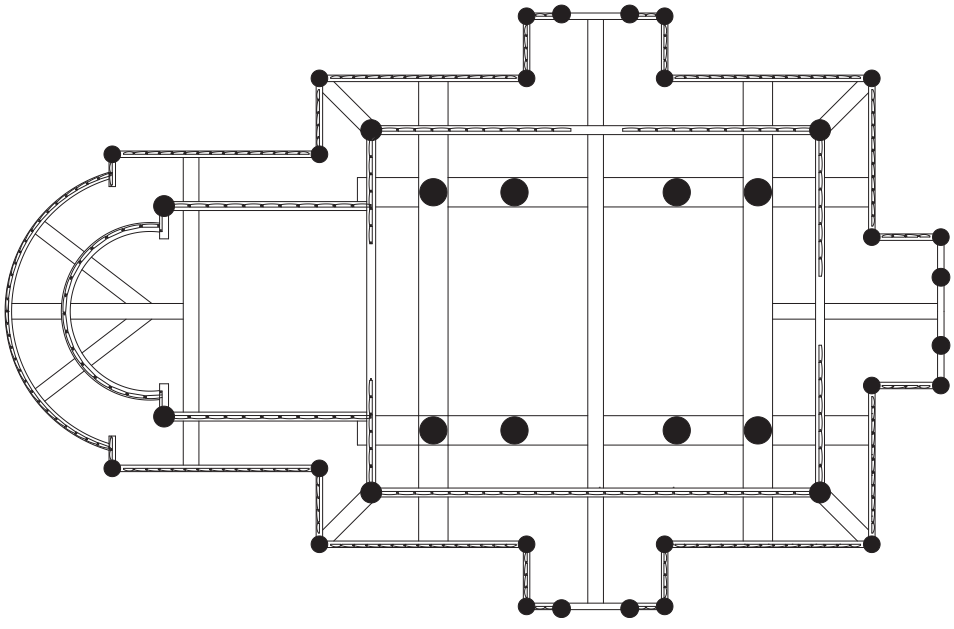
The stave church of Gol is one of just 29 remaining examples of this impressive Norwegian typology. Natively located in Hallingdal and built presumably in the midst of the 13th century, the building was moved to the Norsk Folkemuseum on Bygdøy, Oslo after 1880.[70] King Oscar II let it rebuild in the first Norwegian open-air museum in 1886. One can find many similarities to other churches, especially to Borgund and Hegge, all of them are part of the basilican type with its raised nave and free-standing columns.[71] Unfortunately, not every part of the building is in its original form. The current version is the result of a complete reconstruction and restoration. While the whole middle part originates from the old church, the arcade was widened, and the choir extended. All staves on the inside, a third of the wall planks and one portal is original. The second portal has been preserved as well but is in such a poor condition that it had to be replaced with a copy. For the reconstruction of the exterior, the architects followed the example set by other stave churches. The verges have been remodelled after Hopperstad stavkirke, while the bell tower and the dragon heads on the ridge have Borgund as an example. All roofs are clad with the typical "church shingle", and a thick cover of tar covers all surfaces, protecting against weathering. Even the floor plan and overall dimensions are almost the same as in Borgund, yet a little broader.

Four, freestanding staves are placed along the long side with double spacing in the middle, which is corresponding to the southern entrance. Also, the central posts of the short side are omitted under the triforium. A total of eight columns are forming the nave, and big arches are connecting the corner staves in the east and west. Holes in the sill beams take up the thorns on the bottom of each stave. The triforium is braced by an upper and lower tie running around the whole central space with Saint Andrew's crosses in the middle of it. Horseshoe arches underneath are bearing the load between each column. The staves and the supporting beams have massive dimensions, while the exterior walls are rather low. This measure makes the architecture very powerful but also has a rustic appearance. On top of the central columns spans the steeply pitched scissor truss roof whereas the apsis features a conical roof.

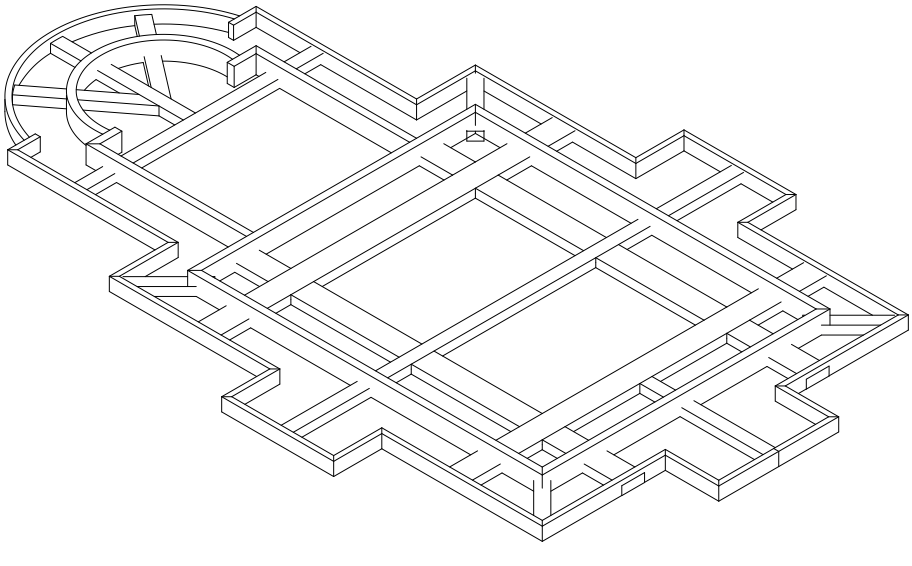
Former windows were closed during the renovation, and the dim, mystic interior of older churches shows its authentic character. Dragon heads adorn the console forming arches, and on top of each stave, masks are grimacing down the half-dark space. As candles were the only light source, the roof must have been as dark as the northern sky, contributing to the spiritual atmosphere.

Both portals are high and narrow and have high cylindrical capitals. Carvings along the sides and the top show pampre and dragon-like animals. Those carvings are unique to the stave church of Gol and cannot be found in any other church.[72] Similar to the Borgund stave church an arcade is running all around the exterior walls of the structure.

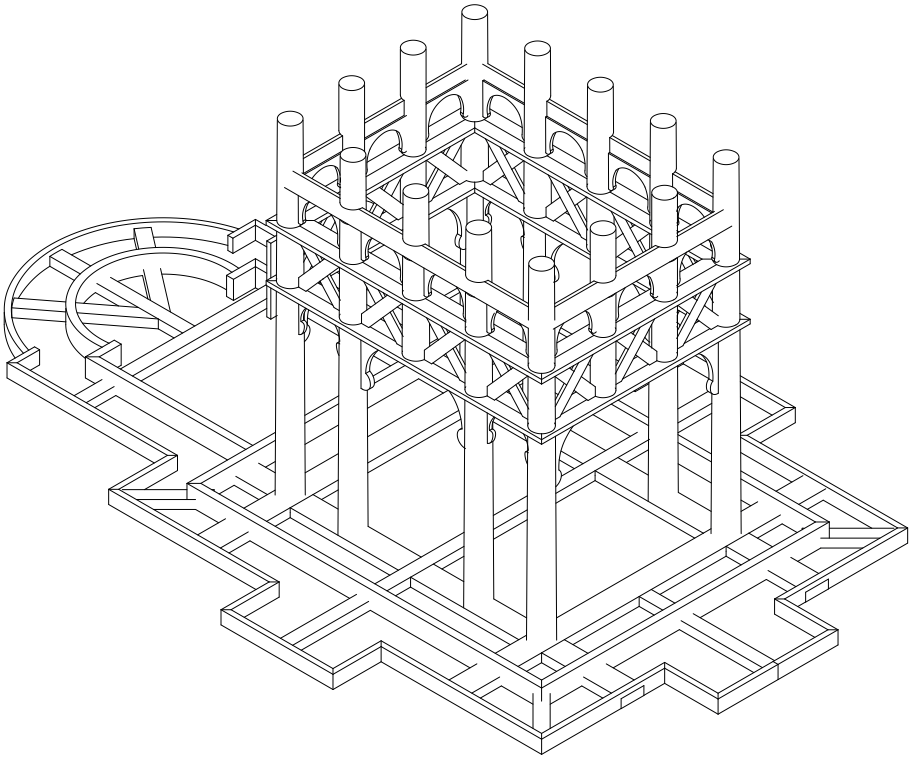
Ill.58 Front elevation, Gol Stavkirke



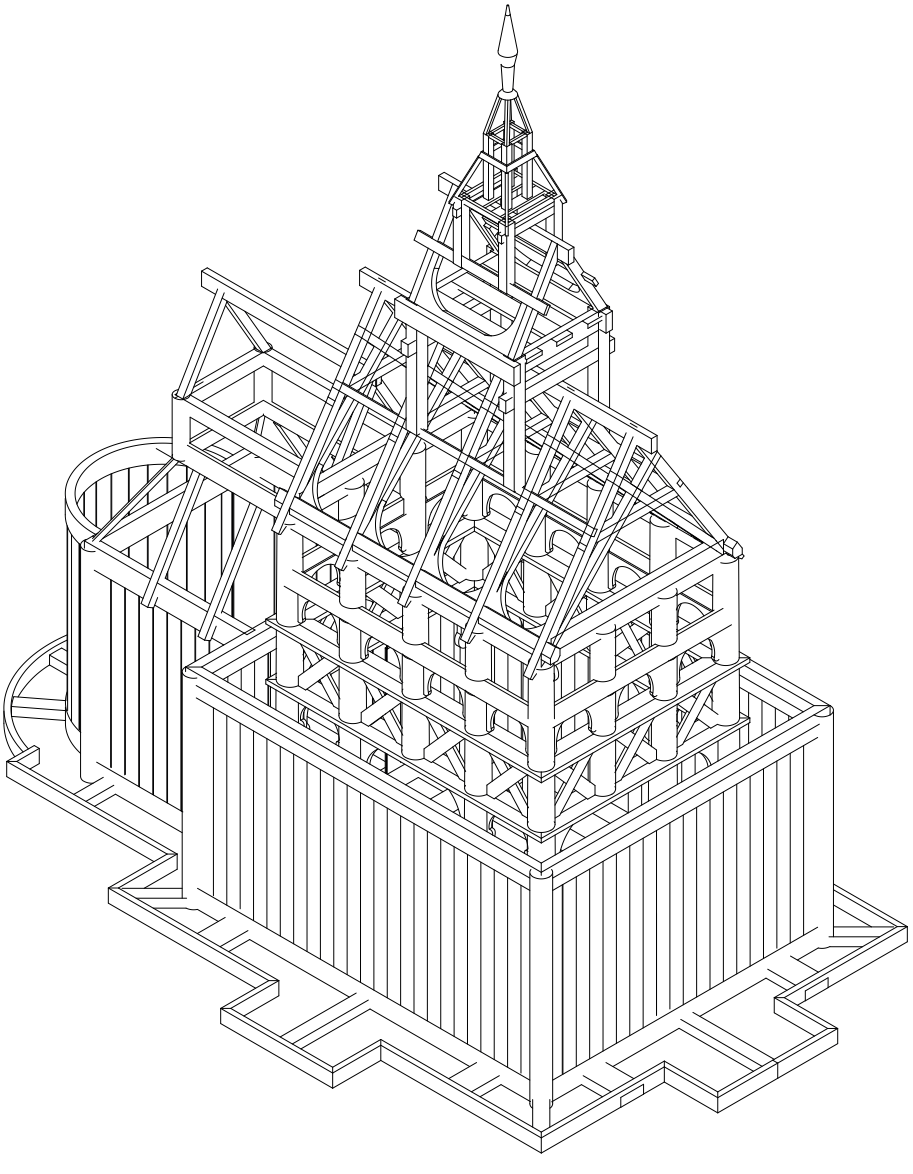
Ill.60 Floor plan, Gol Stavkirke



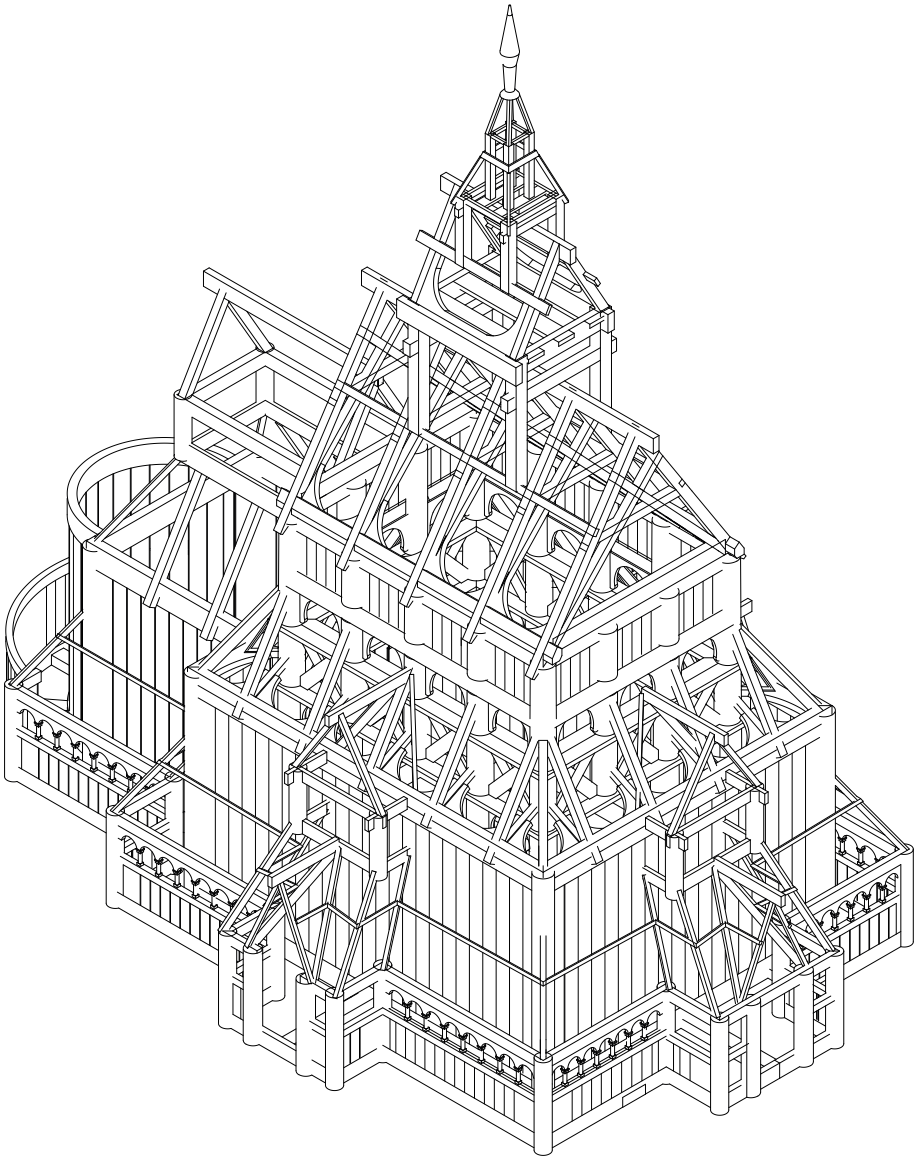
Ill.59 Foundation and sills



Ill.61 Nave



Ill.62 Roof and exterior walls



Ill.63 Entrance and arcade

Ill.64 Arcade

Ill.65 Arcade

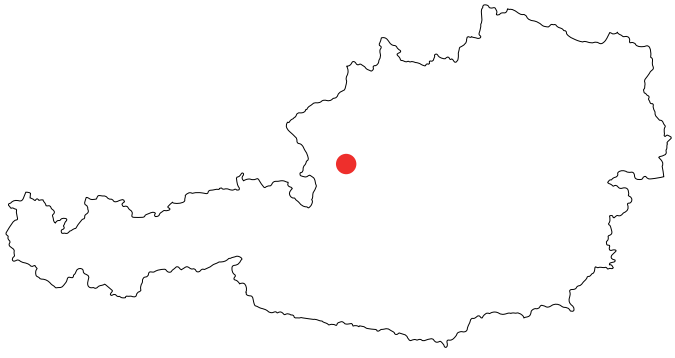
Ill.66 Portal carvings

Ill.67 Nave

Ill.68 Main entrance

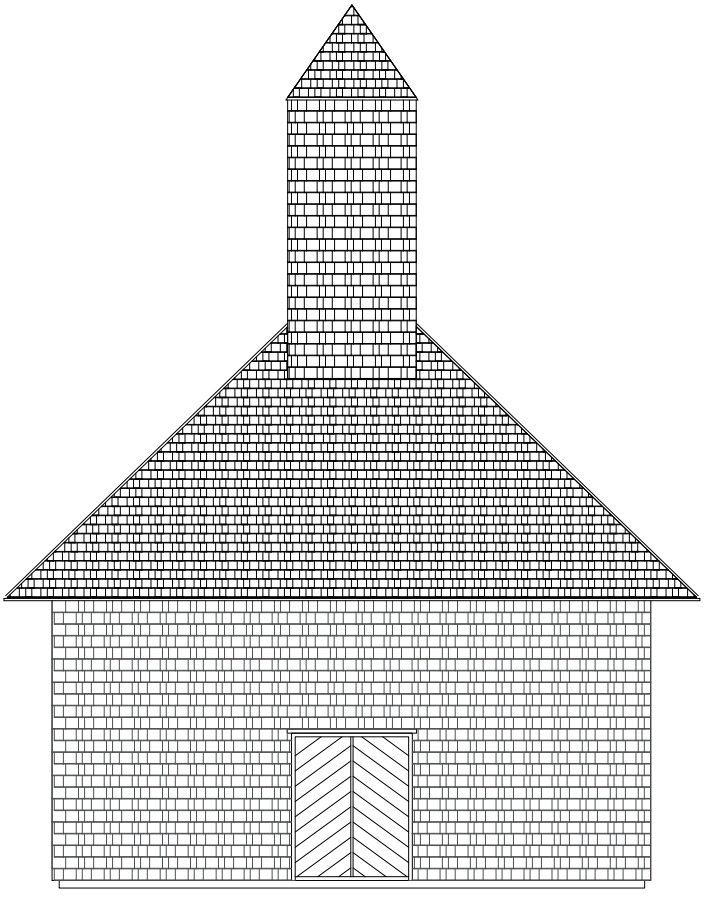
Ill.69 Dragon heads

Ill.70 Roofscape



Location

Ill.71 Map Austria

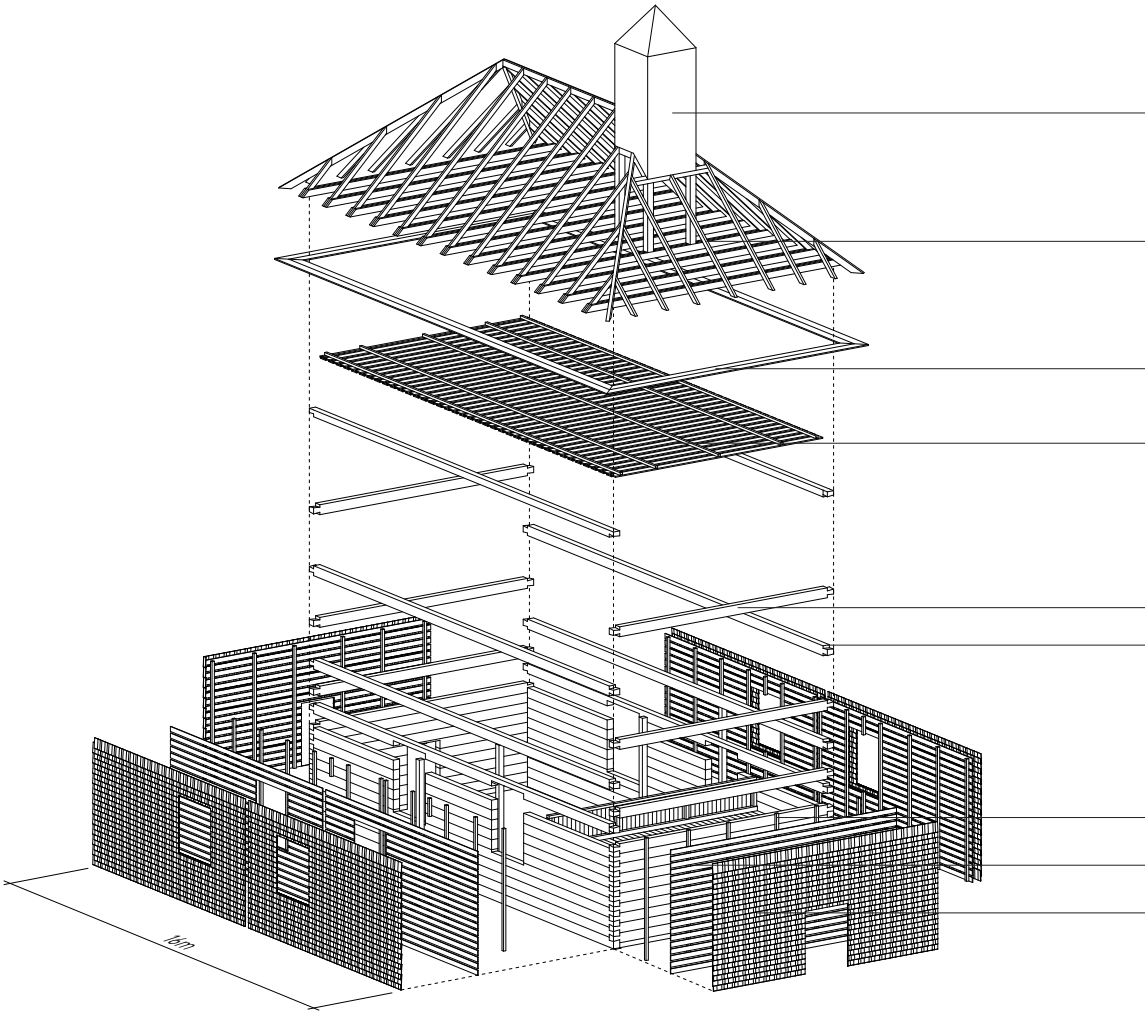


Ill.72 Front elevation, Kolomanskirche

Kolomanskirche

The Kolomansberg is a mountain of the Alpine foothills on the border of Salzburg and Upper Austria. Near the wooded top stands the Kolomanskirche. Already in 1511, a small chapel existed in close proximity of a known healing spring. Later in 1742, abbot Lidl erected the current church on a flat area above the spring.
The Kolomanskirche is the oldest wooden church in Austria. The building consists of a tightly built log construction with dimensions of 8 by 16 metres.[73]
A hipped roof covers the structure and projects evenly on all four sides. On the western a simple, centred bell tower protrudes, breaking the symmetry of the church. The entire, exterior surface is clad with shingles. In contrast to the walls, the roof shingles are three-layered to ensure the sealing off rain. Weathered larch shingles make for a coherent grey appearance while providing sustained durability.
The entrance is located at the western end, sitting centred in the gable wall. The door opens up, revealing the plain layout. A central aisle leads towards the altar. Benches spread out on both sides, with additional seating space on a low gallery. Access to the gallery provides a quarter coiled staircase and being located right beneath the tower; a rope lets anyone ring the bell. Supporting posts and the general execution hint to the later addition of the balcony. Historical records also indicate the installation of the current ceiling, leaving room for speculation of an earlier opening towards the roof. The ceiling features a board on board cladding, fixed with wooden nails. While shingle clad the exterior, inside the walls are whitewashed. Together with four windows, two on each long side, it creates a rather bright interior. Despite the pulpit and altar, the church lacks adornments and appears relatively modest. Opposite the entrance is a second door, leading to a small space behind the altar, which functions as a vestry. The Kolomanskirche captivates not through impressive construction nor rich adornments and ornamentation but its pure form and aesthetic unity. Therefore the solitary church is the destination for many pilgrims.

Ill.73 Front elevation, Kolomanskirche



Ill.74 Assembly drawing, Kolomanskirche

Bell tower

Rafter

Board cladding

Ceiling boards

Log

Dovetail joint

Vertical battens

Sublayer

Larch shingles

Ill.75 Side elevation, Kolomanskirche

Ill.76 Eave, Kolomanskirche

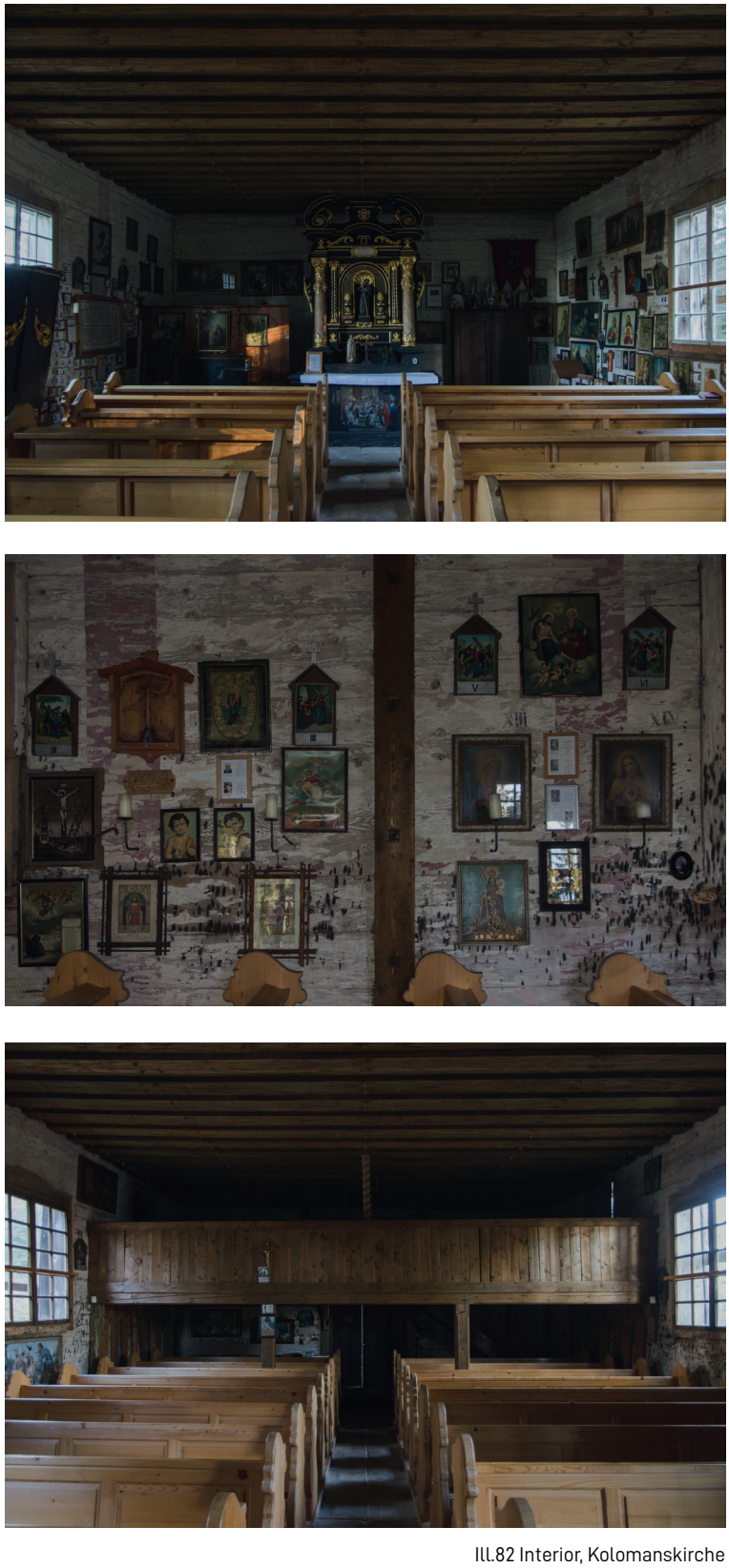
Ill.77 Side elevation, Kolomanskirche

Ill.78 Side elevation, Kolomanskirche

Ill.79 Bell tower, Kolomanskirche

Ill.80 Window, Kolomanskirche

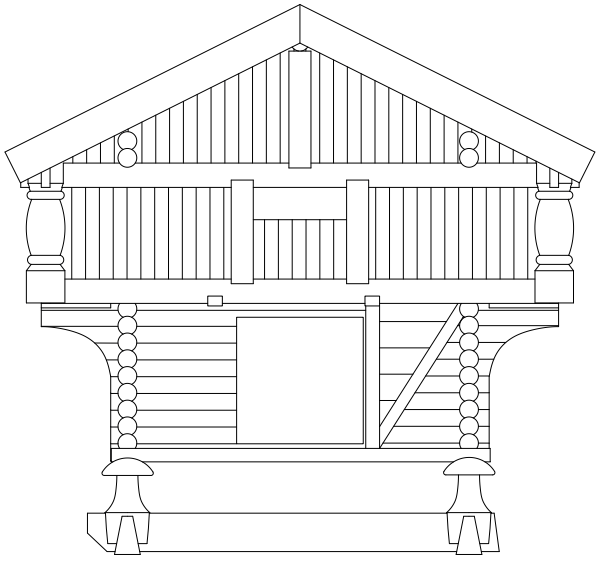
Ill.81 Window, Kolomanskirche



Ill.82 Interior, Kolomanskirche

○ Original location
● Current location

Ill.83 Map Norway



Ill.84 Front elevation, Tveito loft

Tveito Loft

The Tveito loft originates from a homestead in Hovin, Telemark. Research of the corner joints, the Romanesque ornaments of the portal and runic inscriptions hint to a medieval construction date, around 1300. The storehouse is part of the Telemark exhibition at the Norsk Folkemuseum on Bygdøy, and after moving to the museum in 1942, it is on display since 1943.

The building shows the typical characteristics of a Norwegian loft, the massive stumps lift the timber structure off the ground. Those six pillars rest on a frame of logs with conical sections. The four beams are interlocking on each corner, with four stumps placed on the joints. Natural stones support the structure. The foundation was part of the only significant change to the building in the 17th or 18th century. Lifting the storehouses was a popular measure to protect the construction against moisture and vermin.[74]

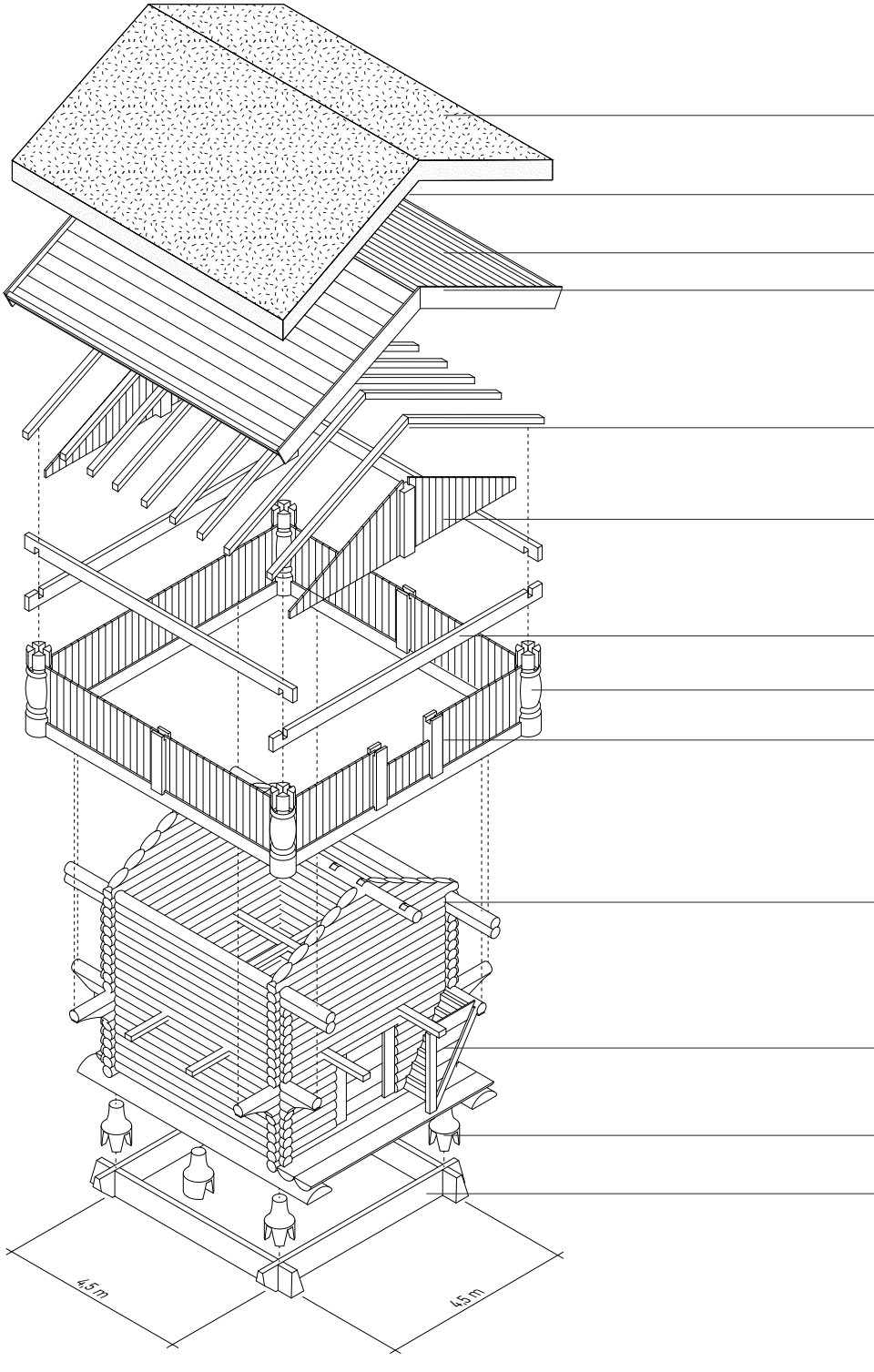
Two semicircular planks joined to the stumps with tenons, form the transition to the notched-log work.

Medieval lofts use smaller round logs, contrary to the ones after the Black Death.[75] The notched-log construction stretches over both storeys and serves as the structural core. The ends of the trunks increasingly project outwards towards the second floor, to carry the cantilevering gallery. Additional joists support the upper level near the centre. The most interesting constructive aspect of the Norwegian loft is the combination of notched-log and stave construction. The cantilevering gallery shares identical structural elements as the stave churches. Cylindrical corner posts, together with sill and cross beam form the supporting frame, filled out with vertical planks mortised into the sill. In this case, the staves are prominent, despite lacking ornament, underlining the structural importance and technical beauty of the construction. The only openings in the gallery are three little windows front and centre. Intermediate staves break up the facades into individual panels. (ADD ROOF ANGLE) The roof project evenly on all four sides. A central purlin and rafters distribute the weight to surrounding walls. Boards clad the rafters and make for the underlayment for the final layers. Sheets of birch bark seal the roof, and two layers of turf fixate them.

Several steps access the open porch and lead towards the entrance of the ground floor, a steep staircase to the right heads up to the gallery. The door of the second floor sits right above the lower one, in the centre of the gable wall.

Generally, the Tveito loft captivates with decent proportions and square floor plan. Each level has a single room. While the ground floor was food storage, the upper level had a bed for sleeping during the summer.

Ill.85 Front elevation, Tveito loft



Ill.86 Assembly drawing, Tveito loft

Turf roof

Birch bark

Board cladding

Barge board

Rafters

Vertical planks

Cross beam

Corner stave

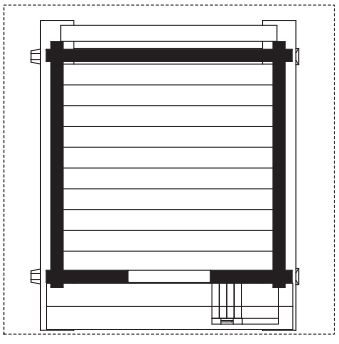
Intermediate stave

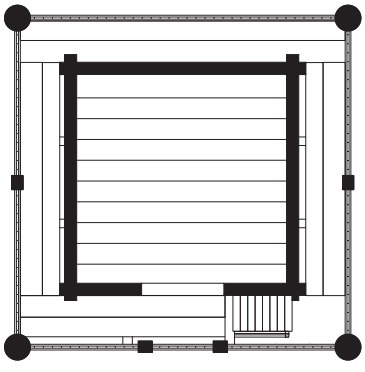
Log-timbered core

Staircase

Wooden stumps

Foundation beams



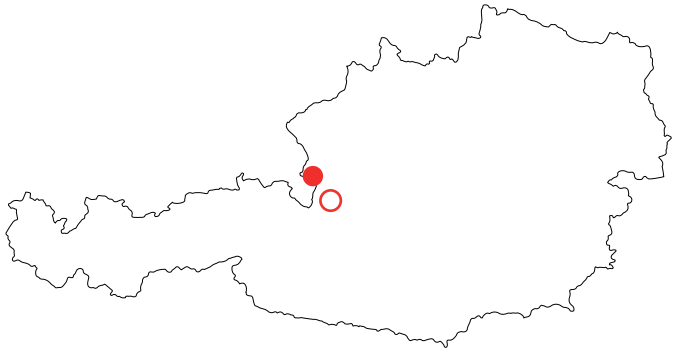


Ill.87 Ground and upper floor, Tveito loft

Ill.88 Corner detail, Tveito loft

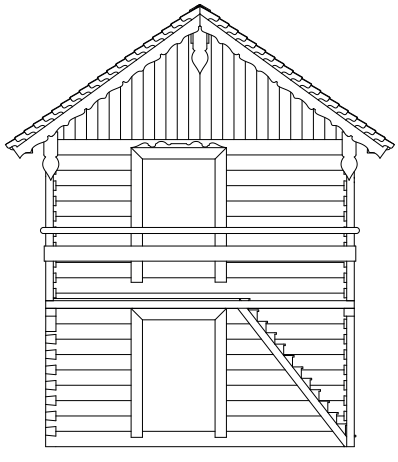
Ill.89 Foundation detail, Tveito loft

Ill.90 Portal, Tveito loft



Original location
Current location

Ill.91 Map Austria



Ill.92 Front elevation, Kellbauernkasten

Kellbauernkasten

The Kellbauernkasten is a granary, a separate storage building for harvested crops, such as wheat, rye or oat. Hence the German name Getreidekasten or Troadkasten. These buildings usually are part of farm setting and were built in 1788 A.D. The original location is about 30 kilometres south of Salzburg, in Kuchl Kellau. As part of the farm, the function of such a building was the secure storage of seed and crops. Neither mice nor fire should damage or destroy the valuable good. Therefore the Kasten needed to be tightly timbered and lifted off the ground to prevent moisture damage. Besides seeds, those buildings also stored other valuables.

Similar to the Norwegian loft, the Troadkasten can be seen as the treasury of the farm. The two storey structure rests on a padstone foundation and consists almost entirely of a notched log construction. Dove-tail joints connect the scantlings on all four corners. The Kellbauernkasten is a relatively small building with a length of 4,2 metres and a width of 4,1 metres. A steep wooden staircase is attached to the front exterior wall and makes the second floor accessible with a balcony-like construction. The two entrances are placed off centre to the left side but aligned with each other. Wooden frames around the doors keep the logs in place. Despite the small size and the steep roof pitch, purlins carry the weight of the roof construction whereby the last two wall elements as inferior purlins serve. Two pillars, one placed on each gable wall bear the central purlin. The secondary structure consists of rafters and boarding, providing the substructure for the shingle roof cladding. From top to bottom the granary is 5,8 metres high. Three layers of overlapping larch shingles protect the building against the elements. Although the roof projects on all four sides, the canopy is only at the front side great enough to protect the exterior walls. The other three facades are uncovered, and therefore the end grain is exposed to rain and more vulnerable to rot. Small curved boards on the end of each purlin are protecting the cross-cut wood.

An additional joist in the middle of the floor plan supports the floorboards of the upper floor, which rest on a protrusion along the outer edges.

Inside, boxes are dividing the room to store and separate different seeds and crops. As the building was taken apart in 1974, every single piece was labelled and in a reconstruction plan noted. The Kellbauernkasten was relocated to the open-air museum Großgmain and rebuilt in 1986. Nowadays it hosts a permanent exhibition on traditional wooden fences.[76]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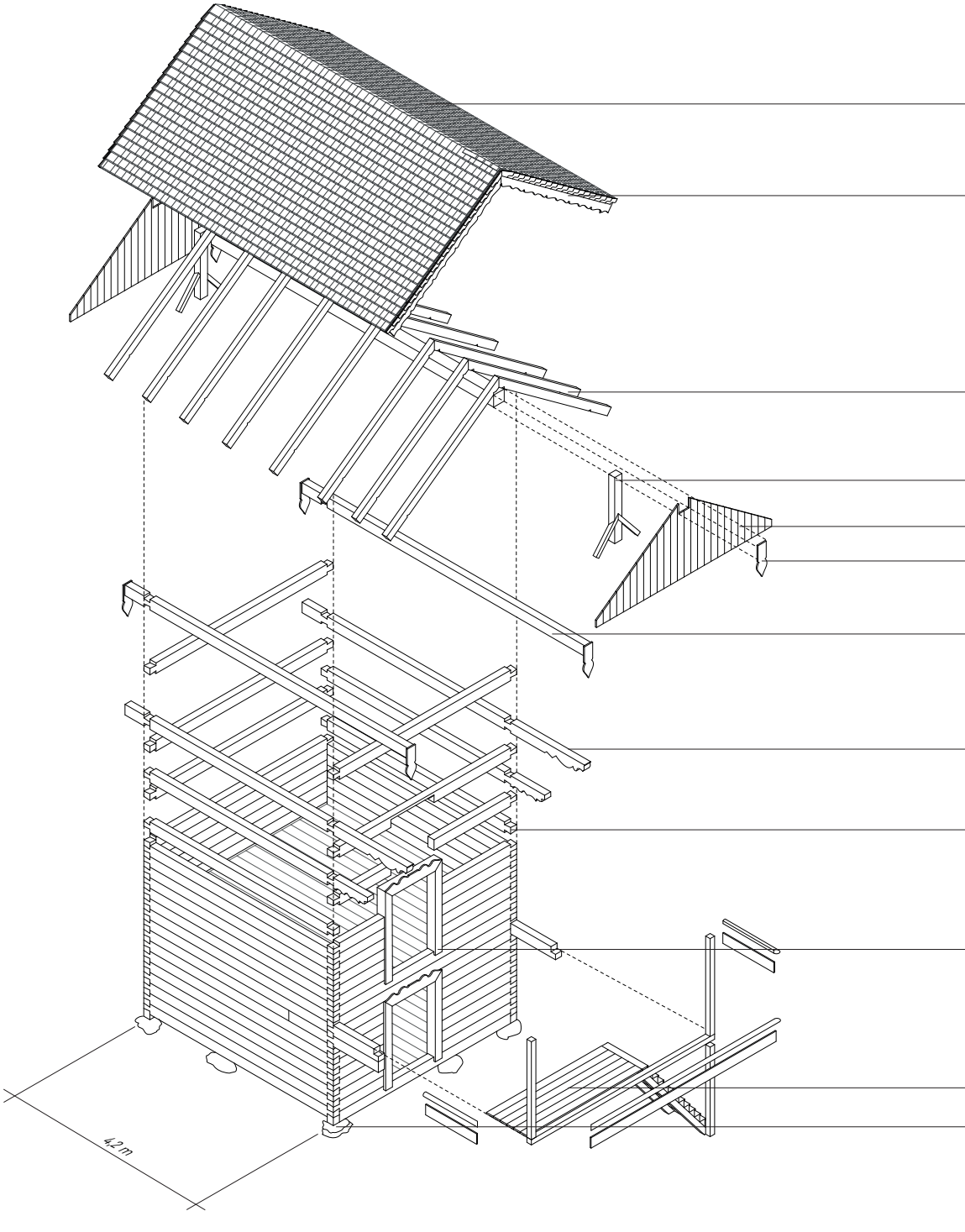


Ill.93 Assembly drawing, Kellbauernkasten

Larch shingle roof

Barge board

Rafters

Post

Board cladding

Purlin board

Purlin

Logs

Dovetail joint

Door frame

Balcony

Padstone foundation

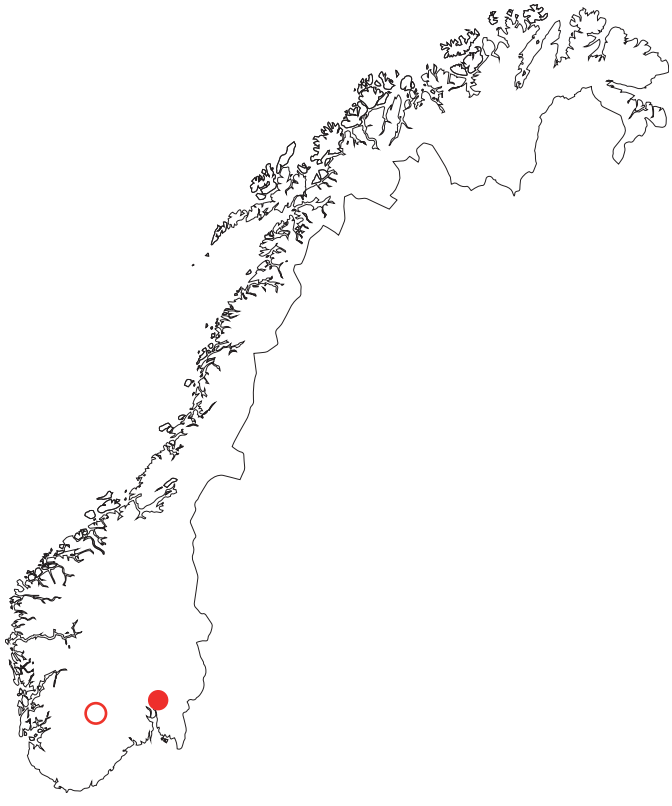
Ill.94 Stairs to upper floor, Kellbauernkasten

Ill.95 Balcony structure integration, Kellbauernkasten

Ill.96 Protruding purlin, Kellbauernkasten

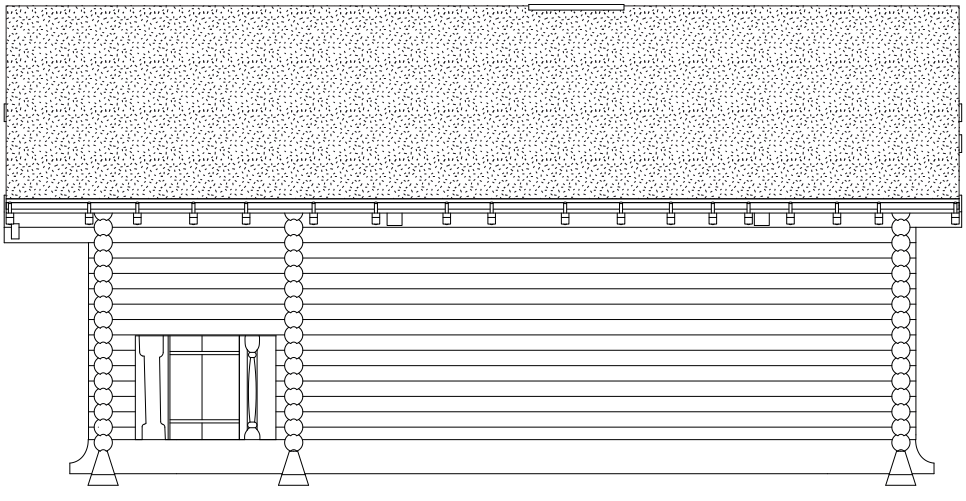
Ill.97 Window, Kellbauernkasten

Ill.98 Padstone, Kellbauernkasten



○ Original location
● Current location

Ill.99 Map Norway



Ill.100 Side elevation Raulandstua

Rauland Stua

The Rauland Stua was part of a farm in Nore og Uvdal in the county of Buskerud. A place in the traditional and well-forested region of Numedal situated in central Norway. The homestead itself is widespread, and fields are inbetween the houses. Two objects exist since the Middle Ages.[77]

The dwelling house is one of the oldest wooden buildings in the country still in existence. Engravings above the door hint to date around 1300 A.D. Dendrochronological examinations, later on, show an even older age, dating back to 1250. In 1895 the building was moved to the Norsk Folkemuseum on Bygdøy, Oslo.[78]

As the central component of a farm, the *stua* is essential to the social life. The floor plan has the archetypical three-room arrangement. A small entrance space in the corner, the large living room with 60 square metres and a cubicle (kove), entered from the living room. A steep staircase accesses the roof space, which stretches across the two small rooms on the ground level.[79] Originally an open hearth occupied the centre of the house. This particular example had a stove in the corner of the living room, which was removed during the movement and unbuilding of the structure. All along the gable end stands an enormous table.

The construction rests on a padstone foundation, lifting the large sill beams off the ground. Those sill beams have a trapezoid cross section and separate the foundation from the rest of the construction. In addition to the four perimeter beams along the exterior edge, there is also another one along the interior wall. At the corners the sill beams overlap and notches on both trunks make for a tight connection. The upper joints show a different execution than the usual *findalslaft* for this time. In fact, it is the first time this new joint was found anywhere in Norway. Hence the name *raulandslaft,* named after this particular building. Looking closer at the notch, the neck has no longer an off-centre location and is in the middle of the round logs cross-section.[80] The logs are stacked up to the roof. The last two or three trunks of the long sides are projecting on both sides, creating a canopy to protect the exterior

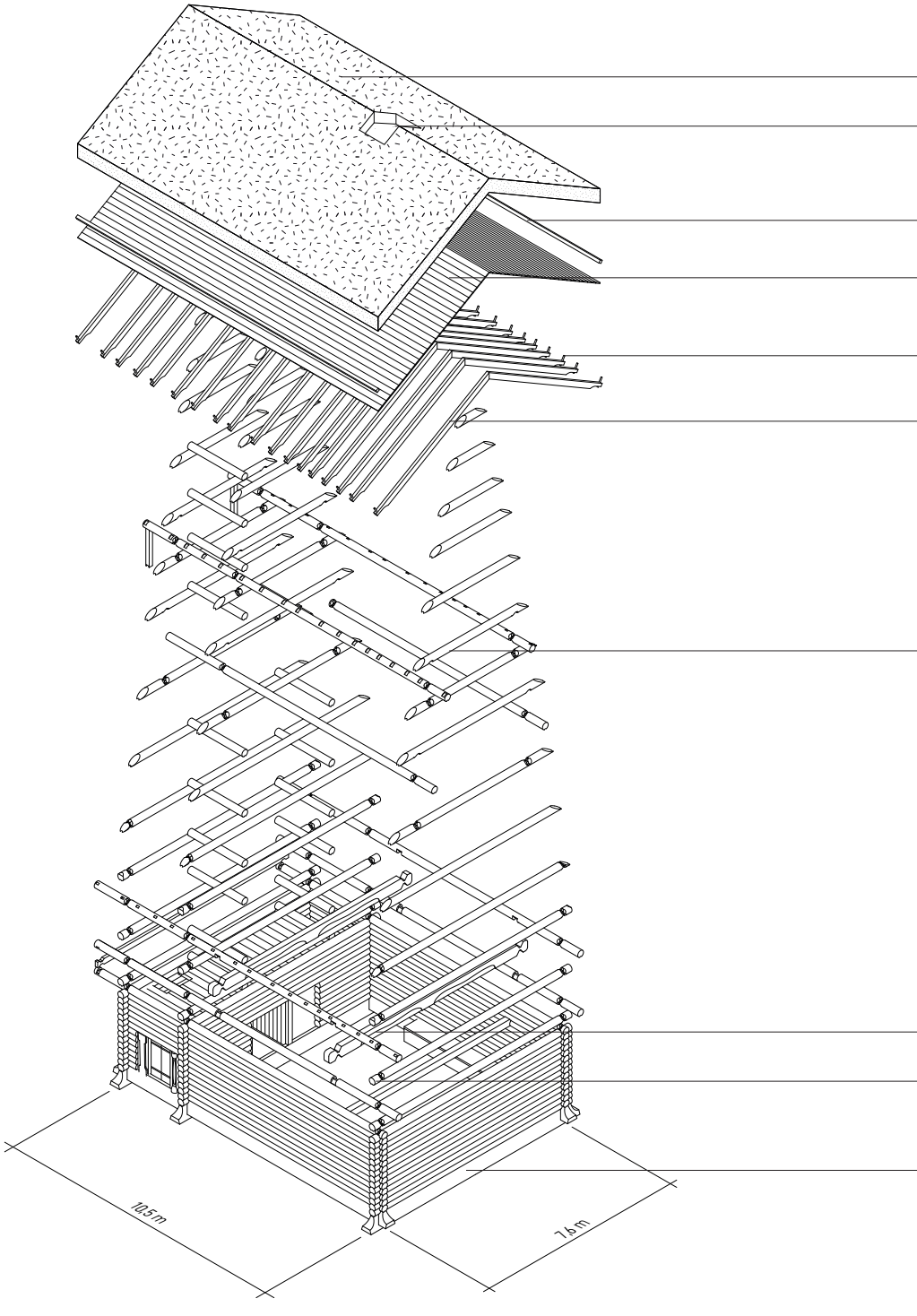
Ill.101 Side elevation Raulandstua

wall and the balcony. Simultaneously are the logs supporting the rafter roof. As an additional measure two trunks are placed half way to the ridge on both sides, distributing the weight of the roof to all four walls. Two joists, running across the living space, brace the exterior walls. To tighten the roof a layer of boards is placed on the rafters. Many layers of birch bark are keeping rainwater out and provide an underlay for the two layers of turf. As mentioned earlier is turf a preferred covering technique. There are no windows in any exterior wall, only an opening at the ridge of the roof provides daylight while functioning as an outlet for smoke of the open hearth.

In order to keep the turf roof from sliding off, a scantling along the eave is held in place by thorns sticking out of each rafter.

On the inside the single opening creates a murky atmosphere. The wooden enclosure adds to that impression. All surfaces are wooden, except the earthen floor. A stationary bench is running along the perimeter and is the only piece of furniture besides the long table. Apart from seating the bench acts as an additional layer of insulation at the most vulnerable place, the transition to the floor.

While the construction itself is straightforward and simple in its appearance, some elements stand out because of their ornamentation. Most notable example is the entrance door and the door frame in particular. Asymmetric in its form, one side equipped with a half-column and overall rich in carvings, the portal reminds of Romanesque stone architecture. [81]



Ill.102 Assembly drawing, Raulandstua

Turf roof

Roof opening

Eave scantling

Board cladding

Thorn

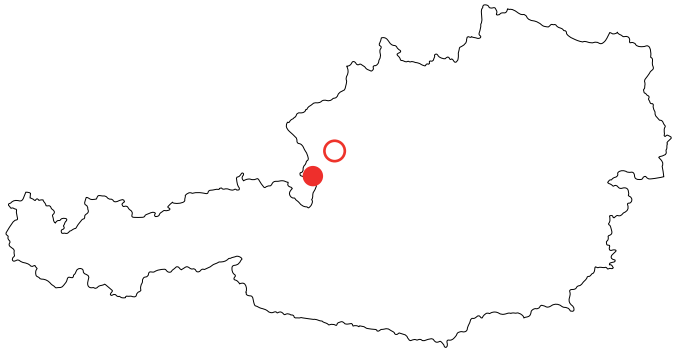
Rafter

Logs

Cross beam

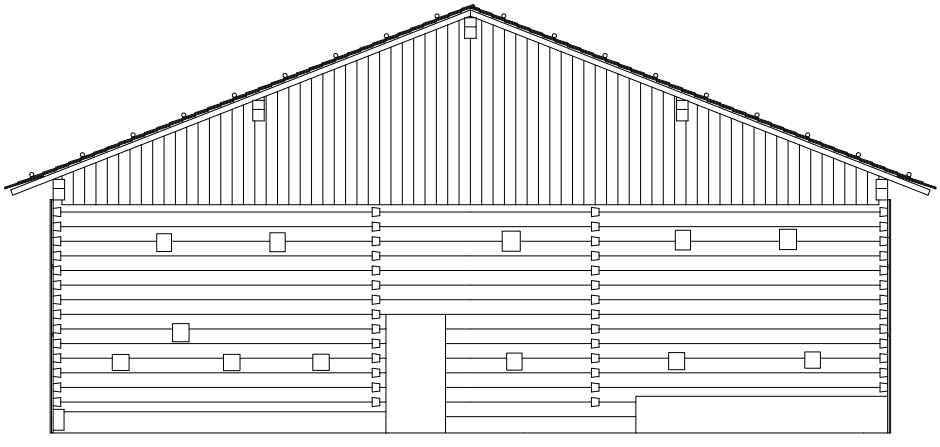
Rauland notch

Sill beam



Original location
Current location

Ill.103 Map Austria



Ill.104 Front elevation Rauchhaus Ederbauer

Rauchhaus Ederbauer

Rauchhaus ("smokehouse") "Ederbauer" was originally located in the northern part of Salzburg, alongside the hilly surroundings of Lake Wallersee. The Rauchhaus can be seen as a predecessor to the well-known Flachgauer Einhof, a typology which combines dwelling and agricultural functions under a single roof. Although not completely proven, it can be assumed that the Einhof developed from the addition of earlier separated parts of dwelling house and barn. Due to the lack of a chimney, the smoke of the hearth escaped unguided through the roof and small openings in the gable wall. Hence the name Rauchhaus. The historical reconstruction of the development is difficult because hardly any examples are remaining. Dendrochronological examinations of the wood date the building back to 1642 A.D., whereas the logging took place from 1637 to 1642. In 1722/23 extensive renovations took place. The room height of the ground floor was lifted by one row of logs, the stable and roof were completely rebuilt. Another indicator of the building's age is the small, glassless windows. Offset to each other to not weaken the stability of the wall and improve illumination and ventilation in the parlour. Each window has an iron thorn to keep intruders out and sliding wooden boards on the inside to close the window if necessary.

The farmhouse shows to typical trisection of dwelling house, threshing floor and barn. A single roof covers all three parts, which are oriented across the ridge. The farm is 14,7 metres wide and 17,4 metres long. The dwelling part consists of a tightly timbered log construction and the spruce scantlings are up to 40 centimetres high. But usually, do not exceed a width of 12 to 13 centimetres. Along the outside walls of the parlour ("Stube") the lowest log is 70 centimetres high and out of oak to increase the durability. All the other walls are resting on natural stones. Dove-tail joints connect the walls on each corner. A wooden dowel at the joint and several along the log ensure additional stability of the construction. Inner walls also brace the structure. The end grain of the logs is exposed and not protected in any way, making it more vulnerable

Ill.105 Front elevation Rauchhaus Ederbauer

to rot. (see chapter Wood). Despite tight tolerances during the erection, cold wind could pass through gaps in the wall, due to warping and cracking of the wood. Moss was necessary to seal the cracks.

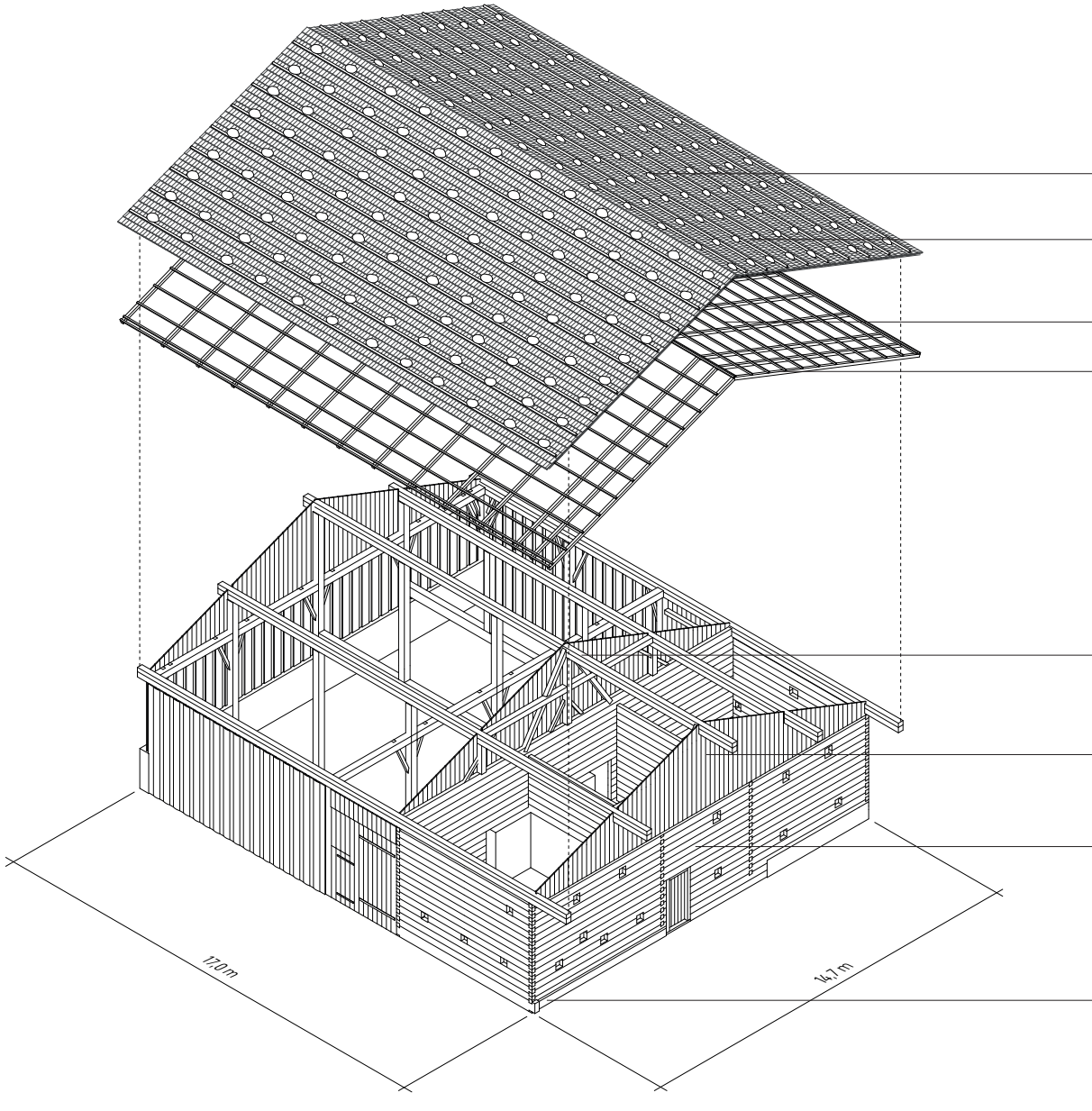
In contrast to the dwelling part, the barn and threshing floor consist of a lighter post construction. Three rows of columns with five columns each create a self-supporting structure together with horizontal elements. The outside is cladded with vertical boards. While the pillars initially stood on bare soil, rot made it necessary to use a padstone foundation or a stone wall.

The roof, spanning over the whole building, is a slightly inclining purlin roof. Parallel to the eave is the load bearing purlins. One running along the ridge, two rest on the log construction or directly on the posts at the barn. The purlins, however, bear the roof cladding, consisting of rafters, battens and the cover itself. In this example, the rafters do not have a bearing function and are mounted to the purlins with wooden nails. Because the timbered walls settle, the rafters were not fixed to the lower purlin. Only then the battens are nailed to the rafters and form the substructure for the roof cladding. The cladding itself is large shingles. Those are installed in three overlapping layers and held in place by hook mounted stakes and weighed down by heavy stones. Additional bargeboards, along the front sides of the roof, hinder the shingles from lifting.
At the main gable wall, the roof projects 1,5 meters and protects the exterior wall against precipitation. The ends of the purlins are moulded at the bottom and have small fascia boards to protect the end grain.

The main entrance of the house lies in the middle of the gable wall and leads directly to the Haus, the centre room, with its open hearth. The kitchen is four metres high and stretches over both floors. It is closed off by a ceiling to the attic. Being directly accessible through the main door has some disadvantages while cooking. Wind and draught can cause flying sparks and is a safety hazard. For this reason, many stoves were surrounded by fireproof walls. In this example, the natural stone forms a T-shape and reaches all the way to the threshing floor. The combination of stove and baking oven between the living room and kitchen had some obvious disadvantages during warm summer days where the room temperature can be unpleasantly hot.
A heavy wooden door separates the living room from the kitchen. The Stube has a characteristic corner position with two exterior walls. Along those walls runs a continuous bench. The main element is the oven, in this case, a reconstructed, very simple example. Opposite stands the dining table, where besides eating the social life took place. The floor is wooden as well. All in all, the whole ensemble is hardly any different than the typical Bavarian, alpine layout. Diagonally across the living room entrance is the door to another, unheated room, the Kammer. That was used for sleeping as well as storing goods. Even the term Kammer does not give a precise answer to its usage.
On the later added upper level, the floor plan stays the same. An implemented staircase in the living room leads to the new bedroom. Before the renovation, both rooms on the second floor were used for storing

Ill.106 Floor board, Rauchhaus Ederbauer

Ill.107 Main entrance, Rauchhaus Ederbauer



Ill.108 Assembly drawing, Rauchhaus Ederbauer

Stones

Laid shingles

Roof battens

Rafters

Purlin

Board cladding

Log-timbered wall

Sill beam

crops and were only accessible from the threshing floor. This is still the case for the second room. Above the corridor and the smoke kitchen hang a rack for drying crop. The cold smoke made the grain last longer and was further used for curing meat.

The fireplace is an essential necessity for living in central Europe. Two ovens are connected to the open hearth. One for heating the living room, the other for baking. Both were fired from the corridor. The stove is 54 centimetres high and had to be reconstructed because of its poor condition. Two wall-mounted, suspended caldrons have been used for heating water over the open fire. Above the stove, a cover made of wattled twigs covered with clay or cow dung prevented the feared flying sparks. Simultaneously the smoke was cooled down. Cooking took place on a tripod with pots and pans.

A board door leads from the corridor kitchen directly to the threshing floor. This part of the farm separates the dwelling part and the barn. Gates open on both sides and make it easily accessible. This arrangement is typical for the *Einhof*. The stable attaches to the three meter wide *Tenne* (threshing floor), only defined by a simple board wall. With 126 square metres the stable was probably open spaced, meaning the cows were moving freely. Because the Ederbauer is lacking a hayloft, hay had been stored in parts of the stable.

Windows and doors weaken the construction and therefor kept as small as possible. Dowels close to the opening improved the stability. But not only technical difficulties resulted in small windows. Coldness during winter was a problem as well and glass was not common in Austria before the 18th century. The skin of a cow stomach or bladder served as a glass substitute. Small, square, sliding boards shut the windows. Doors were low as well, people had to bend down to walk through. All measures to keep as many logs intact as possible.[82]
The combination of small, glassless windows and the smoked wood make for an overall dark and murky impression.

Ill.109 Glassless window, Rauchhaus Ederbauer

Ill.110 Glassless windows, Rauchhaus Ederbauer

Ill.111 Sill beam, Rauchhaus Ederbauer

Ill.112 Unbuilding process, Salzburger Freilichtmuseum

Ill.113 Condition before moving, Salzburger Freilichtmuseum

Ill.114 Condition before moving, Salzburger Freilichtmuseum

Ill.115 Rebuilding, Salzburger Freilichtmuseum

Comparison

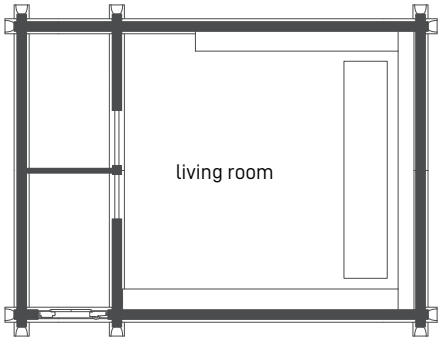
Ill.116 Side elevation Raulandstua, Bygdøy

Stua | Einhof

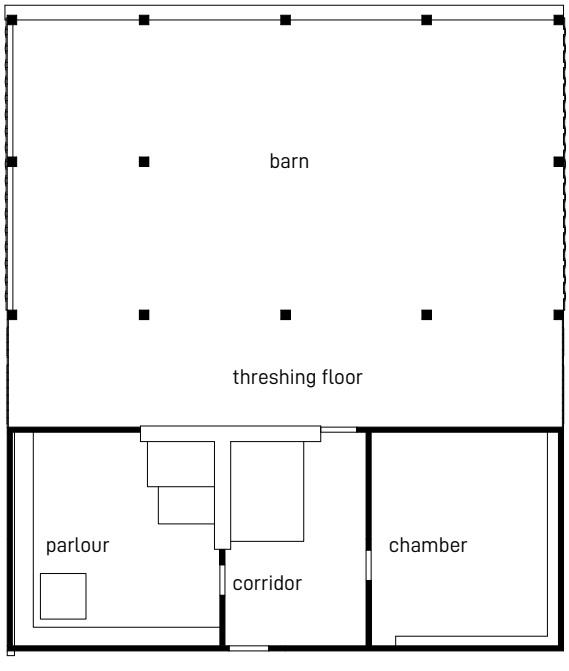
The comparison of the Norwegian cottage and the Austrian farmhouse starts at the topographical differences. In the isolated areas of the Norwegian backcountry, the homesteads kept their original cluster arrangement. The region around Salzburg is flatter and in contrast relative densely populated. Not every farm has to provide everything for themselves. Therefore it was possible to gather all functions under a single roof, the known Flachgauer Einhof emerged. Multiple uses in one building increased the size of the object, noticeably larger than the Raulandstua.
Size and layout influenced the floor plans as well. The entrance to the cottage sits in the corner of the long wall. Followed by an antechamber and eventually the living room, which takes up the majority of the floor space.
The Rauchhaus has its main door on the gable side. A central corridor divides the ground floor into two separate spaces and leads to the threshing floor. In contrast to the stua is the fireplace not in the living

Ill.117 Front elevation Rauchhaus, Salzburger Freilichtmuseum

room but the antechamber. The parlour is in both houses to the only heated room.
Natural light is also handled differently in both buildings. Small, glassless windows let light into the living space in the Austrian example whereas the inside of the cottage only gets brightness through an opening in the roof
although this may result from the age disparity of the objects.
The notched-log construction shows the stage of development of each structure. Where protruding trunk ends were still usual in Norway, main buildings in Austria almost exclusively featured dovetailing as a joining technique. Hewn logs with rectangular cross-section superseded round trunks. A primarily Norwegian feature is the turf roof unlike the laid shingle cladding of the Rauchhaus.
The carvings and rich ornaments around the door are also characteristics of the artistic work of carpenters in Norway.



M 1:200 Ill.118 Floor plan Raulandstua, Bygdøy



Ill.119 Floor plan Rauchhaus, Salzburger Freilichtmuseum M 1:200

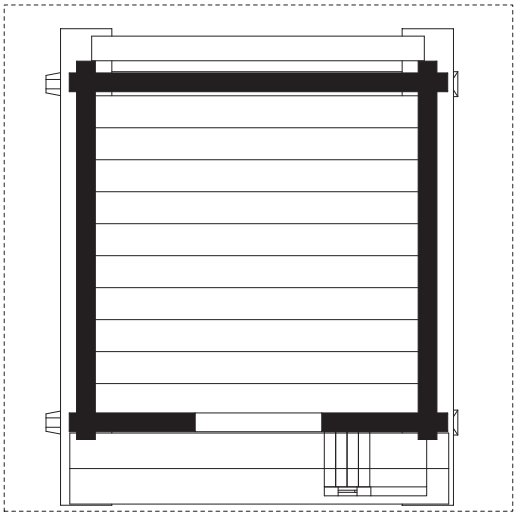
Ill.120 Front elevation Tveito loft, Bygdøy

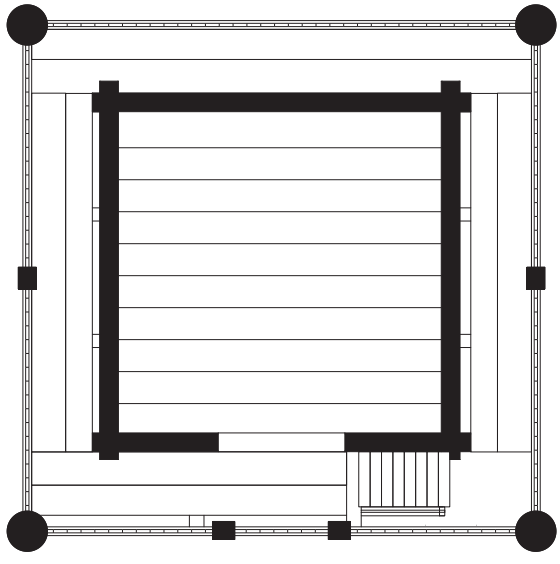
Loft | Troadkasten

Easier comparable than the dwelling typologies are the storage buildings or granaries. The Tveito loft in Norway and the Kellbauernkasten (Troadkasten) in Austria share an identical purpose. Built for storing crops and goods these buildings are the treasury of the homestead.
The two-storey setup allows preserving various things, often also clothes.
Both have a log-timbered core, but the speciality of the loft is the cantilevering gallery on the second floor. On all four sides, the trunks project and additional beams carry the extra construction. The structure of the gallery consists of stave work and adds to the unique appearance.
During the 17th and 18th century, the loft was lifted on stumps to further protect against moisture and pests. This transition cannot be seen in Austria. In general, the Norwegian storehouses are more significant than their Austrian counterparts. But similar to the dwelling situation, the joints show also a clear disparity. Round and protruding on the one side and rectangular and flush on the other side.
The story continues at the roof, where the traditional sod roof clads the

Ill.121 Front elevation Kellbauernkasten, Salzburger Freilichtmuseum

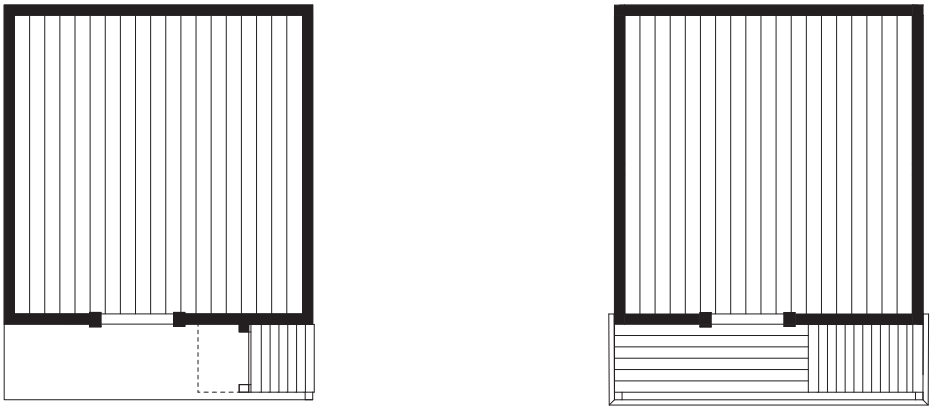
loft and nailed shingles the Getreidekasten.
As the treasury of the farm, people expressed their wealth by adorning the storage building. Carving around the portal and on the corner staves with floral or runic patterns are typical for the Norwegian loft. Artistic expressions are subtler in Austria and concern mostly the execution of the corner joint. The Klingschrot is such a form of adornment, where the carpenter showed off his skill set.





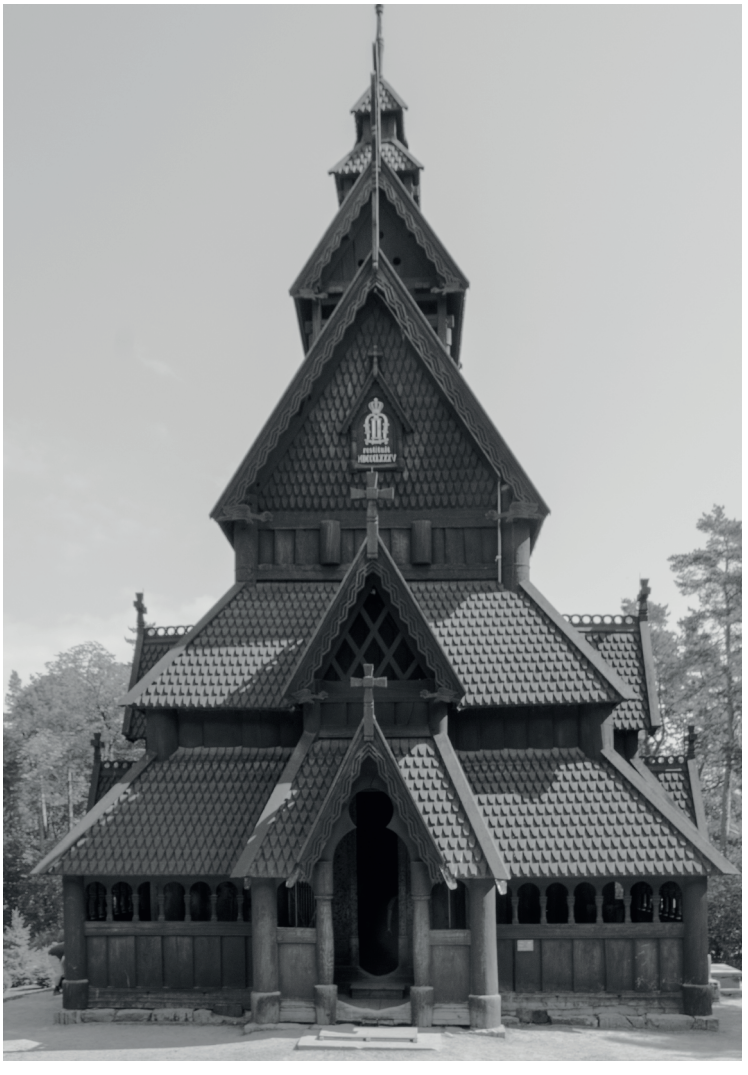
M 1:200

Ill.122 Floor plan Tveito loft, Bygdøy



M 1:200

Ill.123 Floor plan Kellbauernkasten, Salzburger Freilichtmuseum



Ill.124 Front elevation Gol Stavkirke, Bygdøy

Stavkirke | Kolomanskirche

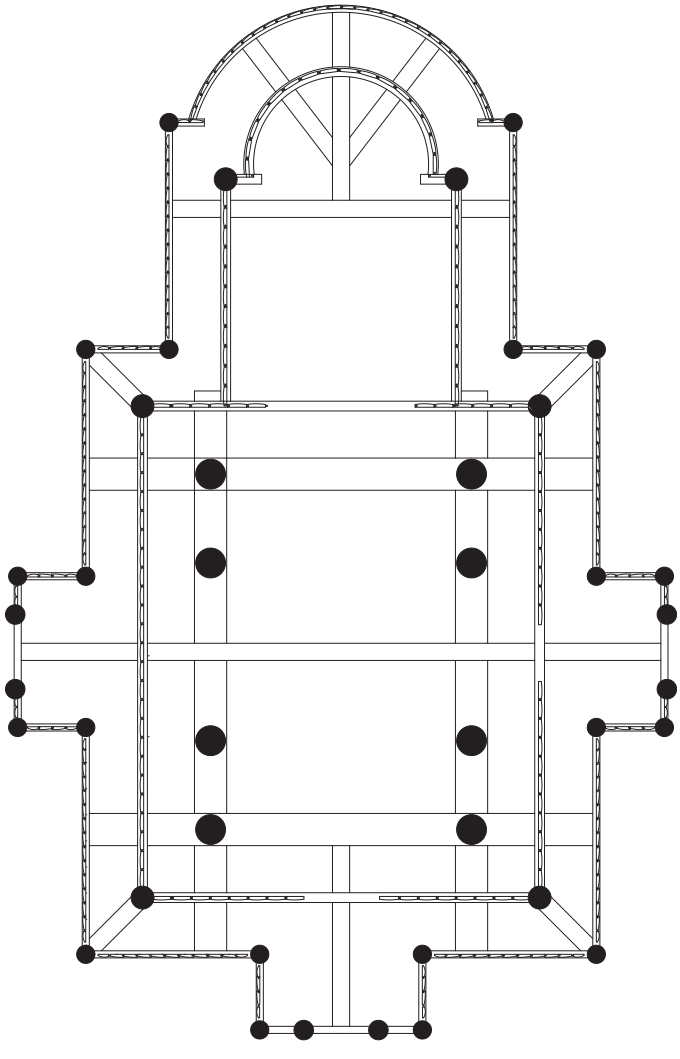
Stave churches in general and the one of Gol, in particular, are such a unique cultural treasure, which makes it hard to compare to the rather small Kolomanskirche. But the original and simple type of the stave churches, like the church of Haltdalen, make for a better comparison.
Both floor plans are based on a simple rectangular shape. The entrance lies at the gable end, opposite the altar, but the stave church has an additional space added to the end, the so-called choir.
The structure of the walls is the most notable, constructional difference. Vertical staves in one side, and horizontally stacked logs on the other. While the Norwegian example shows all constructional elements, the Kolomanskirche has cladding on the outside and whitewashed walls on the inside. The ceiling closes off the interior space, whereas the scissor truss of the Haltdalen church remains visible.
Looking at the stave church from the outside, the most noticeable fea-

Ill.125 Front elevation Kolomanskirche, Tiefgraben

tures are the two steep saddle roofs above the nave and the choir, and the black colour. Every exterior surface is tarred to increase durability against the weather. What taring is for the church in Haltdalen are larch shingles for the Kolomanskirche. The material covers the walls, the hipped roof and the bell tower. The simple type of stave church does not have a bell tower.

Although the floor plan has similarities in shape and simplicity, the interior atmosphere diverges significantly. Reason for this being the disparity in furniture, the ceiling and the existence of windows in the Austrian object. As it is not a museum item and still in regular use, benches take up most of the floor space. Front and centre is the rich adorned altar. Additional seating achieves the gallery in the back of the church.

Contrary, the Haltdalen church is empty, and natural light only comes in through the entrance. But the openness towards the roof let it appear higher and more significant than it is.



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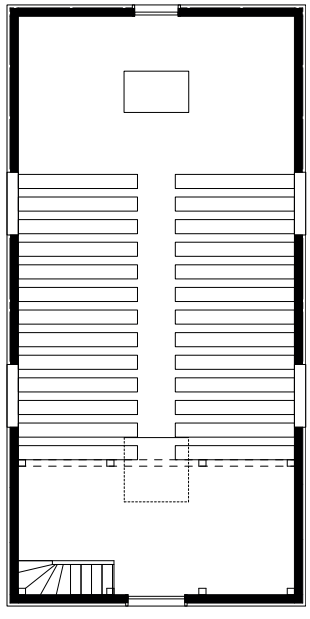
Ill.126 Floor plan Gol Stavkirke, Bygdøy



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Ill.127 Floor plan Kolomanskirche, Tiefgraben

Analysis

As a final step, the analysis will conclude why traditional wooden constructions evolved as they did. After examining buildings in Austria and Norway, the most significant influences are the circumstances and the environment the structure occurs, beginning at the geographical position, and the climate which comes with it.
The climate affected where people could settle and what challenges they faced. In a smaller scale, the topography of an area or region set the stage for the settlements.
The more favourable environments were, the more people they attracted, and the increased population density led to the development of very specific typologies. Norway's sparse population brought up the self-sufficient farmstead, whereas Austrian farmers could rely on nearby villages or cities.
The central position of Austria in the European context also had political consequences. Changing leadership resulted in more regional diverse building traditions. Roman, Slavic and Germanic influences can be found all over the country. Historically, Norway is in a more isolated position, not until the raids of the Vikings the region opened towards Europe.
But the essential factor of wooden building traditions is the material itself — no timber architecture without trees.
Again, topography and climate are the decisive elements for the existence of forests, providing the needed raw material.
Since the appearance of iron tools, people were able to process wood effectively, the sheer amount of time working with the material brought up ever-evolving skills and knowledge. Realising that sapwood is not as durable and in removing it can make the construction longer lasting, or the process of girdling is proof of the desire to always improve the techniques. Phenomena like the shrinking of wood or cleaving timber to keep the fibres intact are, although not scientifically proven, part of the experience of a carpenter. The knowledge of the material properties led to specific use cases, using oak for the sill beams or making use of the

stave's tapering in high churches. Another example is the improvement of the corner joint, creating an even tighter fit. The biggest challenge is the fight against weather and moisture, especially for wooden constructions, sealing the roof is one of those challenges, and people came up with various ideas, from dried birch bark to larch shingles.

But as soon as the technical difficulties were manageable, carpenters started to enhance the buildings artistically. Carvings, already known from Viking ship, became the ornaments on portals. The joints of log-timbered structures also turned into decoration items.

The challenge which eventually banned wooden constructions in an urban setting was the danger of fire. The means to protect against the threat were not developed enough to match stone buildings.

What remains is the enormous amount of care which was put into the erection of magnificent structures we can still experience today. Constructions, entirely of natural materials, which last for hundreds of years are the ultimate form of sustainability. The building process took a long time and lots of resources, hence more effort was invested in craftsmanship and material.

The bare construction is often reduced to a minimum, and the few available materials were used responsibly.

Endnotes

1 cf. The World Bank Group, 2018
2 cf. Rat für Nachhaltige Entwicklung, 2008
3 cf. Treml, 2007
4 cf. Zwerger, 2015, p. 14
5 cf. Christie, 1974, p. 9
6 cf. Zwerger, 2015, pp. 17-18
7 cf. Hauglid, 1980, p. 12)
8 cf. Swoboda, 1975, pp. 6-9
9 cf. Lehfeldt, 1880, pp. 39-40
10 cf. Hansen, 1969, pp. 11-12
11 cf. Swoboda, 1975, pp. 5-13
12 cf. Swoboda, 1975, p. 9
13 cf. Dopsch, 2014, pp. 7-16
14 cf. Dopsch, 1981, p. 387
15 cf. Zauner, 1787, p. IV A b 4/2
16 cf. Gaurek, 2002, pp. 319-321
17 cf. Berg, 1981, p. 9
18 cf. Gunnarsjaa, 2006, pp. 10-30
19 cf. Kavli, 1996
20 cf. Kavli, 1958
21 cf. Christie, 1974, pp. 9-10
22 cf. Hauglid, 1980, pp. 9-22
23 cf. Kavli, 1958, pp. 11-15
24 cf. Christie, 1974, p. 41
25 cf. Kavli, 1958, pp. 15-16
26 cf. Schjelderup & Storsletten, 1999, p. 9
27 cf. Hauglid, 1980, p. 306
28 cf. Phleps, 1942, p. 34
29 cf. Phleps, 1942, pp. 64-65
30 cf. Christie, 1974, pp. 33-35
31 cf. Vreim, 1975, pp. 16-18
32 cf. Vreim, 1975, p. 10
33 cf. Berg, 1989, p. 27
34 cf. Vreim, 1975, p. 46
35 cf. Hauglid, 1980, p. 26
36 cf. Phleps, 1942, p. 56
37 cf. Drange, et al., 2011, pp. 97-103
38 cf. Berg, 1989, pp. 30-33
39 cf. Drange, et al., 2011, p. 93
40 cf. Phleps, 1942, pp. 84-91

41 cf. Drange, et al., 2011, p. 93
42 cf. Godal, 1994, p. 10
43 cf. Christie, 1974, p. 28
44 cf. Godal, 1994, p. 30
45 cf. Phleps, 1942, pp. 97-101
46 cf. Drange, et al., 2011, p. 92
47 cf. Godal, 1994, p. 16
48 cf. Drange, et al., 2011, pp. 91-92
49 cf. Drange, et al., 2011, p. 99
50 cf. Drange, et al., 2011, p. 137
51 cf. Drange, et al., 2011, p. 348
52 cf. Vreim, 1975, p. 54
53 cf. Drange, et al., 2011, p. 348
54 cf. Gjærder, 1952, pp. 244-245
55 cf. Phleps, 1942, pp. 158-191
56 cf. Berg, 1989, pp. 33-34
57 cf. Berg, 1989, p. 58
58 cf. Weidlich, 2002, pp. 57-58
59 cf. Swoboda, 1975, p. 8
60 cf. Swoboda, 1975, p. 19
61 cf. Kavli, 1958, p. 29
62 cf. Bugge & Norberg-Schulz, 1990, p. 19
63 cf. Pöttler, 1985, p. 143
64 cf. Hauglid, 1980, pp. 310-311
65 cf. Førstrup, 1993, pp. 18-20
66 cf. Pöttler, 1985
67 cf. Swoboda, 1975, pp. 11-12
68 cf. Bugge & Norberg-Schulz, 1990, pp. 27-28
69 cf. Christie, 1981, pp. 139
70 cf. Christie, 1978, p. 15
71 cf. Hauglid, 1969, p. 88
72 cf. Anker, 1979, pp. 80-81
73 cf. Gemeinde Tiefgraben, 2018
74 cf. Bjerke, 1950, p. 56
75 cf. Bugge & Norberg-Schulz, 1990, pp. 105-108
76 cf. Becker & Brunner-Gaurek, 2011, p. 136)
77 cf. Berg, 1968, p. 64
78 cf. Bugge & Norberg-Schulz, 1990, p. 65
79 cf. Bjerke, 1950, pp. 44-45
80 cf. Berg, 1990, pp. 116-125
81 cf. Anker & Reimers, 1981, p. 389

82 cf. Mittermüller, 2003, pp. 393-403

Illustrations

Riksantikvaren: 10, 11, 38, 39, 46, 52, 53, 54
Salzburger Freilichtmuseum: 43, 112-115,
Constantin Frommelt: 1, 9, 32

All other illustrations are created by the author.

Literature

Anker, P., 1979. *De norske stavkirker.* Bergen: n.p..
Anker, P. & Reimers, E., 1981. Trearkitektur i bygd og by. In: *Norges Kunsthistorie.* Oslo: Gyldendal, pp. 356-424.
Becker, M. & Brunner-Gaurek, M., 2011. *Führer durch das Salzburger Freilichtmuseum.* Salzburg: Veröffentlichungen des Salzburger Freilichtmuseums.
Berg, A., 1968. *Norske gardstun.* Oslo: Universitetsforlaget.
Berg, A., 1989. *Norske Tømmerhus fra mellomalderen..* Oslo: Landbruksforlaget.
Berg, A., 1990. *Norske Tømmerhus fra mellomalderen. Band 2.* Oslo: Landbruksforlaget.
Berg, K., 1981. Fra helleristninger til dyreornamentikk. In: *Norges Kunsthistorie.* Oslo: Gyldendal Norsk Forlag, pp. 9-35.
Bjerke, G., 1950. *Landbebyggelsen i Norge.* Oslo: Dreyers forlag.
Bjerknes, K., 2001. *Gamle borgerhus i Bergen : [Bind 1].* Bergen: Universitetsbiblioteket.
Bjerknes, K., 2001. *Gamle borgerhus i Bergen: Bind 2.* Bergen: Universitetsbiblioteket.
Bugge, G. & Norberg-Schulz, C., 1990. *Stav og Laft i Norge.* Oslo: Norsk arkitekturforlag.
Christie, H., 1974. *Middelalderen bygger i tre.* Oslo: Universitetsforlaget.
Christie, H., 1978. *Norske Stavkirker.* s.l.:Mittet & Co..
Christie, H., 1981. Stavkirkene - Arkitektur. In: *Norges Kunsthistorie.* Oslo: Gyldendal, pp. 139-252.
Dopsch, H., 1981. *Geschichte Salzburgs.* Salzburg: Pustet.
Dopsch, H., 2014. *Kleine Geschichte Salzburgs - Stadt und Land.* Salzburg: Verlag Anton Pustet.
Drange, T., Aanensen, H. O. & Brænne, J., 2011. *Gamle Trehus.* Oslo: Universitetsforlaget AS.
Førstrup, A., 1993. *Rehabilitering : konstruksjoner i tre.* Oslo: Universitetsforlaget.
Gaurek, M., 2002. Bautradition und obrigkeitliche Verordnungen. In: *Jahrbuch für Hausforschung Band 51.* Marburg: Jonas Verlag.
Gemeinde Tiefgraben, 2018. *Die Wallfahrtskirche am Kolomansberg - Kolomanskirche.* [Online] Available at: http://www.tiefgraben.at/Die_Wallfahrtskirche_am_Kolomansberg_-_Kolomanskirche
Gjærder, P., 1952. *Norske pryd-dører fra middelalderen.* Oslo: Universitetsforlaget.

Godal, J. B., 1994. *Tre til tekking og kleding : frå den eldre materialforståinga.* Oslo: Landbruksforlaget.
Gunnarsjaa, A., 2006. *Norges Arkitekturhistorie.* Oslo: Abstrakt forlag.
Hansen, H. J., 1969. *Holzbaukunst.* Oldenburg ed. Hamburg: Gerhard Stalling Verlag .
Hauglid, R., 1969. *Norske Stavkirker.* Oslo: Dreyers Forlag.
Hauglid, R., 1980. *Laftekunst: laftehusets opprinnelse og eldste historie.* Oslo: Dreyers forlag.
Kavli, G., 1958. *Norwegian architecture : past and present.* Oslo: Dreyer.
Kavli, G., 1996. *Trondheim bygger gjennom 1000 år.* Oslo: Schibsted.
Lehfeldt, P., 1880. *Die Holzbaukunst.* Berlin: Reprint-Verlag-Leipzig.
Mittermüller, F., 2003. *Das Rauchhaus Ederbauer im Salzburger Freilichtmuseum.* Salzburg: Veröffentlichungen des Salzburger Freilichtmuseums.
Pöttler, V. H., 1985. Österreichisches Freilichtmuseum. Stübing: Selbstverlag des österreichischen Freilichtmuseums.
Phleps, H., 1942. *Holzbaukunst. Der Blockbau.* Karlsruhe: Bruderverlag.
Rat für Nachhaltige Entwicklung, 2008. *Waldwirtschaft als Modell für nachhaltige Entwicklung,* Berlin: Rat für Nachhaltige Entwicklung beim Wissenschaftszentrum Berlin gGmbH.
Schjelderup, H. & Storsletten, O., 1999. *Grindbygde hus i Vest-Norge.* Trondheim: Norsk institutt for kulturminneforskning.
Sundt, E., 1976. *Om bygnings-skikken på landet i Norge.* Oslo: Gyldendal.
Swoboda, O., 1975. *Alte Holzbaukunst in Österreich.* Salzburg: Otto Müller Verlag.
The World Bank Group, 2018. *data.worldbank.org.* [Online] Available at: https://data.worldbank.org/indicator/AG.LND.FRST.ZS [Accessed 14 May 2018].
Treml, E., 2007. *Wald in Österreich.* Kuchl: Holztechnikum Kuchl.
Vreim, H., 1975. *Laftehus. Tømring og torvtekking.* Oslo: Noregs Boklag.
Weidlich, A., 2002. Anmerkungen zu Wandmalereien aus dem südöstlichen Bayern. In: *Jahrbuch für Hausforschung 51.* Marburg: Jonas Verlag, pp. 57-64.
Zauner, J. T., 1787. *Auszug der wichtigsten hochfürstlichen Salzburgerischen Landesgesetze zum gemeinnützigen Gebrauch nach alphabetischer Ordnung.* Salzburg: s.n.
Zwerger, K., 2015. *Das Holz und seine Verbindungen.* 3. Auflage ed. Basel: Birkhäuser.