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Engineering Perspectives on Single-Family House Design: A Comparative Study Between Central and Northern Europe

Bachelor's Thesis
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Abstract

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This bachelor's thesis presents a comparative engineering study of a single-family house designed with identical geometry and materials in two different European regions, Slovakia and Finland. The aim was to examine how climate conditions, regulatory requirements, structural loading, energy performance, and economical aspects of construction influence residential building design.

The research follows a structured comparative methodology. First, a unified architectural and structural model of the house was developed. This model served as the basis for all analyses, ensuring that differences comes from external factors rather than design variations. Structural analysis was performed using Eurocode standards and national annexes to identify how local load conditions influence the design. Energy performance was evaluated through dynamic simulation to show how heating and cooling demands are influenced. The analysis highlights the role of national energy legislation, insulation requirements, and envelope standards in shaping the thermal performance of a building. Economic assessment was carried out to explore how construction costs vary due to regional labour markets, material pricing, and technical requirements.

Although, the thesis does not aim to produce a single optimal design, it provides a clear framework for understanding how comparative engineering evaluations are performed and why they are essential when a building is implemented in multiple regions. The thesis emphasizes the importance of climate responsive design, compliance with local standards, and economical feasibility in residential construction, offering engineers and designers a methodological foundation for adapting buildings across varying European contexts.

Keywords	Comparative building design, structural engineering, energy performance, cost estimation
Pages	64 pages and appendices 183 pages

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This experience significantly contributed to the development of my thesis, as it allowed the application of known knowledge from a theoretical background to a real-life scenario, thereby gaining more insight into the subject and narrowing down the scope of my research. The lessons learned during this internship have been invaluable not only for completing this thesis but also for my personal and professional growth.

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1 Introduction

The construction industry is constantly changing due to various factors such as local climate difficulties, stringent energy efficiency policies, and economic conditions. In this environment, engineers must apply innovation and design buildings that meet local construction regulations while providing sustained economic viability and energy efficiency.

In Europe, disparities between Central and Northern European regions greatly impact building design and construction practices for residential buildings. In particular, the differences between the conditions found in the city of Dunajská Streda in Slovakia within Central Europe and the city of Hämeenlinna in Finland within Northern Europe offer great insight and ideal subject for a comparative analysis. While Finland must deal with the challenge of long periods with freezing temperatures and focuses on building design for airtight envelopes, the continental climate found within Slovakia requires both heating and cooling design principles. These two countries can provide valuable insight into how geographical, regulatory, and environmental factors affect construction practices.

This research aims to compare a single-family house built with the same geometry and materials in both regions, highlighting the differences primarily in structural requirements, energy efficiency, and construction costs. Through this comparative study, the research seeks to better understand the complexities of buildings in different environments and how regional characteristics influence architectural and engineering decisions.

2 Scope and limitations

This thesis focuses on the comparative analysis of a single-family house design in Finland and Slovakia, with particular focus on structural, energy, economic, and regulatory perspectives. The study considers structural performance under region-specific loading conditions such as snow and wind, while also examining energy efficiency through simulations based on local climate data and building energy standards. Furthermore, it evaluates the economic aspects by analysing material costs and estimated energy usage. In addition, the research highlights the design adaptations required to meet national regulations and environmental conditions in both regions.

The thesis is not expected to provide a universally applicable design solution but rather to illustrate the differences and challenges of applying one standardized building model in two distinct contexts. The design is created with the same geometric and construction principles and may not accurately represent all local solutions. Internal architectural aspects and behaviour are assumed to be the same and do not require a deep analysis. The economic evaluation is based on local market prices. Finally, while aspects such as life-cycle assessment and carbon footprint deserve consideration and recognition for their relevance and significance, they remain outside the context and scope for this particular research study.

3 Methodology

The thesis follows a comparative case study approach to analyse a single-family house with identical geometry and materials in Slovakia and Finland. The research is structured into five phases, where the first one is the design modelling, developing the architectural and structural model. The second phase is the structural analysis, where the loads are calculated and the utilization ratios are checked under local conditions. The third one is the energy simulation, assessing energy demands using climate data, while the fourth stage is the cost analysis, which estimates construction costs based on local market prices. The final stage is the comparison and evaluation phase, where results are interpreted.

To perform this analysis, a variety of databases were used, including national building codes, climate datasets, and cost databases. The study uses AutoCAD for structural design, ArchiCAD and Lumion for architectural design, Tekla Structures for a detailed view of roof elements, Dlubal RFEM for structural simulations, Mathcad for structural calculations, IDA ICE for dynamic energy modelling, and CENKROS 4 for construction cost estimation.

4 Fundamental considerations

To achieve the goal of the thesis, it is necessary to describe the geographical, climatic, and regulatory context of Slovakia and Finland. These factors play a crucial role in the design and construction of single-family houses, as they influence building envelope performance, structural requirements, and energy efficiency. Equally important is an overview of national regulations, covering structural standards, energy performance, and construction cost frameworks, which establish the requirements that guide residential building practices in each country.

4.1 General description of the building

The family house used for the thesis is a single-storey, non-basement structure without a habitable attic. It is designed as a masonry load-bearing system with a traditional wooden roof structure. The building has an articulated floor plan and forms one dilatation unit with overall ground plan dimensions of 16x14 m and clear ground floor height of 2.65 m.

4.2 Background overview

A country's geographical location and climate are important factors influencing the design of residential buildings. These elements directly impact thermal performance, material selection, structural requirements, and energy demand for heating and cooling. This section provides an overview of climatic and environmental conditions in Slovakia and Finland, highlighting differences in temperature ranges, precipitation, and seasonal variations, as well as traditional construction practices. In addition, key general data such as population, land area, and historical background are presented to provide contextual understanding.

4.2.1 Geographical, demographic, and historical overview

Slovakia is a landlocked country in Central Europe, which covers an area of approximately 49,000 km^2 and has a population of around 5,4 million. The country is bordered by the Czech Republic to the west, Poland to the north, Ukraine to the east, Hungary to the south, and Austria to the southwest, as shown in Figure 1. The country’s topography is diverse, featuring the Carpathian Mountains in the north and central regions and fertile lowlands in the south, mainly along the Danube River. This variation in terrain has historically influenced settlement patterns, agricultural activities, and architectural styles. (Carter et al., 2025)

Figure 1. Map of Slovakia (Carter et al., 2025)

Historically, the geographical position of Slovakia represents a cultural crossroads with influences from the Celts, Romans, and Germanic cultures. During the Middle Ages, the territory was under the Kingdom of Hungary. It later became part of Czechoslovakia during the 20th century and gained its independence again in 1993. These historical influences are reflected in the country's architectural heritage, including castles, churches, and folk houses that are a mix of Gothic, Baroque, and folk styles. (WorkingAbroad, n.d.)

Finland is a country located in Northern Europe, which covers approximately 338,000 km^2 and has a population of 5,6 million. The country is bordered by Russia to the east, Norway to the north, Sweden to the northwest, the Gulf of Bothnia to the southwest, and the Gulf of Finland to the south, as shown in Figure 2. Finland has numerous bodies of water and a relatively flat landscape with slight elevation on the central and southern parts and more rugged and unpopulated land on the northern side. More than 70% of the country's land area is covered by forests, which historically shaped the material choices in construction. (Larson et al., 2023)

Figure 2. Map of Finland (Larson et al., 2023)

Finland has historically been influenced by Sweden and Russia, especially during the periods of Swedish rule and Russian rule. Architecture is reflected by these countries, combining medieval stone churches, Baroque and Neoclassical public buildings, and vernacular wooden houses. (Allplan Blog, 2018)

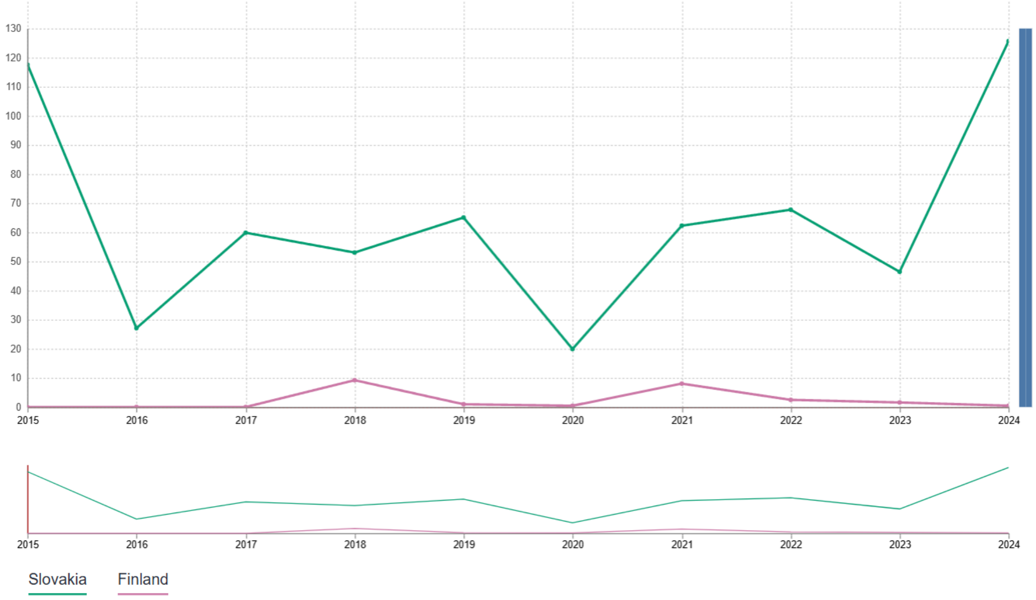
4.2.2 Climatic conditions

Slovakia has a temperate continental climate, characterized by four seasons. Winter is cold, with an average temperature in the lowlands ranging from -2 °C to 2 °C, while in the mountainous areas, it often drops below -10 °C. Summer is warm, with average temperatures between 20 °C and 25 °C, and occasionally peaks exceeding 30 °C. Spring and Autumn are transitional seasons, with moderate temperatures and variable weather conditions. Precipitation is relatively evenly distributed, ranging between 500 mm and 600 mm per year. The annual number of heating degree days (HDD) ranges from 2,500 °C day/year to 3,500 °C day/year, as shown in Figure 3, reflecting significant heating demand in the colder months, while cooling degree days (CDD) are moderate, ranging from 20 °C day/year to 130 °C day/year, as shown in Figure 4. (Climate Data, n.d.-a)

In contrast, Finland has a cold, boreal climate, with long, harsh winters and short, mild summers. In southern Finland, average winter temperatures range from -3 °C to -10 °C, while in northern regions, temperatures often fall below -20 °C. During the summer, it varies between 18 °C and 22 °C, with heat waves on the southern coasts. Spring is short, with rapidly rising temperatures and melting snow, while autumn is characterized by cold temperatures and early snowfall. Precipitation is moderate, ranging between 700 mm and 800 mm per year. Annual heating degree days (HDD) values exceed 5,000 °C day/year, as shown in Figure 3, indicating high heating demand, while cooling degree days (CDD) values remain minimal, typically below 10 °C day/year, as shown in Figure 4. (Climate Data, n.d.-b)

Figure 3. Annual heating degree days (HDD) in Slovakia and Finland (Eurostat, 2025)

Figure 4. Annual cooling degree days (CDD) in Slovakia and Finland (Eurostat, 2025)



4.2.3 Design applications

In Slovakia, timber and stone were the primary resources, with timber primarily used in the mountainous regions and stone or masonry in the lowlands. In rural areas, family houses often feature steeply pitched roofs to shed heavy snow during winter, preventing structural damage. Thick masonry walls, usually made of clay bricks or locally quarried stone, provide high thermal mass by absorbing heat during the day and releasing it at night. Smaller windows were built to reduce heat loss, while walls were protected with roof overhangs from rain and snow. Many historic homes also used joist construction techniques with interlocking corner joints, which offered both structural stability and insulation (Milliard City, 2022). Figure 5 shows a typical family house in Slovakia.

Figure 5. Typical traditional family house in Slovakia (Milliard City, 2022)

In Finland, traditional construction practices are connected with timber as the main resource. Horizontally stacked logs with corner-cut techniques were the most common methods to build residential houses. Steep roofs covered with wooden shingles were used to drain snow and retain heat. Double-glazed windows ensured the reduction of heat losses during long and cold winters. Additionally, Finnish homes often use raised floors or insulated foundations to prevent moisture penetration and frost. Nowadays, residential design continues to use the basics of historical practices, combined with modern techniques (Wikipedia, 2025). Figure 6 shows a typical family house in Finland.

Figure 6. Typical traditional family house in Finland (Wikipedia, 2025)

4.3 Local regulations

National regulations define the legal and technical framework within which buildings must be designed, constructed, and operated. These frameworks also include structural safety, energy efficiency, and cost compliance to ensure that family homes meet expectations for safety, efficiency, and affordability. Although both Slovakia and Finland are strongly influenced by the European Union's regulations, national authorities adopt different standards, reflecting variations in climate, construction traditions, and policy priorities.

4.3.1 Structural and building standards

Structural design requirements in both Slovakia and Finland are primarily regulated by Eurocodes (EN 1990-1999), which provide harmonised rules for the load-bearing capacity, stability, and serviceability of buildings. Each country publishes a national annex that adapts the provisions to local climatic and environmental conditions.

In Slovakia, Eurocodes are completed by Slovak Technical Standards (STN), published by the Slovak Office of Standards, Metrology and Testing (ÚNMS SR). The standards define nationally determined parameters by integrating Eurocode principles with local data, ensuring that structural design reflects the country’s temperate continental climate and traditional construction practices, particularly masonry and reinforced concrete. Compliance is verified by mandatory structural assessments as part of the building permit procedure. (ÚNMS SR, n.d.)

In Finland, structural design also follows Eurocode, which is implemented by the Finnish Standards Association (SFS) and supplemented by National Annexes approved by the Ministry of the Environment (YM). These annexes reflect the country’s boreal climate, with very high snow loads, wind conditions along the coastline, and frost depth values for foundations. Standards place a stronger emphasis on timber construction, which is a dominant material in residential housing. Compliance is monitored by the municipality's building control authorities. (SFS, n.d.)

4.3.2 Energy efficiency requirements

Energy efficiency regulation is one of the most important aspects of modern building design, ensuring that new residential buildings minimize operational energy demand, reduce greenhouse gas emissions, and align with the European Union’s climate and energy goals.

In Slovakia, the regulatory framework focuses on nearly zero-energy buildings (NZEB), which became mandatory for new residential buildings in 2021. The requirements are prescriptive, with strict limits on the thermal transmittance, also known as U-values, of walls, roofs, floors, and openings (Lehocký, 2019). A key document in this context is STN 73 0540-2, which specifies limit values for building envelope elements, primary energy factors, and energy performance limits (STN 73 0540-2, 2012). In addition, energy performance calculations for buildings are specified in Ministerial Decree 324/2016 (Collection of laws on energy performance of buildings 324/2016) and amended by Ministerial Decree 35/2020 (Collection of laws on energy performance of buildings 35/2020).

In Finland, the regulatory approach is more performance-based and focuses on the E-number, a weighted indicator of primary energy demand specified in the Finnish Building

Code RaKMK D3 (Global Buildings Performance Network, n.d.). Due to the harsh climate, building envelope requirements are among the strictest in the European Union, with particularly low U-value limits, specified in Ministry of the Environment Decree 1010/2017 (Decree of the Ministry of the Environment on the Energy Performance of New Buildings 1010/2017). In addition, the energy coefficients for E-number calculation are defined in Government Decree 788/2017 (Government Decree on the numerical values of coefficients for forms of energy used in buildings 788/2017). The E-number limits are defined by Ministry of the Environment Decree 1048/2017 (Decree of the Ministry of the Environment on the Energy Certificate of a Building 1048/2017)

4.3.3 Construction cost factors

The cost of construction depends on material choices, labor costs, and regulatory rules. In Slovakia, lower labor costs help cut overall expenses, but using masonry systems and energy efficiency standards increases material costs. Conversely, Finland faces higher labor costs mainly because of industrialized timber prefabrications, which improve on-site efficiency and shorten construction time.

5 Theory

Before performing any calculations, comparative analysis, or evaluations, it is necessary to understand the fundamental principles behind building design. This section explains different loads acting on the structure, materials used for the building, essential building elements, and important energy-related concepts.

5.1 Load considerations

Loads are the forces or weights acting on a building that influence its stability, strength, and safety. Understanding the types and magnitudes of loads is essential for designing safe and durable structures. Without the correct loads, the design may result in overdesign, which is uneconomical, or underdesign, which can lead to structural failure. Design for loads is typically done using the Ultimate Limit State (ULS) approach, which ensures that the building can safely withstand the maximum expected load. (The Structural World, 2018)

In Slovakia, the load combination equations are applied according to Annex 1, Table A1.2(B), Eq. 6.10 from Eurocode 1990 (SFS EN 1990, 2002, p. 52) as shown in Equation 1. The Ψ_0

values, which account for variable actions, are explained in Annex 1, Table A1.1 (SFS EN 1990, 2002, p. 49), and the K_{FI} factor, which adjusts for reliability class, is shown in Annex 1, Table B3 (SFS EN 1990, 2002, p. 59).

Equation 1. Design values of actions in Slovakia (STR/GEO) (Set B)

$$1{,}35 \cdot K_{FI} \cdot G_{kj,sup} + 1 \cdot G_{kj,inf} + 1{,}5 \cdot K_{FI} \cdot Q_{k,1} + 1{,}5 \cdot K_{FI} \cdot \sum_{i>1} \psi_{0,i} \cdot Q_{k,i}$$

Where:

$G_{kj,sup}$	Characteristic upper value of the permanent action (unfavourable)
$G_{kj,inf}$	Characteristic lower value of the permanent action (favourable)
$Q_{k,1}$	Characteristic value of the leading variable action
$Q_{k,i}$	Characteristic value of the accompanying variable action
K_{FI}	Factor for actions
$\psi_{0,i}$	Combination factor for an accompanying variable action

In Finland, the load combination equations are applied according to Section 3, Table 3, Note 1 from the National Annex (National Building Code of Finland, 2016, p. 23), as shown in Equation 2. The Ψ_0 values are explained in Section 2, Table 1 in the National Annex (National Building Code of Finland, 2016, p. 21), and the K_{FI} factor is taken from the same code for both countries.

Equation 2. Design values of actions in Finland (STR/GEO) (Set B)

$$\begin{cases} 1{,}15 \cdot K_{FI} \cdot G_{kj,sup} + 0{,}9 \cdot G_{kj,inf} + 1{,}5 \cdot K_{FI} \cdot Q_{k,1} + 1{,}5 \cdot K_{FI} \cdot \sum_{i>1} \psi_{0,i} \cdot Q_{k,i} \\ 1{,}35 \cdot K_{FI} \cdot G_{kj,sup} + 0{,}9 \cdot G_{kj,inf} \end{cases}$$

Where:

$G_{kj,sup}$	Characteristic upper value of the permanent action (unfavourable)
$G_{kj,inf}$	Characteristic lower value of the permanent action (favourable)
$Q_{k,1}$	Characteristic value of the leading variable action
$Q_{k,i}$	Characteristic value of the accompanying variable action
K_{FI}	Factor for actions
$\psi_{0,i}$	Combination factor for an accompanying variable action

5.1.1 Dead load

Dead load is a permanent load on the structure that acts throughout its entire lifespan. These loads are primarily caused by the self-weight of both structural and non-structural building components (Civil Practical Knowledge, 2024). In Eurocode terminology, dead load is considered as a permanent action. Its value can be determined similarly in Slovakia and Finland by calculating volume, mass, and density, or by referencing Annex A in Eurocode 1991-1-1 (SFS EN 1991-1-1, 2002, pp. 32-42).

5.1.2 Live load

Live load refers to a temporary force that can change over time. It includes loads from occupants, furniture, movable equipment, and vehicles, depending on the building type and function. Within the Eurocode framework, live loads are classified as variable loads (Civil Practical Knowledge, 2024). In Slovakia, values are specified in Eurocode 1991-1-1 (SFS EN 1991-1-1, 2002), while in Finland, both the National Annex (National Building Code of Finland, 2019) and Eurocode 1991-1-1 (SFS EN 1991-1-1, 2002) specify them partially.

5.1.3 Snow load

Snow load represents a climatic action that results from the accumulation of snow on building roofs and other structural surfaces. It depends on the geographical location, altitude, roof shape, roof slope, exposure to wind, and thermal conditions of the building. Eurocode classifies it as a variable load (Civil Practical Knowledge, 2024). Snow load is calculated using Clause 5.2(3), Equation 5.1 (SFS EN 1991-1-3, 2003, p. 18) as shown in Equation 3. The snow load shape coefficient is derived from Clause 5.3.2(2), Table 5.2 (SFS EN 1991-1-3, 2003, p. 21), while the thermal coefficient is expressed in Clause 5.2(8) (SFS EN 1991-1-3, 2003, p. 20), and the exposure coefficient is expressed in Clause 5.2(7) Table 5.1 (SFS EN 1991-1-3, 2003, p. 20).

In Finland, the National Annex provides recommendations for the snow exposure coefficient in Table 2 of Section 3, and for the characteristic snow load value on the ground in Figure 1 of Section 1 (National Building Code of Finland, 2019, p. 15, 17).

In Slovakia, the recommended value for the exposure coefficient according to the National Annex is given in Clause 4.2(1), and the characteristic snow load value on the ground is specified in Clause 4.1(1) (STN EN 1991-1-3/NA, 2012).

Equation 3. Snow loads on roofs for the persistent/transient design situations

$$S = \mu_i \cdot C_e \cdot C_t \cdot S_k$$

Where:

μ_i	Snow load shape coefficient
C_e	Exposure coefficient
C_t	Thermal coefficient
S_k	Characteristic value of snow load on the ground

5.1.4 Wind load

Wind load is a dynamic climatic action caused by the pressure and suction effects of wind action on the external and internal surfaces of a structure. The intensity of wind depends on geographical location, terrain category, building height, shape, and orientation. Eurocode classifies it as a variable load (Civil Practical Knowledge, 2024). The critical wind load is calculated using the formulas outlined in Clause 4.3-4.5 (SFS EN 1991-1-4, 2005, pp. 19-23). The terrain category and values for z_0 and z_{min} are determined based on visual inspection of the surroundings, as per Table 4.1 and Annex A1 (SFS EN 1991-1-4, 2005, p. 20, p. 92). Wind pressure zones acting on the building are identified to ensure the structure can withstand the anticipated forces.

Basic wind velocity is a key parameter in the determination of wind load, and the exact value is defined in each country’s National Annex. In Slovakia, Clause 4.1(1) (STN EN 1991-1-4/NA, 2010) defines it, while in Finland it is given in Section 2 (National Building Code of Finland, 2019, p. 22).

5.2 Building materials

The selection of building materials is a critical aspect of construction design, influencing the structural integrity, durability, and overall performance of the building. For this project, the primary materials used are concrete, timber, and masonry.

5.2.1 Concrete

Concrete is a composite material made of cement, coarse aggregates, fine aggregates, water, and in some cases, chemical or mineral admixtures. When these components are mixed, hydration occurs, leading to a solid material that can be poured into almost any shape. Concrete has a high compressive strength and long-term durability, which make it suitable for a wide range of structural applications. However, it has relatively low tensile strength, which is usually addressed by reinforcing it with materials like steel bars or mesh. (UltraTech, n.d.)

5.2.2 Timber

Timber refers to wood from trees that is used as a building or carpentry material. It is one of the oldest construction materials and continues to play a significant role in modern building design due to low thermal conductivity, high strength-to-weight ratio, and aesthetics. Timber is categorized into softwoods, which come from coniferous trees such as pine or spruce, and hardwoods, which come from deciduous trees such as oak or teak. The selection depends on the structural requirements, durability, and aesthetic considerations. The durability of timber is influenced by treatment methods, including seasoning, the application of chemical preservatives, and the use of surface finishes or coatings. (Civil Engineering, n.d.)

5.2.3 Masonry

Masonry refers to a construction technique that involves assembling individual units, which are bonded together with mortar. The most common materials used in masonry construction are brick, stone, and concrete. The performance of the masonry depends on the quality of the units and the composition of the mortar. Masonry has high compressive strength, with excellent fire resistance and thermal mass, enabling to store heat efficiently. To compensate for the low resistance to tension and shear forces, reinforced masonry is often employed. Additionally, it does not require highly skilled labor, as the units have uniform size and shape. (Nearby Engineers, n.d.)

5.3 Building elements

The main components of a structure are formed from building elements that collectively provide stability and functionality. Their design, material selection, and construction method directly affect safety, durability, comfort, and energy efficiency. Each component plays a critical role in ensuring that the building performs effectively under various environmental and operational conditions. This section examines the primary building elements used for the project.

5.3.1 Foundation

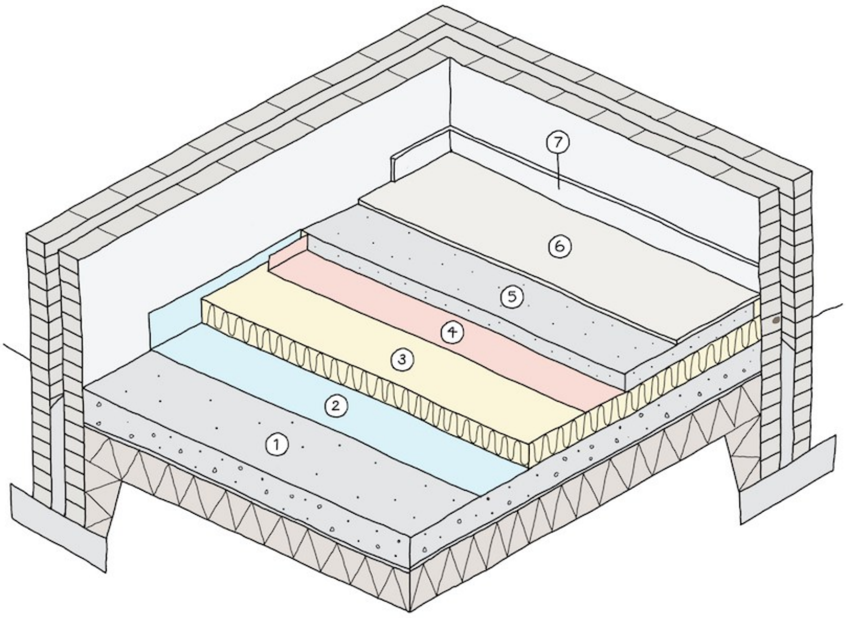
The foundation is the lowest structural element of a building, usually placed below the surface of the ground, and that transfers the load of the building safely and evenly to the underlying soil or rock. The two fundamental requirements in foundation design are that the total settlement of the structure remains within acceptable limits and that differential settlement between different parts of the structure is minimized as much as possible. These requirements apply to both spread foundations, which distribute loads over a wide area of soil, and individual foundations, which support a single or isolated structural element. Foundations are generally categorized into shallow and deep foundations. The design is influenced by several key factors, including soil bearing capacity, groundwater level, load magnitude, and environmental conditions. A comprehensive geotechnical investigation is recommended before designing the foundation. (Nilson et al., 2010, p. 559). Figure 7 shows a building foundation structure.

Figure 7. Building foundation (BMB Steel, 2024)

5.3.2 Floor

A floor is a horizontal structural element that forms the base or platform of a building. Floors provide a stable, level, and durable surface for occupants, furnishing, and equipment. Floors can be classified into ground floor, situated at ground level, which typically supports higher loads and often incorporates thermal and moisture protection to prevent heat loss and rising damp. The intermediate floors, positioned above ground level, provide additional space and must be designed to resist deflection, vibration, and sound transmission. In building construction, a floor typically consists of several layers. The subfloor is the lower part of the structure, provides the primary structural support for the layers above. The underlayment is a thin layer placed over the subfloor to create a smooth, uniform surface. The floor finishing is the top, visible layer, which is selected based on the functional requirements and aesthetic preferences. (Construo, n.d.-a). Figure 8 presents the structural arrangement of a building floor structure.

Figure 8. Building floor (Coates, 2024)



A typical construction buildup for insulating a new concrete floor: 1- Slab; 2- DPM; 3- Rigid insulation; 4- VCL; 5- Screed; 6- Floor finish; 8- Skirting.

5.3.3 Wall

A building wall is a vertical structural element that functions as a barrier or partition, designed to enclose, divide, or support a structure. Walls may be constructed from a variety of materials, including bricks, concrete blocks, stone, timber framing, or metal systems. The performance of walls is significantly influenced by their material composition, thickness, insulation, and finishing treatments. They can be categorized as load-bearing or non-load-bearing, based on their role within the structural system. (Construo, n.d.-b). Figure 9 shows a building wall structure.

Figure 9. Building wall (Constructips, 2021)

5.3.4 Beam and ring beam

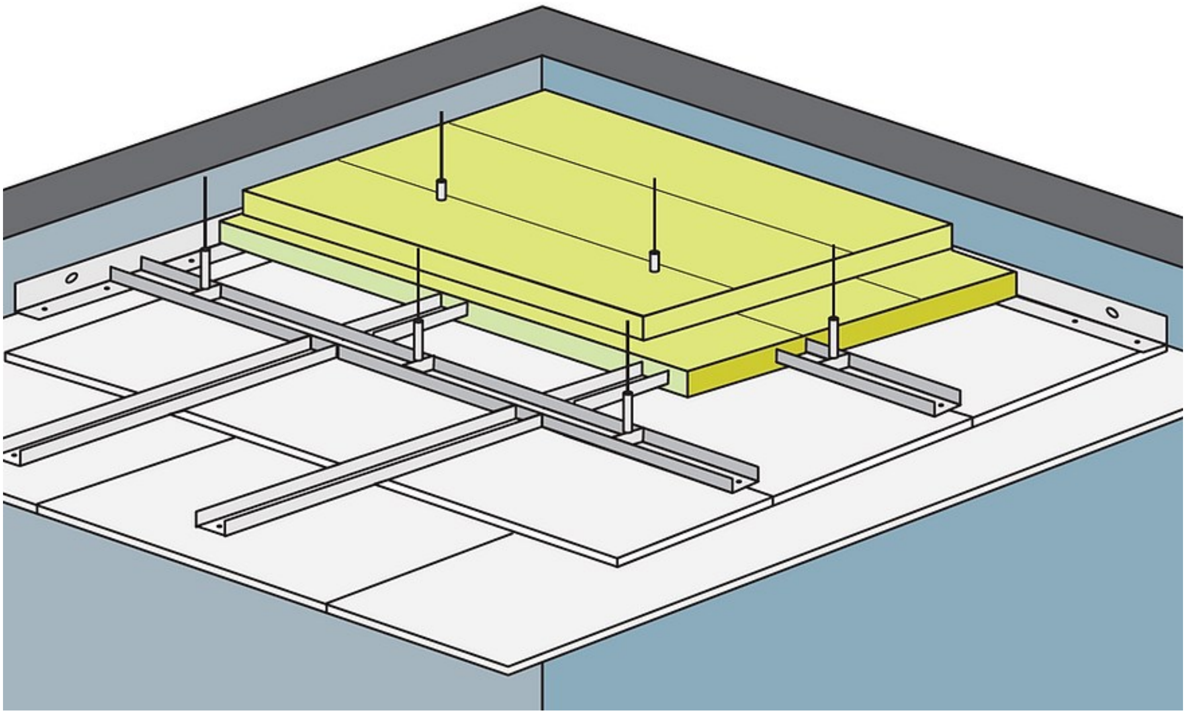
A beam is a horizontal or inclined structural element designed to resist loads applied laterally to its longitudinal axis. It functions as a load-bearing member that supports the weight of structural elements positioned above it. Beams play a fundamental role in the distribution and transfer of loads. Modern beams are manufactured in a variety of shapes and configurations, including rectangular, I-beams, H-beams, T-beams, and box sections, depending on the required application. They can be constructed from materials such as wood, steel, or reinforced concrete. (Chicago Architecture Center, n.d.). A ring beam is a horizontal structural element typically at the top of a building wall, forming a continuous rectangular or closed-loop framework around the structure. The primary function of a ring beam is to bind and stabilize the walls. (Putih, 2024). Figure 10 shows a ring beam structure.

Figure 10. Ring beam (Taloasro, 2022)

5.3.5 Ceiling

The ceiling is the uppermost interior surface of a room or enclosed space. Ceilings are an integral element in building construction, contributing both to the functionality and aesthetic quality of the interior spaces, concealing structural elements, electrical wiring, plumbing, and HVAC systems, while providing a visually unified surface. In addition to its decorative role, the ceiling is integral to a building’s thermal, acoustic, and fire performance. Ceilings can be constructed from a variety of materials, including plaster, drywall, wood, metal, tiles, or acoustic panels. (Construo, n.d.-c). Figure 11 presents the layout of a ceiling structure.

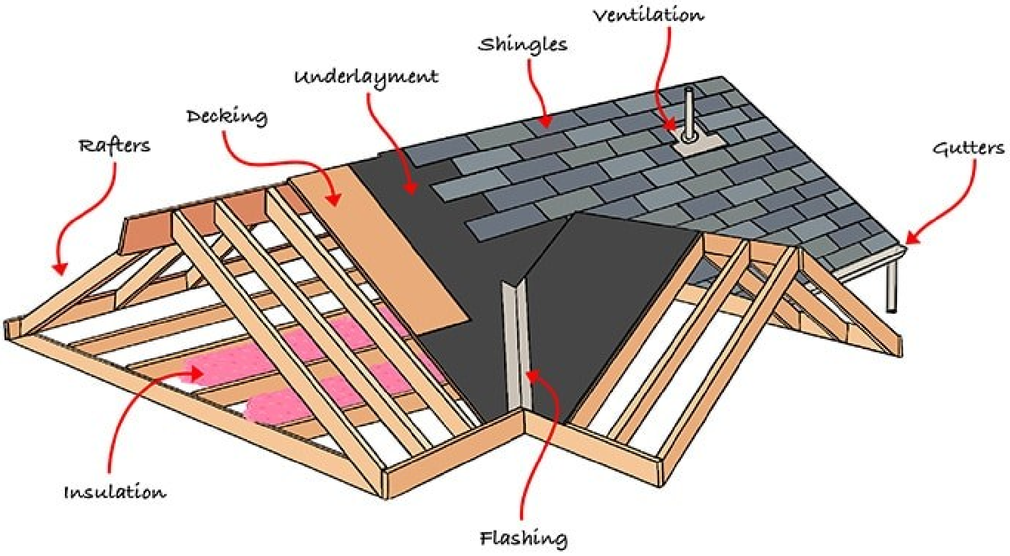
Figure 11. Ceiling structure (Wedge Group, n.d.)



5.3.6 Roof

The roof is the uppermost structural covering of a building, designed to protect the interior space from exterior environmental conditions. It functions as the primary weatherproof barrier, ensuring the comfort, safety, and durability of the structure. The choice of roofing materials and design depends on various factors, including climatic conditions, architectural style, structural requirements, and maintenance considerations. Common roofing materials include asphalt shingles, metal sheets, clay or concrete tiles, slate, and timber shakes. The main load-bearing elements (rafters or trusses) form the structural framework that supports the roof covering and transfers the load. Roofs are constructed in various forms, such as flat, pitched, hipped, gable, domed, or vaulted. (Construo, n.d.-d). Figure 12 illustrates the structural configuration of a roof structure.

Figure 12. Roof structure (Bilicich, 2024)



5.4 Energy principles

Energy principles in building design focuses on minimizing energy consumption while maintaining thermal comfort, indoor air quality, and environmental sustainability. The effective application of these principles is essential for achieving high-performing buildings. This section discusses the key factors that influence the energy performance of a building.

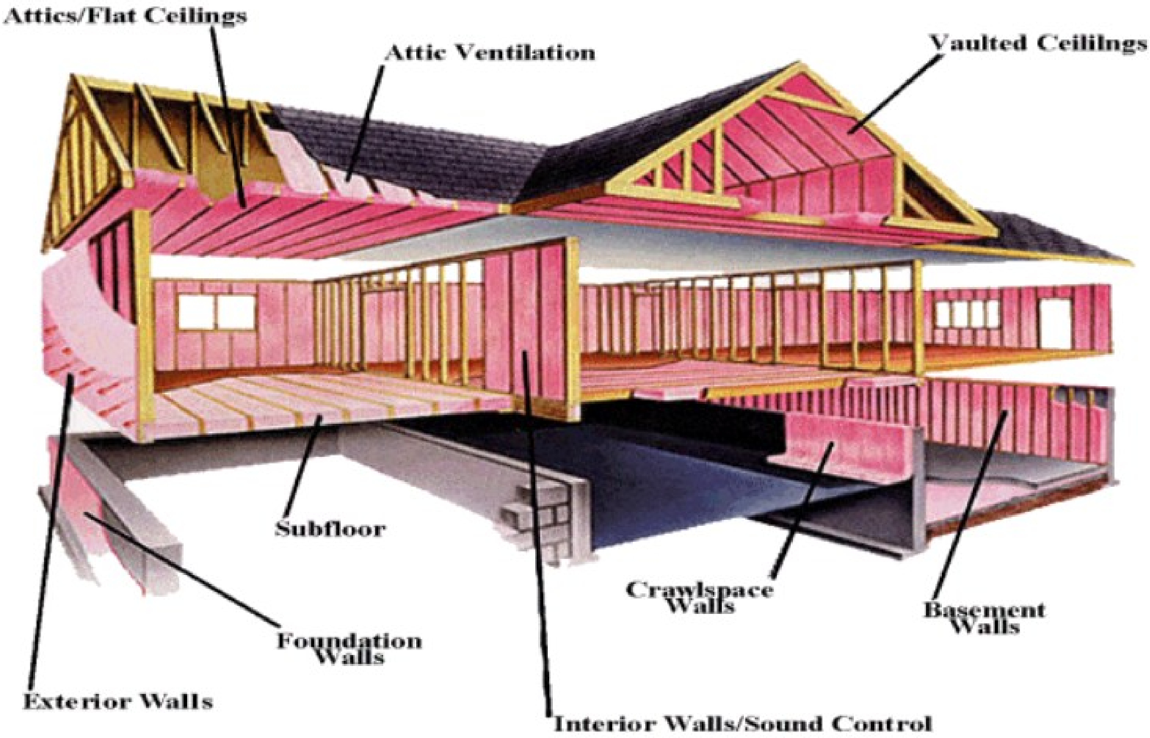
5.4.1 Thermal transmittance

Thermal transmittance, also known as U-value, is the rate of transfer of heat, measured in watts, through a one square meter of a structure, weather it is a single material or a composite, divided by the temperature difference across the structure in Kelvin. The units of measurement are watts per square meter Kelvin (W/m^2K). Lower U-values indicate better thermal resistance, resulting in reduced heat loss in cold climates and minimized heat gain in hot climates. If insulation is fitted poorly, containing gaps and cold bridges, the thermal transmittance can be higher than desired. The U-value of a building element is influenced by several factors, including the thermal conductivity of the material, thickness, layering, and density. Heat losses due to conduction, convection, and radiation are considered in thermal transmittance. (NBS, n.d.)

5.4.2 Insulation

Thermal insulation reduces the rate of heat transfer between interior and exterior environments by preventing heat gain or loss through the building envelope, thereby reducing energy consumption, and improving thermal comfort. It resists the flow of conductive heat, and it is measured by thermal resistance, also known as the R-value. The R-value is expressed in square meters Kelvin per watt (m^2K/W), and the greater it is, the better the material insulates. Another important property of the thermal insulation material is the thermal conductivity, also known as the lambda value (λ), expressed in watts per meter Kelvin (W/mK). Insulation materials have low conductivity, often less than 0.1W/mK. Effective insulation minimizes heat loss during cold periods and heat gain during hot periods, reducing the reliance on mechanical heating and cooling systems. Generally, in residential buildings, insulation is installed for basements, floors, walls, ceilings, and attics, as the placement is shown in Figure 13. (Thermtest, 2024)

Figure 13. Insulation placement of a residential building (123 Remodeling, 2015)



5.4.3 Energy efficiency

Energy efficiency in a building is the practice of designing, constructing, and operating a structure to minimize energy consumption while maintaining occupant comfort, indoor air quality, and functionality. It is a fundamental principle of sustainable building design, aiming to reduce the environmental impact of buildings, lower operational costs, and improve overall energy performance. A key concept in assessing energy efficiency is the E-value, also known as the energy performance index. The E-value is a quantitative measure of the total energy consumption of a building per unit of floor area over a specified period, expressed in kWh/(m^2·year). It accounts for all the energy used for heating, cooling, ventilation, lighting, and domestic hot water. Lower E-value indicates higher energy efficiency. (Gamak, 2023). The classification of E-values for residential buildings in Finland is presented in Table 1, while the corresponding classification for Slovakia is provided in Table 2.

Table 1. Class limits for E-number for residential buildings in Finland in kWh/(m^2·year) (Decree of the Ministry of the Environment on the Energy Certificate of a Building 1048/2017)

Class	**Category 1 – Residential Buildings**		
	$50\ m^2 \leq A_{netto} \leq 150\ m^2$	**$150\ m^2 < A_{netto} \leq 600\ m^2$**	**$A_{netto} > 600\ m^2$**
A	$\leq 110 - 0.2 \times A_{netto}$	$\leq 83 - 0.02 \times A_{netto}$	≤ 70
B	$110 - 0.2 \times A_{netto} <$ E–number $\leq 215 - 0.6 \times A_{netto}$	$83 - 0.02 \times A_{netto} <$ E–number $\leq 131 - 0.04 \times A_{netto}$	$71 \leq$ E–number ≤ 106
C	$215 - 0.6 \times A_{netto} <$ E–number $\leq 252 - 0.6 \times A_{netto}$	$131 - 0.04 \times A_{netto} <$ E–number $\leq 173 - 0.07 \times A_{netto}$	$107 \leq$ E–number ≤ 130
D	$252 - 0.6 \times A_{netto} <$ E–number $\leq 332 - 0.6 \times A_{netto}$	$173 - 0.07 \times A_{netto} <$ E–number $\leq 253 - 0.07 \times A_{netto}$	$131 \leq$ E–number ≤ 210
E	$332 - 0.6 \times A_{netto} <$ E–number $\leq 462 - 0.6 \times A_{netto}$	$253 - 0.07 \times A_{netto} <$ E–number $\leq 383 - 0.07 \times A_{netto}$	$211 \leq$ E–number ≤ 340
F	$462 - 0.6 \times A_{netto} <$ E–number $\leq 532 - 0.6 \times A_{netto}$	$383 - 0.07 \times A_{netto} <$ E–number $\leq 453 - 0.07 \times A_{netto}$	$341 \leq$ E–number ≤ 410
G	$532 - 0.6 \times A_{netto} <$	$453 - 0.07 \times A_{netto} <$	$411 \leq$

Table 2. Class limits for E-number for residential buildings in Slovakia in kWh/(m^2·year) (Collection of laws on energy performance of buildings 324/2016)

Category	**Class**							
	A0	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Residential Buildings	≤ 54	55-108	109-216	217-324	325-432	433-540	541-648	> 648

6 Structural engineering

Structural engineering is a critical aspect of the building design process, ensuring that the structure is capable of safely supporting and transmitting the imposed loads to the ground without excessive failure or deformation. The main objective is to achieve a balance between safety, functionality, economy, and constructability, while complying with applicable design standards and codes such as the Eurocode system (EN 1990 – EN 1999).

In this thesis, the structural design focuses on the main load-bearing components. These components collectively form the primary load path through which horizontal and vertical loads are distributed from the superstructure to the substructure. The structural engineering process involves determining load magnitudes and ensuring that all the structural members can resist these loads.

6.1 Structural calculation methodology

The methodology for structural calculations follows a step-by-step analytical approach consistent with the Eurocode principles. The first step of the procedure was the load identification, in which all relevant actions were determined based on the building's location in Slovakia in the city of Dunajská Streda and in Finland in the city of Hämeenlinna, geometry, and occupancy type. These loads were then combined to find the most critical design scenarios for the ultimate limit state (ULS).

The analysis and load combination process was performed using Dlubal RFEM, a finite element analysis software. The software allows accurate simulation of structural behaviour under various loading conditions. Different load combinations are automatically generated based on the prescribed national annexes, and the most critical combinations are chosen for each structural element. These combinations were then used to assess the load-bearing capacity of key elements with Mathcad, providing a transparent environment for presenting and documenting the calculations.

It is important to mention that the structural performance part focuses primarily on comparing the ultimate limit state between Slovakia and Finland. Serviceability limit state (SLS) is not considered in detail, as it has minimal impact on the comparative evaluation.

6.2 Load analysis

The loads considered in this project were determined according to the Eurocode framework and the corresponding national annexes for Slovakia and Finland. All load types, their theoretical background, and calculation methods are described in detail in section 5.1 of this thesis, where the relevant formulas and parameters are introduced. This section focuses on the practical application of those definitions within the structural design model.

The analysed building is a single-family residential house, classified as consequence class 2 (CC2) in accordance with Table B1 from Eurocode 1990 (SFS EN 1990, 2002, p. 58). This classification defines the reliability requirements adopted for load combinations and material safety factors. Corresponding to CC2, the building falls under reliability class 2 (RC2), which defines the partial safety factor for actions (K_{FI}) as 1 according to Table B3 from Eurocode 1991 (SFS EN 1991-1-1, 2002, p. 59).

Permanent loads include the self-weight of all structural and non-structural elements that stay constant throughout the building's lifespan. For reinforced concrete components such as the foundation, base slab, and ring beam, the loads were calculated analytically using the component volumes and the concrete density of 25 kN/m³ as specified in Table A.1 of Eurocode 1991-1-1 (SFS EN 1991-1-1, 2002, p. 32). For timber components like the roof structure, the self-weight was automatically generated in Dlubal RFEM based on the assigned material and geometry. For masonry elements including walls and plinths, the unit weights were obtained directly from the manufacturer’s data sheets for the specific type of bricks used.

Variable live loads are temporary and depend on building occupancy and use. According to Table 6.1 in Eurocode 1991-1-1 (SFS EN 1991-1-1, 2002, p. 21), the building falls under category A (residential areas). In both Slovakia and Finland, the live load value for category A is 2 kN/m^2. However, in Slovakia, the load is derived from Table 6.2 in Eurocode 1991-1-1 (SFS EN 1991-1-1, 2002, p. 22), while in Finland, it is detailed in Section 3 of the National

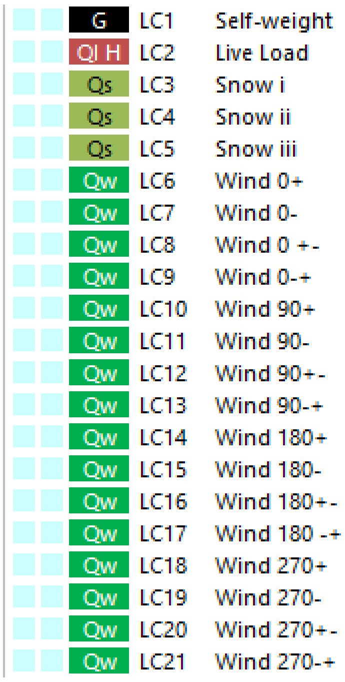
Annex (National Building Code of Finland, 2019, p. 5). Additionally, roof maintenance and access loads were considered, with a recommended magnitude of 0.4 kN/m^2 as per Table 6.10 in Eurocode 1991-1-1 (SFS EN 1991-1-1, 2002, p. 29).

Snow loads are crucial climatic factors, especially when comparing Slovakia and Finland, as both countries experience different snow conditions. As mentioned earlier in this document, snow loads are determined using parameters specified in national snow zone maps and coefficients depending on roof geometry and local site conditions. After gathering all the necessary data, the characteristic snow load was calculated for each location. In Dunajská Streda, in Slovakia, the computed snow load is 0.46 kN/m^2, while in Hämeenlinna, in Finland, it is 2 kN/m^2. These loads were then applied to the timber roof using Dlubal RFEM software, producing a realistic pressure distribution for analysis. The detailed snow load calculations are shown for Slovakia in Appendix 6/2 and for Finland in Appendix 6/3.

Wind actions were assessed following the steps outlined in the theory section of this thesis. It is important to note that since the building has an L shape and Eurocode specifies wind calculations only for square and rectangular shapes, an alternative method was used to determine the wind load. The building was divided into two rectangular sections, which were examined separately. Although this may not provide exact values, it is sufficiently close for comparative analysis. The basic wind velocity (vb,0) was taken as 24 m/s for Slovakia, as specified in Clause 4.1(1) of the National Annex (STN EN 1991-1-4/NA, 2010), and 21 m/s for Finland, referenced in Section 2 of the National Annex (National Building Code of Finland, 2019, p. 22). The terrain category, representing surface roughness and surrounding topography, was designated as category III, representing suburban terrain with a regular cover of buildings and vegetation, according to Annex A.1 of Eurocode 1991-1-4 (SFS EN 1991-1-4, 2025, p. 92). Using these parameters, the peak velocity pressure (qp) and external pressure coefficients (cpe) were calculated for the building’s walls and roof surfaces for each case and location. The resulting wind pressure distributions were then applied to each zone as area loads in the Dlubal RFEM structural model, providing a realistic representation of aerodynamic effects on the building envelope. The detailed wind pressure calculations for each zone are included for Slovakia in Appendix 6/4-21 and for Finland in Appendix 6/22-39.

All load cases, shown in Figure 14, were defined and combined in Dlubal RFEM following the principles and equations explained previously in the theory part. Within the software, all possible load cases were combined automatically according to the Eurocode’s combination factors (Ψ). The software generated the relevant design situations and identified the most critical load combination for each structural element of the roof. The resulting internal forces, bending moments, and support reactions obtained from the software were then exported and verified for the critical elements in Mathcad. This verification process ensures that each element's load-bearing capacity satisfies the design criteria defined in Eurocodes.

Figure 14. Load cases for load combinations (Dlubal Software GmbH, 2025)



G	LC1	Self-weight
QI H	LC2	Live Load
Qs	LC3	Snow i
Qs	LC4	Snow ii
Qs	LC5	Snow iii
Qw	LC6	Wind 0+
Qw	LC7	Wind 0-
Qw	LC8	Wind 0 +-
Qw	LC9	Wind 0-+
Qw	LC10	Wind 90+
Qw	LC11	Wind 90-
Qw	LC12	Wind 90+-
Qw	LC13	Wind 90-+
Qw	LC14	Wind 180+
Qw	LC15	Wind 180-
Qw	LC16	Wind 180+-
Qw	LC17	Wind 180 -+
Qw	LC18	Wind 270+
Qw	LC19	Wind 270-
Qw	LC20	Wind 270+-
Qw	LC21	Wind 270-+

6.3 Structural components and materials

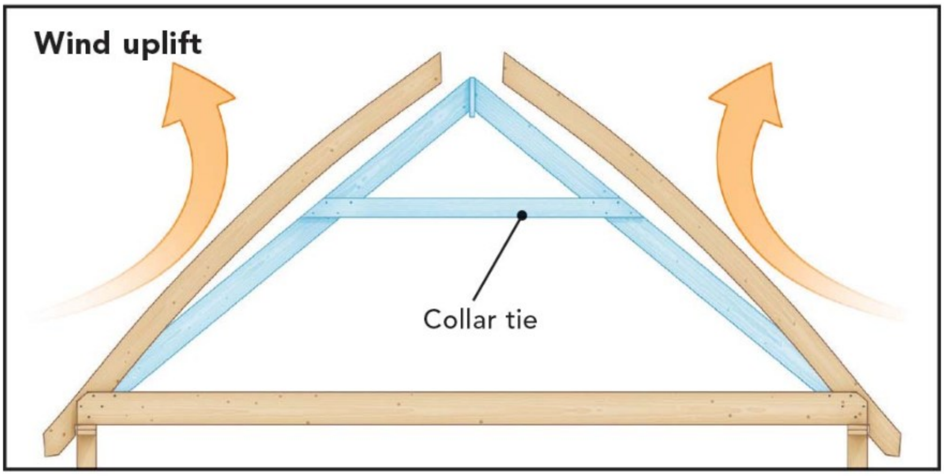
This section outlines the main structural components and materials used in the case study's design phase. Each part serves a specific purpose in maintaining overall strength, load transfer, and durability. All critical components were verified according to the relevant Eurocode and national annex, using Mathcad to ensure transparent and consistent documentation of the analytical process.

6.3.1 Collar tie roof

The roof structure of the building is designed as a timber collar tie roof with rafter ties, a hybrid structural system that effectively combines the advantages of both configurations. This system consists of paired collar ties, also called upper collar ties, positioned in the upper third of the roof height, and paired rafter ties, also called lower collar ties, located near the base of the rafters. These members provide vertical load-bearing capacity and horizontal restraint for the roof structure. The vertical middle column, also called the king post, helps to distribute loads from the ridge beam to the bottom ties, preventing mid-span deflection. All timber elements are supported on top of the timber wall plate.

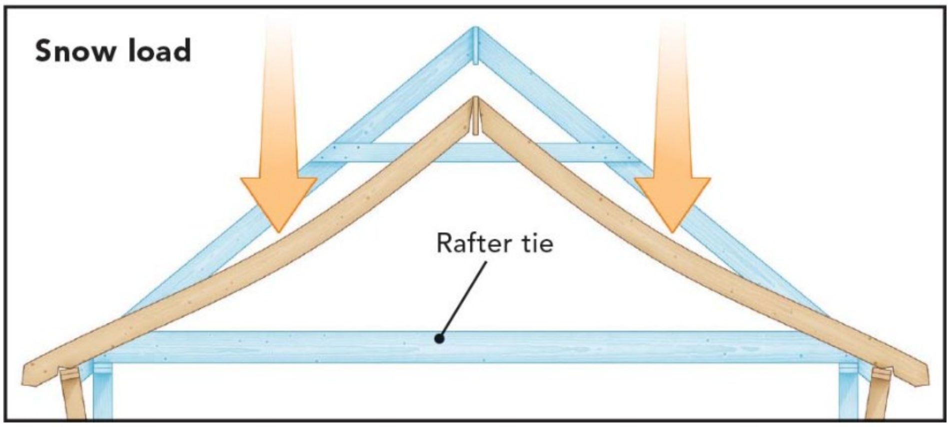
Collar ties are horizontal members placed in the upper third of the roof structure. They typically connect opposing rafters near the ridge and resist the separation of the rafters at the ridge due to uplift forces, which can occur during high winds or unbalanced roof loads. Figure 15 shows the position and function of a collar tie. (Silber, 2014)

Figure 15. Function and position of a collar tie (Silber, 2014)



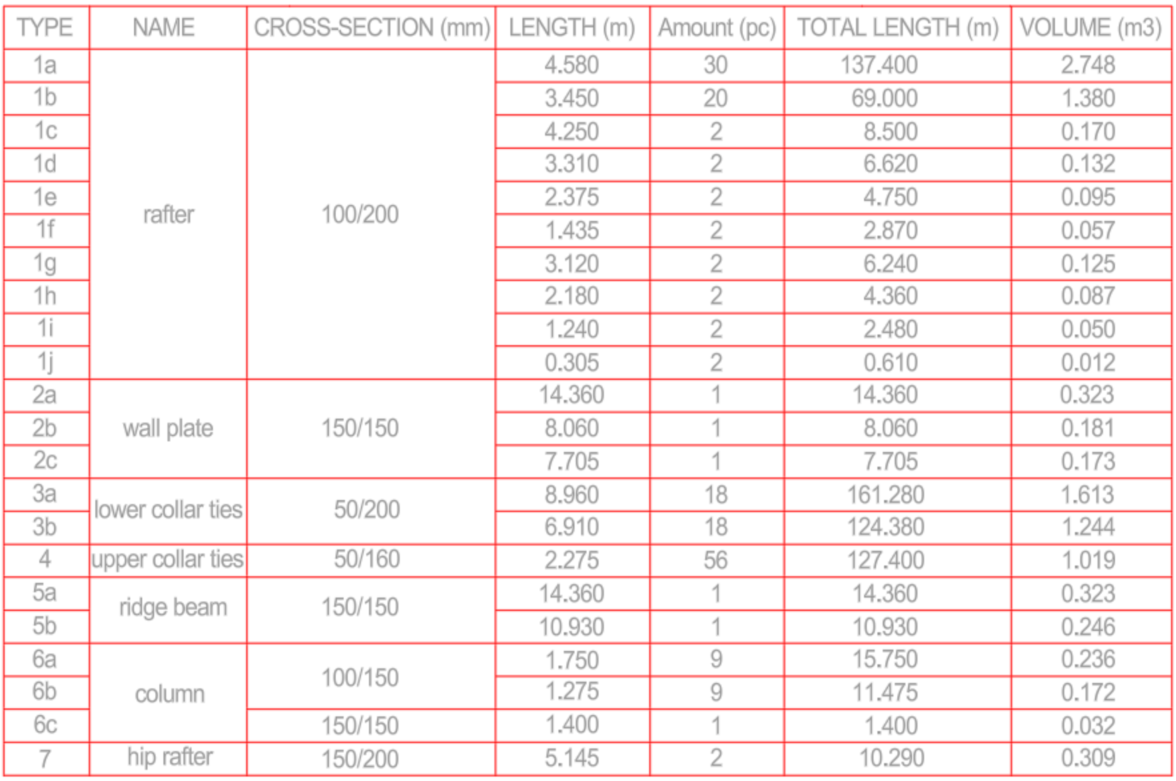
Rafter ties are horizontal members installed in the lower third of the roof structure. They typically connect opposing rafters near the support and resist the outward thrust exerted by the rafters under gravity loads, such as dead loads and snow accumulation. Figure 16 shows the position and function of a rafter tie. (Silber, 2014)

Figure 16. Function and position of a rafter tie (Silber, 2014)



The roof structure is designed as a traditional timber roof system with a 25-degree slope, built on-site, also called a traditional carpentry roof, made of softwood with a strength class of C24. The strength classes and their properties are specified in the European Standard EN 338 (SFS EN 338, 2016). The timber elements have various cross-sectional dimensions, which are listed in the list of timber for the roof structure, shown in Figure 17.

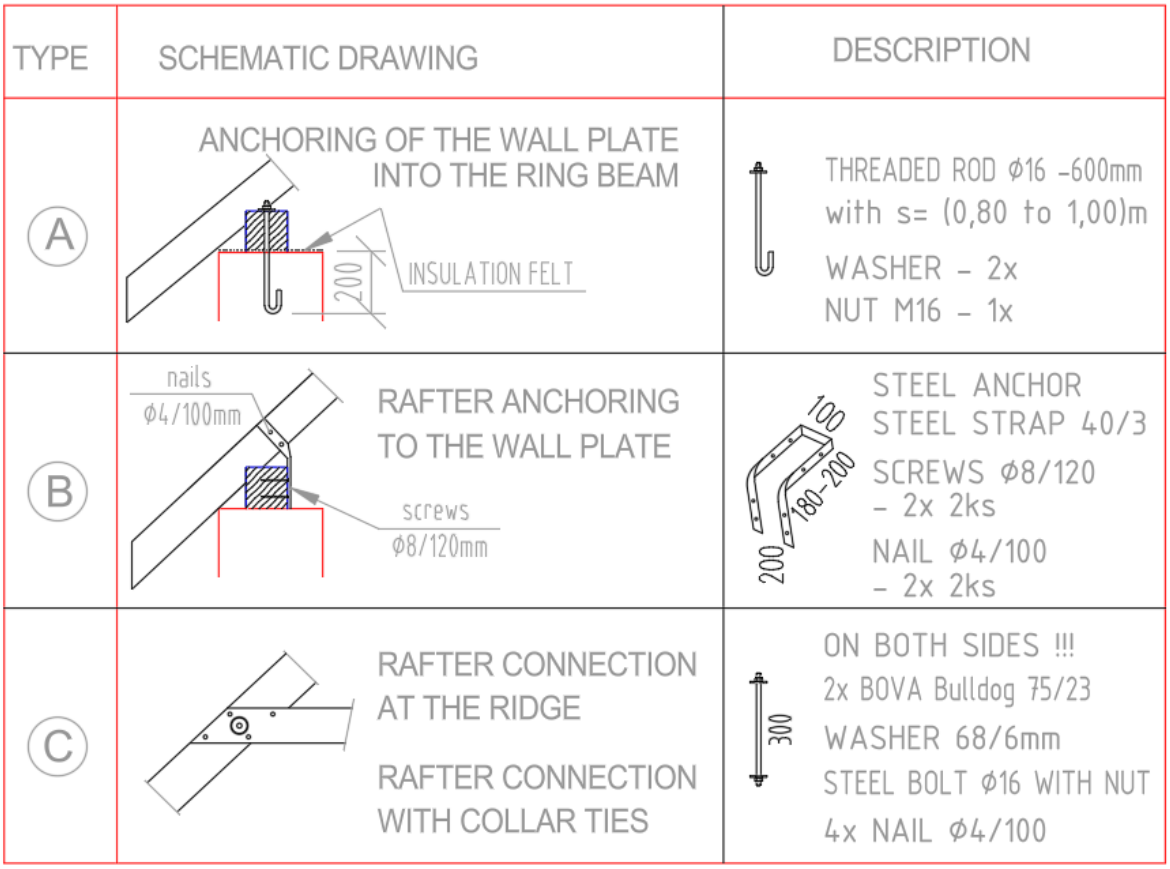
Figure 17. List of timber for the roof structure



TYPE	NAME	CROSS-SECTION (mm)	LENGTH (m)	Amount (pc)	TOTAL LENGTH (m)	VOLUME (m3)
1a	rafter	100/200	4.580	30	137.400	2.748
1b			3.450	20	69.000	1.380
1c			4.250	2	8.500	0.170
1d			3.310	2	6.620	0.132
1e			2.375	2	4.750	0.095
1f			1.435	2	2.870	0.057
1g			3.120	2	6.240	0.125
1h			2.180	2	4.360	0.087
1i			1.240	2	2.480	0.050
1j			0.305	2	0.610	0.012
2a	wall plate	150/150	14.360	1	14.360	0.323
2b			8.060	1	8.060	0.181
2c			7.705	1	7.705	0.173
3a	lower collar ties	50/200	8.960	18	161.280	1.613
3b			6.910	18	124.380	1.244
4	upper collar ties	50/160	2.275	56	127.400	1.019
5a	ridge beam	150/150	14.360	1	14.360	0.323
5b			10.930	1	10.930	0.246
6a	column	100/150	1.750	9	15.750	0.236
6b			1.275	9	11.475	0.172
6c		150/150	1.400	1	1.400	0.032
7	hip rafter	150/200	5.145	2	10.290	0.309

The individual members are connected using a combination of mechanical fasteners and timber joints. At the ridge, rafters are joined with a Bova Bulldog steel rod. In contrast, at the tie connections, M16 steel bolts and nuts are used, with additional nails (4 x Φ4/100 mm) in the corners to ensure temporary stability during assembly. In both cases, 68/6 mm washers are used to distribute local stresses and prevent surface crushing. The rafters are attached to the wall plate using steel traps, secured with nails (2 x Φ4/100 mm) to the rafter and screws (2 x Φ8/120 mm) to the wall plate. Meanwhile, wall plates are anchored to the reinforced concrete ring beam with threaded steel rods (Φ16/600 mm) spaced at 800–1000 mm intervals. All the connection details are shown in Figure 18, while the rafter-to-tie connection validation is provided in Appendix 6/54-57 for Slovakia and in Appendix 6/71-74 for Finland.

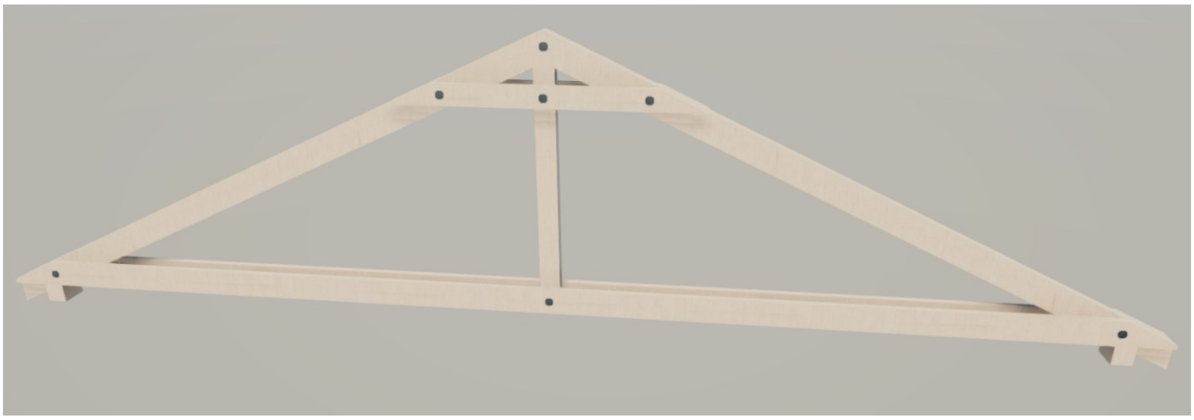
Figure 18. Anchoring elements of the roof structure



TYPE	SCHEMATIC DRAWING	DESCRIPTION
A	ANCHORING OF THE WALL PLATE INTO THE RING BEAM	THREADED ROD Φ16 -600mm with s= (0,80 to 1,00)m WASHER – 2x NUT M16 – 1x
B	RAFTER ANCHORING TO THE WALL PLATE	STEEL ANCHOR STEEL STRAP 40/3 SCREWS Φ8/120 – 2x 2ks NAIL Φ4/100 – 2x 2ks
C	RAFTER CONNECTION AT THE RIDGE RAFTER CONNECTION WITH COLLAR TIES	ON BOTH SIDES !!! 2x BOVA Bulldog 75/23 WASHER 68/6mm STEEL BOLT Φ16 WITH NUT 4x NAIL Φ4/100

The collar tie roof element configuration is shown in Figure 19, while the illustrative layout of the whole roof structure is shown in Appendix 5/1, and the structural layout is shown in Appendix 2/10.

Figure 19. Layout of a roof element



Loads acting on the roof were applied in Dlubal RFEM, where linear static analysis was performed. The resulting internal forces and moments were then verified for the most critical members by calculating the resistances according to the formulas specified in Eurocode

1995-1-1 (SFS EN 1995-1-1, 2004), in the corresponding Amendment 1 (SFS EN 1995-1-1/A1, 2008), and in the book of Swedish Wood Volume 2 (Crocetti et al., 2022). The utilization ratio of performed resistance checks for both countries is shown below, while the complete design of the roof elements is provided in Appendix 6/40-53 for Slovakia and in Appendix 6/58-70 for Finland.

The compression resistance utilization ratio was calculated for rafters, hip rafters, rafter ties, and middle columns. Expression 6.2 from Clause 6.1.4(1) (SFS EN 1995-1-1, 2004, p. 36) must be satisfied, as shown in Equation 4. The resulting values are presented in Table 3.

Equation 4. Compression parallel to the grain for timber elements

$$\sigma_{c,0,d} \leq f_{c,0,d}$$

Where:

$\sigma_{c,0,d}$	Design compressive stress along the grain
$f_{c,0,d}$	Design compressive strength along the grain

Table 3. Assessment of compression resistance utilization ratios in roof members

Compression	**Country**	**Structural element**			
		Rafter	**Hip rafter**	**Rafter tie**	**Column**
Utilization ratio (%)	**Slovakia**	7.67	16.40	2.28	3.00
	Finland	11.58	27.55	3.34	4.80

The shear resistance utilization ratio was calculated for rafters, hip rafters, and rafter ties. Expression 6.13 from Clause 6.1.7(1) (SFS EN 1995-1-1, 2004, p. 41) must be satisfied, as shown in Equation 5. The resulting values are presented in Table 4.

Equation 5. Shear for timber elements

$$\tau_d \leq f_{v,d}$$

Where:

τ_d	Design shear stress
$f_{v,d}$	Design shear strength for the actual condition

Table 4. Assessment of shear resistance utilization ratios in roof members

Shear	**Country**	**Structural element**		
		Rafter	**Hip rafter**	**Rafter tie**
Utilization ratio (%)	**Slovakia**	15.94	37.10	14.49
	Finland	25.79	62.04	15.90

The bending resistance utilization ratio was calculated for rafters, hip rafters, and rafter ties. Expressions 6.11 and 6.12 from Clause 6.1.6(1) (SFS EN 1995-1-1, 2004, p. 41) must be satisfied, as shown in Equation 6. The resulting values are presented in Table 5.

Equation 6. Bending for timber elements

$$\frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$

$$k_m \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$

Where:

$\sigma_{m,y,d}$ and $\sigma_{m,z,d}$	Design bending stresses about the principal axes
$f_{m,y,d}$ and $f_{m,z,d}$	Design bending strengths
k_m	Re-distribution factor for stresses

Table 5. Assessment of bending resistance utilization ratios in roof members

Bending	**Country**	**Structural element**		
		Rafter	**Hip rafter**	**Rafter tie**
Utilization ratio (%)	**Slovakia**	20.33	39.10	28.02
	Finland	32.64	67.12	37.83

From the buckling failure mode, the buckling resistance utilization ratio was calculated for the middle columns, while the lateral torsional buckling utilization ratio was calculated for the rafter ties. Expressions 6.23 and 6.24 from Clause 6.3.2(3) (SFS EN 1995-1-1, 2004, p. 45) must be satisfied for columns, as shown in Equation 7, and Expression 6.35 from Clause

6.3.3(6) (SFS EN 1995-1-1, 2004, p. 47) must be satisfied for rafter ties, as shown in Equation 8. The resulting values are presented in Table 6.

Equation 7. Columns subjected to either compression or combined compression and bending for timber elements

$$\frac{\sigma_{c,0,d}}{k_{c,y}\ f_{c,0,d}} + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$

$$\frac{\sigma_{c,0,d}}{k_{c,z}\ f_{c,0,d}} + k_m \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$

Where:

$\sigma_{m,y,d}$ and $\sigma_{m,z,d}$	Design bending stresses about the principal axes
$\sigma_{c,0,d}$	Design compressive stress along the grain
$f_{m,y,d}$ and $f_{m,z,d}$	Design bending strengths
$f_{c,0,d}$	Design compressive strength along the grain
k_m	Re-distribution factor for stresses
$k_{c,y}$ and $k_{c,z}$	Instability factor for the principal axes

Equation 8. Beams subjected to either bending or combined bending and compression for timber elements

$$\left(\frac{\sigma_{m,d}}{k_{crit}\ f_{m,d}}\right)^2 + \frac{\sigma_{c,d}}{k_{c,z}\ f_{c,0,d}} \leq 1$$

Where:

$\sigma_{m,d}$	Design bending stress
$\sigma_{c,d}$	Design compressive stress
$f_{m,d}$	Design bending strength
$f_{c,0,d}$	Design compressive strength parallel to the grain
k_{crit}	Reduced bending strength factor
$k_{c,z}$	Instability factor

Table 6. Assessment of buckling failure utilization ratios in roof members

Actions	**Country**	**Structural element**	
		Column **Buckling**	**Rafter tie** **Lateral torsional buckling**
Utilization ratio (%)	**Slovakia**	3.14	7.91
	Finland	5.02	14.39

To check the combined bending and axial compression resistance utilization ratio for rafters, hip rafters, and rafter ties. Expressions 6.19 and 6.20 from Clause 6.2.4(1) (SFS EN 1995-1-1, 2004, pp. 43-44) must be satisfied, as shown in Equation 9. The resulting values are presented in Table 7.

Equation 9. Combined bending and axial compression for timber elements

$$\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$

$$\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + k_m \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$

Where:

$\sigma_{m,y,d}$ and $\sigma_{m,z,d}$	Design bending stresses about the principal axes
$\sigma_{c,0,d}$	Design compressive stress along the grain
$f_{m,y,d}$ and $f_{m,z,d}$	Design bending strengths
$f_{c,0,d}$	Design compressive strength along the grain
k_m	Re-distribution factor for stresses

Table 7. Assessment of combined bending and axial compression resistance utilization ratios in roof members

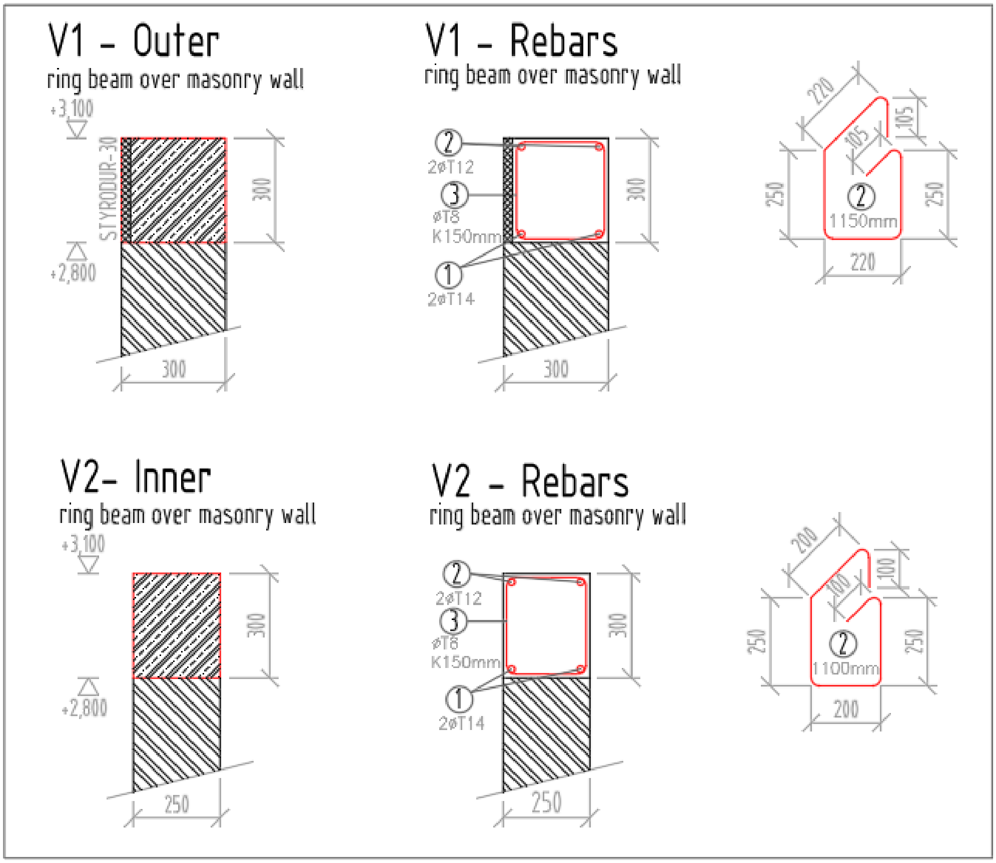
Combined	**Country**	**Structural element**		
		Rafter	**Hip rafter**	**Rafter tie**
Utilization ratio (%)	**Slovakia**	20.92	41.79	28.07
	Finland	33.99	74.71	37.94

6.3.2 Ring beam

The reinforced concrete ring beam is a continuous horizontal element placed at the top of the load-bearing masonry walls, as a critical component that ensures overall stability, load distribution, and structural integrity. Its main function is to tie the masonry walls together and distribute roof loads. Ring beams are designed according to Eurocode 1992-1-1 (SFS EN 1992-1-1, 2004) and the corresponding National Annexes for Slovakia (STN EN 1992-1-1+A1/NA, 2015) and Finland (National Building Code of Finland, 2016).

The ring beams are constructed using concrete with a strength class of C25/30 and reinforcement steel of class B500B. The reinforcement layout includes four longitudinal bars, with two at the top (2 x Φ12 mm) and two at the bottom (2 x Φ14 mm), positioned at the corners of the beam cross-section, along with stirrups (Φ8 mm) spaced every 150 mm to ensure shear resistance. A nominal concrete cover of 25 mm is applied, corresponding to exposure class XC1. The detailed construction configuration of the ring beams is shown in Appendix 2/9, while Figure 20 displays the reinforcement layout. Additionally, prefabricated and cast-in-place reinforced concrete lintels are also included there.

Figure 20. Ring beam layout in scale 1:25



The cross-section dimensions of the ring beams were aligned with the thickness of the masonry wall to achieve full structural continuity. From a construction standpoint, it is cast in situ directly on top of the walls, using formwork and continuous reinforcement, strongly recommended with 6 m long bars, to avoid weak joints. The overlapping of bars must be at least 600 mm, and the bottom reinforcement should never be overlapped above openings, while the design anchorage length is 750 mm. The timber wall plates supporting the roof structures are anchored to the ring beam with threaded steel rods, enabling the safe transfer of tensile forces from the roof to the concrete elements.

Loads were analysed for bending moment and shear forces. Since the ring beam is supported along the length of the masonry wall, the development of significant bending moments within the beam was considered negligible. Likewise, shear forces may be disregarded, as the masonry wall directly sustains the majority of the vertical loads beneath the points of application. The design verification was primarily governed by the assessment of local bending stress and shear force under the most critical roof element load, taking into account the corresponding load distribution width. The provided reinforcement was evaluated to ensure compliance with the minimum reinforcement requirements given in Clause 9.2.1.1(1), Equation 9.1N in Eurocode 1992-1-1 (SFS EN 1992-1-1, 2004, p. 152). The utilization ratio for tensile reinforcement was 34.06%, while for the compression reinforcement it was 46.35%. The detailed calculations for the ring beam are provided in Appendix 6/75-81 for both countries.

The local bending moment resistance utilization ratio must satisfy the formula shown in Equation 10. In Slovakia, the utilization ratio was 19.53%, while in Finland it was calculated as 33.17%.

Equation 10. Bending for the ring beam

$$M_{Ed} \leq M_{Rd}$$

Where:

M_{Ed}	Design bending moment
M_{Rd}	Design bending resistance

The local shear force resistance utilization ratio must satisfy the formula shown in Equation 11. In Slovakia, the utilization ratio was 13.24%, while in Finland it was calculated as 22.47%.

Equation 11. Shear for the ring beam

$$V_{Ed} \leq V_{Rd}$$

Where:

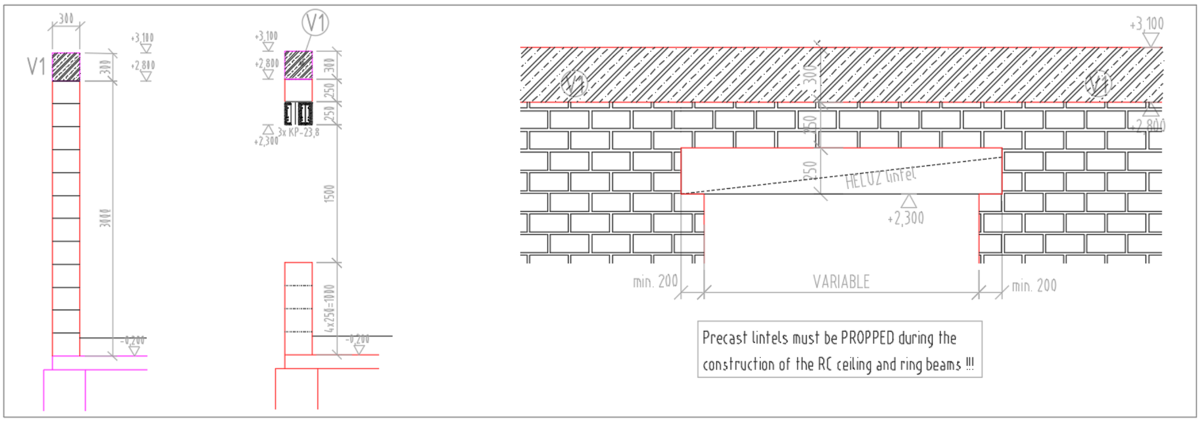
V_{Ed}	Design shear force
V_{Rd}	Design shear resistance

6.3.3 Masonry wall

The building's vertical load-bearing system consists of clay masonry walls designed to support and transfer loads from the roof structure to the foundations. The walls were designed and verified according to Eurocode 1996-1-1 (SFS EN 1996-1-1, 2012) and the corresponding National Annexes for Slovakia (STN EN 1996-1-1/NA, 2024) and Finland (National Building Code of Finland, 2016). Additionally, European Standards EN 771-1 (SFS EN 771-1+A1, 2015) and 772-1 (SFS EN 772-1+A1, 2015) have contributed critical information for assessing the structural capacity and material properties of clay masonry walls.

The masonry walls are constructed using Porotherm Profi P12 clay blocks with a thin-layer of full-surface adhesive mortar, creating a uniform and efficient masonry load-bearing system (Wienerberger, n.d.). The outer load-bearing walls have a thickness of 300 mm, while the inner ones have 250 mm, both with an effective height of 3 meters. The walls support a combination of vertical loads from roof elements, ring beam, and self-weight, along with horizontal loads from wind actions. The connection between the walls and the reinforced concrete ring beam ensures these loads are effectively redistributed and that local stress concentrations are minimized. Figure 21 illustrates the masonry wall layout with additional detail on openings and lintel placement in the masonry walls.

Figure 21. Masonry wall layout



Precast lintels must be PROPPED during the construction of the RC ceiling and ring beams !!!

The design calculations accounted for the combined effects of vertical compression and bending caused by eccentricity of horizontal loads. The resulting compressive stresses were verified at the top, middle, and bottom sections of the wall height. The ultimate limit states verifications were performed according to Clause 6.1.2 from EN 1996-1-1 (SFS EN 1996-1-1, 2012, pp. 60-63), and the utilization ratios were checked using formula shown in Equation 12. The detailed calculation method is included in Appendix 6/82-86 for Slovakia and in Appendix 6/87-90 for Finland.

Reduction for eccentricities and slenderness were evaluated in accordance with EN 1996-1-1, Clause 6.1.2.2 (SFS EN 1996-1-1, 2012, pp. 61-63), considering initial construction imperfections, load eccentricity, and wind pressure. The maximum design eccentricity at the bottom of the wall was approximately 70 mm in Slovakia, corresponding to a reduction factor of 0.54 for slenderness and eccentricity effects. In contrast, in Finland, the value was approximately 37 mm, which causes a reduction factor of 0.75. The wall slenderness ratio was 10, which satisfied the National Annex limit (λ ≤ 27) in both countries.

Equation 12. Vertical load applied to a masonry wall

$$N_{Ed} \leq N_{Rd}$$

Where:

N_{Ed}	Design vertical load applied to the masonry wall
N_{Rd}	Design vertical resistance of a single leaf wall per unit length

The calculated compressive resistance of the masonry wall was adequate at all levels. The utilization ratio was lowest at the top of the wall, at 8% for Slovakia and 11.9% for Finland,

and highest at the base, 15.4% for Slovakia and 15.5% for Finland, indicating that the wall remains well within the allowable design limits. The analysis confirmed that the ULS requirements were fully satisfied.

Serviceability checks confirmed that both height-to-thickness ratios and length-to-thickness ratios meet the requirements of Figure F.1 from Annex F of EN 1996-1-1 (SFS EN 1996-1-1, 2012, p. 109). The calculation is included in Appendix 6/91.

6.3.4 Base floor

The base floor acts as a reinforced concrete slab on ground, designed to distribute vertical loads from the building uniformly to the underlying soil. The design was performed according to Eurocode 1992-1-1 (SFS EN 1992-1-1, 2004) and the corresponding National Annexes for Slovakia (STN EN 1992-1-1+A1/NA, 2015) and Finland (National Building Code of Finland, 2016).

The slab is made of concrete class C20/25 reinforced with steel grade B500B. A KY-14 welded mesh with dimensions of Φ8/150 x Φ8/150 and size of 2400 x 6000 mm is placed near the bottom of the slab to resist bending and control cracking. The KARI meshes are overlapped by 450 mm, equivalent to three grid spaces in both directions. The nominal thickness of the slab is 150 mm, providing sufficient rigidity and strength for the imposed load. A nominal concrete cover of 30 mm is applied, corresponding to exposure class XC2.

The base floor slab is fully supported on a well-compacted gravel layer, where the slab directly transmits permanent and variable loads through bearing actions. Under these conditions, the induced bending moments in the slab are negligible, as they are primarily governed by the stiffness of the supporting soil. Shear forces can also be disregarded since the underlying soil directly resists the majority of the applied load.

The slab was analysed by checking the utilization of the reinforcement areas. The calculated minimum required reinforcement was 150.3 mm^2/m, while the provided reinforcement area is 335.1 mm^2/m. The utilization is 44.85%, which shows that the KY-14 mesh is more than sufficient to control cracking. Consequently, for both countries, only mesh reinforcement is required for the base slab. The detailed calculations for the base slab are provided in Appendix 6/92-93 for both countries.

6.3.5 Strip footing

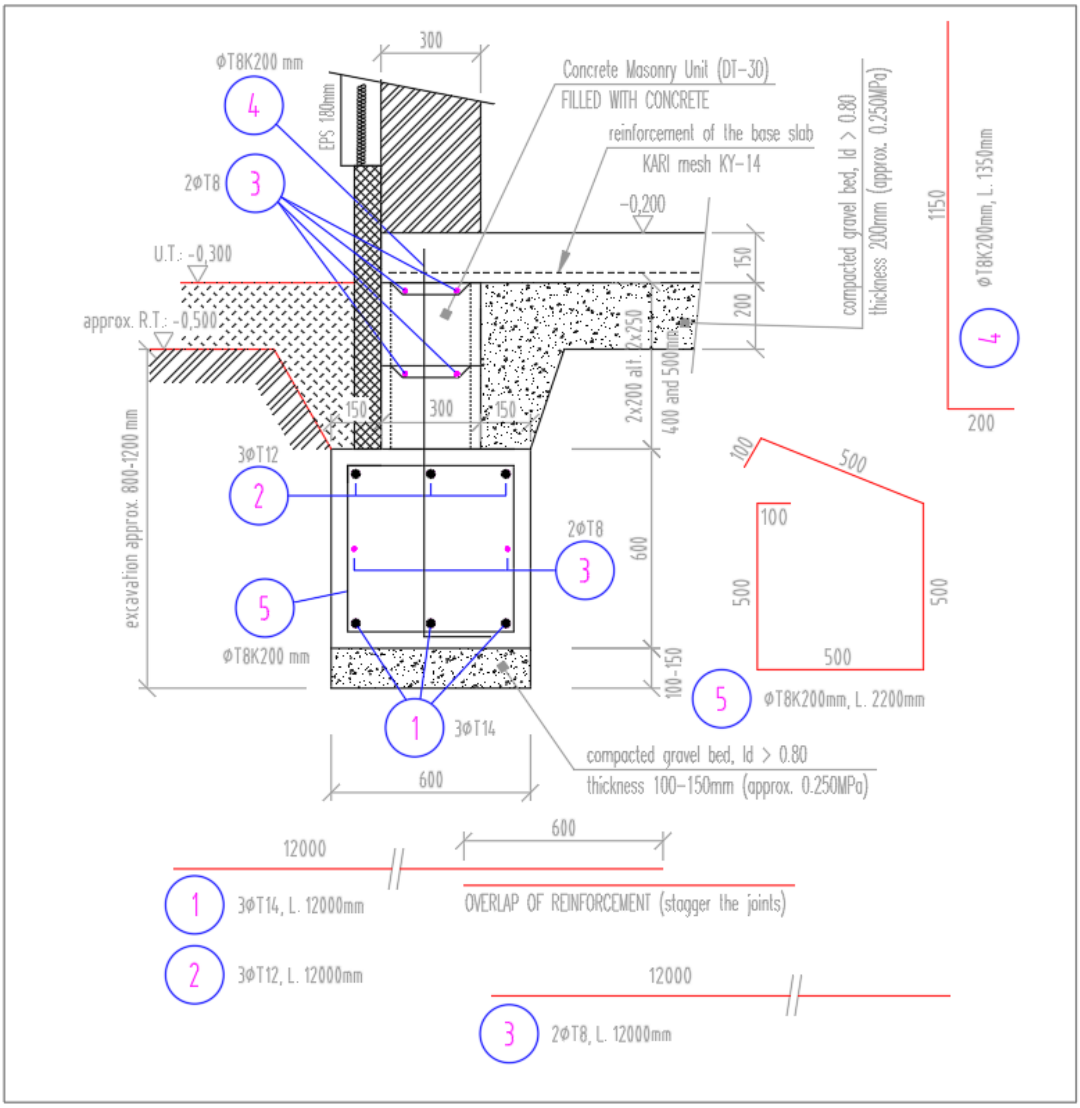
The building is supported by reinforced concrete strip footings that form the main foundation system, transferring vertical and horizontal loads from the superstructures into the supporting soil. The footing system was designed and verified in accordance with Eurocode 1992-1-1 (SFS EN 1992-1-1, 2004) and the corresponding National Annexes for Slovakia (STN EN 1992-1-1+A1/NA, 2015) and Finland (National Building Code of Finland, 2016).

The foundation system includes continuous reinforced concrete strip footings cast on a compacted gravel sub-base. This setup offers sufficient bearing capacity and reduces the risk of differential settlement. Above the footing, a concrete masonry block plinth wall, also known as foundation wall, is built. Structurally, the plinth wall supports vertical loads, provides lateral stability, and elevates the superstructure above ground level, thereby decreasing the effects of soil moisture and frost.

The strip footings are built using concrete class C20/25 with B500B reinforcement steel. The same concrete is used to fill the plinth wall. A nominal concrete cover of 50 mm is applied, matching exposure class XC2 for foundations. Footings, plinth walls, and the base slab are connected with vertical reinforcement (Φ8 mm) spaced every 200 mm for the building and every 300 mm for the terrace. This monolithic connection improves the overall integrity of the foundation system and ensures even stress transfer between components.

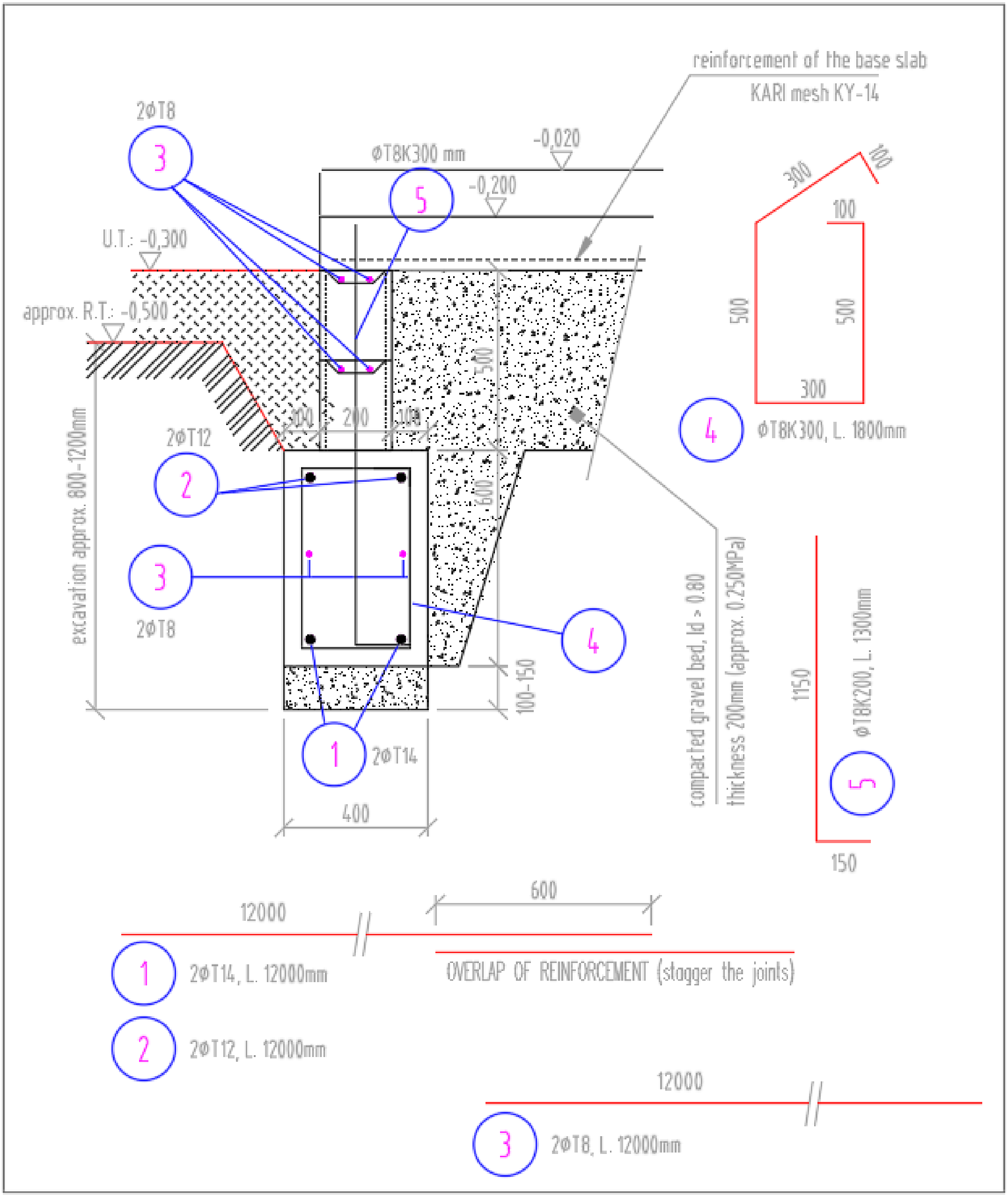
Footings under the building are dimension 600 x 600 mm and their reinforcement includes six primary longitudinal bars, with three at the top (3 x Φ12 mm) and three at the bottom (3 x Φ12 mm). Two longitudinal bars (2 x Φ8 mm) are spaced at mid-height to resist tensile stresses acting at different levels along the footing due to uneven soil pressure. Stirrups (Φ8 mm) spaced every 200 mm provide shear resistance. Two layers of Premac DT-30 are placed above the footing, with two longitudinal bars (2 x Φ8 mm) at the top of each layer to turn the blocks into a reinforced unit (Premac, n.d.). Figure 22 illustrates the detail of the building footing.

Figure 22. Schematic reinforcement of building footings in scale 1:25



Footings under the terrace are dimension 600 x 400 mm and are reinforced with four primary longitudinal bars, using two for the top (2 x Φ12 mm) and two for the bottom (2 x Φ14 mm). Two additional longitudinal bars (2 x Φ8 mm) are spaced in the middle height to resist tensile stresses caused by uneven soil pressure at different levels along the footing. Stirrups (Φ8 mm) are spaced at 300 mm intervals to provide shear resistance. Two layers of Premac DT-20 are placed above the footing, each with two longitudinal bars (2 x Φ8 mm) at the top to form a reinforced unit (Premac, n.d.). Figure 23 illustrates the detail of the terrace footing.

Figure 23. Schematic reinforcement of terrace footings in scale 1:25



Special attention was given to the L – shaped and T – shaped intersections of the strip footings, where two or more walls meet. These zones experience complex stress distributions, including torsional and biaxial bending effects. To prevent cracking and ensure full continuity of force transfer, corner reinforcement bars were bent into the adjoining footing. The overlap length must be at least 900 mm, while the anchorage length should be at least 950 mm. For the longitudinal reinforcement, it is recommended to use 12 m long bars with an overlap of 600 mm. Figure 24 shows the detail of L – shaped corner, and Figure 25 shows the detail of T – shaped corner.

Figure 24. Schematic reinforcement of L – shaped corners

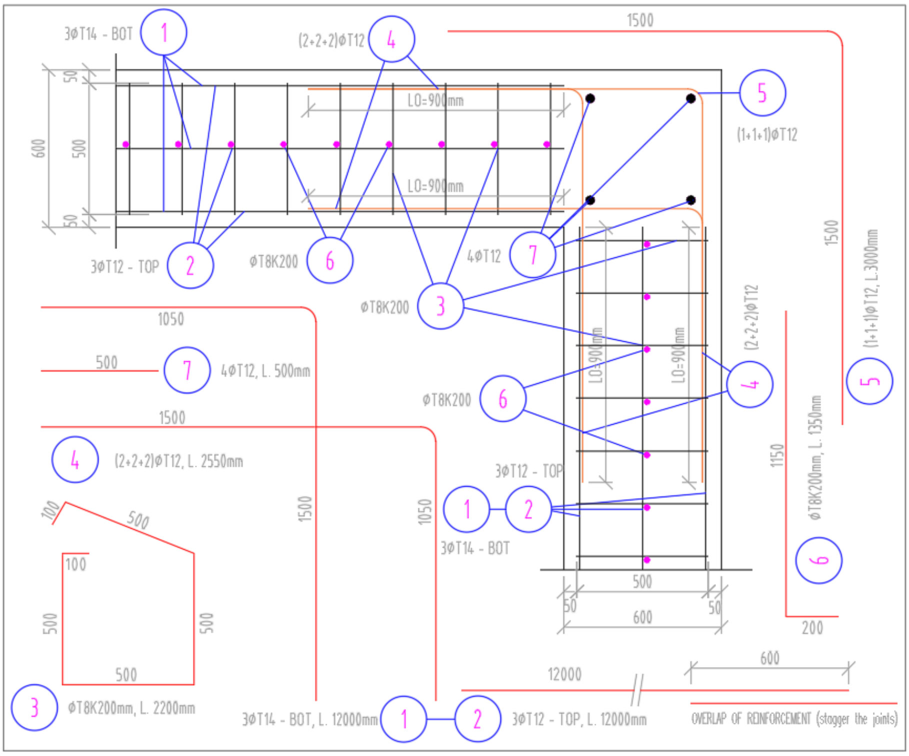
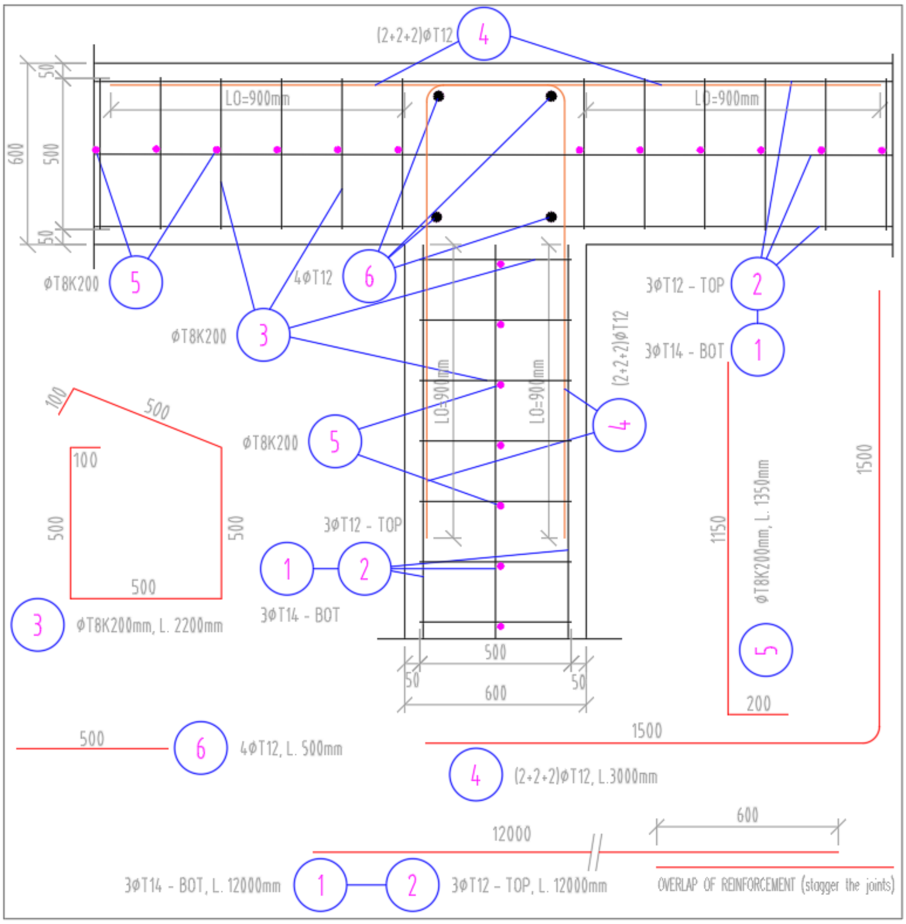


Figure 25. Schematic reinforcement of T – shaped corners



Design verification was performed for bending resistance using Equation 10 and for shear resistance using Equation 11. For Slovakia, the bending utilization ratio was 16.52%, and the shear utilization ratio was 8.05%. In contrast, for Finland, the bending utilization ratio was 21.46%, while the shear utilization ratio was 11.63%. The minimum required reinforcement was also checked using Clause 9.2.1.1(1), Equation 9.1N in Eurocode 1992-1-1 (SFS EN 1992-1-1, 2004, p. 152). The results showed that the designed amount of reinforcement is adequate.

According to the simplified classification of Clause 2.1, Eurocode 1997-1 (SFS EN 1997-1, 2004, pp. 19-21), the project falls under geotechnical category 1, which involves a small residential structure with shallow strip foundations on uniform, medium-dense sandy to clayey soil under dry and stable conditions, with an assumed bearing capacity of 200 kPa for the subsoil. However, an engineering-geological survey (EGS) is strongly recommended to verify the actual soil properties.

Bearing pressure under the footing was calculated according to Clause 6.5.2.1(1) in EN 1997-1 (SFS EN 1997-1, 2004, p. 63), also shown in Equation 13. In Slovakia, the bearing resistance utilization ratio was 57.90%, corresponding to 116 kPa, while in Finland it was 83.65%, corresponding to 167 kPa, ensuring that the design allowable soil pressure of 200 kPa is sufficiently safe against bearing failure. The detailed design calculations are provided in Appendix 6/94-100 for Slovakia and in Appendix 6/101-106 for Finland.

Equation 13. Bearing resistance utilization ratio for soil below foundations

$$V_d \leq R_d$$

Where:

V_d	Design total vertical load applied to the bottom of the footing
R_d	Design soil bearing resistance

7 Energy performance

This section assesses the energy performance of the designed residential building under two climatic and regulatory conditions: Dunajská Streda in Slovakia and Hämeenlinna in Finland. Both countries use national calculation methodologies specified to their climate, building traditions, and energy infrastructure.

7.1 Energy calculation methodology

The energy performance of the single-family house was evaluated using a dynamic simulation method to determine annual heating, cooling, total delivered energy, and E-number.

The thermal properties of the building envelope were determined using a layer-by-layer approach in Ubakus. The design software provided U-values, surface resistances, and temperature-dependent moisture behaviour of each assembly. Results were exported and imported into IDA ICE software to ensure alignment between material layers and thermal mass representation.

Dynamic simulations were conducted in IDA Indoor Climate and Energy (IDA ICE), which calculates hourly variations of heat balance, internal gains, and HVAC operation. The models utilized typical meteorological year (TMY) weather data for each location. The same building geometry and zoning were applied in both cases.

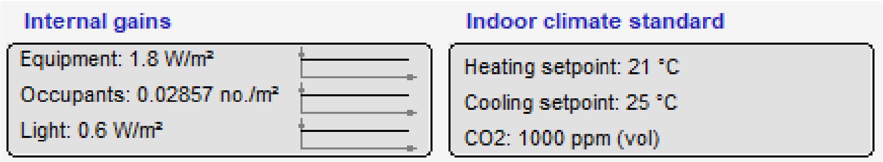
7.2 Input data and parameters

The reliability of energy performance simulations heavily depends on the accuracy and consistency of input data. Therefore, all parameters used in the dynamic energy model were defined carefully to represent realistic operating conditions and to ensure comparability between the Slovak and Finnish case studies. Identical building geometry, internal gains, and schedules were used in both models, while only climate files, national primary-energy factors, and building envelope layers to meet national U-value limits varied.

The building geometry corresponds to a detached single-family house with a net heated floor area of about 140 m². Weather files were not directly selected for the cities used in this project because they were unavailable in the software. Instead, the closest available city weather files were used, which were Bratislava for Slovakia and Helsinki for Finland.

Indoor environmental conditions followed standard residential occupancy schedules. The heating setpoint was 21 °C, while cooling was set to 25 °C. The schedule for internal gains was set to always on, with equipment using 1.8 W/m², equivalent to 3 W/m² with a usage rate of 60% in a day. Lights were set to 0.6 W/m², equivalent to 6 W/m² with a 10% usage rate in a day, and the number of occupants per square meter was 0.02857, corresponding to four occupants with full-day usage. The selected parameters are also shown in Figure 26.

Figure 26. Parameters for internal gains and indoor climate



Internal gains

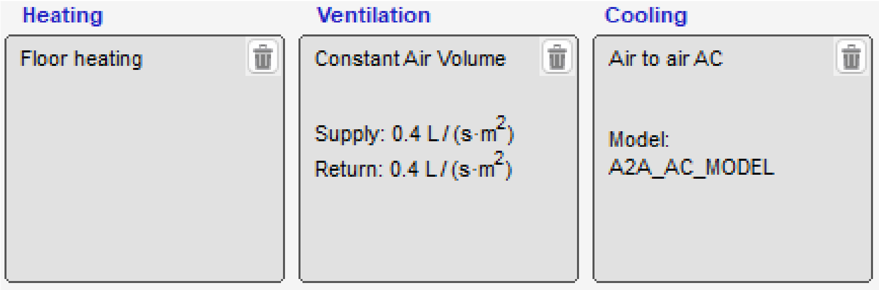
Equipment: 1.8 W/m^2
Occupants: 0.02857 no./m^2
Light: 0.6 W/m^2

Indoor climate standard

Heating setpoint: 21 °C
Cooling setpoint: 25 °C
CO2: 1000 ppm (vol)

Space heating was provided by a hydronic floor heating system with a thermostat controller and a design power of 35 W/m2. The floor heating system was supplied by a generic district heater acting as a top-up energy source. Space cooling was supplied by an air-to-air air conditioner with a cooling capacity of 8 kW. The building used a mechanical supply and exhaust ventilation system equipped with return air CO2 control and 60% heat recovery efficiency. The air flow of the ventilation system was set to 0.4 dm3/(s·m2). The selected parameters are also shown in Figure 27.

Figure 27. Parameters for heating, cooling, and ventilation systems



Heating

Floor heating

Ventilation

Constant Air Volume

Supply: 0.4 L / (s·m^2)
Return: 0.4 L / (s·m^2)

Cooling

Air to air AC

Model:
A2A_AC_MODEL

The domestic hot water demand was fixed at 35 kWh/m^2 per year. A 0.3 m^3 hot water tank was connected to the domestic hot water system. To represent on-site renewable electricity production, a 30 m^2 photovoltaic array with a 25° tilt facing south orientation was included in the building with an overall efficiency of 20%.

7.2.1 Energy coefficients for forms of energy used in buildings

Energy coefficients represent the ratio between total primary energy input and the useful energy delivered to the building. These coefficients depend on the energy source and its renewable share, ensuring a uniform basis for evaluating different energy carriers and allowing national comparison of building performance. In most cases, electricity carries the highest coefficient due to production and grid transmission losses, while renewable energy benefits from a lower value.

In Slovakia, energy coefficients are set by Ministerial Decree 324/2016 (Collection of laws on energy performance of buildings 324/2016). The coefficients used in this case are listed in Table 8.

Table 8. Energy coefficients for forms of energy used in Slovakia (Collection of laws on energy performance of buildings 324/2016)

Energy form	Energy coefficient
Electricity	2.20
Fossil fuels	1.10
District heating	0.70
District cooling	0.70
Renewable energy (local)	0.00

In Finland, energy coefficients are defined by Government Decree 788/2017 (Government Decree on the numerical values of coefficients for forms of energy used in buildings 788/2017). The applied coefficients for this case are shown in Table 9.

Table 9. Energy coefficients for forms of energy used in Finland (Government Decree on the numerical values of coefficients for forms of energy used in buildings 788/2017)

Energy form	Energy coefficient
Electricity	1.20
Fossil fuels	1.00
District heating	0.50
District cooling	0.28
Renewable energy (local)	0.50

7.3 Thermal performance

The thermal performance of the building envelope was evaluated using a detailed layer-by-layer analysis of thermal transmittance. Additionally, the temperature and humidity distributions were analysed within each layer, along with moisture proofing, to assess the condensation risk of the structures. The structures are made out of multiple layers, each serving a specific function. The same layout and materials were selected for both countries, however, modifications had to be made with the thicknesses of some layers to ensure that the national U-limits are achieved.

In Slovakia, the thermal transmittance limits are defined by STN 73 0540-2 (STN 73 0540-2, 2012). The applied limit values for this case are shown in Table 10.

Table 10. Thermal transmittance limit values for Slovakia (STN 73 0540-2, 2012)

Envelope component	**U-value limit ($W/m^2 \cdot K$)**
External wall	0.15
Ceiling bounded by unheated attics	0.10
Floor against the ground	0.25
Window / Door	0.85

In Finland, the thermal transmittance limits are defined by the Ministry of the Environment Decree 1010/2017 (Decree of the Ministry of the Environment on the Energy Performance of New Buildings 1010/2017). The applied limit values for this case are shown in Table 11.

Table 11. Thermal transmittance limit values for Finland (Decree of the Ministry of the Environment on the Energy Performance of New Buildings 1010/2017)

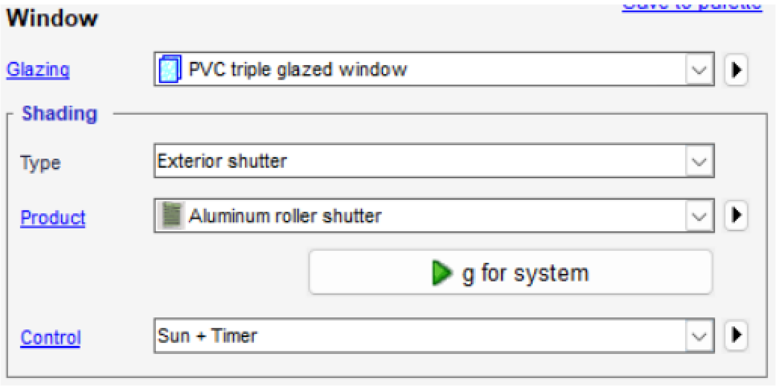
Envelope component	**U-value limit ($W/m^2 \cdot K$)**
External wall	0.12
Ceiling bounded by unheated attics	0.07
Floor against the ground	0.16
Window / Door	0.70

7.3.1 Opening infill elements

Opening infills include windows and doors. Their design ensures adequate thermal continuity and airtightness. For both countries, the same profiles were used for the design simulations.

The windows are made of multi-chamber anthracite coloured PVC profiles with triple glazing, argon infill, and low-emissivity coatings. The overall U-value of the windows is 0.65 W/m^{2}K, providing excellent insulation and energy efficiency, and remaining under the national limit value in both cases. External aluminium roller shutters are installed for solar shading. Windows are sealed with internal airtight, vapor-impermeable sealing foil and external vapor-permeable sealing foil to achieve high airtightness and damp proofing. Window dimensions are provided in Appendix 2/1, while the window setup is shown in Figure 28.

Figure 28. Parameters for windows



Window

Glazing: PVC triple glazed window

Shading

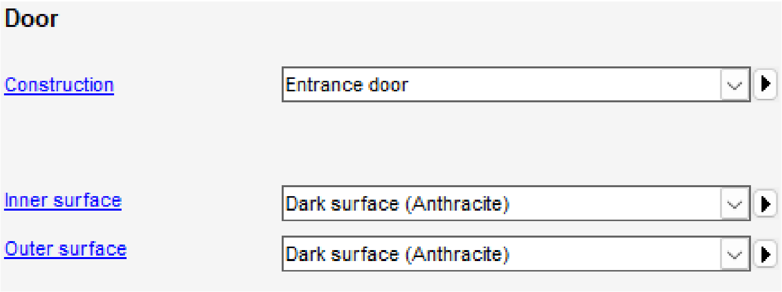
Type: Exterior shutter

Product: Aluminum roller shutter

Control: Sun + Timer

The external doors are insulated anthracite coloured PVC elements with multi-chamber profiles, achieving a U-value of 0.7 W/m^{2}K, which is under the national limit value in Slovakia, however, in Finland, it is exactly the limit value that is still accepted. Where glazing is included, triple low-emissivity argon-filled units are used for visual consistency and performance. Doors are sealed from the interior and exterior in the same way as windows. Door dimensions are provided in Appendix 2/1, while the door setup is shown in Figure 29.

Figure 29. Parameters for doors



Door

Construction: Entrance door

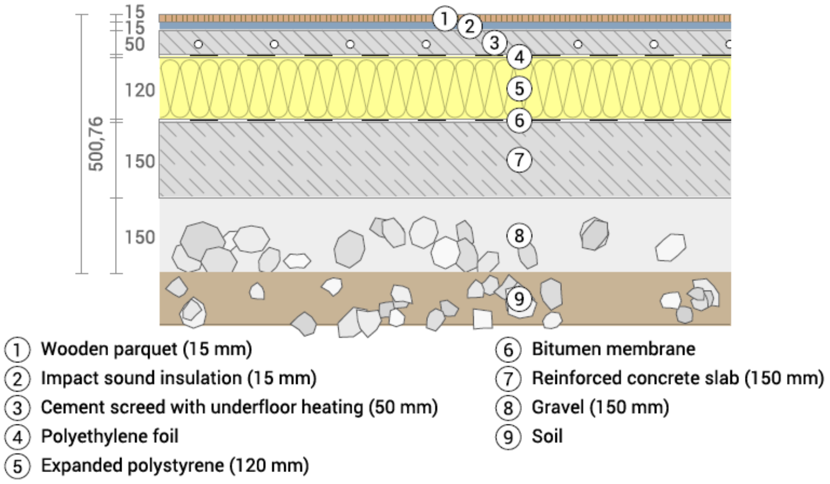
Inner surface: Dark surface (Anthracite)

Outer surface: Dark surface (Anthracite)

7.3.2 Ground floor structure

The ground floor structure acts as the interface between the building and the ground. Its design must ensure structural stability, reduce heat loss, and prevent moisture from seeping in from the soil. The ground floor structure for Slovakia is shown in Figure 30, and for Finland in Figure 31. The detailed ground floor thermal performance is included in Appendix 7/23-26 for Slovakia and in Appendix 7/27-30 for Finland.

Figure 30. Ground floor structure in Slovakia



In Slovakia, the designed ground floor structure achieved a U-value of 0.24 W/m^{2}K, which is under the national limit of 0.25 W/m^{2}K. The total thickness of the floor is 500 mm. The layers for are described below.

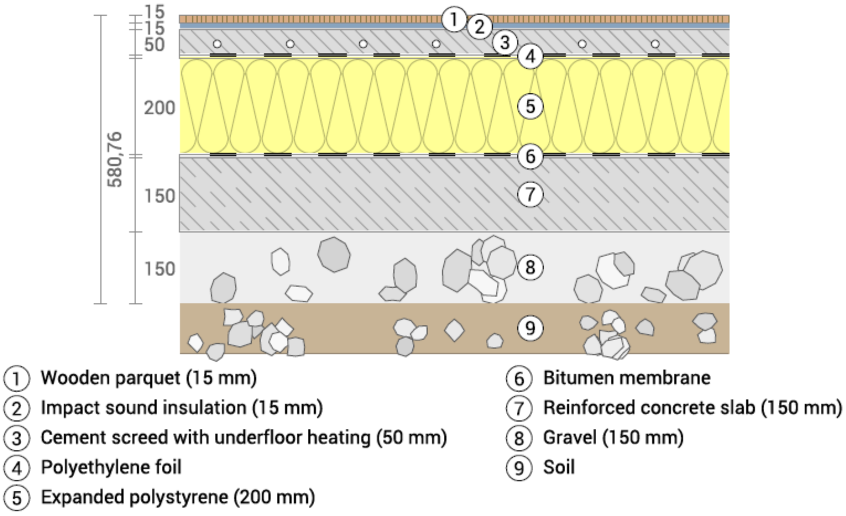
The top layer of the floor is a 15 mm laminated wooden parquet, serving as the visible interior finish. It provides a warm, comfortable, aesthetic walking surface, and it is suitable for use with underfloor heating systems due to its low thermal resistance. Directly beneath the parquet lies a 15 mm impact sound insulation board layer, which absorbs noises from footsteps and improves the acoustic performance of the interior spaces.

The next layer is a 50 mm cement screed with underfloor heating pipes. This layer ensures even heat distribution and forms a flat surface for the floor finish. Beneath the screed, a 0.26 mm polyethylene foil with an Sd-value of 100 m acts as a vapor barrier, preventing moisture from entering the insulation and protecting the heating system.

Below this, the main thermal insulation layer consists of 120 mm of expanded polystyrene (EPS), which reduces heat loss to the ground and maintains a stable indoor temperature. The EPS also provides enough compressive strength to support the floor load. Under the insulation, a 0.5 mm bitumen membrane acts as a moisture barrier to prevent moisture from passing through from the ground, while allowing the structure to breathe, preventing trapped vapor and helping keep the interior dry.

Under these layers, the load-bearing element of the system is a 150 mm reinforced concrete slab C20/25, which distributes loads evenly and provides rigidity and stability. The bottom layer of the floor is a 150 mm compacted gravel bed, functioning as a drainage and capillary-breaking layer, and stabilises the slab on the existing soil, which is directly below the gravel layer.

Figure 31. Ground floor structure in Finland

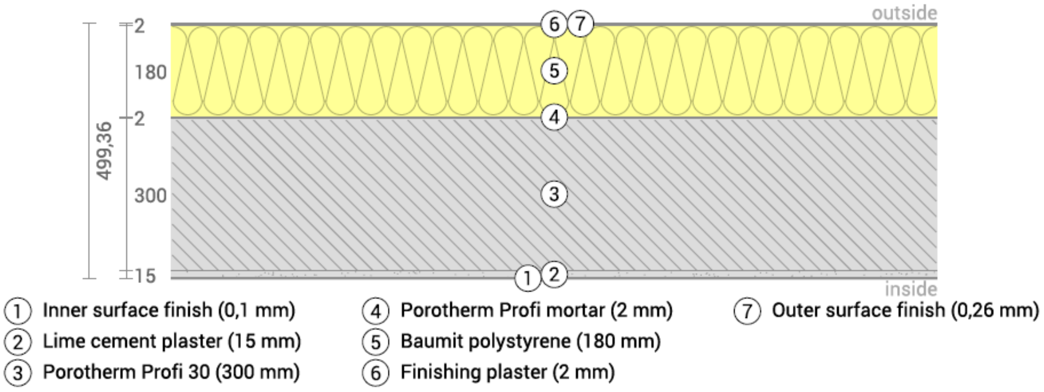


In Finland, the thermal insulation thickness is increased from 120 mm to 200 mm, as shown in Figure 31. This change significantly reduces heat loss through the floor and results in a lower U-value of 0.15 W/m²K. This value allows it to stay within the national limit set at 0.16 W/m²K. The thicker insulation layer also raises the total floor thickness to 580 mm.

7.3.3 External wall structure

The external wall structure is designed to provide structural stability, thermal insulation, and weather protection. Thermal bridges are minimized through insulated prefabricated and cast-in-place lintels, corner treatment, and consistent insulation thickness. The detailing ensures airtightness with continuous insulation around the window and door openings. External wall structure for Slovakia is shown in Figure 32, and for Finland in Figure 33. The detailed ground floor thermal performance is provided in Appendix 7/13-17 for Slovakia and in Appendix 7/18-22 for Finland.

Figure 32. External wall structure in Slovakia



In Slovakia, the designed external wall structure achieved a U-value of 0.15 W/m²K, which matches the national limit of 0.15 W/m²K. The total wall thickness is approximately 500 mm. The layers are described below.

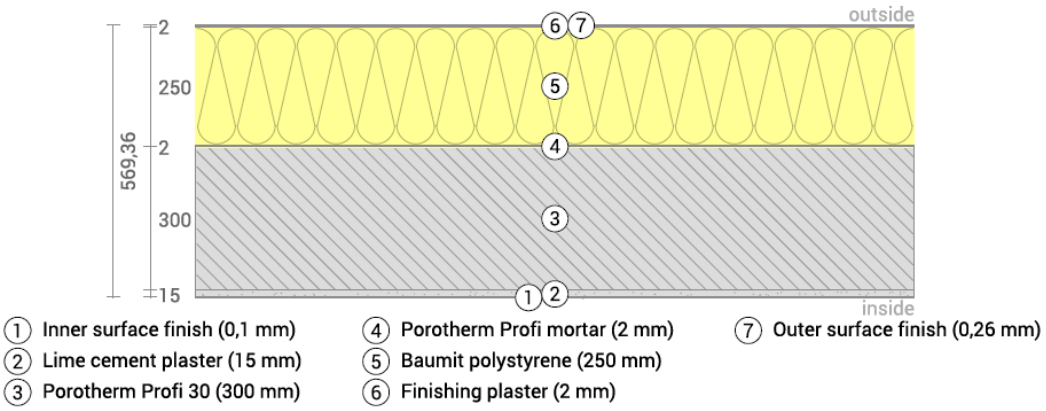
The inner surface of the wall assembly starts with a 0.1 mm paint layer that acts as the final interior finish, giving the wall a smooth and aesthetic appearance. Directly beneath the paint, a 15 mm lime cement plaster functions as the internal render. This layer provides an even base for painting, helps regulate vapor, and enhances acoustic and fire performance.

The main load-bearing layer consists of 300 mm Porotherm Profi 30 Thermobrick masonry, bonded with 2 mm Porotherm Profi mortar. These hollow clay blocks have excellent compressive strength and good thermal properties due to their porous structure.

On the exterior side, the thermal insulation layer is formed by a 180 mm expanded façade polystyrene (EPS-F). This thick insulation layer minimizes heat loss through the wall, ensuring a low U-value for the wall. The EPS boards are fixed with adhesive and mechanical anchors, providing continuous insulation across the façade and eliminating thermal bridges.

The insulation is protected by a 2 mm finishing plaster layer, which provides weather resistance and an even texture. Finally, the outermost layer is a 0.26 mm paint coating, offering colour stability and additional surface durability.

Figure 33. External wall structure in Finland

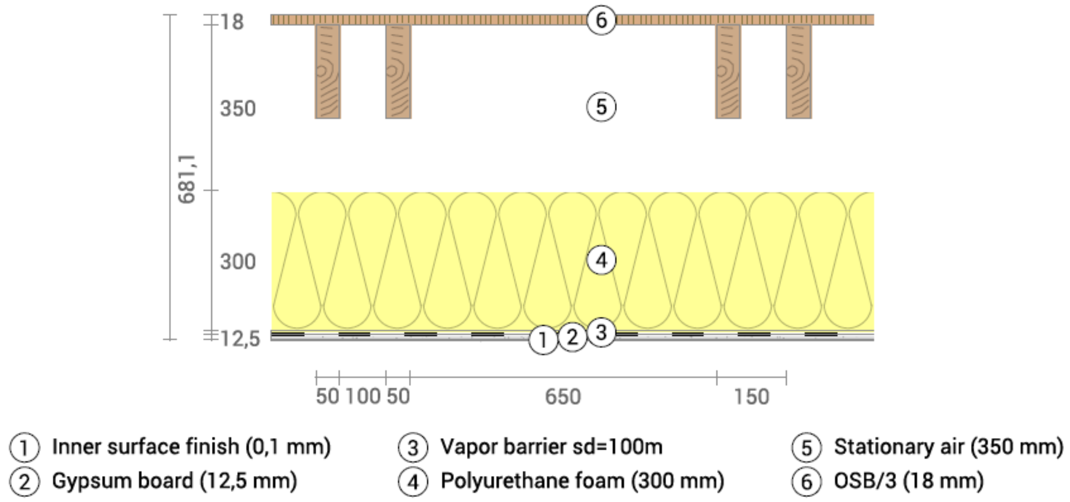


In Finland, the thermal insulation thickness is increased from 180 mm to 250 mm, as shown in Figure 33. This change significantly reduces heat loss through the wall and results in a lower U-value of 0.12 W/m^{2}K. This value allows it to meet the national limit, which is set precisely at 0.12 W/m^{2}K. The thicker insulation layer also raises the total wall thickness to approximately 570 mm.

7.3.4 Ceiling structure

The ceiling structure separates the heated living space from the unheated attic space and plays a crucial role in thermal insulation, airtightness, and acoustic comfort. The ceiling structure for Slovakia is shown in Figure 34, and for Finland in Figure 35. The detailed ceiling thermal performance is provided in Appendix 7/3-7 for Slovakia and in Appendix 7/8-12 for Finland.

Figure 34. Ceiling structure in Slovakia



In Slovakia, the designed ceiling structure has a U-value of 0.08 W/m²K, which is below the national limit of 0.10 W/m²K. The total thickness of the ceiling is approximately 680 mm. The layers are described below.

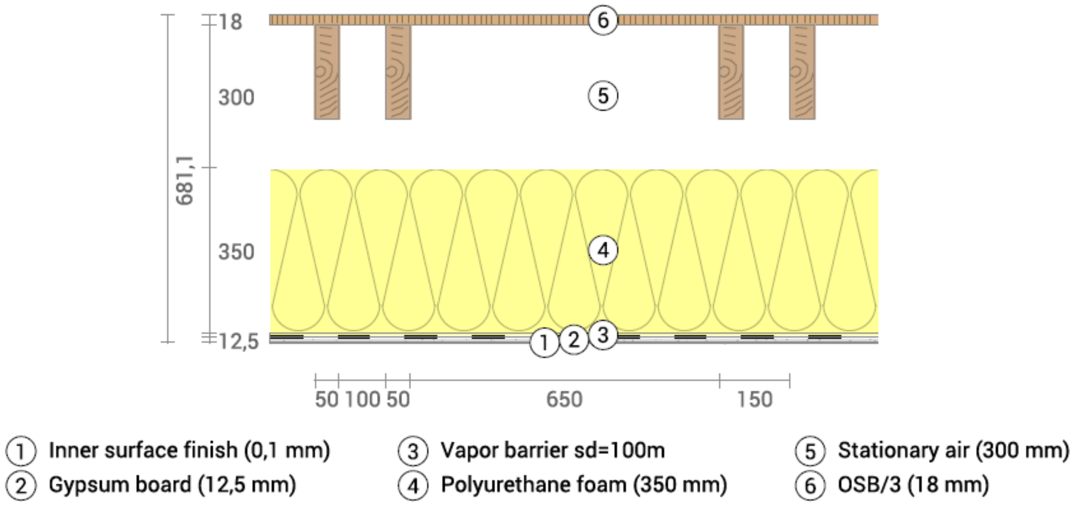
The inner surface of the ceiling begins with a 01. mm pain layer, which provides a smooth and clean decorative finish for the interior. Above the paint is a 12.5 mm gypsum board (drywall) that forms the visible ceiling surface. The gypsum board provides good fire resistance, acoustic insulation, and serves as a base for finishing material. Gypsum boards are suspended on a double-level galvanized steel CD profile substructure arranged in two directions, which hides building services. The steel substructure is hung by 450 mm long rigid steel rods fixed to the bottom of the rafter tie.

Directly above the second layer, a 0.5 mm vapour barrier membrane with an Sd-value of 100 m serves as the airtight and moisture-control layer. This membrane prevents warm, humid indoor air from penetrating the insulation layer, where condensation could occur in cold conditions.

The main thermal insulation is a 300 mm layer of spray polyurethane foam. This material offers excellent thermal resistance and fills all gaps. Its closed-cell structure also acts as a secondary moisture barrier. Above the insulation, the structure includes a 350 mm unventilated stationary air cavity where the main load-bearing rafter tie timber elements are placed. One component consists of two 50/200 mm spruce planks positioned 100 mm apart. The rafter ties are spaced at 850 mm on center.

The outermost layer is made of 18 mm oriented strand board (OSB/3) sheathing. This layer enhances the structure's rigidity and provides a stable walking surface for the attic space.

Figure 35. Ceiling structure in Finland



In Finland, the thermal insulation thickness has been increased from 300 mm to 350 mm, as shown in Figure 35. This change significantly reduces heat loss through the ceiling and results in a lower U-value of 0.07 W/m^{2}K. This value allows compliance with the national limit, which permits a maximum thermal transmittance of 0.07 W/m^{2}K. The thicker insulation layer does not add to the overall ceiling thickness but decreases the stationary air gap by 50 mm.

7.4 Energy simulation

The energy simulation provided detailed results for the building’s performance throughout the year. The following data summarizes the overall energy performance of the building, including on-site generation and additional CO_2 emissions. The detailed simulation results with diagrams are available in Appendix 7/31-34 for Slovakia and Appendix 7/35-38 for Finland.

In Slovak climate conditions, the overall energy performance was -3726.2 kWh of total primary energy, 1789.9 kWh of non-renewable primary energy, and 137.7 kg of CO2 emissions. The photovoltaic system generated 7406.4 kWh of electricity annually.

In Finnish climate conditions, the overall energy performance reached 4381.5 kWh of total primary energy, 6316.3 kWh of non-renewable primary energy, and 1432.6 kg of CO2 emissions. The photovoltaic system produced 6575.4 kWh of electricity annually.

7.5 Energy performance number

The energy performance indicator measures the annual non-renewable primary energy used per square meter of heated floor space, including heating, cooling, ventilation, domestic hot water, lighting, and auxiliary energy.

For the Slovak case, the resulting E-number was calculated as 12.8 kWh/(m^2·year), which indicates that the building qualifies as category A0 according to Ministerial Decree 324/2016 (Collection of laws on energy performance of buildings 324/2016). Residential buildings in this category have an energy performance indicator below 54 kWh/(m2·year) and meet the criteria for a nearly zero energy building (NZEB). The list of E-number categories and limits for Slovakia is provided in Table 2.

For the Finnish case, the resulting E-number was calculated as 45.1 kWh/(m^2·year). To determine the category, equations provided by the Ministry of the Environment Decree 1048/2017 (Decree of the Ministry of the Environment on the Energy Certificate of a Building 1048/2017) were used. The calculated energy performance number, based on a net heated area of 140 m^2, corresponds to category A, which has an indicator limit of 82 kWh/(m^2·year) in this case, according to Equation 14. The residential building in this category meets the requirements for a nearly zero energy building (NZEB). The list of E-number categories and limits for Finland is provided in Table 1.

Equation 14. Energy performance number for a residential building in category A

$$E_{number} \leq 110 - 0.2 \times A_{netto}$$

Where:

E_{number}	Calculated energy performance number of the building
$110 - 0.2 \times A_{netto}$	National limit for the energy performance number category A

8 Economic assessment

The economic assessment evaluates the financial aspects of the single-family house design by analysing construction costs in both Slovakia and Finland. This section focuses on material and labor costs. The goal is to determine how regional differences in market prices and labor rates affect the overall project cost. The assessment mainly concentrates on the structural shell and paved surfaces, excluding building systems and furniture costs.

8.1 Cost calculation methodology

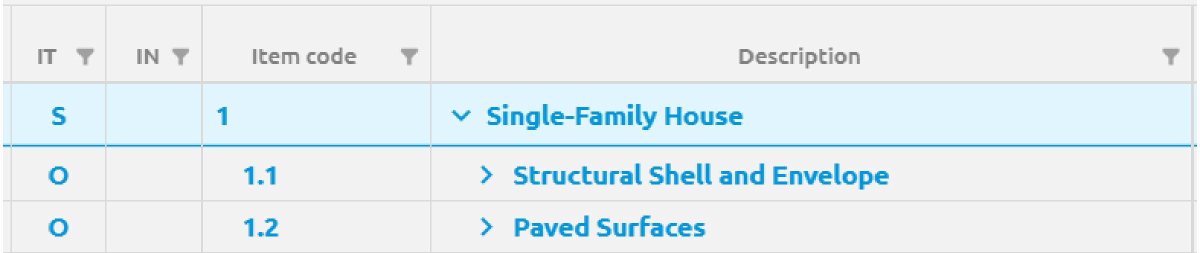
The cost calculation methodology uses a systematic approach based on material quantity and unit price databases specific to each country. The analysis was performed with CENKROS 4 estimating software, which offers reliable local market data for Slovakia. For Finland, the prices were obtained from the Taloon website (Taloon, n.d.) and the Rakennusosien kustannuksia handbook (Rakennustieto, 2025).

All costs were calculated excluding value-added tax (VAT), but the summary includes the tax to reflect total construction expenses. In Slovakia, the standard VAT rate is 23%, with a reduced rate of 5% (Finančná správa, n.d.), while in Finland, the standard rate is 25.5% and the reduced rate is 14% (Vero, n.d.).

8.2 Cost components

The total construction cost of the building was divided into two main components, which were further broken down into subcomponents to allow for detailed comparison. Material, labor, and installation costs are then listed for all subcomponents. The main components are shown in Figure 36.

Figure 36. Main cost components



IT	IN	Item code	Description
S		1	Single-Family House
O		1.1	Structural Shell and Envelope
O		1.2	Paved Surfaces

8.2.1 Structural shell and envelope

The structural shell and envelope form the core of the building cost. This part accounts for most of the cost, as it includes works that ensure the building's stability, enclosure, and thermal protection. Structural shell and envelope components are shown in Figure 37.

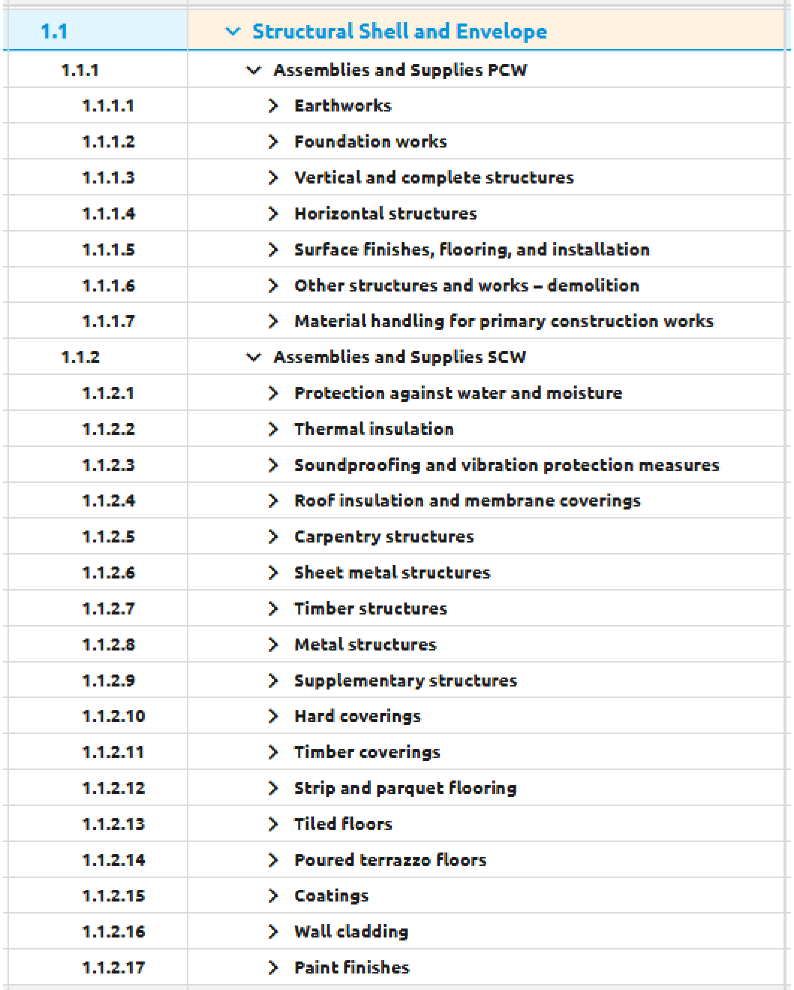
The primary construction works (PCW) include earthworks, which involve site preparation, removing topsoil, excavating for foundations, and compacting the soil. Foundation works also fall under this, where reinforced concrete footings and the base slab are constructed using formwork. The vertical and horizontal structures consist of clay masonry walls, reinforced concrete ring beams, and lintels. These components make up the load-bearing system of the building.

Surface finishes and flooring works include the installation of levelling screed and surface coatings. These layers ensure even surfaces for final finishes. This category also covers minor demolition, and adjustment works performed during construction, such as removing formwork, preparing scaffolding, or fixing small structural defects.

The secondary construction works (SCW) complement the structural assembly by providing protection and insulation. This includes waterproofing and moisture barriers, ensuring that no groundwater or condensation affects the structure. The thermal insulation layers, mainly EPS, XPS, and PUR foam, significantly reduce heat loss and ensure the designed U-values. Soundproofing and vibration isolation materials applied to floors enhance acoustic comfort, while the roof membrane covering ensures a watertight roof.

Carpentry and timberwork form the structural framework of roofs and ceilings, while sheet metal and steel components are used for connecting elements and drainage. Additional items like supplementary structures, coverings, coatings, surface finishes, and final paint layers complete both the external and internal appearance of the building.

Figure 37. Structural shell and envelope components



1.1	Structural Shell and Envelope
1.1.1	Assemblies and Supplies PCW
1.1.1.1	Earthworks
1.1.1.2	Foundation works
1.1.1.3	Vertical and complete structures
1.1.1.4	Horizontal structures
1.1.1.5	Surface finishes, flooring, and installation
1.1.1.6	Other structures and works – demolition
1.1.1.7	Material handling for primary construction works
1.1.2	Assemblies and Supplies SCW
1.1.2.1	Protection against water and moisture
1.1.2.2	Thermal insulation
1.1.2.3	Soundproofing and vibration protection measures
1.1.2.4	Roof insulation and membrane coverings
1.1.2.5	Carpentry structures
1.1.2.6	Sheet metal structures
1.1.2.7	Timber structures
1.1.2.8	Metal structures
1.1.2.9	Supplementary structures
1.1.2.10	Hard coverings
1.1.2.11	Timber coverings
1.1.2.12	Strip and parquet flooring
1.1.2.13	Tiled floors
1.1.2.14	Poured terrazzo floors
1.1.2.15	Coatings
1.1.2.16	Wall cladding
1.1.2.17	Paint finishes

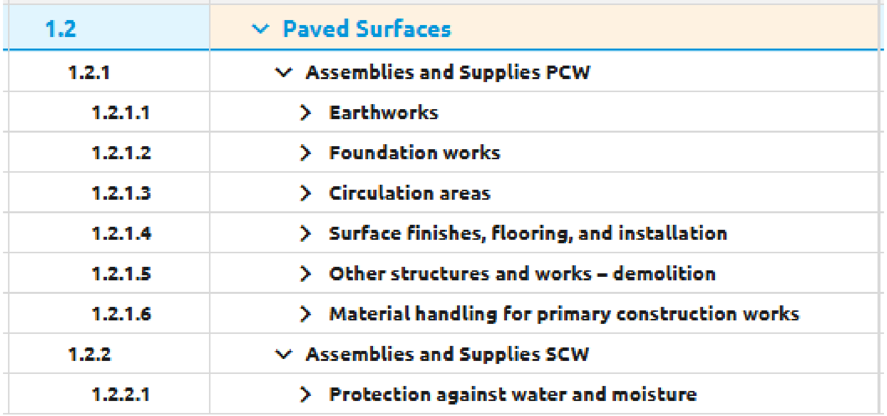
8.2.2 Paved surfaces

The paved surfaces represent the external works and include hard landscaping around the building, such as walkways. Paved surface components are shown in Figure 38.

Primary construction works include earthworks, such as excavation, levelling, and subsoil compaction. The foundation is created with a gravel and sand bedding, which is compacted to ensure a stable and well-draining base for the pavement. Circulation areas are designed with proper slopes for water drainage and edged with curb stones to maintain stability. Surface finishes consist of installing concrete interlocking pavers, laid on compacted crushed stone with joints filled with sand.

The secondary construction works involve installing a geotextile membrane that functions as an infiltration layer.

Figure 38. Paved surfaces components



1.2	⌄ Paved Surfaces
1.2.1	⌄ Assemblies and Supplies PCW
1.2.1.1	› Earthworks
1.2.1.2	› Foundation works
1.2.1.3	› Circulation areas
1.2.1.4	› Surface finishes, flooring, and installation
1.2.1.5	› Other structures and works – demolition
1.2.1.6	› Material handling for primary construction works
1.2.2	⌄ Assemblies and Supplies SCW
1.2.2.1	› Protection against water and moisture

8.3 Cost estimation

In Slovakia, the total construction cost amounts to approximately €222 277.09 excluding VAT and €273 400.82 including VAT, while in Finland it is approximately €384 776.48 excluding VAT and €482 894.48 including VAT.

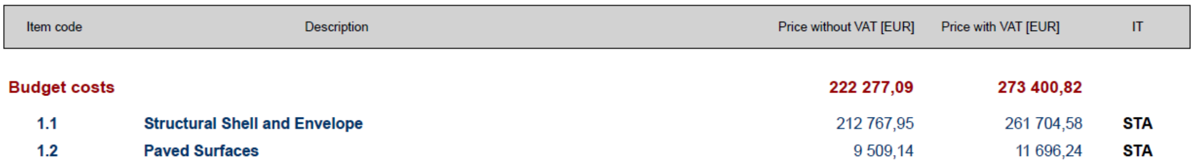
The structural shell and envelope represent the major portion of the investment. The cost of this component is €212 767.95 excluding VAT and €261 704.58 including VAT in Slovakia, and €363 305.24 excluding VAT and €455 948.08 including VAT in Finland, covering all primary and secondary construction works.

The paved surfaces item reached a total cost of €9 509.14 excluding VAT and €11 696.24 including VAT in Slovakia, and €21 471.24 excluding VAT and €26 946.41 including VAT in Finland. This component, while smaller compared to the main structure, gives functional and visual integration with the surrounding site.

The presented cost estimates are indicative and due to frequent fluctuations in material, labor, and energy costs influenced by national economic conditions, these values may not be fully accurate at the time of implementation. Therefore, the cost estimation should be considered preliminary and may require secondary verification.

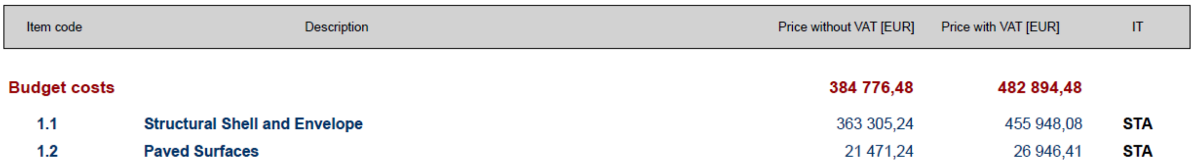
The overall cost estimate for Slovakia is shown in Figure 39, and for Finland in Figure 40. The detailed cost components are included in Appendix 8/1-8 for Slovakia and in Appendix 8/9-16 for Finland.

Figure 39. Total cost estimation in Slovakia



Item code	Description	Price without VAT [EUR]	Price with VAT [EUR]	IT
Budget costs		**222 277,09**	**273 400,82**	
1.1	**Structural Shell and Envelope**	212 767,95	261 704,58	**STA**
1.2	**Paved Surfaces**	9 509,14	11 696,24	**STA**

Figure 40. Total cost estimation in Finland



Item code	Description	Price without VAT [EUR]	Price with VAT [EUR]	IT
Budget costs		**384 776,48**	**482 894,48**	
1.1	**Structural Shell and Envelope**	363 305,24	455 948,08	**STA**
1.2	**Paved Surfaces**	21 471,24	26 946,41	**STA**

9 Comparative analysis

This chapter provides a comparison of the structural, energy, and economic results obtained for the single-family house design in Slovakia and Finland. The purpose is to identify key differences between the two countries.

9.1 Comparative evaluation of structural engineering

The comparison of structural engineering between Slovakia and Finland reveals that the most significant differences arise from the climatic loads specified in the national annexes. While the building geometry and materials stay the same in both countries, they face different environmental conditions.

The greatest contrast was determined in the snow load. In Slovakia, the characteristic snow load on the roof is calculated as 0.46 kN/m^2, whereas in Finland it reaches 2 kN/m^2, which is more than four times higher. This results in considerably larger bending moments, shear forces, and support reactions in the Finnish case.

Wind loads also show variation, although their influence remains secondary compared to snow. Slovakia uses a basic wind velocity of 24 m/s, while Finland applies 21 m/s. Even though Slovakia has slightly higher wind speeds, the overall wind effect remains relatively small.

Permanent loads from self-weights remain identical in both countries since material properties and dimensions do not change between cases. Similarly, live loads for residential buildings and roof loads are the same, following the Eurocode values.

As a consequence of these loads, the timber roof structure is subjected to significantly higher internal forces and support reactions in Finland. The design forces are approximately 67.5% higher in Finland in Hämeenlinna than in Slovakia in Dunajská Streda. The maximum forces in roof structure for both cases, calculated using Dlubal RFEM, are listed in Table 12.

Table 12. Maximum forces acting on the roof structure in Slovakia and Finland

Load	Slovakia	Finland	Difference (%)
Axial force (kN)	71.55	120.15	~ 67.5
Shear force (kN)	13.77	23.02	
Bending moment (kN*m)	6.63	11.15	
Support reaction (kN)	49.28	82.47	

The utilizations checks of the roof elements also showed clear differences between the two countries. However, despite these, all roof elements in both cases remain within the required safety limits. The only roof component that approaches its capacity limit is the rafter and rafter/collar tie connection, which showed a utilization of approximately 62% in Slovakia but rises to about 93% in Finland. Although this still satisfies the design criteria, to ensure additional safety, it is recommended to use larger mechanical fasteners or higher bolt grade.

The increased roof reactions also lead to higher axial compression force in the load-bearing walls in Finland. The calculated maximum compression force was 85.34 kN/m, while in Slovakia it reached 54.43 kN/m, or approximately 57% higher in Finland. Although the difference in axial forces is significant, the design utilization ratio of masonry wall remained almost identical in both countries, 15.52% in Finland and 15.40% in Slovakia. This occurred because the design masonry compressive strength differs between the two national annexes, resulting from variations in the applied safety factors and material coefficients.

At the foundation level, the strip footings are subjected to higher soil pressures in Finland. The design bearing resistance was assumed to 200 kPa in both countries, while the design action was calculated as 69.5 kN/m in Slovakia and 100.4 kN/m in Finland, which is approximately 44.5% higher in the Nordic country. This resulted in utilization ratios of about

58% for Slovakia and 84% for Finland. Although both values remain below the allowable soil bearing resistance, the Finnish foundation experiences more demanding load environment due to the heavier snow load and higher wall reactions.

For simplicity and to preserve comparability between the two case studies, frost depth effects were not included in the comparative analysis. Taking frost depth and insulation into account would require changing foundation geometry, insulation strategies and drainage detailing to a degree that would make the comparison non-equivalent.

The reinforced concrete ring beam and the base floor differences between the Slovak and Finnish cases are relatively small and do not have any significant effect on their structural performance. Consequently, no design modifications are required.

Considering the entire load path of the structure, these calculated results indicate an overall representative increase in design actions of approximately 55-60% in Finland.

9.2 Comparative evaluation of energy performance

The comparison of energy performance between Slovakia and Finland revealed differences coming primarily from climatic severity, national U-value limits, and the primary energy coefficients. Although the building geometry, internal gains, mechanical systems, and operational schedules were kept identical in both simulations, the external climate and national energy regulations influenced the final performance indicators.

A major difference came from the heating demand imposed by the two climates. Finland's colder boreal environment requires a considerably higher heating energy, while Slovakia's milder climate results in lower heating. This is reflected in the dynamic simulation results, in Slovakia, the building had an overall heat demand of 10006.4 kWh with 1789.9 kWh of non-renewable primary energy and 137.7 kg of CO_2 emissions. By contrast in Finland, it resulted in 12349.8 kWh of annual heat demand, 6316.3 kWh of non-renewable primary energy, and 1432.6 kg of CO_2 emissions. That shows approximately 20% more heat demand, 250% higher non-renewable primary energy consumption, and 940% more emission in Finland caused by the higher environmental burden.

The photovoltaic (PV) system production also differed between the two climates. Due to higher annual solar radiation and more favourable weather conditions, the PV system generated about 12.5% more energy in Slovakia reaching 7406.4 kWh, whereas in Finland production decreased to 6575.4 kWh.

The comparison of building envelope performance showed that the Finnish case requires noticeably lower U-values than Slovakia, resulting in thicker insulation layers in several structural elements. To comply with the strict Finnish limits, the external wall insulation was increased by 70 mm, the ceiling was thickened by 50 mm, and the ground floor received a thicker thermal layer by 80 mm. These modifications ensure sufficient thermal resistance under the harsher climate, reduce heat losses, and maintain compliance with national regulations.

The Slovak calculation method produced an E-number of 12.8 kWh/(m^2·year), categorising the building as A0, which is the highest national class for nearly zero-energy buildings. The Finnish method resulted in an E-number of 45.1 kWh/(m^2·year), corresponding to category A, which also satisfies the national criteria. Finland applies lower primary-energy coefficients for electricity, 1.20 compared to Slovakia’s 2.20, but compensates for this advantage with significantly stricter U-value limits. Slovakia, in contrast, allows slightly higher U-values but benefits from greater annual solar gains, leading to more favourable overall energy balances.

9.3 Comparative evaluation of economic assessment

This section provides a comparative evaluation of the construction costs for the single-family house in Slovakia and Finland. The aim is to examine how differences in labour prices, material costs, and national regulations influence the total economic outcome.

The economic comparison showed that building the same house in Finland is substantially more expensive than in Slovakia. The total construction cost excluding VAT is €222 277.09 for Slovakia and €384 776.48 for Finland. This corresponds to an approximately €1306.90/m^2 in Slovakia and €2262.33/m^2, an increase of about 73.1% for the Finnish case.

The structural shell and envelope accounted for the majority of the expenditure in both countries. In Slovakia it was 95.7% of the total, while in Finland it covered 94.4% of the total price.

The higher Finnish cost is caused by local market and regulatory factors. Labour and on-site productivity differences, together with higher unit prices for several materials and assemblies in Finland made the cost increase.

10 Conclusion

This thesis examined the design of a single-family house constructed with identical geometry and materials in two contrasting European regions, Slovakia and Finland. The goal was to analyse how climatic, regulatory, and economic factors influence structural performance, energy balance, and overall construction feasibility.

The structural analysis demonstrated that snow load is the most influential climatic action differentiating the two countries. As a result, Finnish design cases consistently showed higher utilization ratios across all key members. Although all the elements remained safely within Eurocode limits, the increased stresses highlight the necessary for more robust design strategies in Nordic climates.

The energy performance analysis emphasized the influence of national regulations and heating demand on building envelope design. Finland's strict energy requirements, combined with its colder climate, demanded thicker insulation layers and more airtight envelope. Conversely, Slovakia's milder climate required a more balanced approach between heating and cooling performance, with envelope requirements that are less demanding.

The economic assessment confirmed that construction costs vary considerably between the two regions. Finland's higher labour costs and the need for enhanced insulation contributed to a greater overall financial investment, despite similar material quantities. Meanwhile, Slovakia benefited from lower prices, leading to lower construction cost. These cost values are indicative and may vary due to ongoing changes in material and labour prices in each country, therefore, they should be verified and updated prior to practical use.

Overall, the comparative analysis showed that designing a single universal building model for different European climates is feasible structurally, however climate-driven regulations influences the building design with necessary adjustments. Beyond the analytical outcomes, this thesis provides value as a practical and educational resource for students, designers, engineers, and stakeholders involved in residential construction. The thesis does not aim to deliver a final, universally applicable building design, rather, it serves as an exploration of the challenges and possibilities that emerge when applying one standardized house model to two distinct environments. Further research, such as life cycle assessment, deeper economic comparison, or investigation of alternative materials would help refine these insights.

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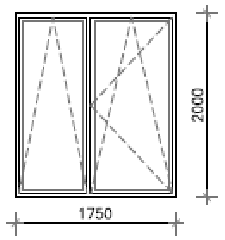
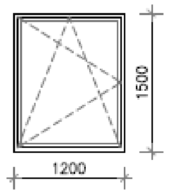
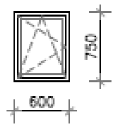
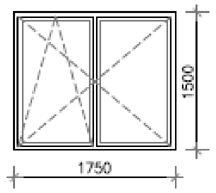
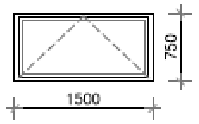
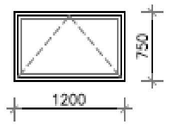
Appendix 1. Architectural visualization

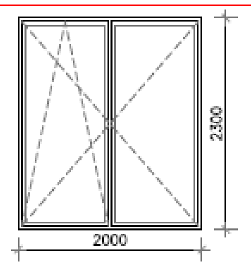
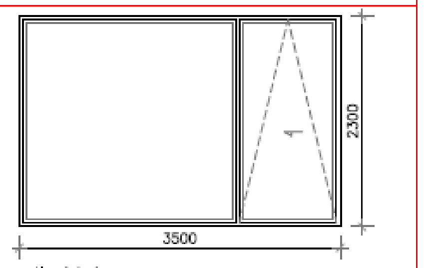
lumion

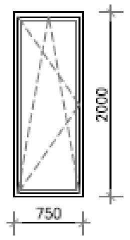
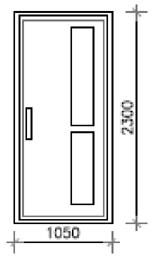
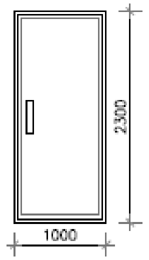
lumion

Appendix 2. Technical drawings

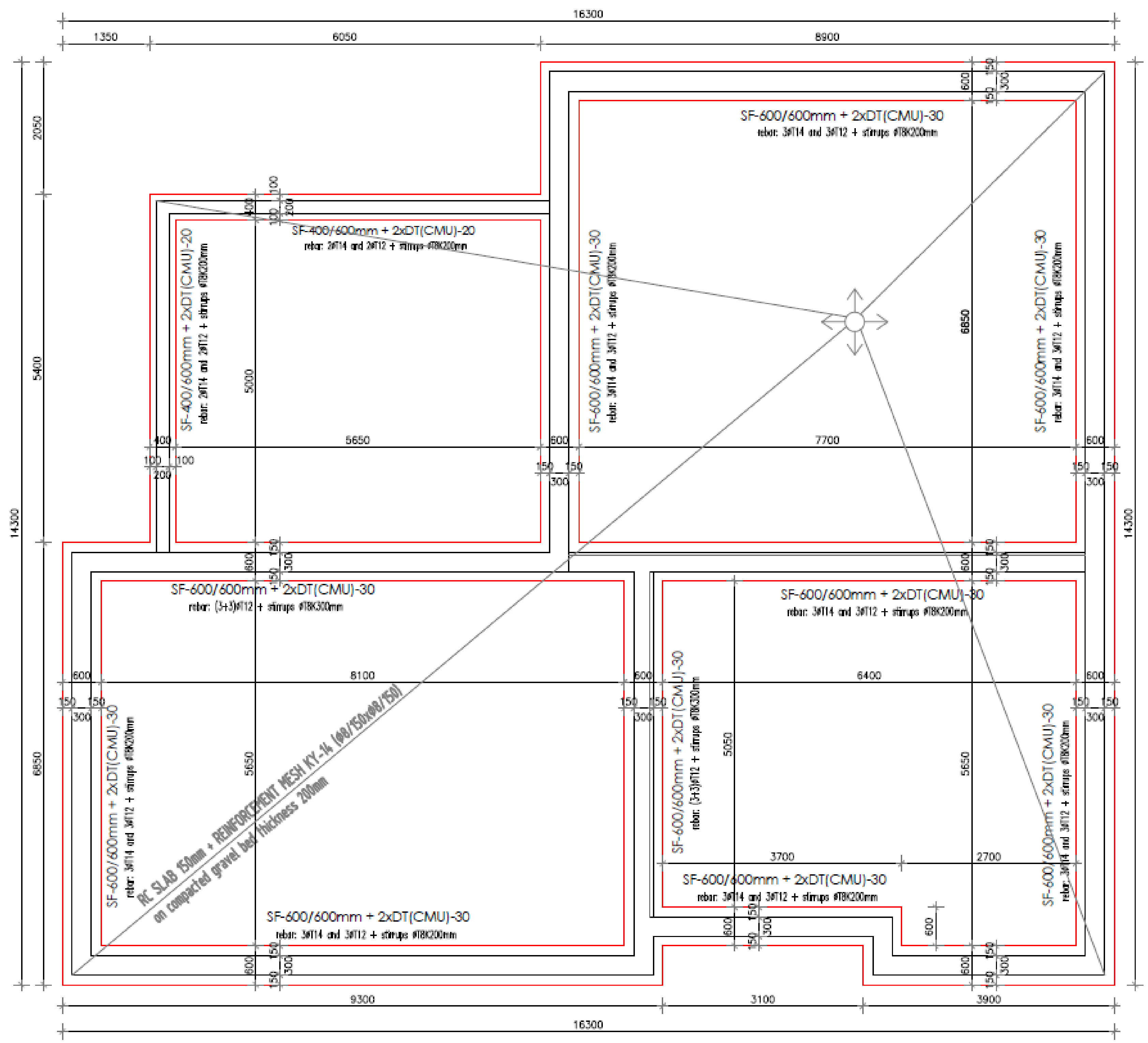
List of windows and doors:	01		02		03	
Schematic representation	 Looking from the interior		 Looking from the interior		 Looking from the interior	
Dimensions in mm	Construction opening 1750x2000		Construction opening 1200x1500		Construction opening 600x750	
Description	Exterior window, glazed, tilt–and–turn, fixed		Exterior window, glazed, tilt–and–turn, fixed		Exterior window, glazed, tilt–and–turn, fixed	
Fittings	Part of delivery		Part of delivery		Part of delivery	
Number of pieces	1st floor	2nd floor	1st floor	2nd floor	1st floor	2nd floor
	1	–	1	–	1	–
	Total: 1 pc		Total: 1 pc		Total: 1 pc	
Glazing	According to the supplier		According to the supplier		According to the supplier	
Colour	Colour: ANTHRACITE		Colour: ANTHRACITE		Colour: ANTHRACITE	

List of windows and doors:	04		05		06	
Schematic representation	 Looking from the interior		 Looking from the interior		 Looking from the interior	
Dimensions in mm	Construction opening 1750x1500		Construction opening 1500x750		Construction opening 1200x750	
Description	Exterior window, glazed, tilt–and–turn, fixed		Exterior door window, glazed, tilt–only		Exterior window, glazed, tilt–only	
Fittings	Part of delivery		Part of delivery		Part of delivery	
Number of pieces	1st floor	2nd floor	1st floor	2nd floor	1st floor	2nd floor
	2	–	1	–	1	–
	Total: 2 pc		Total: 1 pc		Total: 1 pc	
Glazing	According to the supplier		According to the supplier		According to the supplier	
Colour	Colour: ANTHRACITE		Colour: ANTHRACITE		Colour: ANTHRACITE	

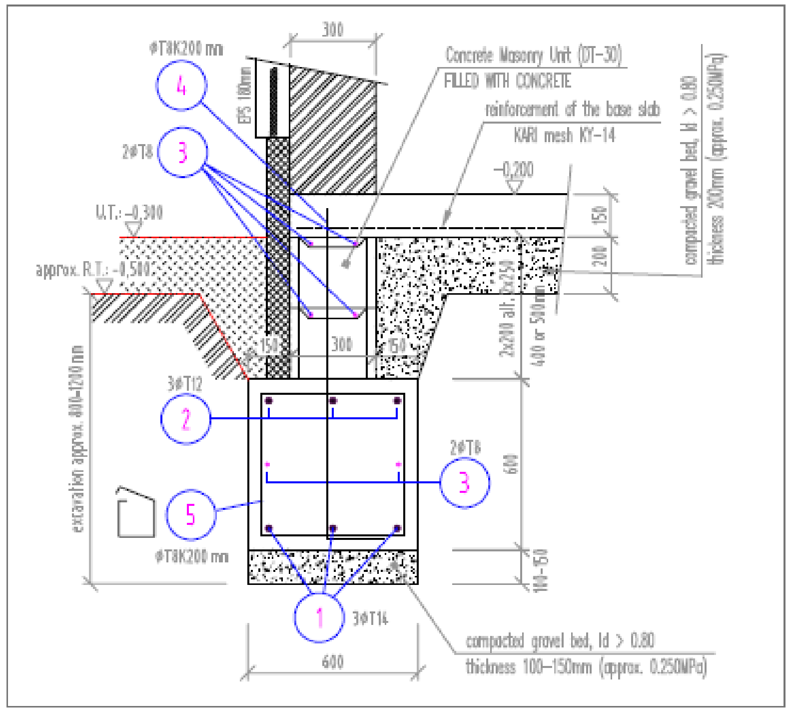
List of windows and doors:	07		08	
Schematic representation	 Looking from the interior		 Looking from the interior	
Dimension in mm	Construction opening 2000x2300		Construction opening 3500x2300	
Description	Exterior window, glazed, tilt–and–turn, fixed		Exterior terrace window, glazed, tilt, fixed, sliding	
Fittings	Part of delivery		Part of delivery	
Number of pieces	1st floor	2nd floor	1st floor	2nd floor
	1	–	1	–
	Total: 1 pc		Total: 1 pc	
Glazing	According to the supplier		According to the supplier	
Colour	Colour: ANTHRACITE		Colour: ANTHRACITE	

List of windows and doors:	09		VD1		VD2	
Schematic representation	 Looking from the interior		 Looking from the interior		 Looking from the interior	
Dimensions in mm	Construction opening 750x2000		Construction opening 1050x2300		Construction opening 1000x2300	
Description	Exterior window, glazed, tilt–and–turn, fixed		Entrance door with partially glazed door leaf 1050 mm, hinged		Entrance door with solid door leaf 1000 mm, hinged	
Fittings	Part of delivery		Part of delivery		Part of delivery	
Number of pieces	1st floor	2nd floor	1st floor	2nd floor	1st floor	2nd floor
	1	–	1	–	1	–
	Total: 2 pc		Total: 1 pc		Total: 1 pc	
Glazing	According to the supplier		According to the supplier		According to the supplier	
Colour	Colour: ANTHRACITE		Colour: ANTHRACITE		Colour: ANTHRACITE	

FAMILY HOUSE / FOUNDATION PLAN



Schematic reinforcement of foundation strips: detail, scale 1:25



Concrete:	C 20/25
Reinforcement:	B-500B (O 10505-R)
Concrete cover:	50mm - strip footing, 30mm - slab

Reinforcement of the ground slab:
(of the binding concrete)
- Mesh at the BOTTOM surface KY-14
  (KY-14 = Ø8/150 x Ø8/150 -2400x6000mm)
- Overlapping of KARI meshes is 450 mm
  (3 grid spaces in both directions)

NOTES:

Before beginning concreting of the foundations, it is necessary to mark locations and leave openings for the passage of sewage pipes through the foundation structure.
Backfilling must be compacted to 0.25MPa.
Before concreting the blinding layer, it is necessary to install horizontal sewage lines according to the project documentation, section: sanitary engineering.
Place a gravel bedding layer of 200mm thickness under the foundations.
The actual properties of the foundation soil at the level of the foundation base and the presence of groundwater in the subsoil must be specified during the excavation works. Based on the findings, it is necessary to adjust the foundation dimensions or reassess the method of foundation construction.
Quantity of gravel needed for bedding thickness 0.15 to 0.25m for 210.07m² = approx. 42.01m³.
Quantity of concrete for foundation strips = approx. 28.85m³.
Quantity of concrete for casting the base slab 200.07m² thickness 150mm = approx. 30.01m³.
Other concrete works: concreting into blocks in foundations, columns, lintels, reinforced areas, stairs.
Concrete – C20/25 – XC2 – Cl 0.4 – Dmax16 – S3
Reinforcement steel BSt500 (10505.0 R)
Covering: 50mm for foundation strips, 30mm for base slab.

NOTES:
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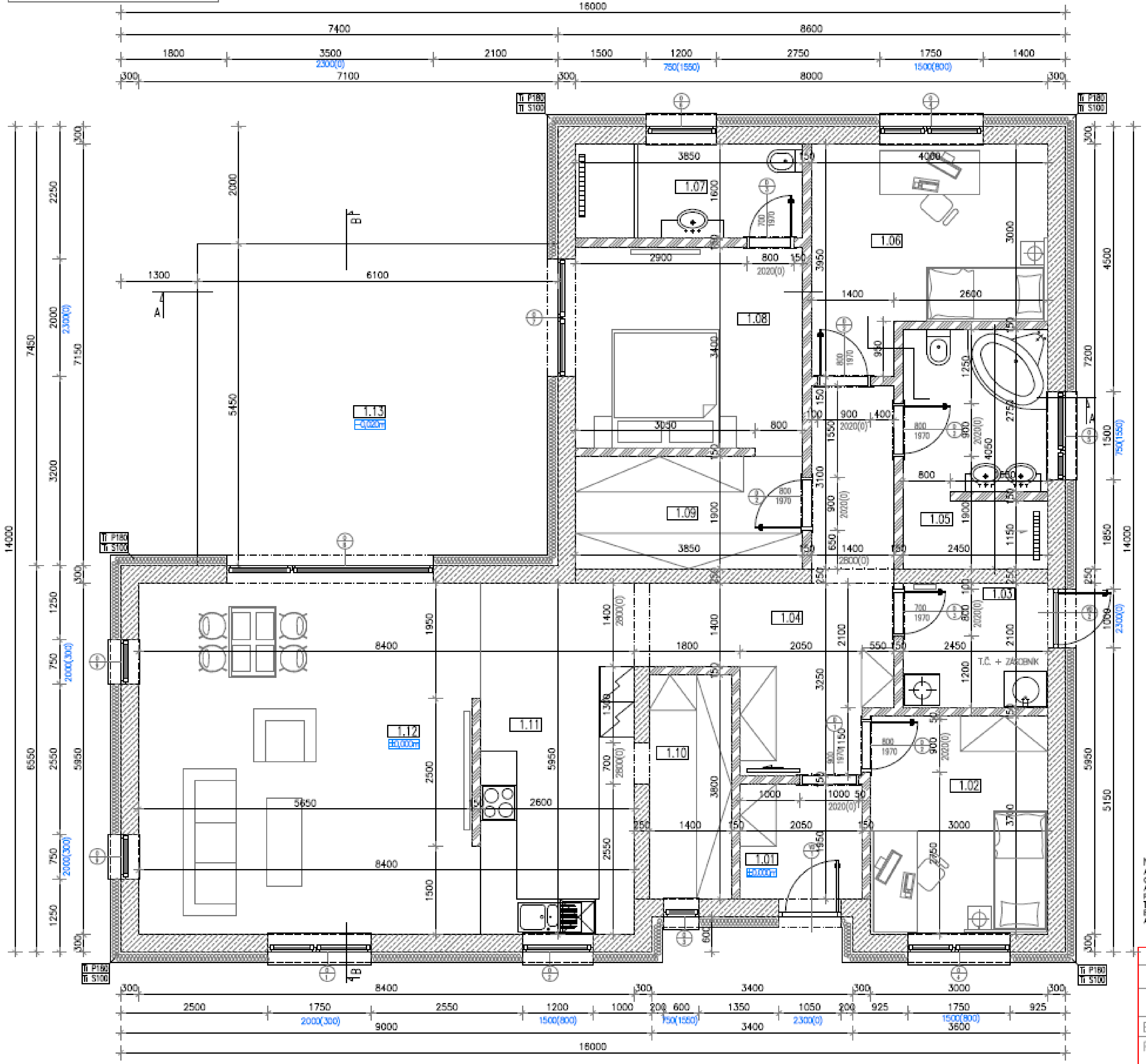
ANY UNCERTAINTIES OR INCONSISTENCIES IN THE PROJECT MUST BE REPORTED TO THE RESPONSIBLE DESIGNER OF THE RELEVANT PROJECT SECTION!
THE DESIGNED DIMENSIONS OF ALL BUILDING PRODUCTS AND STRUCTURES MUST BE VERIFIED BY MEASUREMENT DIRECTLY ON SITE BEFORE BEING SENT TO MANUFACTURE!
ANY CHANGES DURING CONSTRUCTION MUST BE CONSULTED WITH THE DESIGNER.

DESIGNER: DÁNIEL MIKOLAI
RESPONSIBLE DESIGNER:
STAMP:
BUILDING DESIGN – BUILDING PERMIT APPLICATION
PROJECT TITLE: SINGLE-FAMILY HOUSE
PLOT NO.:
CADASTRAL AREA:
MUNICIPALITY:
DISTRICT:
INVESTOR:
STRUCTURE: SINGLE-FAMILY HOUSE
DRAWING: FOUNDATION PLAN
SHEET SIZE: 2xA4
SCALE: 1:75
DATE: 06/2025
DRAWING NO.: A1

FAMILY HOUSE / GROUND FLOOR PLAN



LEGEND OF MATERIALS

- ▨ EXTERIOR AND LOAD-BEARING MASONRY POROTHERM PROFI (P12), thickness 300mm, 250mm, with thin-layer full-surface adhesive POROTHERM PROFI, WITH EXTERNAL INSULATION SYSTEM BAUMIT EPS-F thickness 180mm AND INTERNAL PLASTER
- ▨ PARTITION WALLS PORFIX thickness 150mm with thin-layer full-surface adhesive, WITH INTERNAL PLASTER
- ▦ CONCRETE MASONRY UNIT BLOCKS (CMU) DT-20, 30 – HR. 200mm, 300mm
- ▨ REINFORCED CONCRETE STRUCTURE
  CONCRETE – ACCORDING TO STRUCTURAL DESIGN
- ▧ PLAIN CONCRETE STRUCTURES
  CONCRETE C12/15
- ▒ COMPACTED GRAVEL EMBANKMENT – DANUBE GRAVEL, FRACTION #20-30
- ▧ ORIGINAL SOIL
  FILLED SOIL
- ▒ GRAVEL FILL – SORTED ROUNDED GRAVEL, FRACTION #20-30
- ☰ WATERPROOFING
- ☰ THERMAL INSULATION (FACADE POLYSTYRENE, MINERAL WOOL, EXTRUDED POLYSTYRENE)

LEGEND OF DESCRIPTIONS

- D/X WOODEN CASED (LINED) DOORS
- VD/X ENTRANCE DOOR
- O/X WINDOW / GLAZED WALL
- GB/X GARAGE DOOR / SECTIONAL
- VM VENTILATION GRILLE
  150x150mm
- KV SHEET METAL PRODUCT,
  EAVES GUTTER AND DOWNPIPE
- KOM THREE-COMPONENT CHIMNEY FOR FIREPLACE
  SCHIEDEL UNI
- TI NX THERMAL INSULATION – MINERAL WOOL,
  thickness 100mm, 180mm
- TI PX THERMAL INSULATION – FACADE POLYSTYRENE,
  thicknesses 50, 70, 80, 100, 120, 150mm, 180
- TI SX THERMAL INSULATION – STYRODUR,
  thicknesses 30, 50, 80, 100mm
- ▦ STONE ANTI-SLIP EXTERIOR PAVING
  COLOR ACCORDING TO INVESTOR'S CHOICE, thickness 8 cm

PX FLOORS

P1
- WOODEN PARQUET, THICKNESS 15mm
- IMPACT SOUND INSULATION, THICKNESS 15mm
- CONCRETE SCREED, THICKNESS 50mm
- UNDERFLOOR HEATING SYSTEM BOARD, THICKNESS 30mm
- THERMAL INSULATION – EPS POLYSTYRENE, THICKNESS 120mm
- WATERPROOFING (ASPHALT MEMBRANE OR PLASTIC FOIL)
- LOAD-BEARING REINFORCED CONCRETE SLAB, THICKNESS 150mm
- GRAVEL BED, THICKNESS 150mm

P2
- PORCELAIN STONEWARE TILES (GRES) 600x600 MM, THICKNESS 10mm
- TILE ADHESIVE, THICKNESS 10mm
- CONCRETE SCREED, THICKNESS 60mm
- UNDERFLOOR HEATING SYSTEM BOARD, THICKNESS 30mm
- THERMAL INSULATION – EPS POLYSTYRENE, THICKNESS 120mm
- WATERPROOFING (ASPHALT MEMBRANE OR PLASTIC FOIL)
- LOAD-BEARING REINFORCED CONCRETE SLAB, THICKNESS 150mm
- GRAVEL BED, THICKNESS 150mm

SX ROOFS

S1
- CONCRETE OR ALTERNATIVELY CERAMIC ROOF TILES, ANTHRACITE COLOR
- ROOF BATTENS 30/50 MM
- COUNTER-BATTENS 40/60 MM
- ROOFING MEMBRANE (SECONDARY WATERPROOFING LAYER)
- RAFTERS (ACCORDING TO STRUCTURAL DESIGN)

STRX CEILINGS

STR1
- WALKABLE LAYER – OSB BOARDS, THICKNESS 18 (22) mm (FULL SHEATHING)
- SPRAYED INSULATION – POLYURETHANE FOAM, THICKNESS 300mm
- VAPOR BARRIER FOIL
- SUSPENDED GYPSUM BOARD CEILING (DRYWALL), THICKNESS 12.5mm

LEGEND OF ROOMS

ROOM NO.	ROOM NAME	FLOORS	WALLS	CEILINGS	AREA /m²
1.01	ENTRANCE	P2	GYPSUM PLASTER (G.P.)	STR1	4.05
1.02	ROOM 1	P1	GYPSUM PLASTER (G.P.)	STR1	11.10
1.03	UTILITY ROOM	P1	GYPSUM PLASTER (G.P.)	STR1	5.15
1.04	CORRIDOR	P2	GYPSUM PLASTER (G.P.)	STR1	14.67
1.05	BATHROOM	P2	GRES TILE CLADDING AND G.P.	STR1	9.66
1.06	ROOM 2	P1	GYPSUM PLASTER (G.P.)	STR1	13.33
1.07	BATHROOM	P1	GRES TILE CLADDING AND G.P.	STR1	6.16
1.08	BEDROOM	P1	GYPSUM PLASTER (G.P.)	STR1	13.21
1.09	DRESSING ROOM	P1	GYPSUM PLASTER (G.P.)	STR1	7.32
1.10	STORAGE ROOM	P1	GYPSUM PLASTER (G.P.)	STR1	5.32
1.11	KITCHEN	P1	GYPSUM PLASTER (G.P.)	STR1	15.43
1.12	LIVING ROOM	P1	GYPSUM PLASTER (G.P.)	STR1	34.04
TOTAL USABLE FLOOR AREA OF THE GROUND FLOOR					139.43
1.13	TERRACE	TERAZZO	-	STR2	33.16

NOTES:
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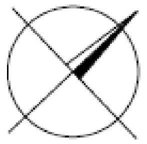


DESIGNER:
DÁNIEL MIKOLAI
RESPONSIBLE DESIGNER:
STAMP:

BUILDING DESIGN FOR – BUILDING PERMIT APPLICATION

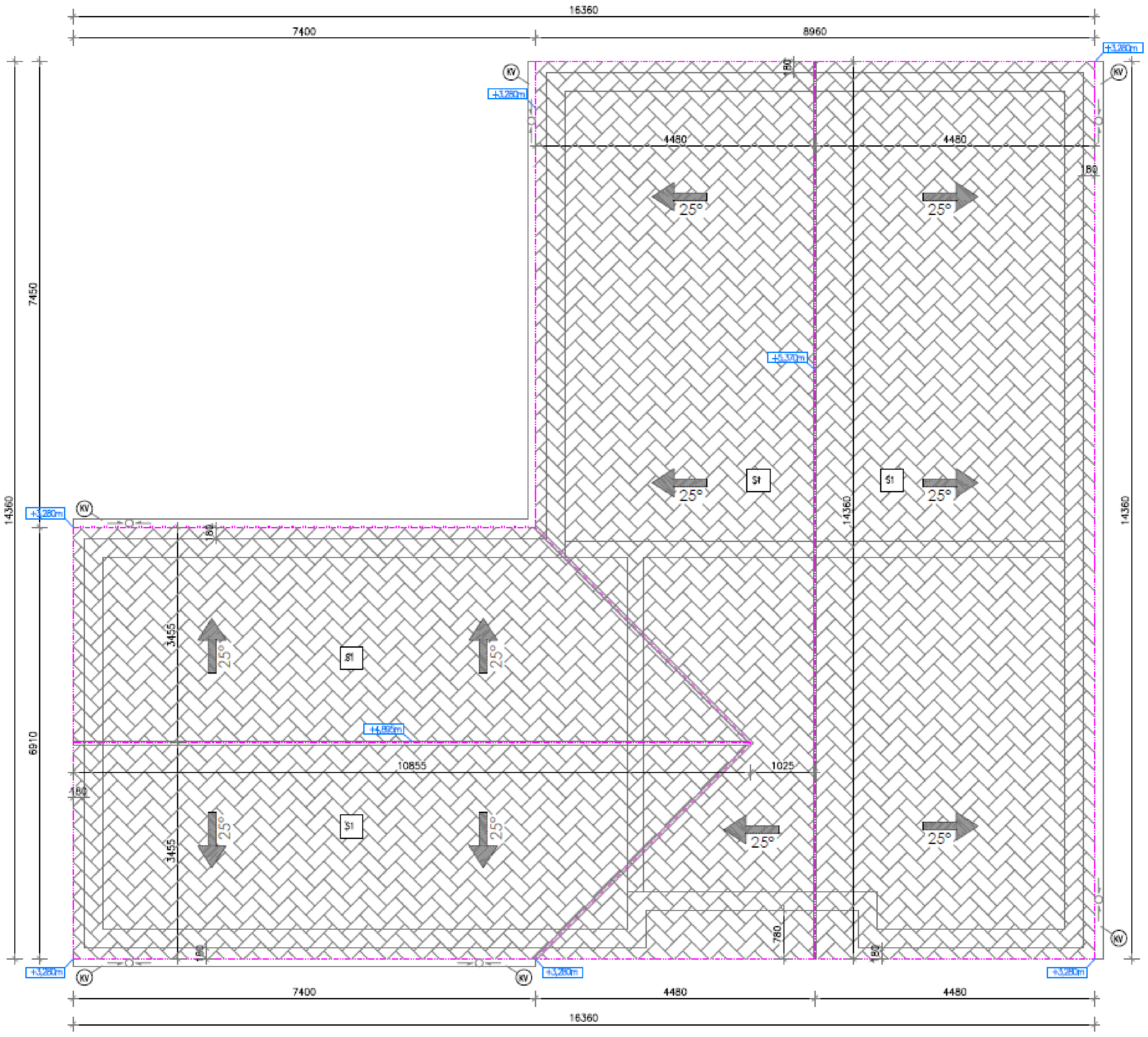
PROJECT TITLE:
SINGLE-FAMILY HOUSE

PLOT NO.:
CADASTRAL AREA:
MUNICIPALITY:
DISTRICT:

INVESTOR:

STRUCTURE: SINGLE-FAMILY HOUSE
DRAWING: GROUND FLOOR PLAN ±0,000m
SHEET SIZE: 2xA4
SCALE: 1:75
DATE: 06/2025
DRAWING NO.: A2

FAMILY HOUSE / ROOF PLAN



LEGEND OF ROOF DESCRIPTION

▨	ROOF COVERING ROOF AREA OF THE FAMILY HOUSE: 179.79 m² ROOF SLOPE OF THE FAMILY HOUSE: 25°

SX ROOFS

S1
- CONCRETE OR ALTERNATIVELY CERAMIC ROOF TILES, ANTHRACITE COLOR
- ROOF BATTENS 30/50 MM
- COUNTER-BATTENS 40/60 MM
- ROOFING MEMBRANE (SECONDARY WATERPROOFING LAYER)
- RAFTERS (ACCORDING TO STRUCTURAL DESIGN)

NOTES:

INSTALLATION AND APPLICATION OF THE ROOF COVERING MUST BE CARRIED OUT IN ACCORDANCE WITH THE MANUFACTURER'S TECHNICAL SPECIFICATIONS!

GUTTER SYSTEM TO BE EQUIPPED WITH A PROTECTIVE MESH
ROOF SYSTEM TO BE EQUIPPED WITH ACCESSORIES (SNOW GUARD, BIRD-PROTECTION MESH)

PARTS OF THE EAVES STRUCTURE:

EAVES GUTTER ø125mm, COLOR ACCORDING TO THE INVESTOR'S CHOICE
DRAIN PIPE ø125mm, COLOR ACCORDING TO THE INVESTOR'S CHOICE
ROOF FLASHING AT WALL JUNCTIONS
FLASHING OF THE FACADE CHIMNEY
FLASHING OF THE VENTILATION PIPE

NOTES:
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LEGEND OF DESCRIPTIONS

D/X	WOODEN CASED (LINED) DOORS
VD/X	ENTRANCE DOOR
O/X	WINDOW / GLAZED WALL
GB/X	GARAGE DOOR / SECTIONAL
VM	VENTILATION GRILLE 150x150mm
KV	SHEET METAL PRODUCT, EAVES GUTTER AND DOWNPIPE
KOM	THREE-COMPONENT CHIMNEY FOR FIREPLACE SCHIEDEL UNI
TI NX	THERMAL INSULATION – MINERAL WOOL, thickness 100mm, 180mm
TI PX	THERMAL INSULATION – FACADE POLYSTYRENE, thicknesses 50, 70, 80, 100, 120, 150mm, 180
TI SX	THERMAL INSULATION – STYRODUR, thicknesses 30, 50, 80, 100mm
▦	STONE ANTI-SLIP EXTERIOR PAVING COLOR ACCORDING TO INVESTOR'S CHOICE, thickness 8 cm

DESIGNER:
DÁNIEL MIKOLAI
RESPONSIBLE DESIGNER:
STAMP:

BUILDING DESIGN FOR – BUILDING PERMIT APPLICATION

PROJECT TITLE:
SINGLE-FAMILY HOUSE

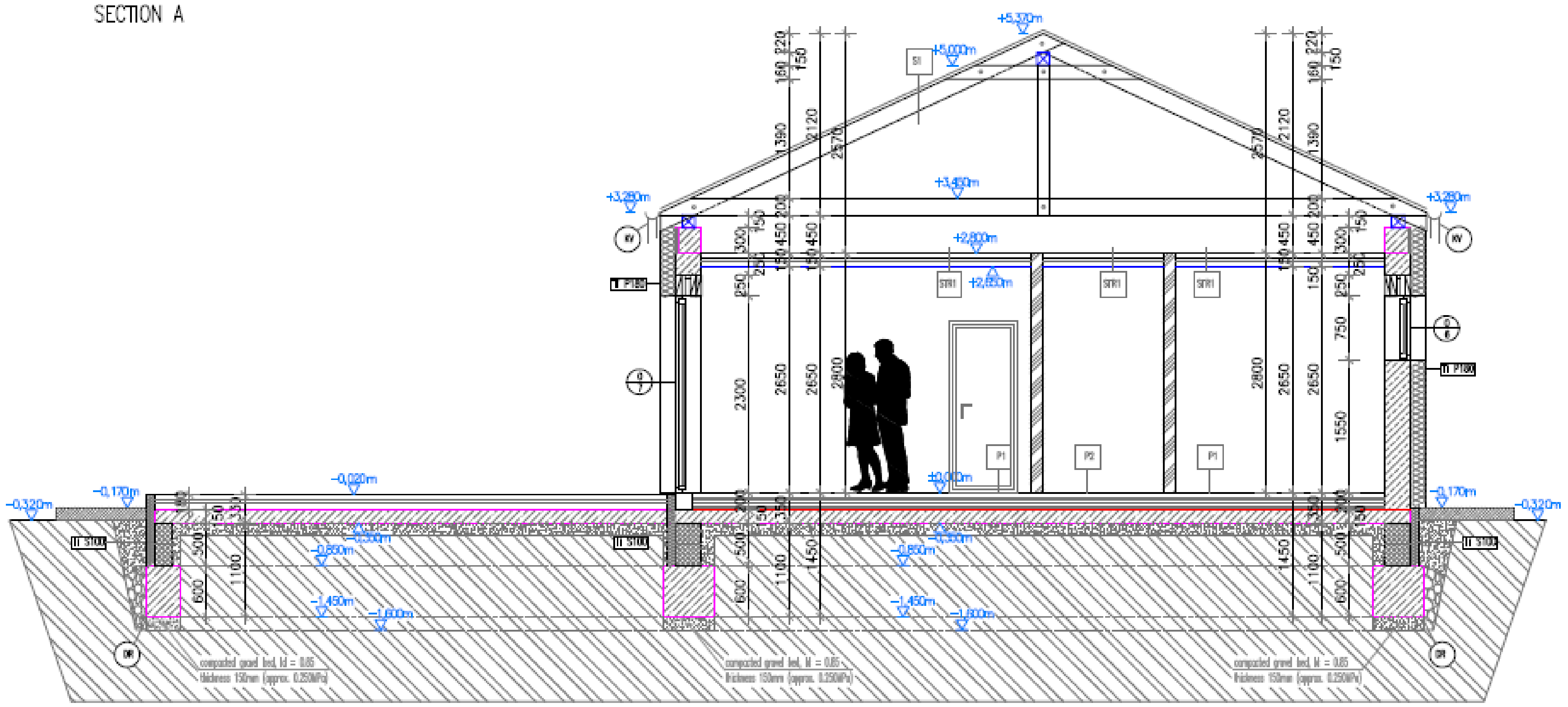
PLOT NO.:
CADASTRAL AREA:
MUNICIPALITY:
DISTRICT:

INVESTOR:

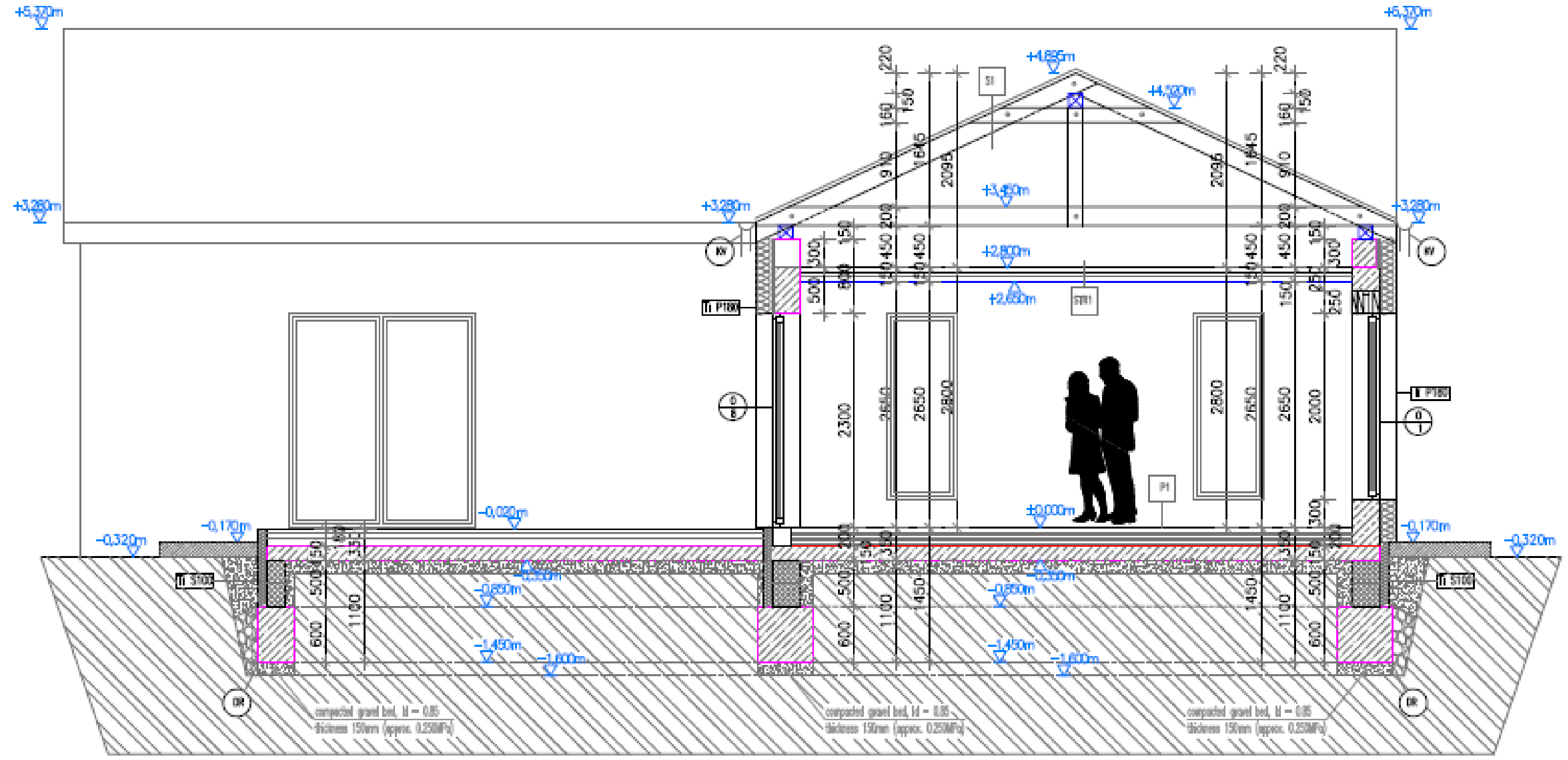
STRUCTURE: SINGLE-FAMILY HOUSE
DRAWING: ROOF PLAN
SHEET SIZE: 2xA4
SCALE: 1:75
DATE: 06/2025
DRAWING NO.: A3

FAMILY HOUSE / SECTIONS A, B

SECTION A



SECTION B



LEGEND OF MATERIALS

▨ EXTERIOR AND LOAD-BEARING MASONRY POROTHERM PROFI (P12), thickness 300mm, 250mm, with thin-layer full-surface adhesive POROTHERM PROFI, WITH EXTERNAL INSULATION SYSTEM BAUMIT EPS-F thickness 180mm AND INTERNAL PLASTER

▨ PARTITION WALLS PORFIX thickness 150mm with thin-layer full-surface adhesive, WITH INTERNAL PLASTER

▨ CONCRETE MASONRY UNIT BLOCKS (CMU) DT-20, 30 - HR. 200mm, 300mm

▨ REINFORCED CONCRETE STRUCTURE
CONCRETE - ACCORDING TO STRUCTURAL DESIGN

▨ PLAIN CONCRETE STRUCTURES
CONCRETE C12/15

▨ COMPACTED GRAVEL EMBANKMENT - DANUBE GRAVEL, FRACTION #20-30

▨ ORIGINAL SOIL
FILLED SOIL

▨ GRAVEL FILL - SORTED ROUNDED GRAVEL, FRACTION #20-30

▭ WATERPROOFING

▤ THERMAL INSULATION (FACADE POLYSTYRENE, MINERAL WOOL, EXTRUDED POLYSTYRENE)

LEGEND OF DESCRIPTIONS

D/X WOODEN CASED (LINED) DOORS

VD/X ENTRANCE DOOR

O/X WINDOW / GLAZED WALL

GB/X GARAGE DOOR / SECTIONAL

VM VENTILATION GRILLE
150x150mm

KV SHEET METAL PRODUCT,
EAVES GUTTER AND DOWNPIPE

KOM THREE-COMPONENT CHIMNEY FOR FIREPLACE
SCHIEDEL UNI

Ti NX THERMAL INSULATION - MINERAL WOOL,
thickness 100mm, 180mm

Ti PX THERMAL INSULATION - FACADE POLYSTYRENE,
thicknesses 50, 70, 80, 100, 120, 150mm, 180

Ti SX THERMAL INSULATION - STYRODUR,
thicknesses 30, 50, 80, 100mm

▦ STONE ANTI-SLIP EXTERIOR PAVING
COLOR ACCORDING TO INVESTOR'S CHOICE, thickness 8 cm

PX FLOORS

P1
- WOODEN PARQUET, THICKNESS 15mm
- IMPACT SOUND INSULATION, THICKNESS 15mm
- CONCRETE SCREED, THICKNESS 50mm
- UNDERFLOOR HEATING SYSTEM BOARD, THICKNESS 30mm
- THERMAL INSULATION - EPS POLYSTYRENE, THICKNESS 120mm
- WATERPROOFING (ASPHALT MEMBRANE OR PLASTIC FOIL)
- LOAD-BEARING REINFORCED CONCRETE SLAB, THICKNESS 150mm
- GRAVEL BED, THICKNESS 150mm

P2
- PORCELAIN STONEWARE TILES (GRES) 600x600 MM, THICKNESS 10mm
- TILE ADHESIVE, THICKNESS 10mm
- CONCRETE SCREED, THICKNESS 60mm
- UNDERFLOOR HEATING SYSTEM BOARD, THICKNESS 30mm
- THERMAL INSULATION - EPS POLYSTYRENE, THICKNESS 120mm
- WATERPROOFING (ASPHALT MEMBRANE OR PLASTIC FOIL)
- LOAD-BEARING REINFORCED CONCRETE SLAB, THICKNESS 150mm
- GRAVEL BED, THICKNESS 150mm

SX ROOFS

S1
- CONCRETE OR ALTERNATIVELY CERAMIC ROOF TILES, ANTHRACITE COLOR
- ROOF BATTENS 30/50 MM
- COUNTER-BATTENS 40/60 MM
- ROOFING MEMBRANE (SECONDARY WATERPROOFING LAYER)
- RAFTERS (ACCORDING TO STRUCTURAL DESIGN)

STRX CEILINGS

STR1
- WALKABLE LAYER - OSB BOARDS, THICKNESS 18 (22) mm (FULL SHEATHING)
- SPRAYED INSULATION - POLYURETHANE FOAM, THICKNESS 300mm
- VAPOR BARRIER FOIL
- SUSPENDED GYPSUM BOARD CEILING (DRYWALL), THICKNESS 12.5mm

LEGEND OF ROOF DESCRIPTION

☒ ROOF COVERING
ROOF AREA OF THE FAMILY HOUSE: 179.79 m²
ROOF SLOPE OF THE FAMILY HOUSE: 25°

NOTES:

INSTALLATION AND APPLICATION OF THE ROOF COVERING MUST BE CARRIED OUT IN ACCORDANCE WITH THE MANUFACTURER'S TECHNICAL SPECIFICATIONS!

GUTTER SYSTEM TO BE EQUIPPED WITH A PROTECTIVE MESH
ROOF SYSTEM TO BE EQUIPPED WITH ACCESSORIES (SNOW GUARD, BIRD-PROTECTION MESH)

PARTS OF THE EAVES STRUCTURE:

EAVES GUTTER ø125mm, COLOR ACCORDING TO THE INVESTOR'S CHOICE
DRAIN PIPE ø125mm, COLOR ACCORDING TO THE INVESTOR'S CHOICE
ROOF FLASHING AT WALL JUNCTIONS
FLASHING OF THE FACADE CHIMNEY
FLASHING OF THE VENTILATION PIPE

NOTES:
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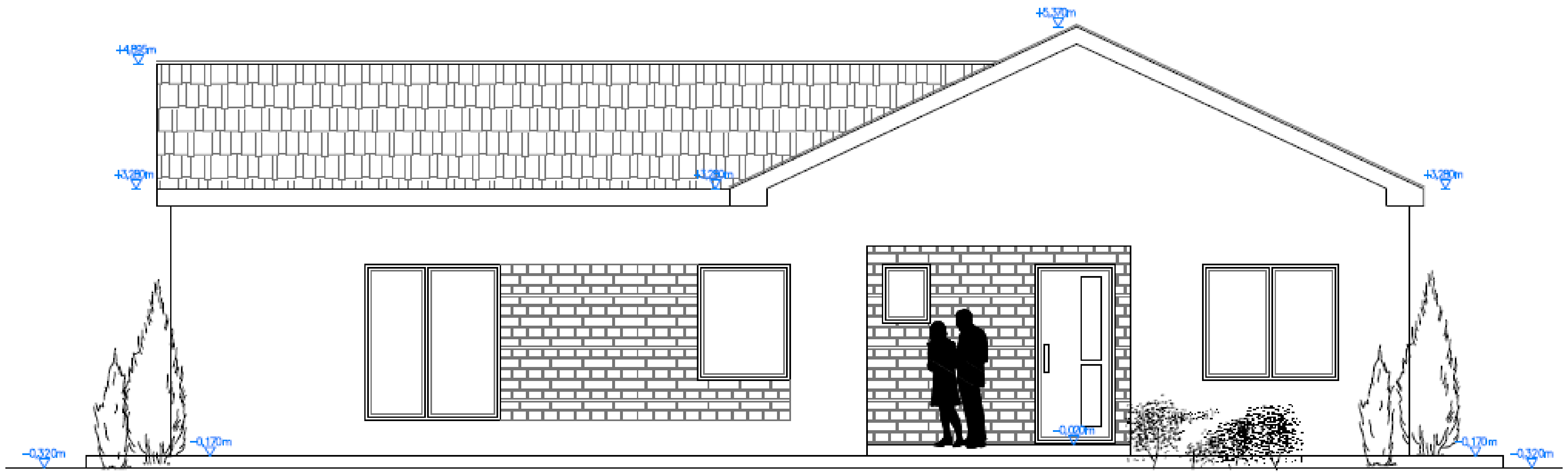
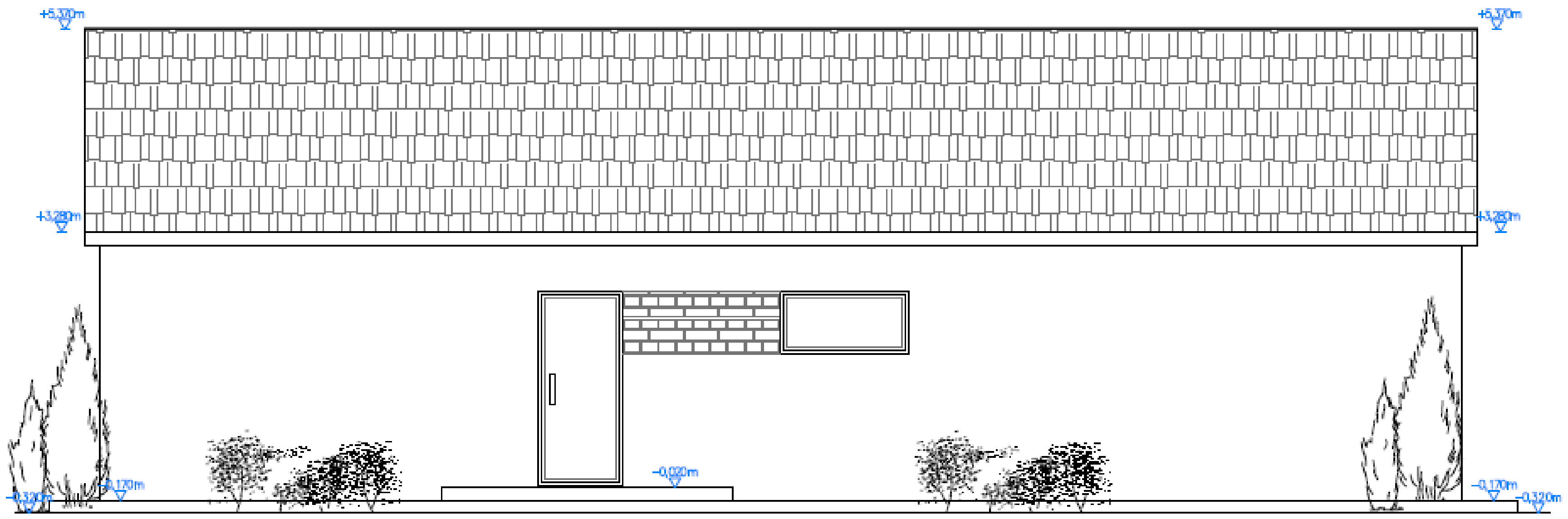
STAMP:
BUILDING DESIGN FOR - BUILDING PERMIT APPLICATION
PROJECT TITLE: SINGLE-FAMILY HOUSE
PLOT NO.:
CADASTRAL AREA:
MUNICIPALITY:
DISTRICT:
INVESTOR:
STRUCTURE: SINGLE-FAMILY HOUSE
DRAWING: SECTIONS A, B
SHEET SIZE: 2xA4
SCALE: 1:75
DATE: 06/2025
DRAWING NO.: A4

FAMILY HOUSE / ELEVATIONS 1

FRONT VIEW



SIDE VIEW



FX FACADES

F1
CONTACT FACADE SYSTEM STO THERM CLASSIC 1
- COATING: STO COLOR LOTUSAN, WHITE COLOR (ALT. BY INVESTOR'S CHOICE)
- PLASTER: STOLIT K/MP/R
- FIBERGLASS MESH: STO GLASSFASEGEWEBE
- REINFORCEMENT COMPOUND: STO ARMAT CLASSIC (CEMENT-FREE SYSTEM)
- ADHESIVE: STO BAUKLEBER

F2
CONTACT FACADE SYSTEM STO THERM CLASSIC 1
- COATING: STO COLOR LOTUSAN, WHITE COLOR (ALT. BY INVESTOR'S CHOICE)
- FIBERGLASS MESH: STO GLASSFASEGEWEBE
- REINFORCEMENT COMPOUND: STO ARMAT CLASSIC (CEMENT-FREE SYSTEM)
- ADHESIVE: STO BAUKLEBER

SX ROOFS

S1
- CONCRETE OR ALTERNATIVELY CERAMIC ROOF TILES, ANTHRACITE COLOR
- ROOF BATTENS 30/50 MM
- COUNTER-BATTENS 40/60 MM
- ROOFING MEMBRANE (SECONDARY WATERPROOFING LAYER)
- RAFTERS (ACCORDING TO STRUCTURAL DESIGN)

LEGEND OF DESCRIPTIONS

D / X	WOODEN CASED (LINED) DOORS
VD / X	ENTRANCE DOOR
O / X	WINDOW / GLAZED WALL
GB / X	GARAGE DOOR / SECTIONAL
VM	VENTILATION GRILLE 150x150mm
KV	SHEET METAL PRODUCT, EAVES GUTTER AND DOWNPIPE
KOM	THREE-COMPONENT CHIMNEY FOR FIREPLACE SCHIEDEL UNI
TI MX	THERMAL INSULATION - MINERAL WOOL, thickness 100mm, 180mm
TI PX	THERMAL INSULATION - FACADE POLYSTYRENE, thicknesses 50, 70, 80, 100, 120, 150mm, 180
TI SX	THERMAL INSULATION - STYRODUR, thicknesses 30, 50, 80, 100mm
▦	STONE ANTI-SLIP EXTERIOR PAVING COLOR ACCORDING TO INVESTOR'S CHOICE, thickness 8 cm

LEGEND OF ROOF DESCRIPTION

▨ ROOF COVERING
ROOF AREA OF THE FAMILY HOUSE: 179.79 m^2
ROOF SLOPE OF THE FAMILY HOUSE: 25°

NOTES:

INSTALLATION AND APPLICATION OF THE ROOF COVERING MUST BE CARRIED OUT IN ACCORDANCE WITH THE MANUFACTURER'S TECHNICAL SPECIFICATIONS!

GUTTER SYSTEM TO BE EQUIPPED WITH A PROTECTIVE MESH
ROOF SYSTEM TO BE EQUIPPED WITH ACCESSORIES (SNOW GUARD, BIRD-PROTECTION MESH)

PARTS OF THE EAVES STRUCTURE:

EAVES GUTTER ⌀125mm, COLOR ACCORDING TO THE INVESTOR'S CHOICE
DRAIN PIPE ⌀125mm, COLOR ACCORDING TO THE INVESTOR'S CHOICE
ROOF FLASHING AT WALL JUNCTIONS
FLASHING OF THE FACADE CHIMNEY
FLASHING OF THE VENTILATION PIPE

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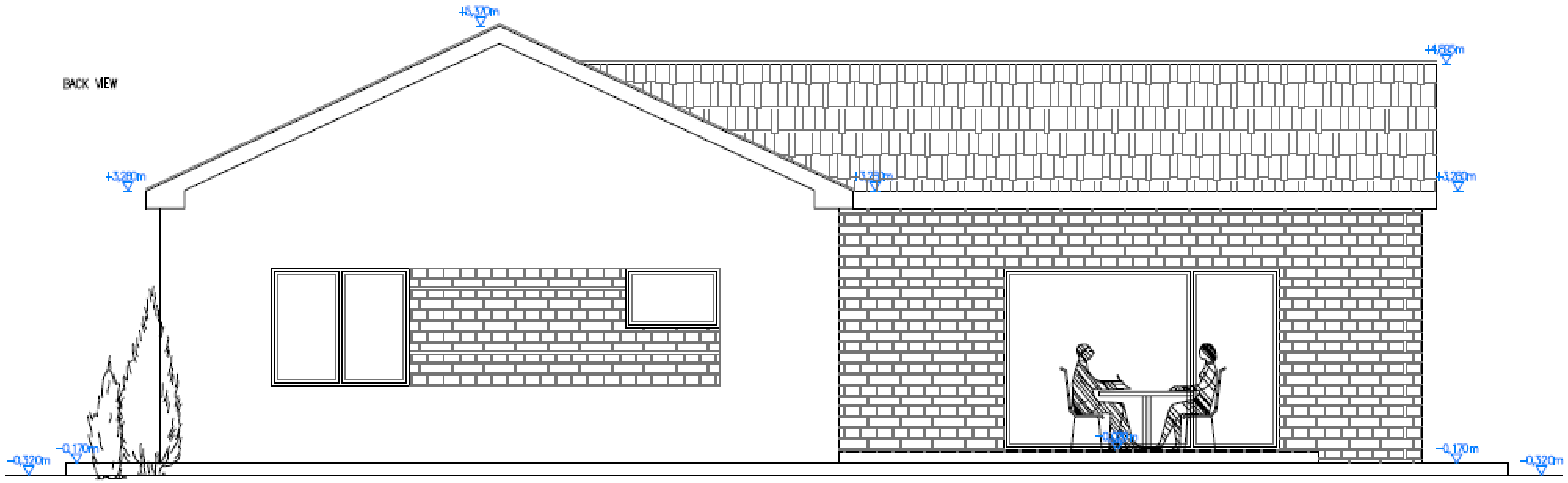
PLOT NO.:
CADASTRAL AREA:
MUNICIPALITY:
DISTRICT:
INVESTOR:

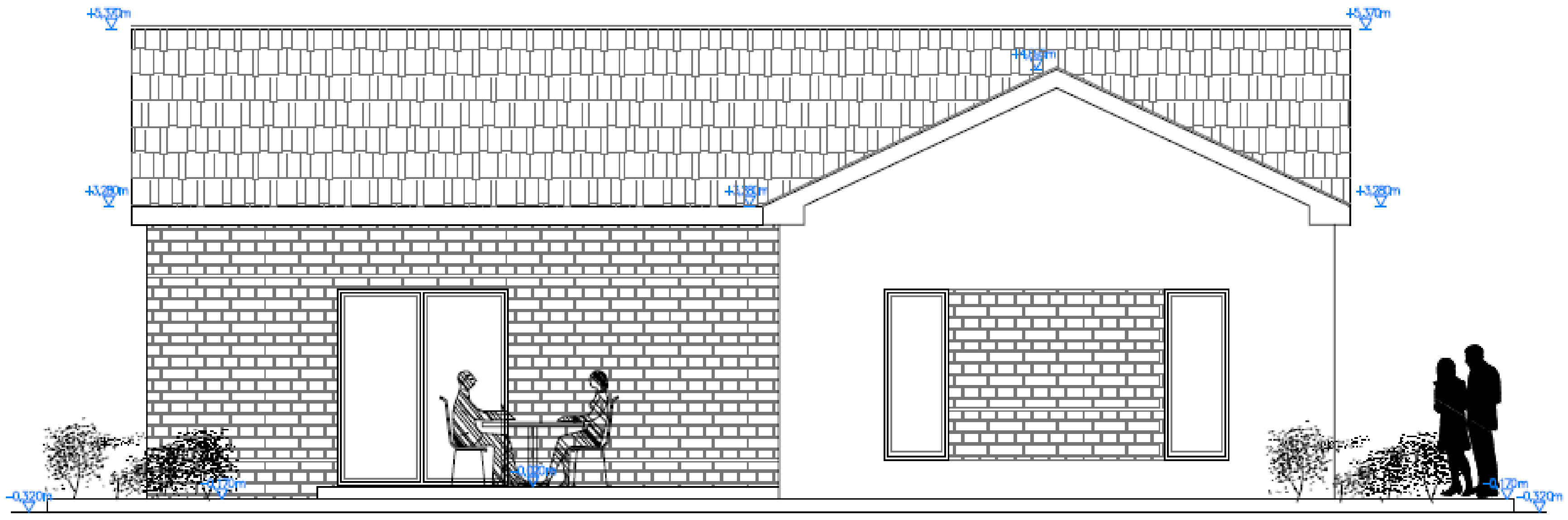
STRUCTURE: SINGLE-FAMILY HOUSE
DRAWING: ELEVATIONS 1
SHEET SIZE: 2xA4
SCALE: 1:75
DATE: 06/2025
DRAWING NO.: A5

FAMILY HOUSE / ELEVATIONS 2

BACK VIEW



SIDE VIEW



FX FACADES

F1
CONTACT FACADE SYSTEM STO THERM CLASSIC 1
- COATING: STO COLOR LOTUSAN, WHITE COLOR (ALT. BY INVESTOR'S CHOICE)
- PLASTER: STOLIT K/MP/R
- FIBERGLASS MESH: STO GLASSFASEGEWEBE
- REINFORCEMENT COMPOUND: STO ARMAT CLASSIC (CEMENT-FREE SYSTEM)
- ADHESIVE: STO BAUKLEBER

F2
CONTACT FACADE SYSTEM STO THERM CLASSIC 1
- COATING: STO COLOR LOTUSAN, WHITE COLOR (ALT. BY INVESTOR'S CHOICE)
- FIBERGLASS MESH: STO GLASSFASEGEWEBE
- REINFORCEMENT COMPOUND: STO ARMAT CLASSIC (CEMENT-FREE SYSTEM)
- ADHESIVE: STO BAUKLEBER

SX ROOFS

S1
- CONCRETE OR ALTERNATIVELY CERAMIC ROOF TILES, ANTHRACITE COLOR
- ROOF BATTENS 30/50 MM
- COUNTER-BATTENS 40/60 MM
- ROOFING MEMBRANE (SECONDARY WATERPROOFING LAYER)
- RAFTERS (ACCORDING TO STRUCTURAL DESIGN)

LEGEND OF DESCRIPTIONS

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GB/X – GARAGE DOOR / SECTIONAL
VM – VENTILATION GRILLE 150x150mm
KV – SHEET METAL PRODUCT, EAVES GUTTER AND DOWNPIPE
KOM – THREE-COMPONENT CHIMNEY FOR FIREPLACE SCHIEDEL UNI
TI MX – THERMAL INSULATION – MINERAL WOOL, thickness 100mm, 180mm
TI PX – THERMAL INSULATION – FACADE POLYSTYRENE, thicknesses 50, 70, 80, 100, 120, 150mm, 180
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▦ – STONE ANTI-SLIP EXTERIOR PAVING COLOR ACCORDING TO INVESTOR'S CHOICE, thickness 8 cm

LEGEND OF ROOF DESCRIPTION

▨ ROOF COVERING
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ROOF SLOPE OF THE FAMILY HOUSE: 25°

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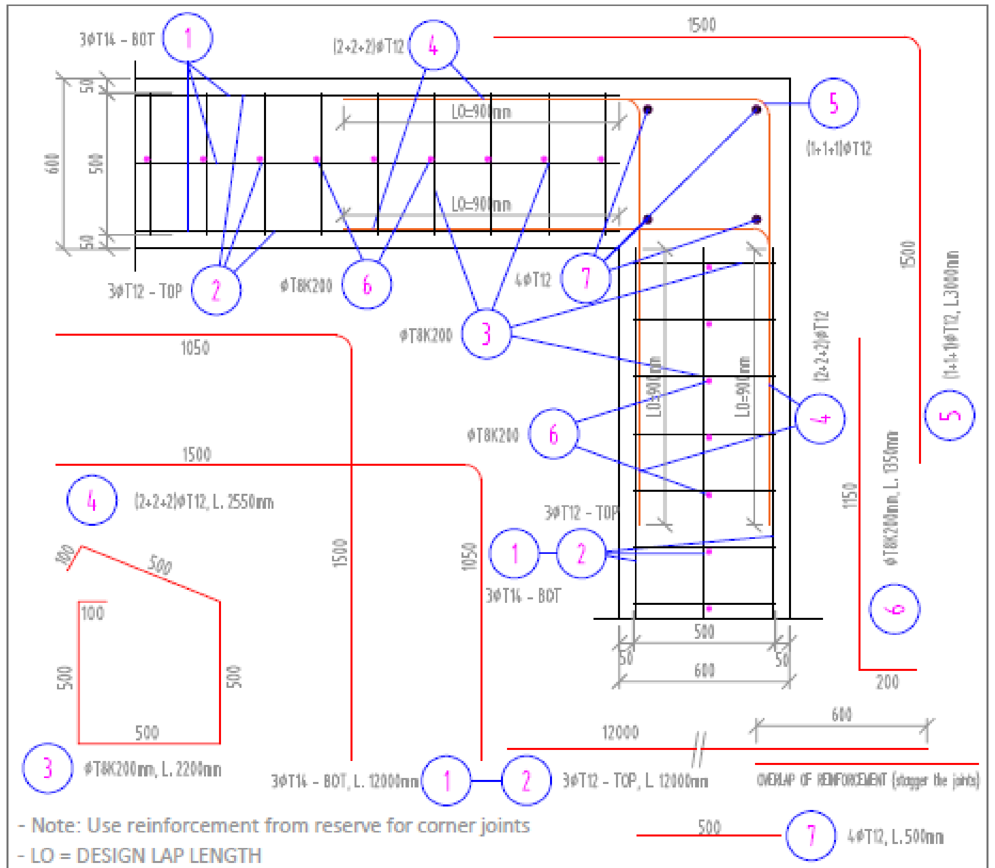
PROJECT TITLE: SINGLE-FAMILY HOUSE
PLOT NO.:
CADASTRAL AREA:
MUNICIPALITY:
DISTRICT:
INVESTOR:
STRUCTURE: SINGLE-FAMILY HOUSE
DRAWING: ELEVATIONS 2
SHEET SIZE: 2xA4
SCALE: 1:75
DATE: 06/2025
DRAWING NO.: A6

Schematic Shape of Foundations:

detail, scale 1:25

Schematic reinforcement of main "L" corners:

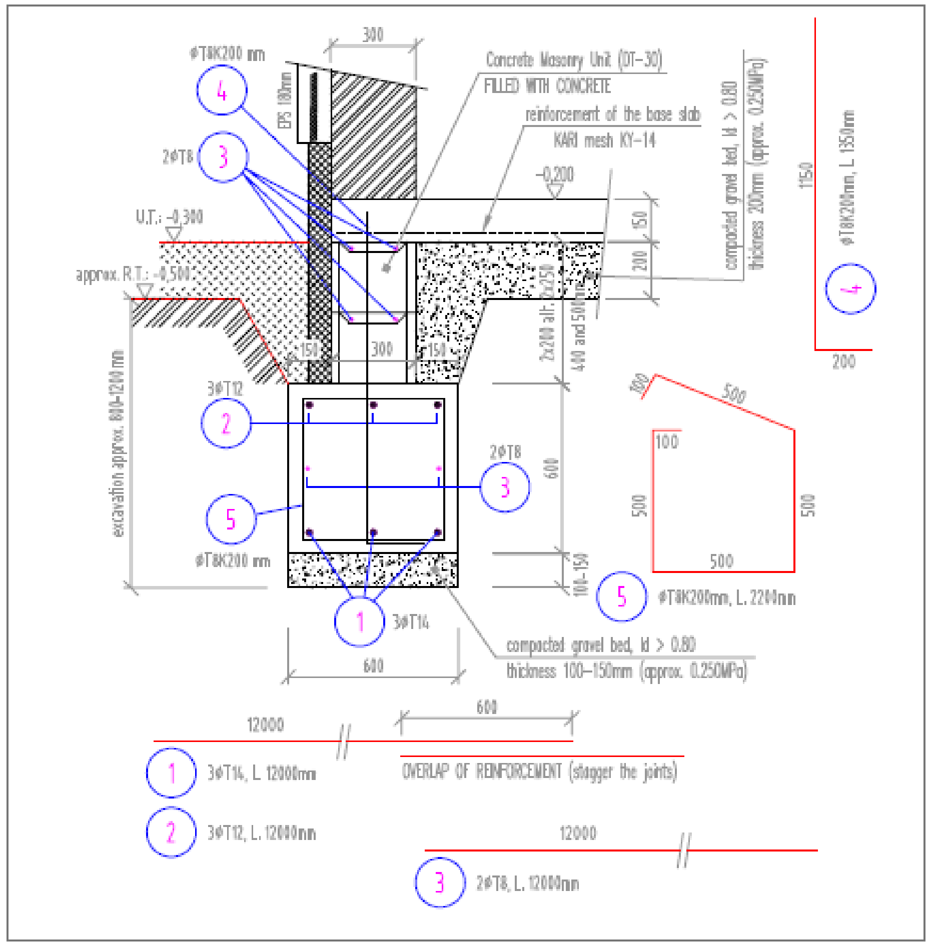
detail, top view, scale 1:25



- Note: Use reinforcement from reserve for corner joints
- LO = DESIGN LAP LENGTH
- Please apply the same method for the terrace, adjusted according to the relevant dimensions.

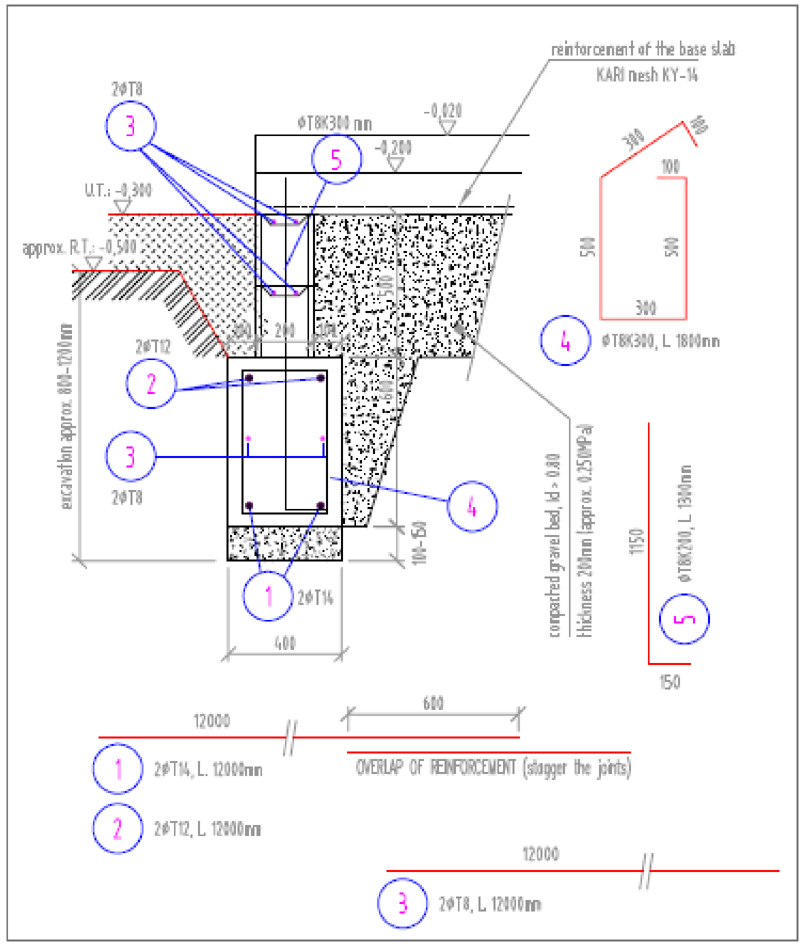
Schematic reinforcement of main foundation strips:

detail, cut view, scale 1:25



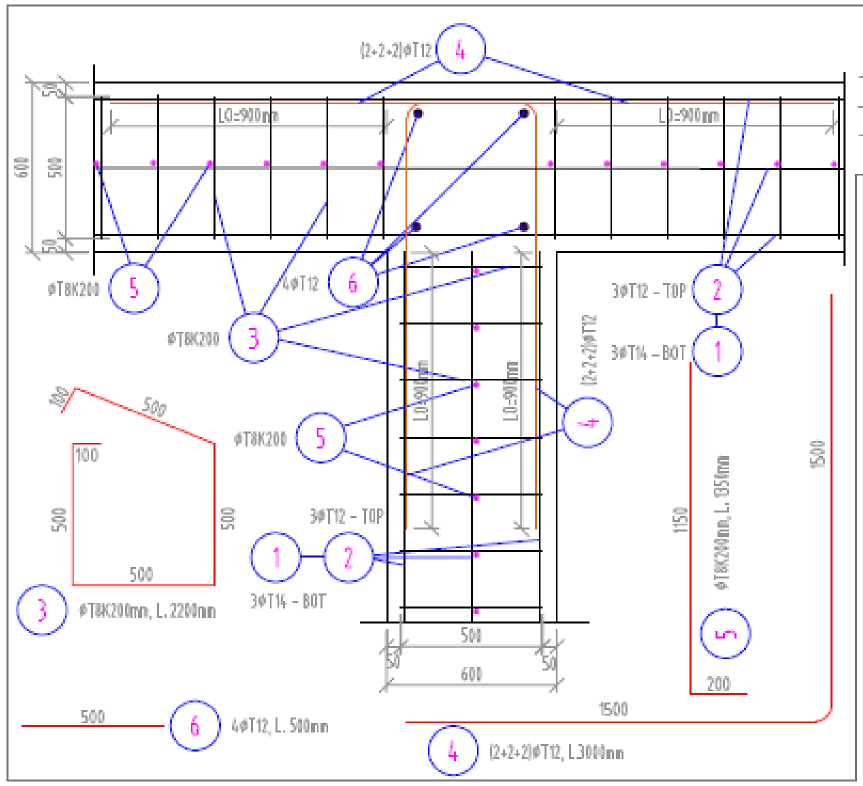
Schematic reinforcement of terrace foundation strips:

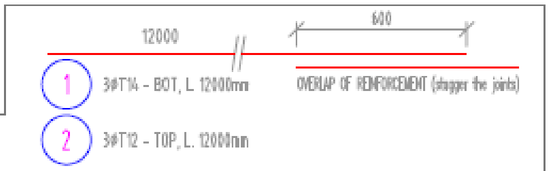
detail, cut view, scale 1:25



Schematic reinforcement of main "T" corners:

detail, top view, scale 1:25





- Note: Use reinforcement from reserve for corner joints
- LO = DESIGN LAP LENGTH
- Please apply the same method for the terrace, adjusted according to the relevant dimensions.

Concrete:	C 20/25
Reinforcement:	B-500B (O 10505-R)
Concrete cover:	50mm - strip footing, 30mm - slab

Before starting excavation work, it is absolutely necessary to mark all underground utilities and service lines located on the subject plot!

Before starting the concreting of foundations, it is necessary to mark and leave openings for the passage of pipes / cables through the foundation structures.

NOTES – GEOLOGY:

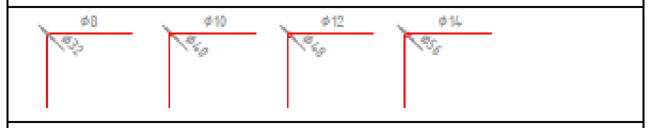
- Foundations are designed without an engineering-geological survey (IGP), based on the ASSUMED bearing capacity of the subsoil of 200 kPa (according to the principles of the 1st geo. category). However, before construction, it is necessary to verify that the actual soil in the foundation base corresponds to the design assumptions! A DETAILED ENGINEERING-GEOLOGICAL SURVEY IS STRONGLY RECOMMENDED!!!
- In the foundation base, standard soil conditions (estimated) are assumed, with fine-grained medium dense sandy to clayey soils of stiff consistency, medium plasticity, and a tabular bearing capacity Rdt = 200 kpa (without the influence of groundwater level).
- In the event that the actual foundation soils differ from the design assumptions, the proposed foundation method (dimensions, shape, reinforcement) must be reassessed and individually adjusted, or the foundation structures must be adapted to the actual soil conditions. If this is not done, the responsible author of the assessment does not take responsibility for any defects caused by incorrect foundation, faulty structures, or any resulting issues.

IMPORTANT WARNINGS:

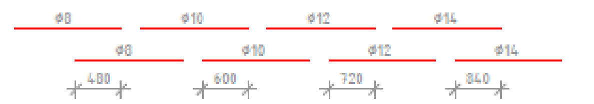
- In the area where the family house is to be built, I strongly warn about the possible presence of fill materials, highly plastic fine-grained soils, loose to liquid sands/gravels in the foundation subsoil (low bearing capacity, compressibility, volume instability, and sensitivity to water). Their consistency and compaction state are influenced by moisture or groundwater. therefore, I strongly RECOMMEND carrying out a detailed geotechnical survey to determine the actual soil conditions in the foundation trench.

- During excavation work or after exposing the foundation trench, it is recommended to invite a responsible geologist and structural engineer to ensure that the identified conditions (geotechnical parameters and classification of foundation soils) are in accordance with the project documentation (to verify design assumptions), and, if necessary, to carry out essential modifications.
- During foundation works, it is necessary to prevent potential moisture increase - such as from roof drainage, rain, utility network failures – and to protect the foundation trench from weather conditions (to avoid degradation of the foundation soil), as these factors may cause changes in the consistency of cohesive soils and a subsequent reduction in their bearing capacity (due to altered properties of the foundation soils compared to the initial design assumptions!!
- Uncovering of the foundation trench is recommended to be carried out immediately before concreting works (to minimize the risk of damage to the trench due to weather or mechanical influences). excavation work should be done during dry periods, and the foundation trench must be protected from soaking, freezing, and flooding – therefore, the last 100 mm of the covering soil layer should be removed just before concreting, and the bottom of the trench should be cleaned manually! immediately after excavation, create a layer of compacted gravel bedding / blinding concrete to protect the foundation trench, and FOUNDATIONS MAY ONLY BE BUILT ON UNDISTURBED FOUNDATION TRENCHES!

BENDING OF REINFORCEMENT



SPLICING OF REINFORCEMENT



DESIGNED ACCORDING TO EC2

CONCRETE EN 206+A1 – C20/25 – XC2 – CL 0.4 – Dmax 16 – S3
REINFORCEMENT STEEL – B500B (EN 10080)

UNLESS OTHERWISE SPECIFIED, THE METHOD DEMONSTRATED ABOVE SHALL BE APPLIED CONSISTENTLY!!!

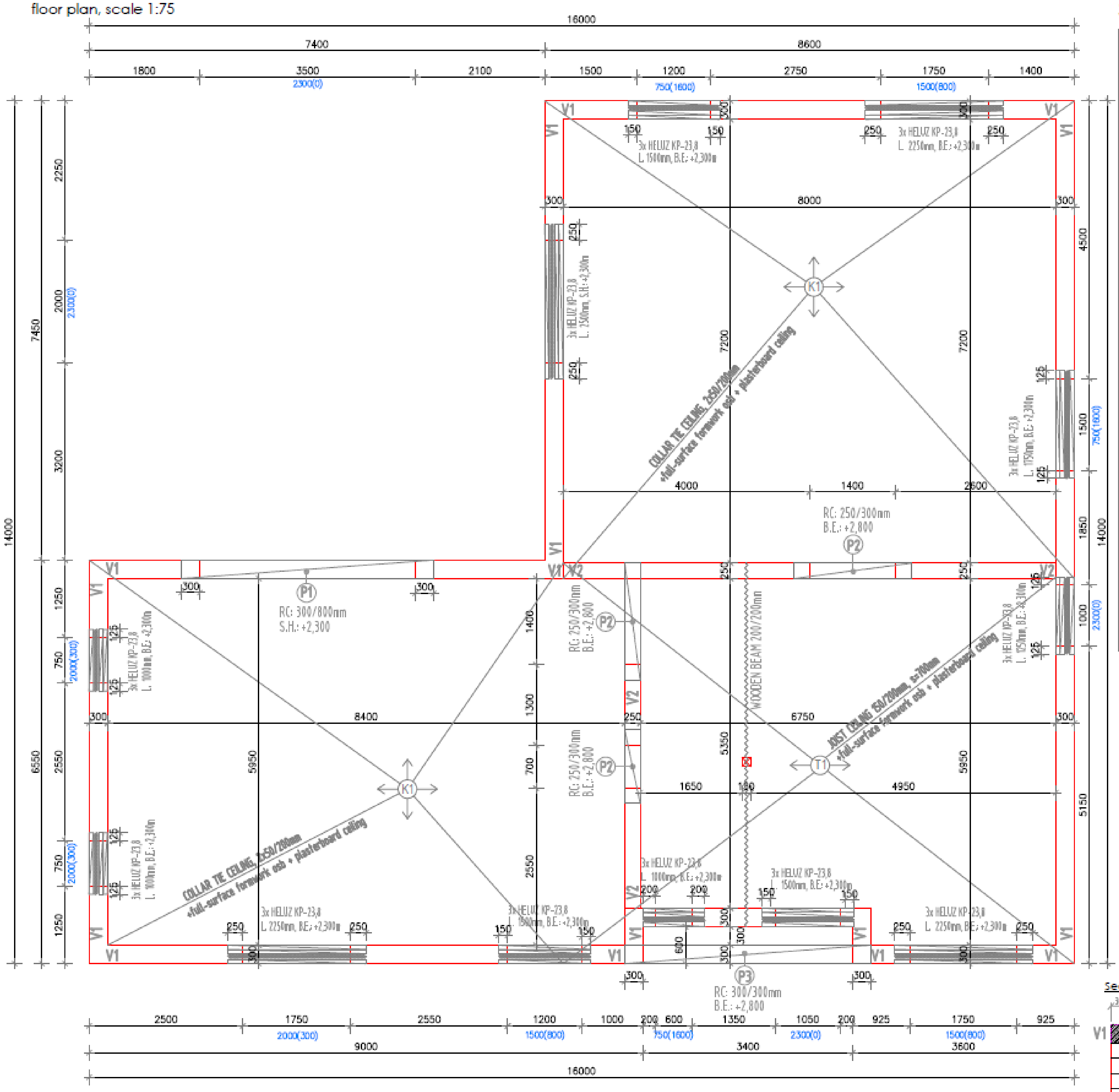
Reinforcement of the ground slab:

(of the blinding concrete)

- Mesh at the BOTTOM surface KY-14 (KY-14 = Ø8/150 x Ø8/150 -2400x6000mm)
- Overlapping of KARI meshes is 450 mm (3 grid spaces in both directions)

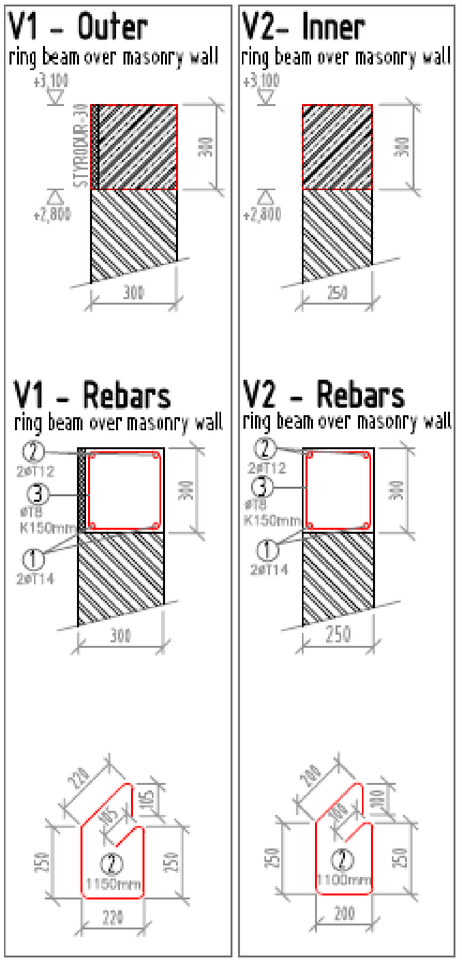
Schematic Layout and Composition of the Ground Floor:

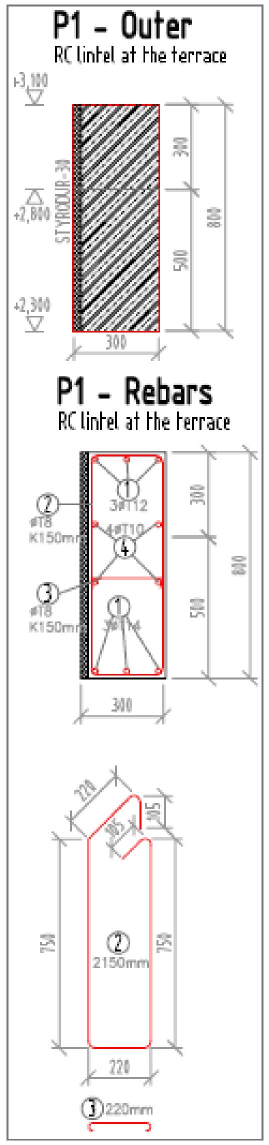
floor plan, scale 1:75

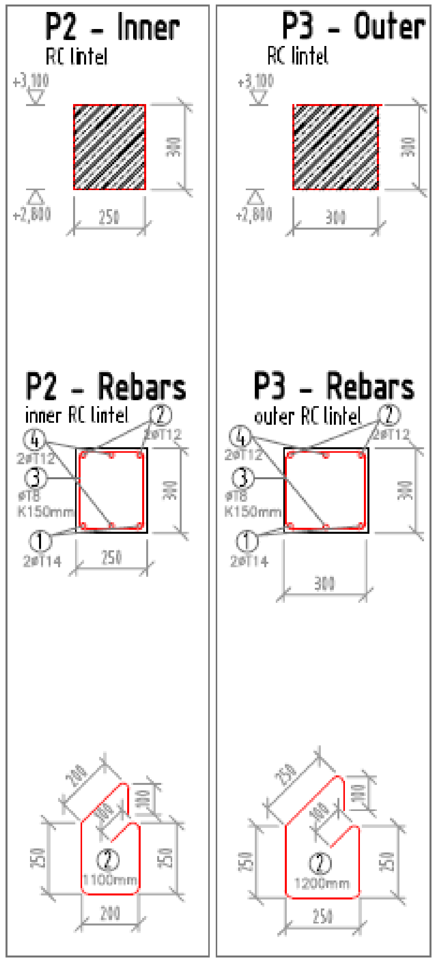


Cross-sections:

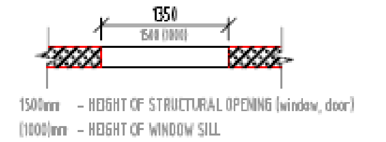
Scale 1:25







LEGEND – Floor Plan of Openings:

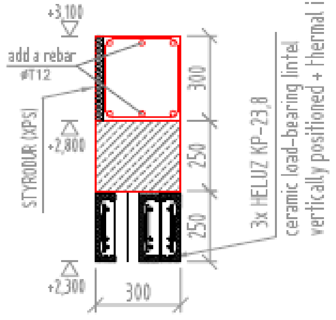


1500mm – HEIGHT OF STRUCTURAL OPENING (window, door)

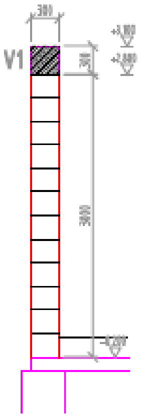
(1000)mm – HEIGHT OF WINDOW SILL

Concrete:	C 25/30
Concrete cover:	25mm
Reinforcement:	B-500B (O 10505-R)
Masonry:	- Clay ceramic bricks POROTHERM PROFI 30, 25 (P12) with thin-layer full-surface adhesive

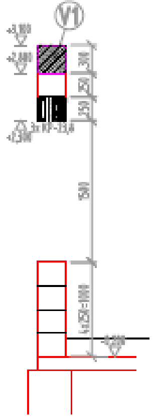
Lintels above openings in the exterior wall



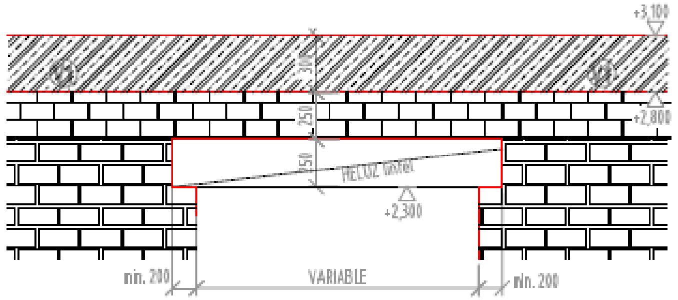
Section through masonry:



Section through window:



View of prefabricated lintels above openings:



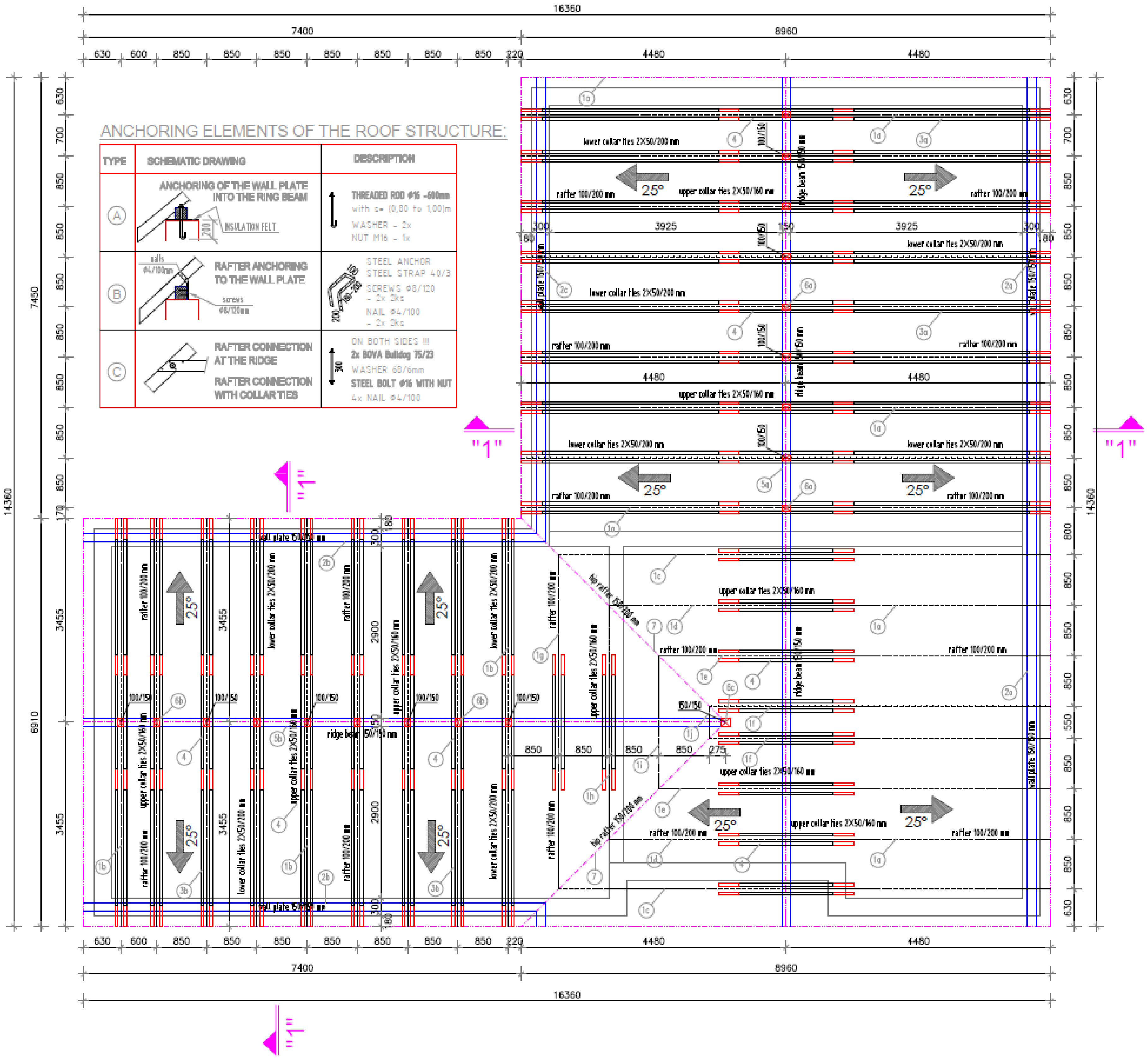
Precast lintels must be PROPPED during the construction of the RC ceiling and ring beams !!

NOTES:

- Follow all recommendations, technical regulations, and construction principles of the supplier or manufacturer of the building system (POROTHERM) during construction!
- During the construction process, it is strictly FORBIDDEN to use ceiling structures for storing construction materials!
- Construction modifications (openings, niches, cut-outs) must be coordinated and executed according to the individual disciplines (sanitation, electrical, heating, gas, ventilation).
- All dimensions of load-bearing elements and their horizontal + vertical placement in the structure (positions) must be checked during construction work on site.
- In case of any discrepancies from the project or discovery of unforeseen conditions, the responsible designer must be consulted.
- HELUZ prefabricated lintels must be PROPPED during concreting work of lintels and bond beams!

Schematic Shape and Composition of Wooden Roof Truss:

floor plan, scale 1:75

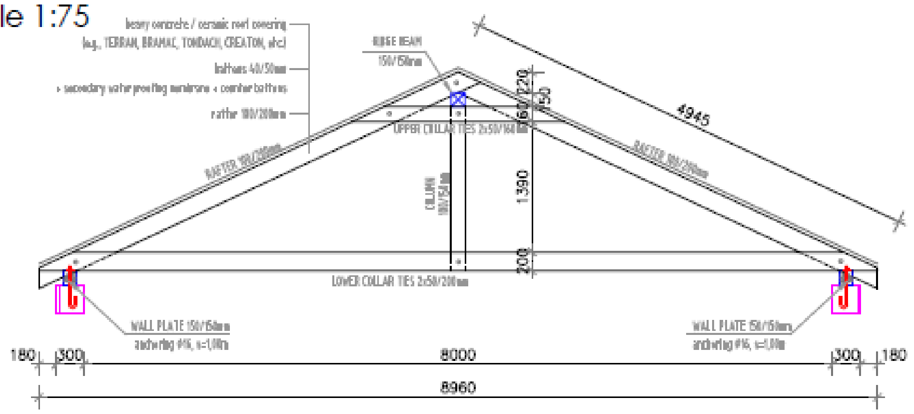


ANCHORING ELEMENTS OF THE ROOF STRUCTURE:

TYPE	SCHEMATIC DRAWING	DESCRIPTION
Ⓐ	ANCHORING OF THE WALL PLATE INTO THE RING BEAM INSULATION FELT 200	THREADED ROD Ø16 -600mm with s= (0,80 to 1,00)m WASHER - 2x NUT M16 - 1x
Ⓑ	nails Ø4/100mm RAFTER ANCHORING TO THE WALL PLATE screws Ø8/120mm	STEEL ANCHOR STEEL STRAP 40/3 SCREWS Ø8/120 - 2x 2ks NAIL Ø4/100 - 2x 2ks
Ⓒ	RAFTER CONNECTION AT THE RIDGE RAFTER CONNECTION WITH COLLAR TIES	ON BOTH SIDES !!! 2x BOVA Bulldog 75/23 WASHER 68/6mm STEEL BOLT Ø16 WITH NUT 4x NAIL Ø4/100

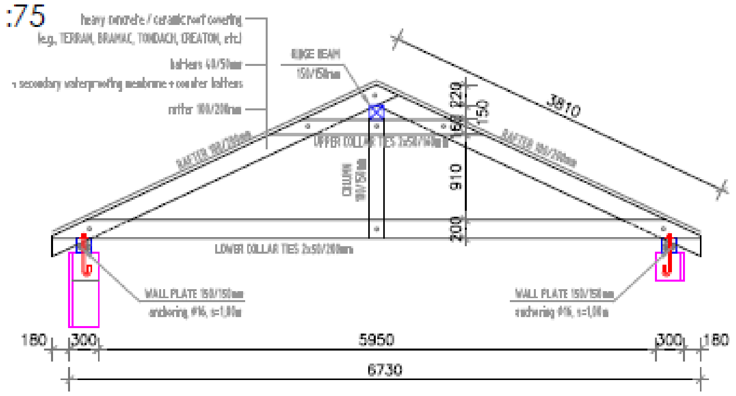
Cross-section "1":

Scale 1:75



Cross-section "2":

Scale 1:75



ROOF COMPOSITION:
- heavy roof covering: TERRAN, BRAMAC, TONDACH, etc.
- battens 40/50 mm + secondary waterproofing + counter-battens

LIST OF TIMBER FOR THE ROOF STRUCTURE:

TYPE	NAME	CROSS-SECTION (mm)	LENGTH (m)	Amount (pc)	TOTAL LENGTH (m)	VOLUME (m3)
1a	rafter	100/200	4.580	30	137.400	2.748
1b			3.450	20	69.000	1.380
1c			4.250	2	8.500	0.170
1d			3.310	2	6.620	0.132
1e			2.375	2	4.750	0.095
1f			1.435	2	2.870	0.057
1g			3.120	2	6.240	0.125
1h			2.180	2	4.360	0.087
1i			1.240	2	2.480	0.050
1j			0.305	2	0.610	0.012
2a	wall plate	150/150	14.360	1	14.360	0.323
2b			8.060	1	8.060	0.181
2c			7.705	1	7.705	0.173
3a	lower collar ties	50/200	8.960	18	161.280	1.613
3b			6.910	18	124.380	1.244
4	upper collar ties	50/160	2.275	56	127.400	1.019
5a	ridge beam	150/150	14.360	1	14.360	0.323
5b			10.930	1	10.930	0.246
6a	column	100/150	1.750	9	15.750	0.236
6b			1.275	9	11.475	0.172
6c		150/150	1.400	1	1.400	0.032
7	hip rafter	150/200	5.145	2	10.290	0.309

- The proposed anchoring methods must be calculated in detail in the implementation project by the responsible design engineer!
- All dimensions and quantities must be measured on site before starting work!
- Any changes to the structural project and architectural design, as well as in the case of unforeseen circumstances discovered during the construction process that were not considered in the presented project, must be consulted with the lead designer and the responsible structural engineer, or another authorized person must be involved.

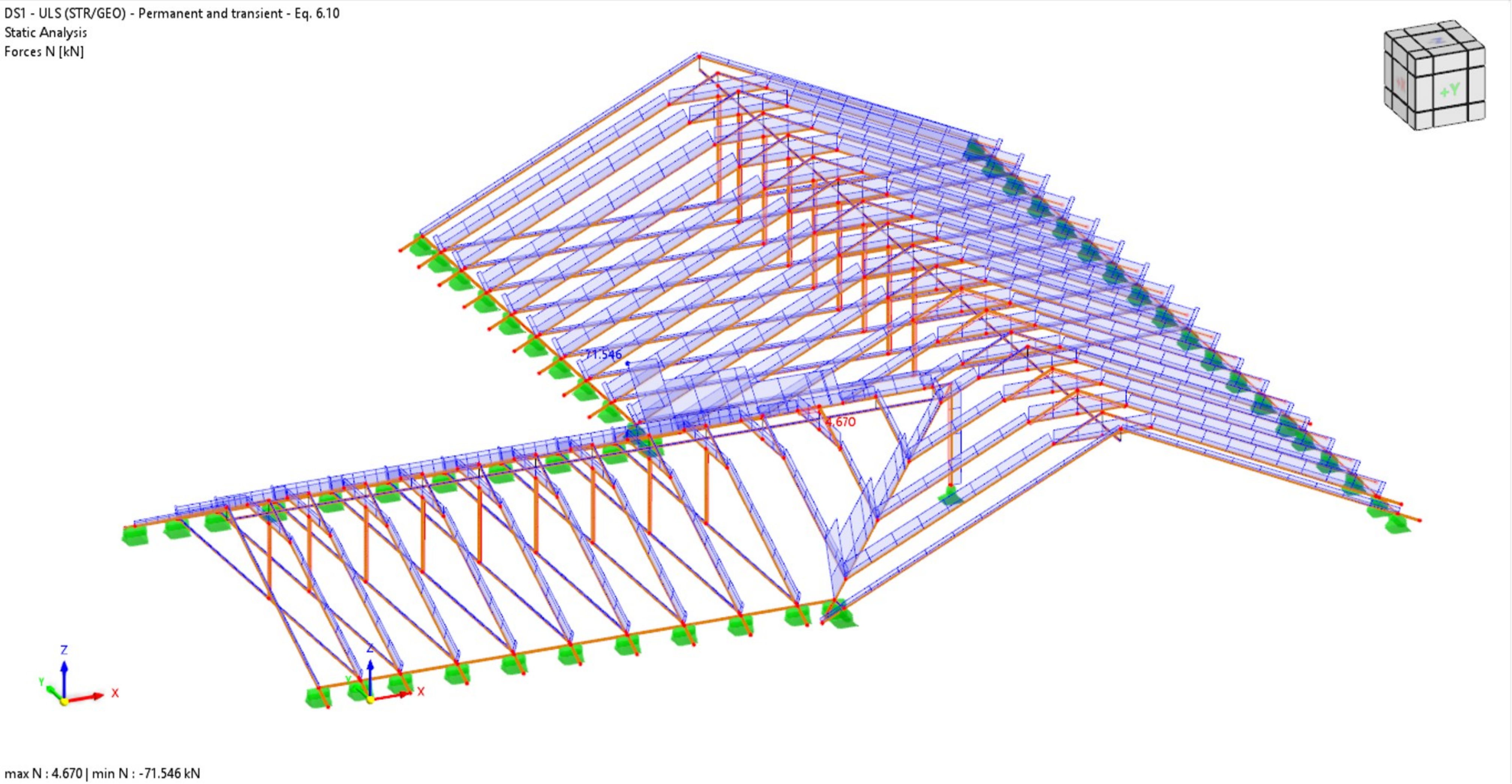
NOTES:

- Wooden structures must be impregnated with a treatment for long-term protection of the wood against fungi, insects, mold, and weathering effects.
- Steel structures must be protected against corrosion - either with a double protective coating or galvanization.
- Anchoring of the wall plate: anchor bolts Ø16 spaced approx. (0.80 to 1.00)m, i.e. threaded rods to be pre-embedded in concrete during the execution of the ring beams!
- For joining of roof structure elements, use bolts, nails, screws, and connecting elements from the BMF or BOVA system.
- All wooden elements of the roof structure must be executed as carpentry constructions, and all connection details must also be carried out using standard carpentry methods!
- The submitted project has been prepared to the extent agreed upon between the client and the designer, i.e., a structural assessment for the building permit, and DOES NOT REPLACE THE EXECUTION PROJECT, which must be prepared in the next stage of project documentation prior to implementation (as required by the construction contractor or builder).

MATERIAL:

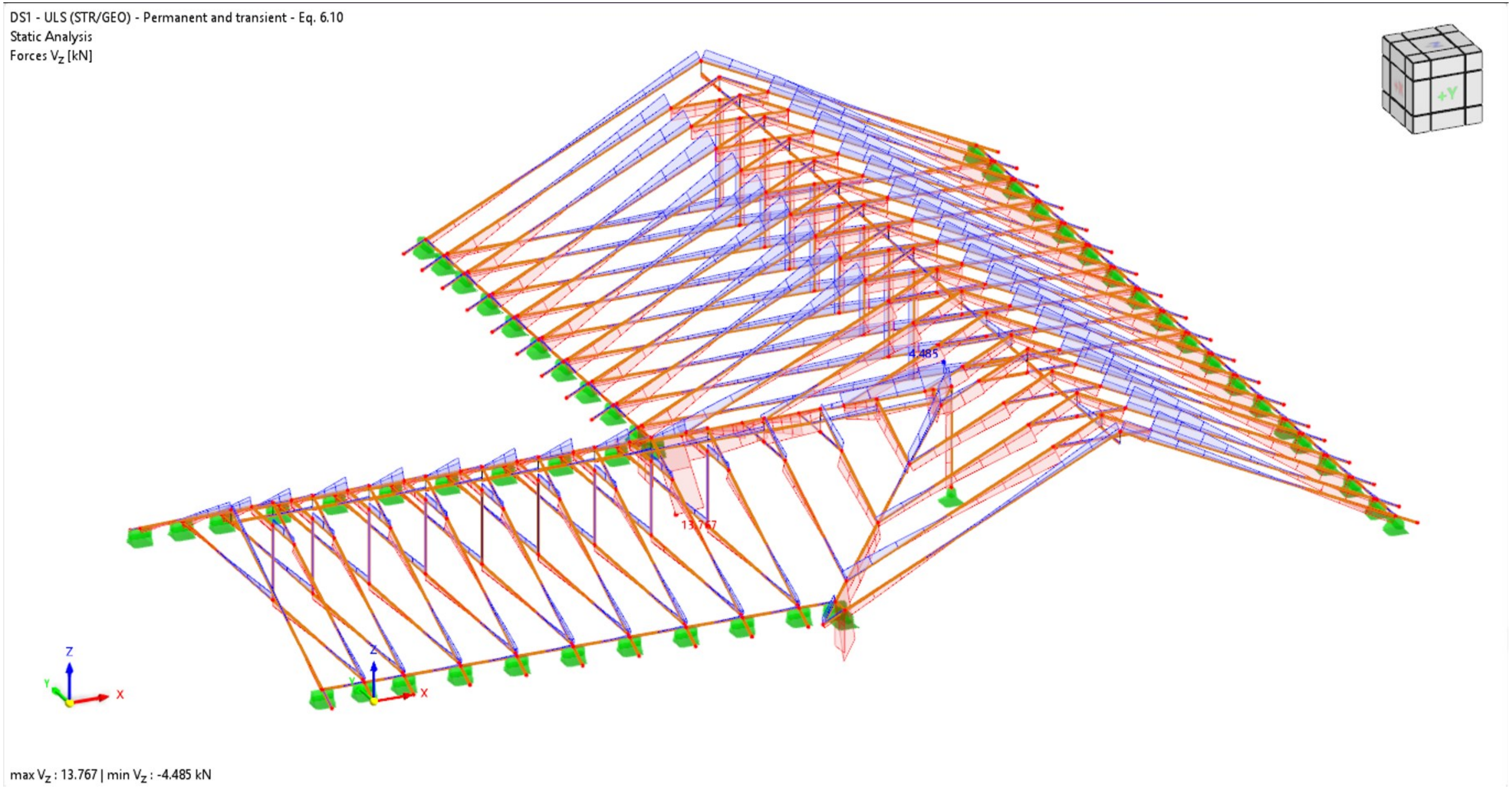
- softwood timber (spruce), strength class C24
- designed according to EC-5 (maximum timber moisture content 16%)
- wooden structures must be impregnated with a protective agent for long-term protection of the wood against fungi, insects, mold, and deterioration due to weather exposure

Appendix 3. Load simulations for Slovakia



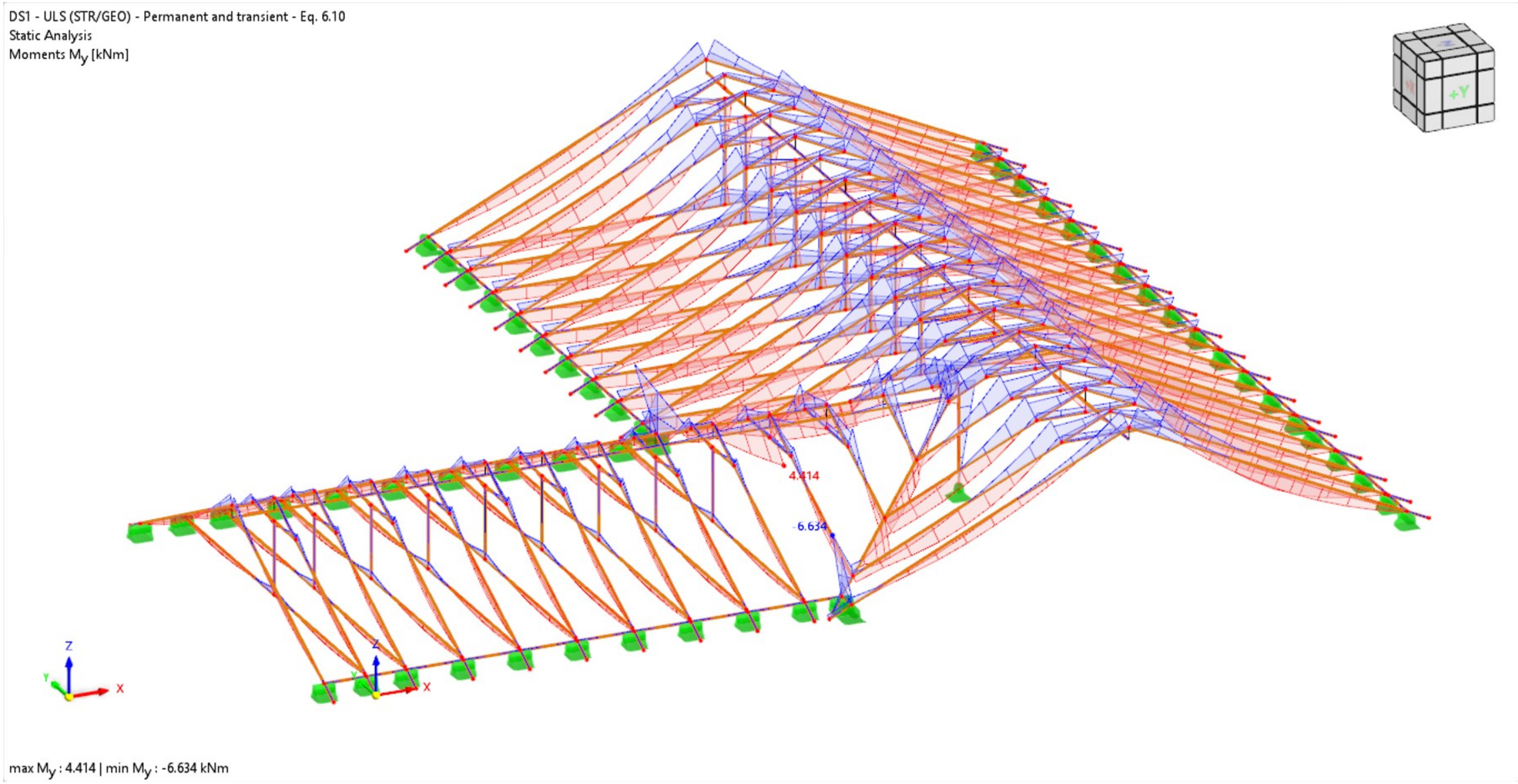
DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10
Static Analysis
Forces N [kN]

max N : 4.670 | min N : -71.546 kN



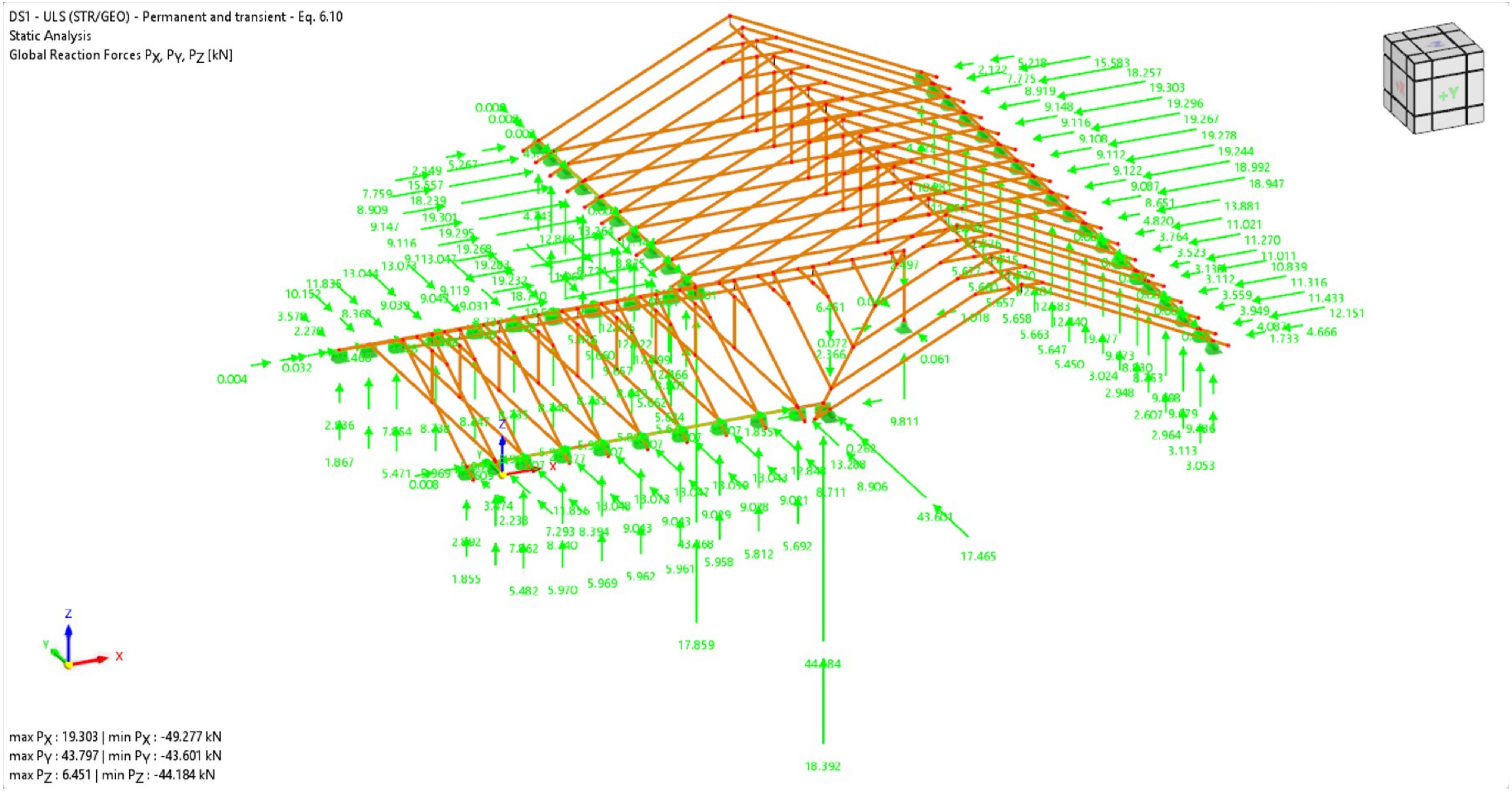
DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10
Static Analysis
Forces V_z [kN]

max V_z : 13.767 | min V_z : -4.485 kN



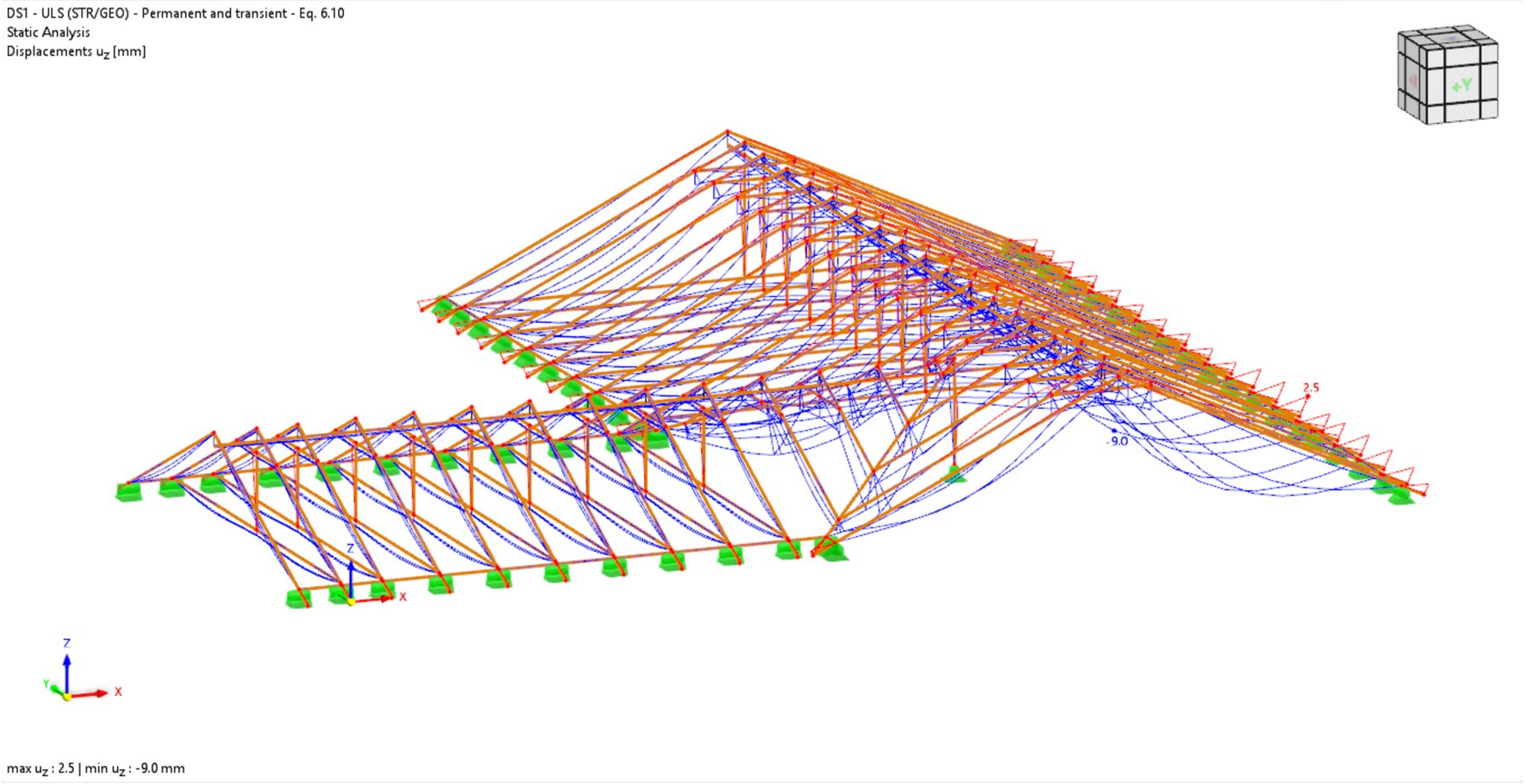
DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10
Static Analysis
Moments M_y [kNm]

max M_y : 4.414 | min M_y : -6.634 kNm



DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10
Static Analysis
Global Reaction Forces P_X, P_Y, P_Z [kN]

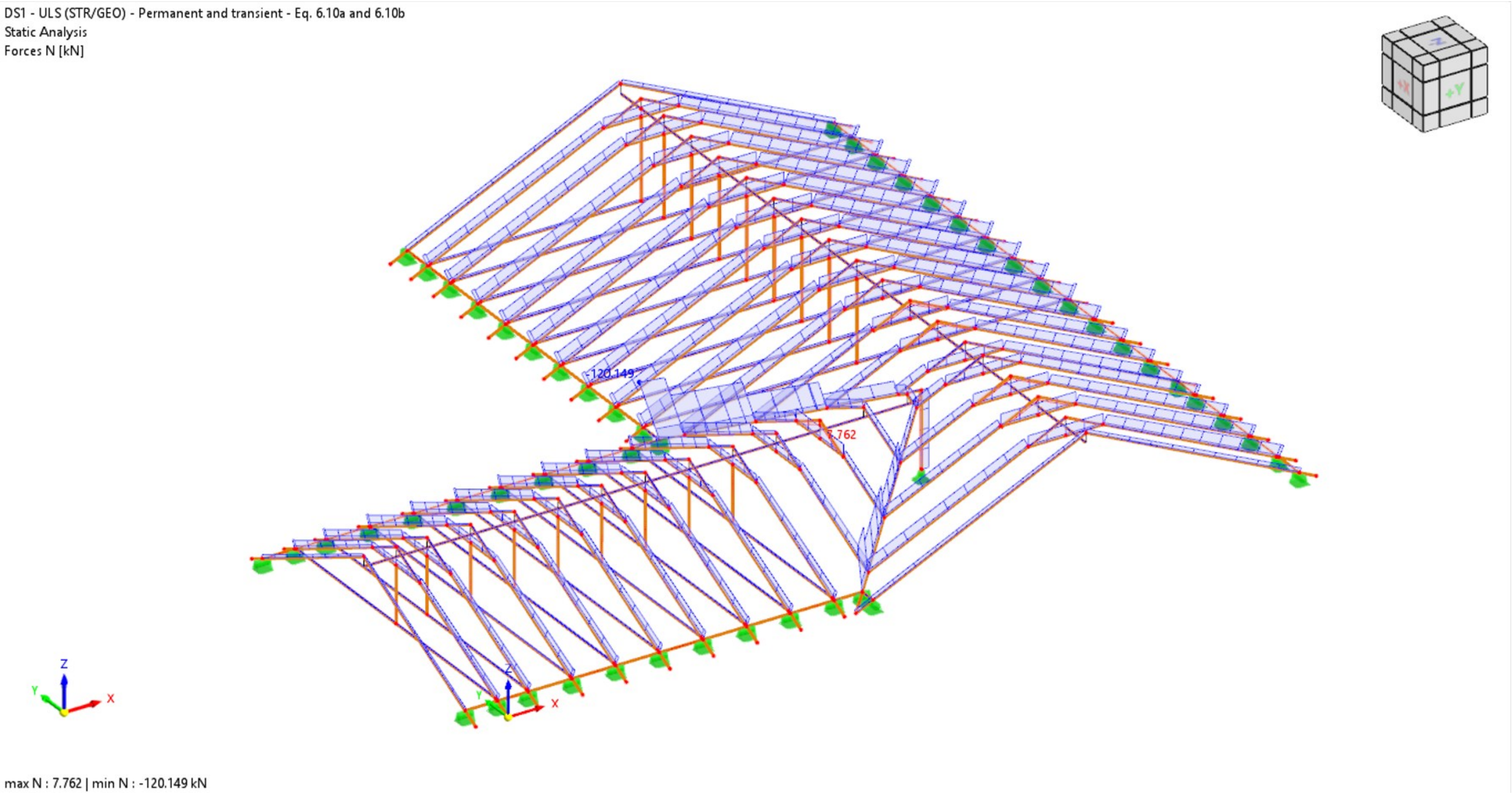
max P_X : 19.303 | min P_X : -49.277 kN
max P_Y : 43.797 | min P_Y : -43.601 kN
max P_Z : 6.451 | min P_Z : -44.184 kN



DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10
Static Analysis
Displacements u_Z [mm]

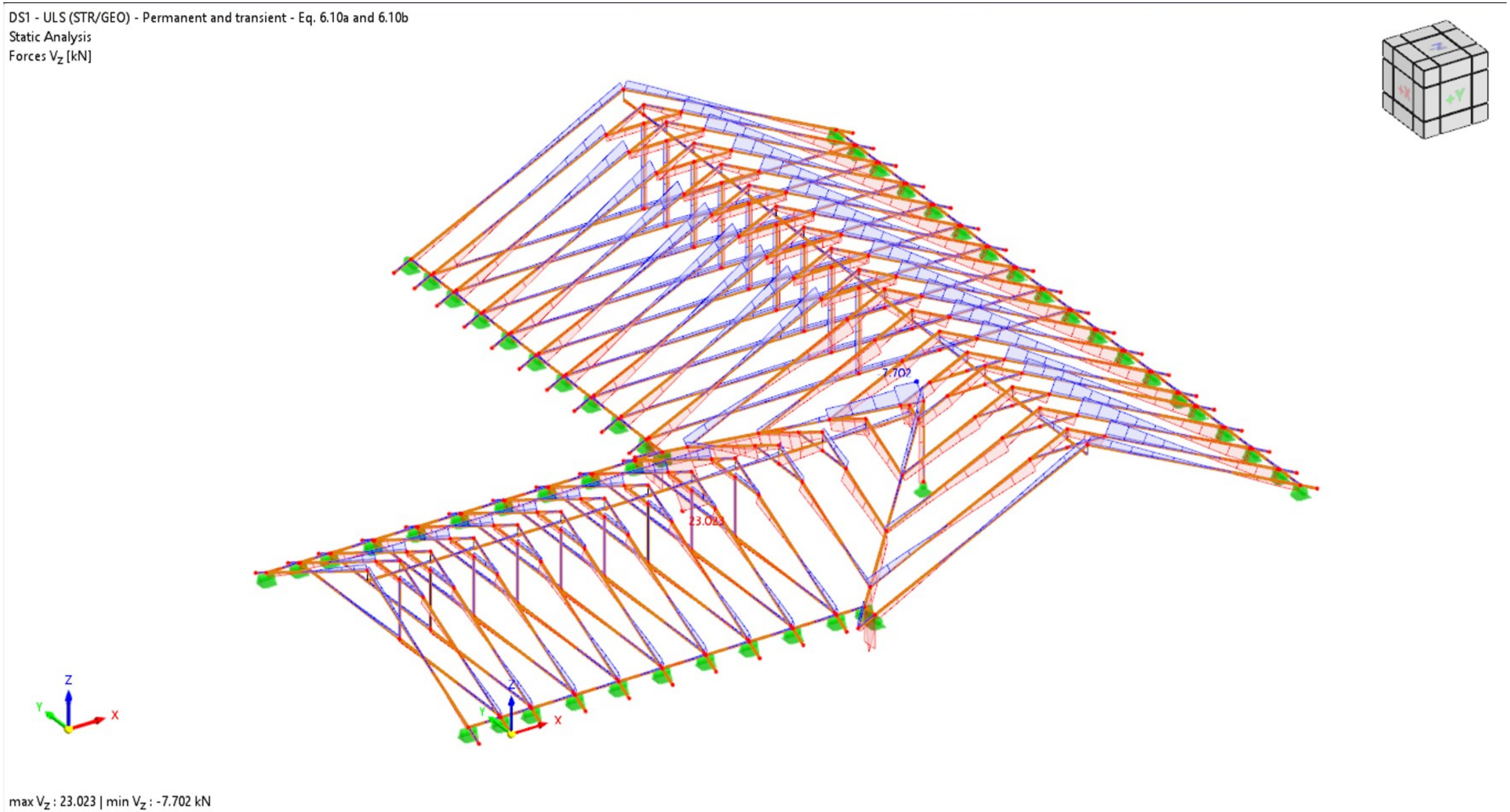
max u_Z : 2.5 | min u_Z : -9.0 mm

Appendix 4. Load simulations for Finland



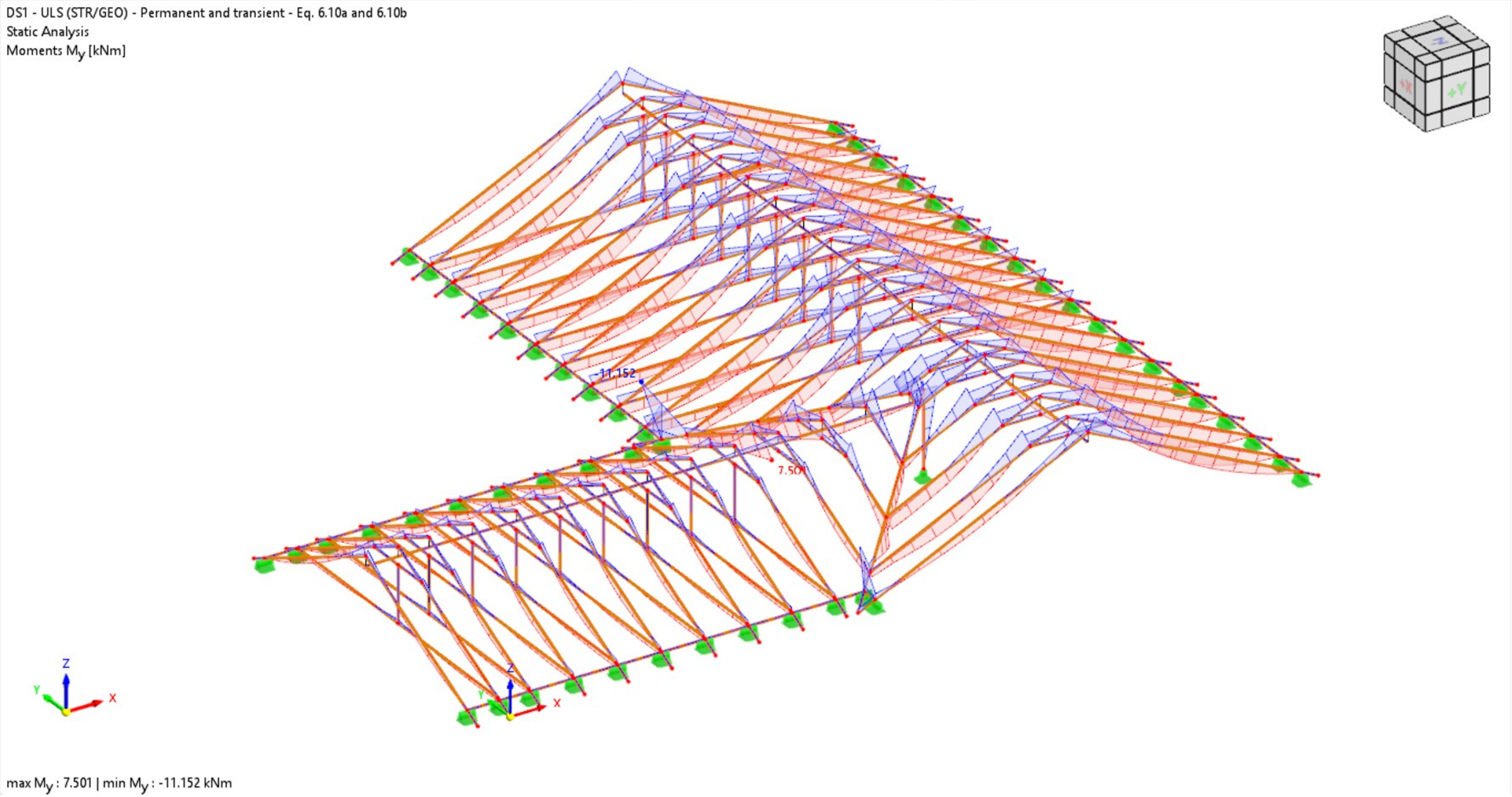
DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10a and 6.10b
Static Analysis
Forces N [kN]

max N : 7.762 | min N : -120.149 kN



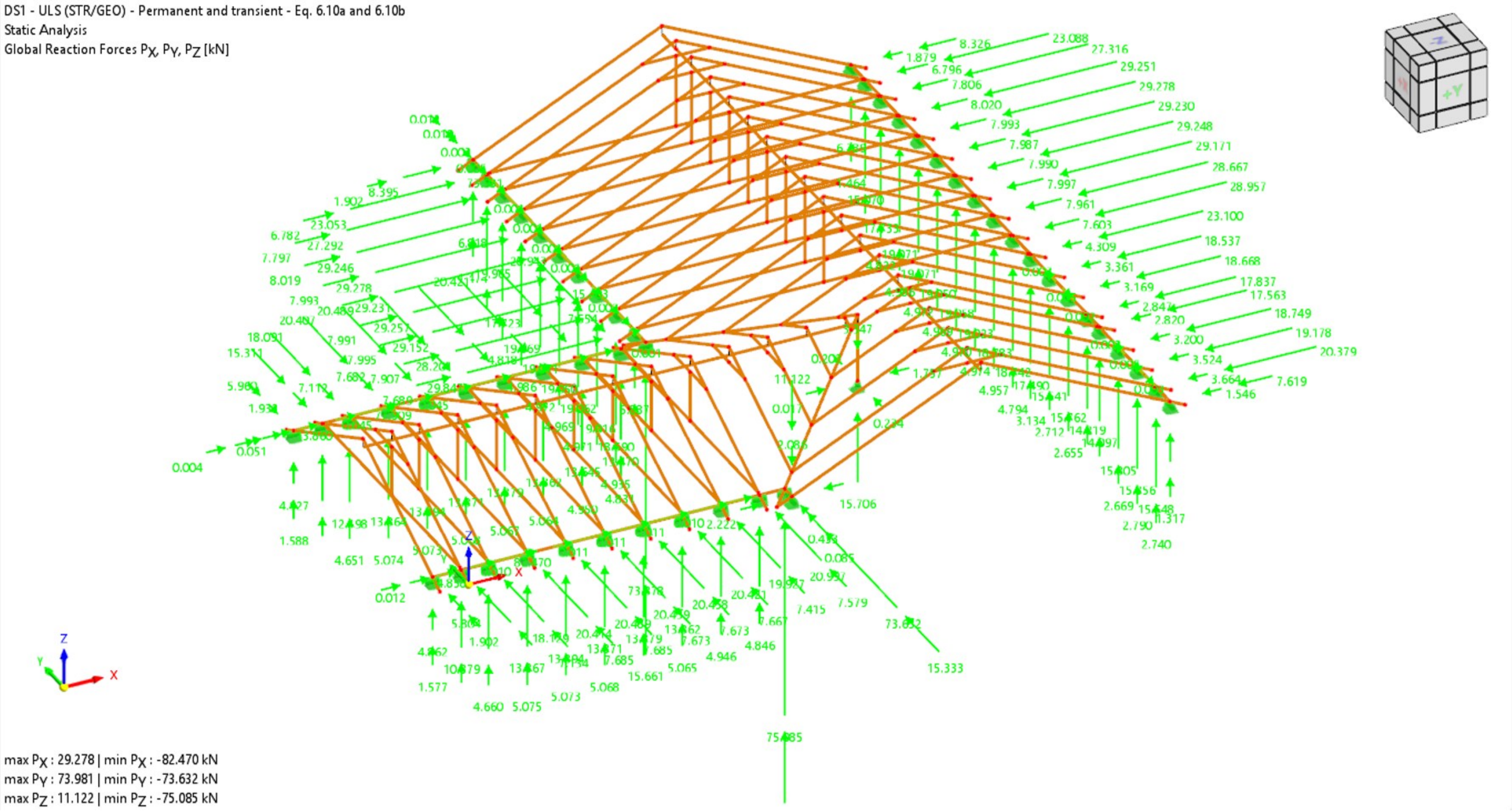
DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10a and 6.10b
Static Analysis
Forces V_z [kN]

max V_z : 23.023 | min V_z : -7.702 kN



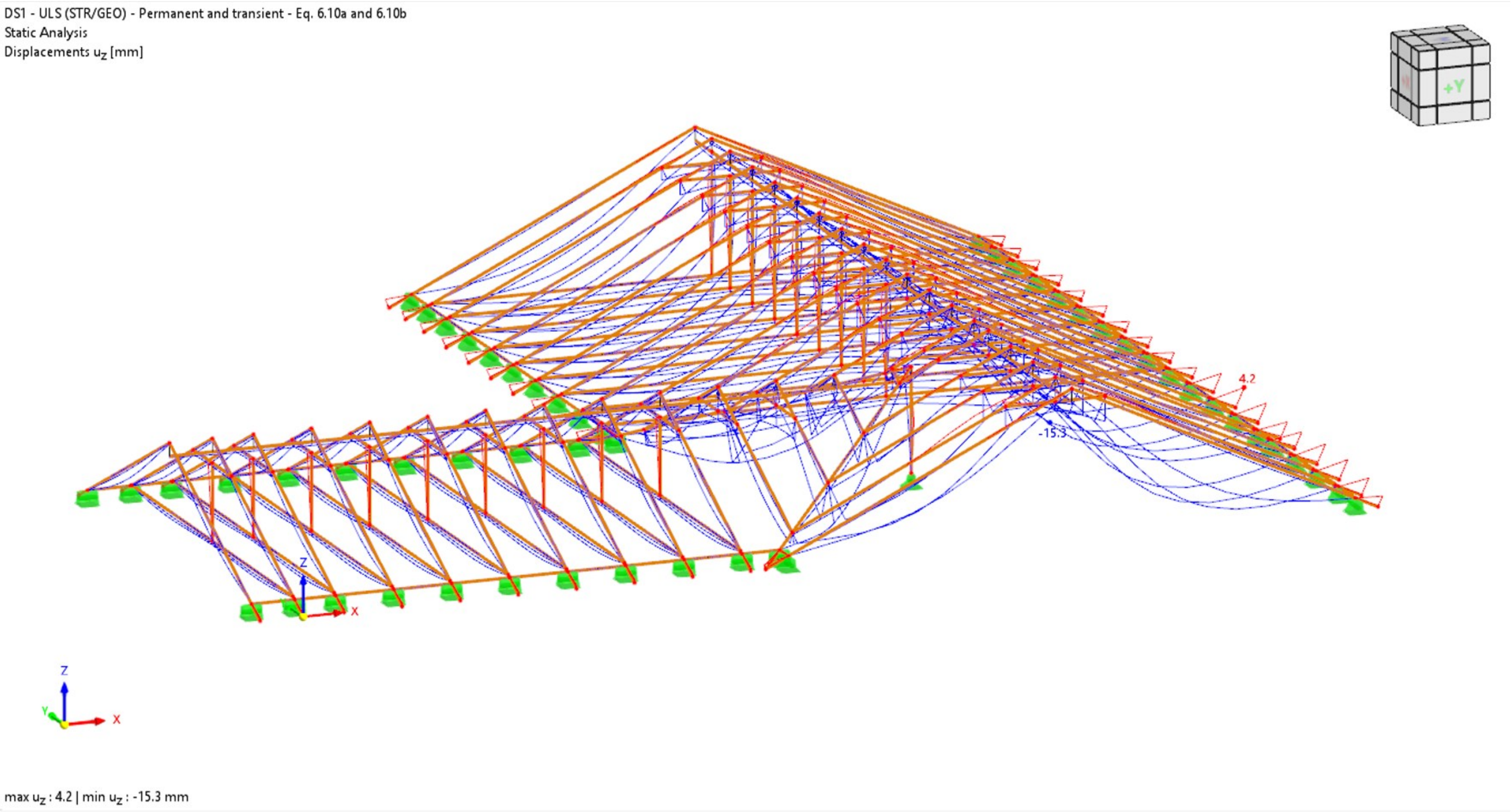
DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10a and 6.10b
Static Analysis
Moments M_y [kNm]

max M_y : 7.501 | min M_y : -11.152 kNm



DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10a and 6.10b
Static Analysis
Global Reaction Forces P_X, P_Y, P_Z [kN]

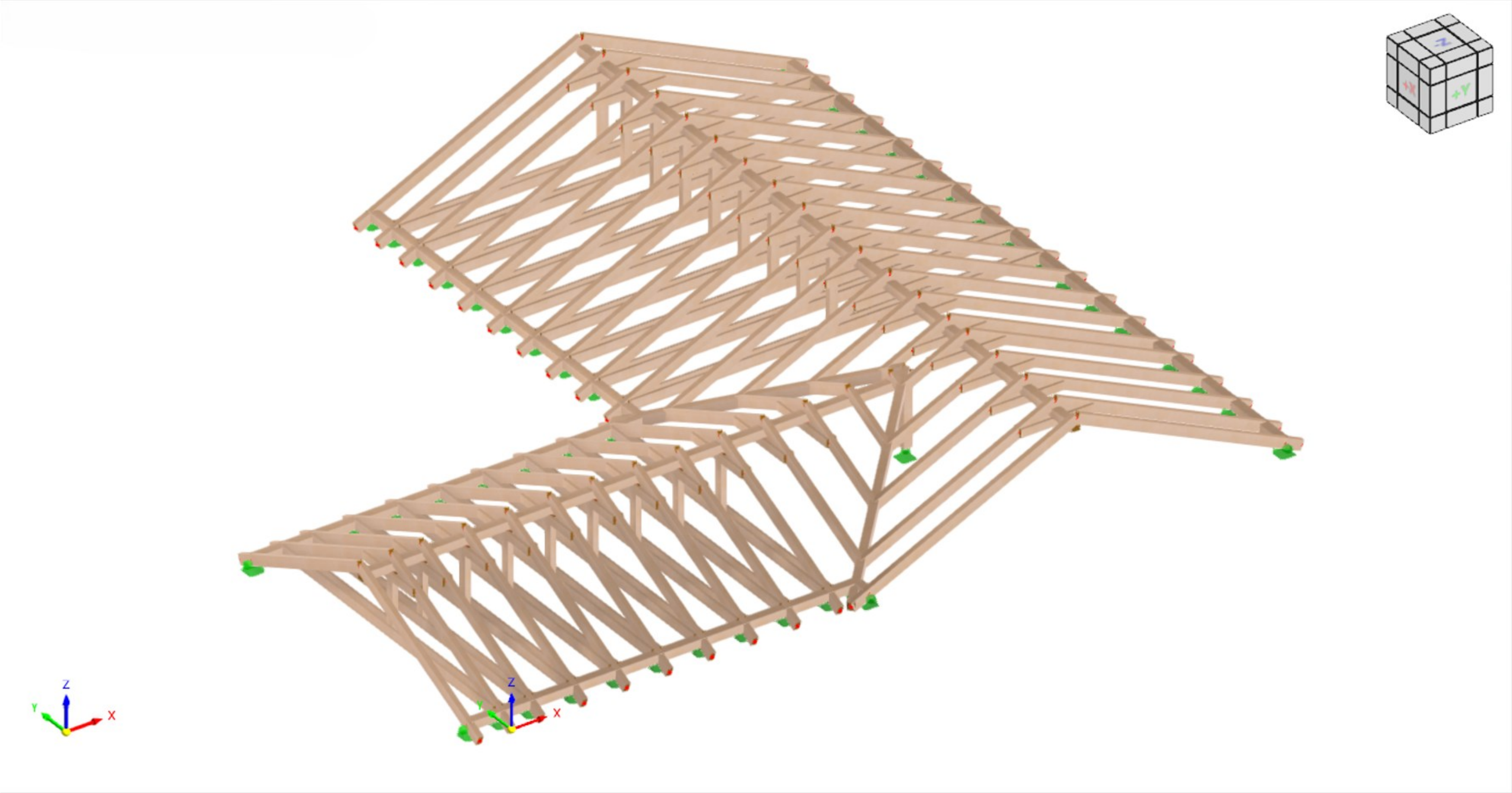
max P_X : 29.278 | min P_X : -82.470 kN
max P_Y : 73.981 | min P_Y : -73.632 kN
max P_Z : 11.122 | min P_Z : -75.085 kN



DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10a and 6.10b
Static Analysis
Displacements u_Z [mm]

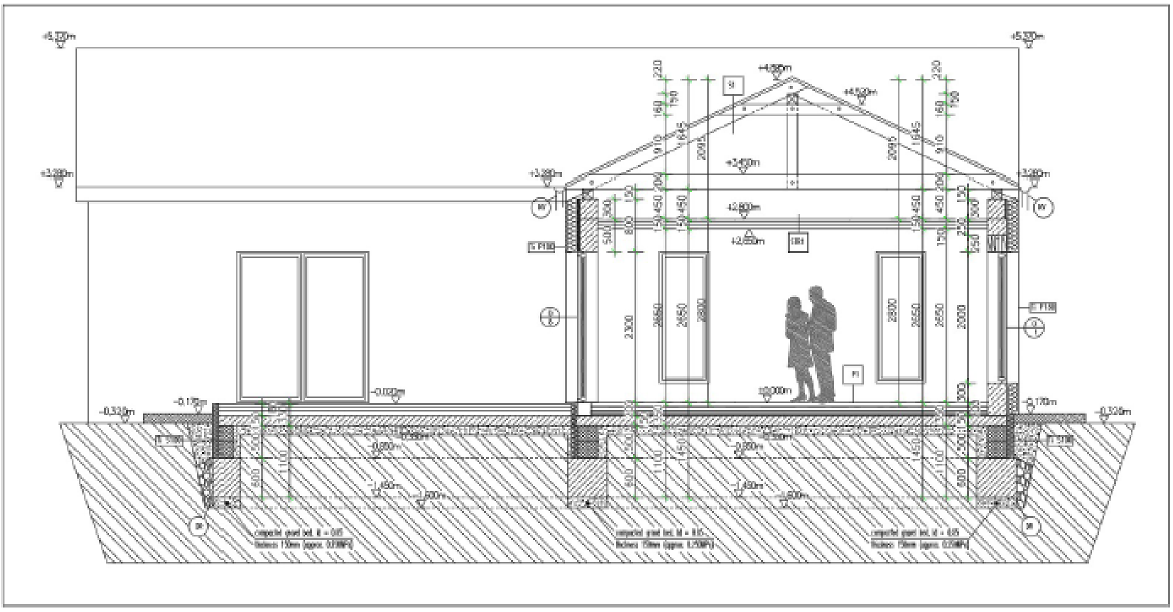
max u_Z : 4.2 | min u_Z : -15.3 mm

Appendix 5. Gable collar tie roof structure



Appendix 6. Design calculations

Design Calculations



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Snow Load - Slovakia

Roof slope $\alpha := 25\ °$

Exposure coefficient $C_e := 1$ SFS EN 1991-1-3 - 5.2(7) Table 5.1

Thermal coefficient $C_t := 1$ STN EN 1991-1-3/NA - 4.2(1)

Snow zone 1 coefficient $a := 0.454$ STN EN 1991-1-3/NA - 4.1(1)

Snow zone 1 coefficient $b := 970$ STN EN 1991-1-3/NA - 4.1(1)

Altitude above sea level (m) $A := 115$ STN EN 1991-1-3/NA - 4.1(1)

Characteristic value of the snow load on the ground in Dunajská Streda

$$s_k := \left(a + \frac{A}{b}\right) \cdot 1\ \frac{kN}{m^2} = 0.573\ \frac{kN}{m^2}$$

STN EN 1991-1-3/NA - 4.1(1)

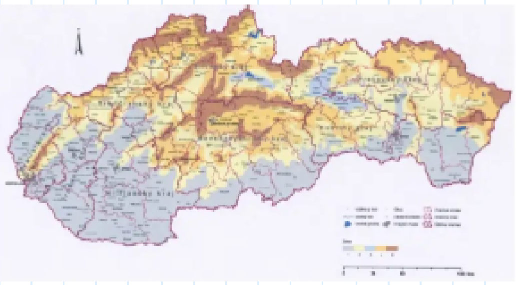
Snow load shape coefficient 1

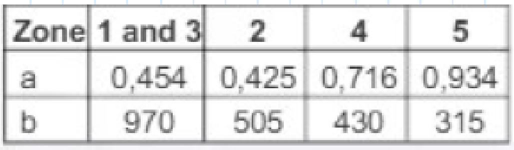
$$\mu_1 := \begin{cases} 0.8 & \text{if } 0\ deg \le \alpha \le 30\ deg \\ \dfrac{0.8 \cdot \left(60 - \dfrac{\alpha}{deg}\right)}{30} & \text{else if } 30\ deg < \alpha < 60\ deg \\ 0 & \text{else if } \alpha \ge 60\ deg \end{cases} = 0.8$$

SFS EN 1991-1-3 - 5.3.2(2) Table 5.2

Load arrangement for undrifted duo-pitched roof $\mu_i := \mu_1 = 0.8$

Snow load $S_k := \mu_i \cdot C_e \cdot C_t \cdot s_k = 0.46\ \frac{kN}{m^2}$ SFS EN 1991-1-3 - 5.2(3) (5.1)





Zone	1 and 3	2	4	5
a	0,454	0,425	0,716	0,934
b	970	505	430	315

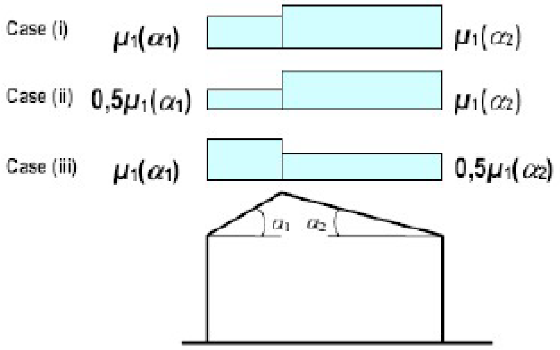


Figure 5.3: Snow load shape coefficients - pitched roofs

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Snow Load - Finland

Roof slope $\alpha := 25\,°$

Exposure coefficient $C_e := 1$ SFS EN 1991-1-3 - 5.2(7) Table 5.1

Thermal coefficient $C_t := 1$ SFS EN 1991-1-3/NA - 3 Table 2

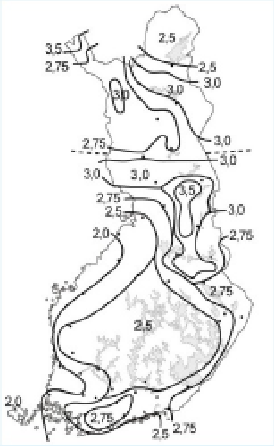
Characteristic value of the snow load on the ground in Hämeenlinna $s_k := 2.5\,\frac{kN}{m^2}$ SFS EN 1991-1-3/NA - 1 Figure 1

Snow load shape coefficient 1 SFS EN 1991-1-3 - 5.3.2(2) Table 5.2

$$\mu_1 := \left\| \begin{array}{l} \text{if } 0\,deg \le \alpha \le 30\,deg \\ \quad \| 0.8 \\ \text{else if } 30\,deg < \alpha < 60\,deg \\ \quad \left\| \dfrac{0.8 \cdot \left(60 - \dfrac{\alpha}{deg}\right)}{30} \right. \\ \text{else if } \alpha \ge 60\,deg \\ \quad \| 0 \end{array} \right\| = 0.8$$

Load arrangement for undrifted duo-pitched roof $\mu := \mu_1 = 0.8$

Snow load $S_k := \mu \cdot C_e \cdot C_t \cdot s_k = 2\,\frac{kN}{m^2}$ SFS EN 1991-1-3 - 5.2(3) (5.1)



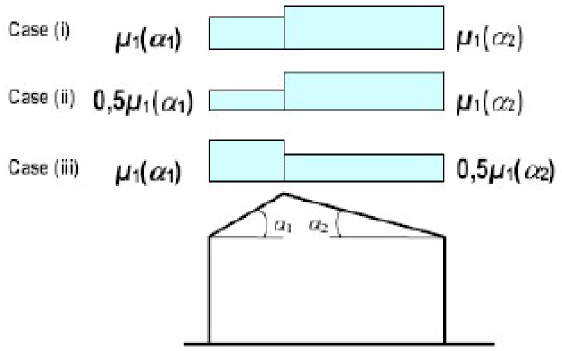


Figure 5.3: Snow load shape coefficients - pitched roofs

Non-Commercial Use Only

Wind Load - Slovakia - Higher Unit

Peak Velocity Calculation

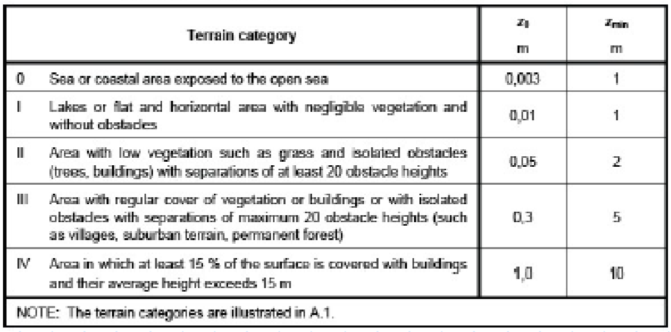
SFS EN 1991-1-1 - 4.3-4.5(p. 19-23)

Height of the structure $Z := 5.37\ m$

Roughness length and min. height $\begin{bmatrix} Z_0 \\ Z_{min} \end{bmatrix} :=$ Terrain category: III

Maximum height $Z_{max} := 200\ m$

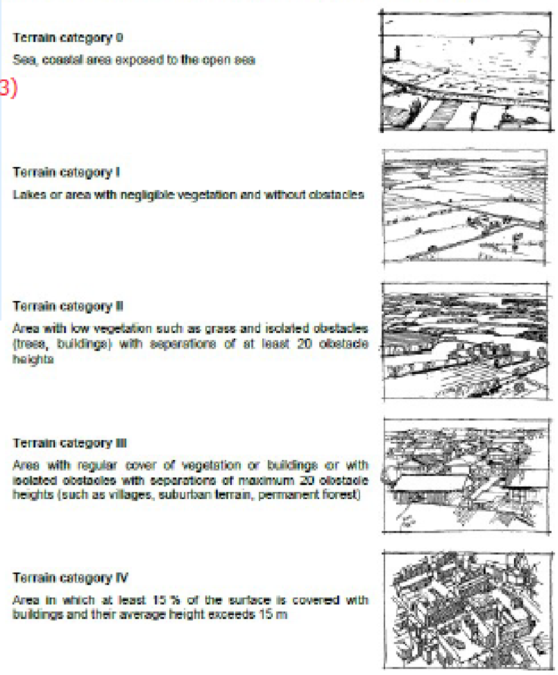
Table 4.1 — Terrain categories and terrain parameters



Terrain category		z_0 m	z_{min} m
0	Sea or coastal area exposed to the open sea	0,003	1
I	Lakes or flat and horizontal area with negligible vegetation and without obstacles	0,01	1
II	Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights	0,05	2
III	Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)	0,3	5
IV	Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m	1,0	10

NOTE: The terrain categories are illustrated in A.1.

A.1 Illustrations of the upper roughness of each terrain category



Terrain category 0

Sea, coastal area exposed to the open sea

Terrain category I

Lakes or area with negligible vegetation and without obstacles

Terrain category II

Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights

Terrain category III

Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)

Terrain category IV

Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m

Terrain factor

$$K_r := \begin{cases} \text{if } Z_0 \le 0.003\ m \\ \quad 0.18 \\ \text{else} \\ \quad 0.19 \cdot \left(\dfrac{Z_0}{0.05\ m} \right)^{0.07} \end{cases} = 0.215$$

Terrain roughness

$$C_r := \begin{cases} \text{if } Z_{min} \le Z \le Z_{max} \\ \quad K_r \cdot \ln\left(\dfrac{Z}{Z_0} \right) \\ \text{else if } Z \le Z_{min} \\ \quad K_r \cdot \ln\left(\dfrac{Z_{min}}{Z_0} \right) \end{cases} = 0.621$$

Expression (4.4)

$c_r(z) = k_r \cdot \ln\left(\frac{z}{z_0} \right)$ for $z_{min} \le z \le z_{max}$

$c_r(z) = c_r(z_{min})$ for $z \le z_{min}$

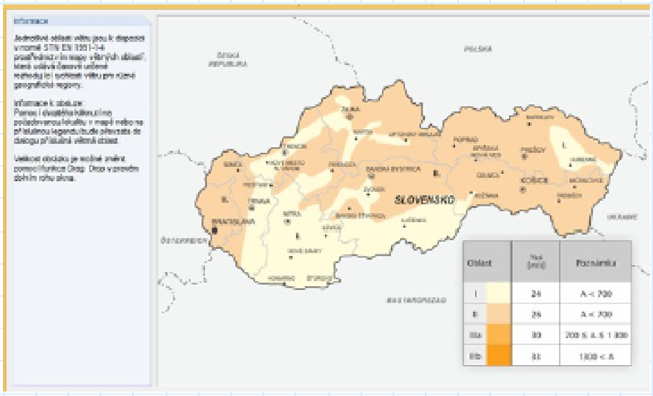
Turbulance factor $K := 1$

Ortography factor $C_o := 1$

Basic wind velocity $v_b := 24\ \frac{m}{s}$

Basic wind pressure $q_b := 360\ Pa$

Air density $\rho := 1.25\ \frac{kg}{m^3}$



Mean wind velocity $v_m := C_r \cdot C_o \cdot v_b = 14.913\ \frac{m}{s}$

$v_m(z) = c_r(z) \cdot c_o(z) \cdot v_b$ Expression (4.3)

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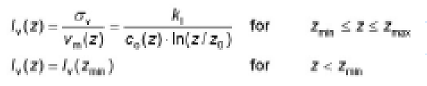
Wind turbulence

$$I_v := \left\| \begin{array}{l} \text{if } Z_{min} \le Z \le Z_{max} \\ \quad \left\| \dfrac{K}{C_o \cdot \ln\left(\dfrac{Z}{Z_0}\right)} \right. \\ \text{else if } Z \le Z_{min} \\ \quad \left\| \dfrac{K}{C_o \cdot \ln\left(\dfrac{Z_{min}}{Z_0}\right)} \right. \end{array} \right. = 0.347$$

Expression (4.7)



$$I_v(z) = \frac{\sigma_v}{v_m(z)} = \frac{k_I}{c_o(z)\cdot \ln(z/z_0)} \quad \text{for} \quad z_{min} \le z \le z_{max}$$

$$I_v(z) = I_v(z_{min}) \quad \text{for} \quad z < z_{min}$$

Peak velocity pressure $q_p := (1 + 7 \cdot I_v) \cdot \frac{1}{2} \cdot \rho \cdot v_m^{\ 2} = 476.25\ Pa$

External pressure coefficient $Ce := \frac{q_p}{q_b} = 1.32$

Wind Calculation on the Walls in Direction 1 (0°) - Higher Unit

SFS EN 1991-1-1 - 5-7.2.2(p. 24-37)

Height of the building $h_{w1} := 5.37\ m$

Wall length imposed to wind $b_{w1} := 14\ m$

Wall length parallel to wind $d_{w1} := 8.6\ m$

Elevation $e_1 := min(b_{w1}, 2 \cdot h_{w1}) = 10.74\ m$

Ratio $\frac{h_{w1}}{d_{w1}} = 0.624$

Length of zone D $D_1 := b_{w1} = 14\ m$

Length of zone E $E_1 := b_{w1} = 14\ m$

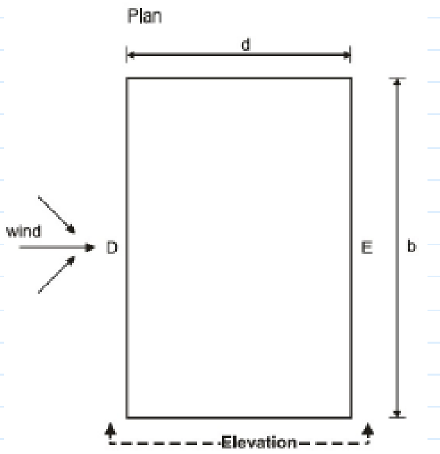


Figure (7.5)

Length of zone A

$$A_1 := \left\| \begin{array}{l} \text{if } e_1 < d_{w1} \\ \quad \left\| \dfrac{e_1}{5} \right. \\ \text{else if } e_1 \ge d_{w1} \\ \quad \left\| \dfrac{e_1}{5} \right. \\ \text{else if } e_1 \ge 5 \cdot d_{w1} \\ \quad \left\| d_{w1} \right. \end{array} \right. = 2.148\ m$$

Length of zone B

$$B_1 := \left\| \begin{array}{l} \text{if } e_1 < d_{w1} \\ \quad \left\| \dfrac{4}{5} \cdot e_1 \right. \\ \text{else if } e_1 \ge d_{w1} \\ \quad \left\| d_{w1} - \dfrac{e_1}{5} \right. \\ \text{else if } e_1 \ge 5 \cdot d_{w1} \\ \quad \left\| 0\ m \right. \end{array} \right. = 6.452\ m$$

Length of zone C

$$C_1 := \left\| \begin{array}{l} \text{if } e_1 < d_{w1} \\ \quad \left\| d_{w1} - e_1 \right. \\ \text{else if } e_1 \ge d_{w1} \\ \quad \left\| 0\ m \right. \\ \text{else if } e_1 \ge 5 \cdot d_{w1} \\ \quad \left\| 0\ m \right. \end{array} \right. = 0\ m$$

Figure (7.5)

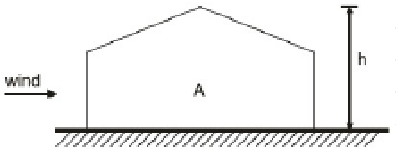


Figure (7.5)

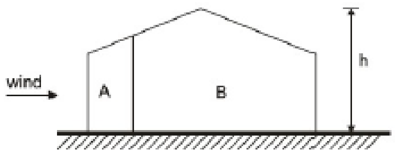
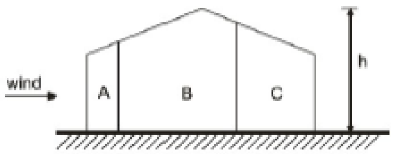


Figure (7.5)



Non-Commercial Use Only

Areas of zones for wind on the wall

Zone A	Zone B	Zone C	Zone D	Zone E
$A_{area.1} := A_1 \cdot h_{w1}$	$B_{area.1} := B_1 \cdot h_{w1}$	$C_{area.1} := C_1 \cdot h_{w1}$	$D_{area.1} := D_1 \cdot h_{w1}$	$E_{area.1} := E_1 \cdot h_{w1}$
$A_{area.1} = 11.535\ m^2$	$B_{area.1} = 34.647\ m^2$	$C_{area.1} = 0\ m^2$	$D_{area.1} = 75.18\ m^2$	$E_{area.1} = 75.18\ m^2$

Internal pressure coefficients

Negative $C_{pi1} := 0.2$

Positive $C_{pi2} := -0.3$

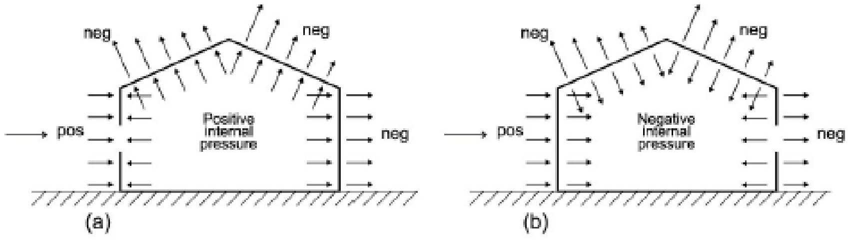
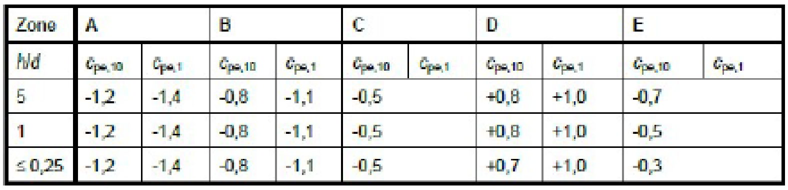


Figure (5.1)

External pressure coefficients

Table 7.1 — Recommended values of external pressure coefficients for vertical walls of rectangular plan buildings



Zone	A		B		C		D		E	
h/d	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,7	
1	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,5	
≤ 0,25	-1,2	-1,4	-0,8	-1,1	-0,5		+0,7	+1,0	-0,3	

For zones with area of less than $10\ m^2$, we use $C_{pe.1}$, for the rest $C_{pe.10}$!!!

$ZoneA_1 := -1.2$ $ZoneB_1 := -0.8$

$ZoneD_1 := 0.8$ $ZoneE_1 := -0.5$

External pressure values for the zones

$$\begin{bmatrix} C_{peA.1} \\ C_{peB.1} \\ C_{peD.1} \\ C_{peE.1} \end{bmatrix} := \begin{bmatrix} ZoneA_1 \\ ZoneB_1 \\ ZoneD_1 \\ ZoneE_1 \end{bmatrix} = \begin{bmatrix} -1.2 \\ -0.8 \\ 0.8 \\ -0.5 \end{bmatrix}$$

Total pressure coefficient at zone A

$$C_{pA.1} := \left\| \begin{array}{l} \text{if } ZoneA_1 < 0 \\ \quad \| C_{peA.1} - C_{pi1} \\ \text{else} \\ \quad \| C_{peA.1} - C_{pi2} \end{array} \right. = -1.4$$

Total pressure coefficient at zone B

$$C_{pB.1} := \left\| \begin{array}{l} \text{if } ZoneB_1 < 0 \\ \quad \| C_{peB.1} - C_{pi1} \\ \text{else} \\ \quad \| C_{peB.1} - C_{pi2} \end{array} \right. = -1$$

Total pressure coefficient at zone D

$$C_{pD.1} := \left\| \begin{array}{l} \text{if } ZoneD_1 < 0 \\ \quad \| C_{peD.1} - C_{pi1} \\ \text{else} \\ \quad \| C_{peD.1} - C_{pi2} \end{array} \right. = 1.1$$

Total pressure coefficient at zone E

$$C_{pE.1} := \left\| \begin{array}{l} \text{if } ZoneE_1 < 0 \\ \quad \| C_{peE.1} - C_{pi1} \\ \text{else} \\ \quad \| C_{peE.1} - C_{pi2} \end{array} \right. = -0.7$$

Wind pressure for each zone in direction 1 (0°)

$$\begin{bmatrix} W_{A.1} \\ W_{B.1} \\ W_{D.1} \\ W_{E.1} \end{bmatrix} := \begin{bmatrix} C_{pA.1} \cdot q_p \\ C_{pB.1} \cdot q_p \\ C_{pD.1} \cdot q_p \\ C_{pE.1} \cdot q_p \end{bmatrix} = \begin{bmatrix} -666.749 \\ -476.25 \\ 523.875 \\ -333.375 \end{bmatrix} Pa$$

Non-Commercial Use Only

Wind Calculation on the Walls in Direction 2 (90°) - Higher Unit

SFS EN 1991-1-1 - 5-7.2.2(p. 24-37)

Height of the building $h_{w2} := 5.37\ m$

Wall length imposed to wind $b_{w2} := 8.6\ m$

Wall length parallel to wind $d_{w2} := 14\ m$

Elevation $e_2 := min\left(b_{w2}, 2 \cdot h_{w2}\right) = 8.6\ m$

Ratio $\frac{h_{w2}}{d_{w2}} = 0.384$

Length of zone D $D_2 := b_{w2} = 8.6\ m$

Length of zone E $E_2 := b_{w2} = 8.6\ m$

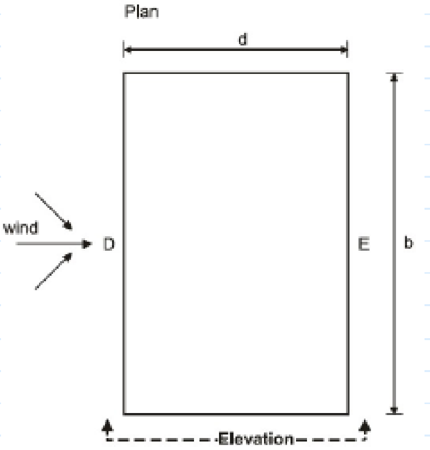


Figure (7.5)

Length of zone A

$$A_2 := \begin{array}{l} \text{if } e_2 < d_{w2} \\ \quad \frac{e_2}{5} \\ \text{else if } e_2 \geq d_{w2} \\ \quad \frac{e_2}{5} \\ \text{else if } e_2 \geq 5 \cdot d_{w2} \\ \quad d_{w2} \end{array} = 1.72\ m$$

Length of zone B

$$B_2 := \begin{array}{l} \text{if } e_2 < d_{w2} \\ \quad \frac{4}{5} \cdot e_2 \\ \text{else if } e_2 \geq d_{w2} \\ \quad d_{w2} - \frac{e_2}{5} \\ \text{else if } e_2 \geq 5 \cdot d_{w2} \\ \quad 0\ m \end{array} = 6.88\ m$$

Length of zone C

$$C_2 := \begin{array}{l} \text{if } e_2 < d_{w2} \\ \quad d_{w2} - e_2 \\ \text{else if } e_2 \geq d_{w2} \\ \quad 0\ m \\ \text{else if } e_2 \geq 5 \cdot d_{w2} \\ \quad 0\ m \end{array} = 5.4\ m$$

Figure (7.5)

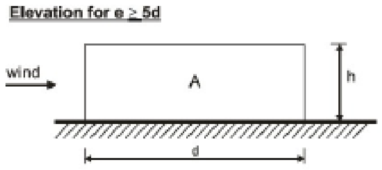


Figure (7.5)

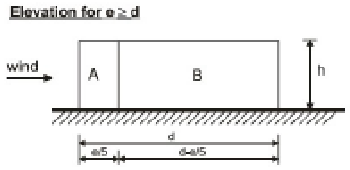
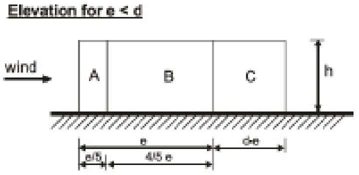


Figure (7.5)



Areas of zones for wind on the wall

Zone A

$A_{area.2} := A_2 \cdot h_{w2}$

$A_{area.2} = 9.236\ m^2$

Zone B

$B_{area.2} := B_2 \cdot h_{w2}$

$B_{area.2} = 36.946\ m^2$

Zone C

$C_{area.2} := C_2 \cdot h_{w2}$

$C_{area.2} = 28.998\ m^2$

Zone D

$D_{area.2} := D_2 \cdot h_{w2}$

$D_{area.2} = 46.182\ m^2$

Zone E

$E_{area.2} := E_2 \cdot h_{w2}$

$E_{area.2} = 46.182\ m^2$

Non-Commercial Use Only

External pressure coefficients

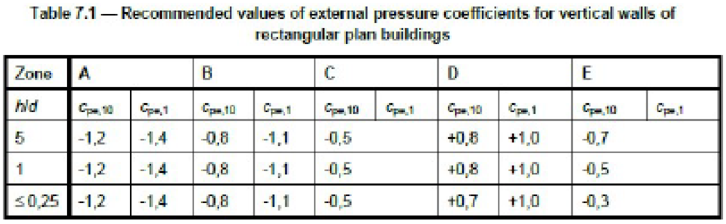


Table 7.1 — Recommended values of external pressure coefficients for vertical walls of rectangular plan buildings

Zone	A		B		C		D		E	
h/d	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,7	
1	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,5	
≤ 0,25	-1,2	-1,4	-0,8	-1,1	-0,5		+0,7	+1,0	-0,3	

For zones with area of less than $10\ m^2$, we use $C_{pe.1}$, for the rest $C_{pe.10}$!!!

$ZoneA_2 := -1.4$ $\qquad ZoneB_2 := -0.8$

$ZoneC_2 := -0.5$ $\qquad ZoneD_2 := 0.8$

$ZoneE_2 := -0.5$

External pressure values for the zones

$$\begin{bmatrix} C_{peA.2} \\ C_{peB.2} \\ C_{peC.2} \\ C_{peD.2} \\ C_{peE.2} \end{bmatrix} := \begin{bmatrix} ZoneA_2 \\ ZoneB_2 \\ ZoneC_2 \\ ZoneD_2 \\ ZoneE_2 \end{bmatrix} = \begin{bmatrix} -1.4 \\ -0.8 \\ -0.5 \\ 0.8 \\ -0.5 \end{bmatrix}$$

Total pressure coefficient at zone A

$$C_{pA.2} := \left\| \begin{array}{l} \text{if } ZoneA_2 < 0 \\ \quad \left\| C_{peA.2} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peA.2} - C_{pi2} \right. \end{array} \right. = -1.6$$

Total pressure coefficient at zone B

$$C_{pB.2} := \left\| \begin{array}{l} \text{if } ZoneB_2 < 0 \\ \quad \left\| C_{peB.2} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peB.2} - C_{pi2} \right. \end{array} \right. = -1$$

Total pressure coefficient at zone C

$$C_{pC.2} := \left\| \begin{array}{l} \text{if } ZoneC_2 < 0 \\ \quad \left\| C_{peC.2} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peC.2} - C_{pi2} \right. \end{array} \right. = -0.7$$

Total pressure coefficient at zone D

$$C_{pD.2} := \left\| \begin{array}{l} \text{if } ZoneD_2 < 0 \\ \quad \left\| C_{peD.2} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peD.2} - C_{pi2} \right. \end{array} \right. = 1.1$$

Total pressure coefficient at zone E

$$C_{pE.2} := \left\| \begin{array}{l} \text{if } ZoneE_2 < 0 \\ \quad \left\| C_{peE.2} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peE.2} - C_{pi2} \right. \end{array} \right. = -0.7$$

Wind pressure for each zone in direction 2 (90°)

$$\begin{bmatrix} W_{A.2} \\ W_{B.2} \\ W_{C.2} \\ W_{D.2} \\ W_{E.2} \end{bmatrix} := \begin{bmatrix} C_{pA.2} \cdot q_p \\ C_{pB.2} \cdot q_p \\ C_{pC.2} \cdot q_p \\ C_{pD.2} \cdot q_p \\ C_{pE.2} \cdot q_p \end{bmatrix} = \begin{bmatrix} -761.999 \\ -476.25 \\ -333.375 \\ 523.875 \\ -333.375 \end{bmatrix} Pa$$

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Wind Calculation on the Roof in Direction 1 (0 °) - Higher Unit

SFS EN 1991-1-1 - 5-7.2.2(p. 24-37)

Wind direction 0 degrees

Direction of Wind $DirecW = 0$

Height of the building $h_{w0} := 5.37\ m$

Wind direction $b_{w0} := 14.36\ m$

Crosswind direction $d_{w0} := 8.96\ m$

Elevation $e_0 := min\left(b_{w0}, 2 \cdot h_{w0}\right) = 10.74\ m$

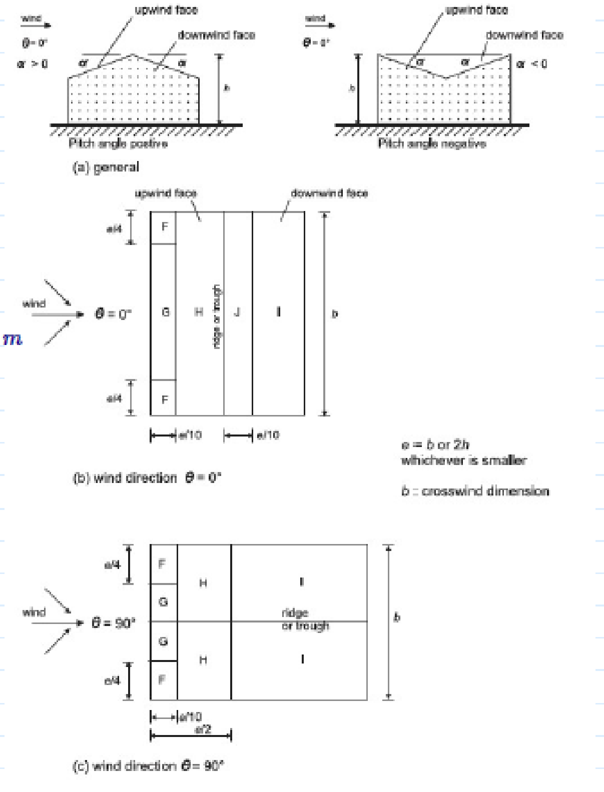

Figure 7.8 — Key for duopitch roofs

Zones for wind direcetion 0 degrees

Zone F length in y-direction $Fy_0 := \frac{e_0}{4} = 2.685\ m$

Zone F length in x-direction $Fx_0 := \frac{e_0}{10} = 1.074\ m$

Zone G length in y-direction $Gy_0 := b_{w0} - 2\left(\frac{e_0}{4}\right) = 8.99\ m$

Zone G length in x-direction $Gx_0 := \frac{e_0}{10} = 1.074\ m$

Zone H length in y-direction $Hy_0 := b_{w0} = 14.36\ m$

Zone H length in x-direction $Hx_0 := \frac{d_{w0}}{2} - \frac{e_0}{10} = 3.406\ m$

Zone J length in y-direction $Jy_0 := b_{w0} = 14.36\ m$

Zone J length in x-direction $Jx_0 := \frac{e_0}{10} = 1.074\ m$

Zone I length in y-direction $Iy_0 := b_{w0} = 14.36\ m$

Zone I length in x-direction $Ix_0 := \frac{d_{w0}}{2} - \frac{e_0}{10} = 3.406\ m$

Area of zones for wind direction 0 degrees

Zone F	**Zone G**	**Zone H**	**Zone I**	**Zone J**
$A_{F.0} := Fy_0 \cdot Fx_0$	$A_{G.0} := Gy_0 \cdot Gx_0$	$A_{H.0} := Hy_0 \cdot Hx_0$	$A_{I.0} := Iy_0 \cdot Ix_0$	$A_{J.0} := Jy_0 \cdot Jx_0$
$A_{F.0} = 2.884\ m^2$	$A_{G.0} = 9.655\ m^2$	$A_{H.0} = 48.91\ m^2$	$A_{I.0} = 48.91\ m^2$	$A_{J.0} = 15.423\ m^2$

Non-Commercial Use Only

External pressure coefficients

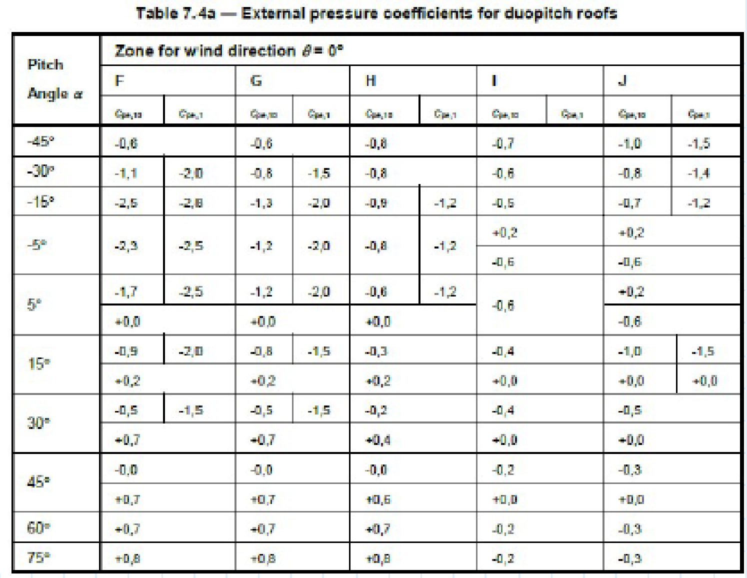

Table 7.4a — External pressure coefficients for duopitch roofs

Pitch Angle α	Zone for wind direction θ = 0°									
	F		G		H		I		J	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
-45°	-0,6		-0,6		-0,8		-0,7		-1,0	-1,5
-30°	-1,1	-2,0	-0,8	-1,5	-0,8		-0,6		-0,8	-1,4
-15°	-2,5	-2,8	-1,3	-2,0	-0,9	-1,2	-0,5		-0,7	-1,2
-5°	-2,3	-2,5	-1,2	-2,0	-0,8	-1,2	+0,2		+0,2	
							-0,6		-0,6	
5°	-1,7	-2,5	-1,2	-2,0	-0,6	-1,2	-0,6		+0,2	
	+0,0		+0,0		+0,0				-0,6	
15°	-0,9	-2,0	-0,8	-1,5	-0,3		-0,4		-1,0	-1,5
	+0,2		+0,2		+0,2		+0,0		+0,0	+0,0
30°	-0,5	-1,5	-0,5	-1,5	-0,2		-0,4		-0,5	
	+0,7		+0,7		+0,4		+0,0		+0,0	
45°	-0,0		-0,0		-0,0		-0,2		-0,3	
	+0,7		+0,7		+0,6		+0,0		+0,0	
60°	+0,7		+0,7		+0,7		-0,2		-0,3	
75°	+0,8		+0,8		+0,8		-0,2		-0,3	

For zones with area of less than $10\ m^2$, we use $C_{pe.1}$, for the rest $C_{pe.10}$!!!

Case A for Zones

$ZoneF_{0.a} := 0.7$

$ZoneG_{0.a} := 0.7$

$ZoneH_{0.a} := 0.4$

$ZoneI_{0.a} := 0$

$ZoneJ_{0.a} := 0$

Case B for Zones

$ZoneF_{0.b} := -1.5$

$ZoneG_{0.b} := -1.5$

$ZoneH_{0.b} := -0.2$

$ZoneI_{0.b} := -0.4$

$ZoneJ_{0.b} := -0.5$

External pressure values for the zones

$$\begin{bmatrix} C_{peF.0.a} \\ C_{peG.0.a} \\ C_{peH.0.a} \\ C_{peI.0.a} \\ C_{peJ.0.a} \end{bmatrix} := \begin{bmatrix} ZoneF_{0.a} \\ ZoneG_{0.a} \\ ZoneH_{0.a} \\ ZoneI_{0.a} \\ ZoneJ_{0.a} \end{bmatrix} = \begin{bmatrix} 0.7 \\ 0.7 \\ 0.4 \\ 0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} C_{peF.0.b} \\ C_{peG.0.b} \\ C_{peH.0.b} \\ C_{peI.0.b} \\ C_{peJ.0.b} \end{bmatrix} := \begin{bmatrix} ZoneF_{0.b} \\ ZoneG_{0.b} \\ ZoneH_{0.b} \\ ZoneI_{0.b} \\ ZoneJ_{0.b} \end{bmatrix} = \begin{bmatrix} -1.5 \\ -1.5 \\ -0.2 \\ -0.4 \\ -0.5 \end{bmatrix}$$

Total pressure coefficient at zone F

$$C_{pF.0.a} := \left\| \begin{array}{l} \text{if } ZoneF_{0.a} < 0 \\ \quad \| C_{peF.0.a} - C_{pi1} \\ \text{else} \\ \quad \| C_{peF.0.a} - C_{pi2} \end{array} \right\| = 1$$

$$C_{pF.0.b} := \left\| \begin{array}{l} \text{if } ZoneF_{0.b} < 0 \\ \quad \| C_{peF.0.b} - C_{pi1} \\ \text{else} \\ \quad \| C_{peF.0.b} - C_{pi2} \end{array} \right\| = -1.7$$

Total pressure coefficient at zone G

$$C_{pG.0.a} := \left\| \begin{array}{l} \text{if } ZoneG_{0.a} < 0 \\ \quad \| C_{peG.0.a} - C_{pi1} \\ \text{else} \\ \quad \| C_{peG.0.a} - C_{pi2} \end{array} \right\| = 1$$

$$C_{pG.0.b} := \left\| \begin{array}{l} \text{if } ZoneG_{0.b} < 0 \\ \quad \| C_{peG.0.b} - C_{pi1} \\ \text{else} \\ \quad \| C_{peG.0.b} - C_{pi2} \end{array} \right\| = -1.7$$

Total pressure coefficient at zone H

$$C_{pH.0.a} := \left\| \begin{array}{l} \text{if } ZoneH_{0.a} < 0 \\ \quad \| C_{peH.0.a} - C_{pi1} \\ \text{else} \\ \quad \| C_{peH.0.a} - C_{pi2} \end{array} \right\| = 0.7$$

$$C_{pH.0.b} := \left\| \begin{array}{l} \text{if } ZoneH_{0.b} < 0 \\ \quad \| C_{peH.0.b} - C_{pi1} \\ \text{else} \\ \quad \| C_{peH.0.b} - C_{pi2} \end{array} \right\| = -0.4$$

Total pressure coefficient at zone I

$$C_{pI.0.a} := \left\| \begin{array}{l} \text{if } ZoneI_{0.a} < 0 \\ \quad \| C_{peI.0.a} - C_{pi1} \\ \text{else} \\ \quad \| C_{peI.0.a} - C_{pi2} \end{array} \right\| = 0.3$$

$$C_{pI.0.b} := \left\| \begin{array}{l} \text{if } ZoneI_{0.b} < 0 \\ \quad \| C_{peI.0.b} - C_{pi1} \\ \text{else} \\ \quad \| C_{peI.0.b} - C_{pi2} \end{array} \right\| = -0.6$$

Total pressure coefficient at zone J

$$C_{pJ.0.a} := \left\| \begin{array}{l} \text{if } ZoneJ_{0.a} < 0 \\ \quad \| C_{peJ.0.a} - C_{pi1} \\ \text{else} \\ \quad \| C_{peJ.0.a} - C_{pi2} \end{array} \right\| = 0.3$$

$$C_{pJ.0.b} := \left\| \begin{array}{l} \text{if } ZoneJ_{0.b} < 0 \\ \quad \| C_{peJ.0.b} - C_{pi1} \\ \text{else} \\ \quad \| C_{peJ.0.b} - C_{pi2} \end{array} \right\| = -0.7$$

Wind pressure for each zone in direction 1 (0 °)

$$\begin{bmatrix} W_{F.0.a} \\ W_{G.0.a} \\ W_{H.0.a} \\ W_{I.0.a} \\ W_{J.0.a} \end{bmatrix} := \begin{bmatrix} C_{pF.0.a} \cdot q_p \\ C_{pG.0.a} \cdot q_p \\ C_{pH.0.a} \cdot q_p \\ C_{pI.0.a} \cdot q_p \\ C_{pJ.0.a} \cdot q_p \end{bmatrix} = \begin{bmatrix} 476.25 \\ 476.25 \\ 333.375 \\ 142.875 \\ 142.875 \end{bmatrix} Pa$$

$$\begin{bmatrix} W_{F.0.b} \\ W_{G.0.b} \\ W_{H.0.b} \\ W_{I.0.b} \\ W_{J.0.b} \end{bmatrix} := \begin{bmatrix} C_{pF.0.b} \cdot q_p \\ C_{pG.0.b} \cdot q_p \\ C_{pH.0.b} \cdot q_p \\ C_{pI.0.b} \cdot q_p \\ C_{pJ.0.b} \cdot q_p \end{bmatrix} = \begin{bmatrix} -809.624 \\ -809.624 \\ -190.5 \\ -285.75 \\ -333.375 \end{bmatrix} Pa$$

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Wind Calculation on the Roof in Direction 2 (90°) - Higher Unit

SFS EN 1991-1-1 - 7.2.5(p.43-46)

Wind direction 90 degrees

Direction of Wind $DirecW = 90$

Height of the building $h_{w90} := 5.37\ m$

Wind direction $b_{w90} := 8.96\ m$

Crosswind direction $d_{w90} := 14.36\ m$

Elevation $e_{90} := min\left(b_{w90}, 2 \cdot d_{w90}\right) = 8.96\ m$

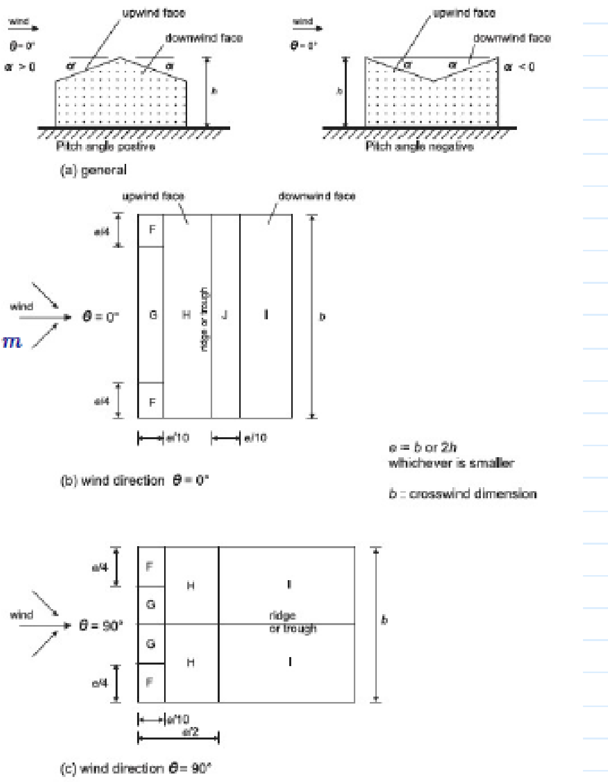

Figure 7.8 — Key for duopitch roofs

Zones for wind direction 90 degrees

Zone F length in y-direction $Fy_{90} := \frac{e_{90}}{4} = 2.24\ m$

Zone F length in x-direction $Fx_{90} := \frac{e_{90}}{10} = 0.896\ m$

Zone G length in y-direction $Gy_{90} := \frac{b_{w90}}{2} - \left(\frac{e_{90}}{4}\right) = 2.24\ m$

Zone G length in x-direction $Gx_{90} := \frac{e_{90}}{10} = 0.896\ m$

Zone H length in y-direction $Hy_{90} := \frac{b_{w90}}{2} = 4.48\ m$

Zone H length in x-direction $Hx_{90} := \frac{e_{90}}{2} - \frac{e_{90}}{10} = 3.584\ m$

Zone I length in y-direction $Iy_{90} := \frac{b_{w90}}{2} = 4.48\ m$

Zone I length in x-direction $Ix_{90} := d_{w90} - \frac{e_{90}}{2} = 9.88\ m$

Area of zones for wind direction 90 degrees

Zone F	Zone G	Zone H	Zone I
$A_{F.90} := Fy_{90} \cdot Fx_{90}$	$A_{G.90} := Gy_{90} \cdot Gx_{90}$	$A_{H.90} := Hy_{90} \cdot Hx_{90}$	$A_{I.90} := Iy_{90} \cdot Ix_{90}$
$A_{F.90} = 2.007\ m^2$	$A_{G.90} = 2.007\ m^2$	$A_{H.90} = 16.056\ m^2$	$A_{I.90} = 44.262\ m^2$

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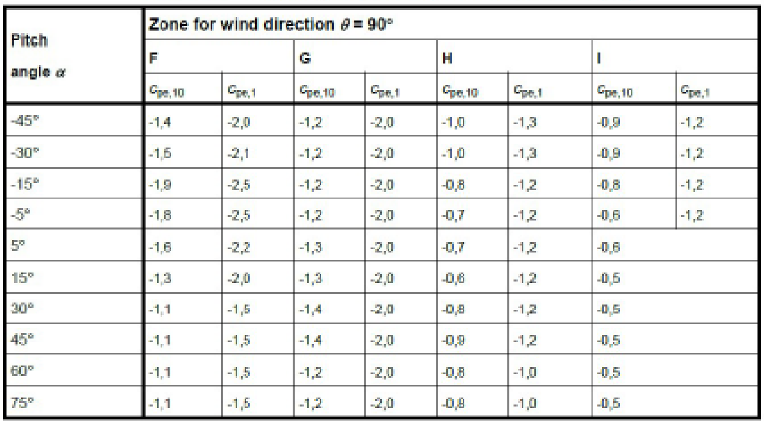
External pressure coefficients

Table 7.4b — External pressure coefficients for duopitch roofs



Pitch angle α	Zone for wind direction θ = 90°							
	F		G		H		I	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
-45°	-1,4	-2,0	-1,2	-2,0	-1,0	-1,3	-0,9	-1,2
-30°	-1,5	-2,1	-1,2	-2,0	-1,0	-1,3	-0,9	-1,2
-15°	-1,9	-2,5	-1,2	-2,0	-0,8	-1,2	-0,8	-1,2
-5°	-1,8	-2,5	-1,2	-2,0	-0,7	-1,2	-0,6	-1,2
5°	-1,6	-2,2	-1,3	-2,0	-0,7	-1,2	-0,6	
15°	-1,3	-2,0	-1,3	-2,0	-0,6	-1,2	-0,5	
30°	-1,1	-1,5	-1,4	-2,0	-0,8	-1,2	-0,5	
45°	-1,1	-1,5	-1,4	-2,0	-0,9	-1,2	-0,5	
60°	-1,1	-1,5	-1,2	-2,0	-0,8	-1,0	-0,5	
75°	-1,1	-1,5	-1,2	-2,0	-0,8	-1,0	-0,5	

$ZoneF_{90} := -1.5$ $\quad ZoneH_{90} := -0.8$

$ZoneG_{90} := -2.0$ $\quad ZoneI_{90} := -0.5$

External pressure values for the zones

$$\begin{bmatrix} C_{peF.90} \\ C_{peG.90} \\ C_{peH.90} \\ C_{peI.90} \end{bmatrix} := \begin{bmatrix} ZoneF_{90} \\ ZoneG_{90} \\ ZoneH_{90} \\ ZoneI_{90} \end{bmatrix} = \begin{bmatrix} -1.5 \\ -2 \\ -0.8 \\ -0.5 \end{bmatrix}$$

For zones with area of less than $10\ m^2$, we use $C_{pe.1}$, for the rest $C_{pe.10}$!!!

Total pressure coefficient at zone F

$$C_{pF.90} := \left\| \begin{array}{l} \text{if } ZoneF_{90} < 0 \\ \quad \left\| C_{peF.90} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peF.90} - C_{pi2} \right. \end{array} \right. = -1.7$$

Total pressure coefficient at zone G

$$C_{pG.90} := \left\| \begin{array}{l} \text{if } ZoneG_{90} < 0 \\ \quad \left\| C_{peG.90} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peG.90} - C_{pi2} \right. \end{array} \right. = -2.2$$

Total pressure coefficient at zone H

$$C_{pH.90} := \left\| \begin{array}{l} \text{if } ZoneH_{90} < 0 \\ \quad \left\| C_{peH.90} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peH.90} - C_{pi2} \right. \end{array} \right. = -1$$

Total pressure coefficient at zone I

$$C_{pI.90} := \left\| \begin{array}{l} \text{if } ZoneI_{90} < 0 \\ \quad \left\| C_{peI.90} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peI.90} - C_{pi2} \right. \end{array} \right. = -0.7$$

Wind pressure for each zone in direction 2 (90°)

$$\begin{bmatrix} W_{F.90} \\ W_{G.90} \\ W_{H.90} \\ W_{I.90} \end{bmatrix} := \begin{bmatrix} C_{pF.90} \cdot q_p \\ C_{pG.90} \cdot q_p \\ C_{pH.90} \cdot q_p \\ C_{pI.90} \cdot q_p \end{bmatrix} = \begin{bmatrix} -809.624 \\ -1.048 \cdot 10^3 \\ -476.25 \\ -333.375 \end{bmatrix} Pa$$

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Wind Load - Slovakia - Lower Unit

Peak Velocity Calculation

SFS EN 1991-1-1 - 4.3-4.5(p. 19-23)

Height of the structure $Z := 4.895\ m$

Roughness length and min. height $\begin{bmatrix} Z_0 \\ Z_{min} \end{bmatrix} :=$ Terrain category: III

Maximum height $Z_{max} := 200\ m$

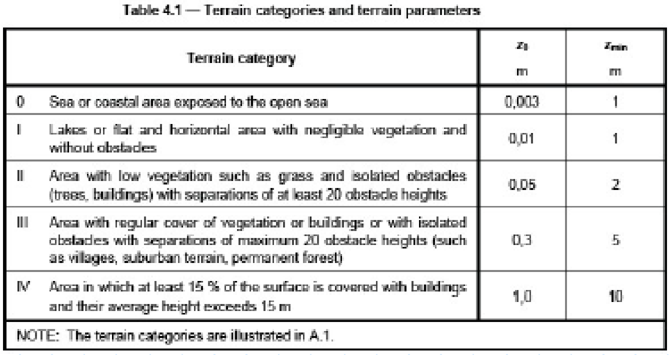
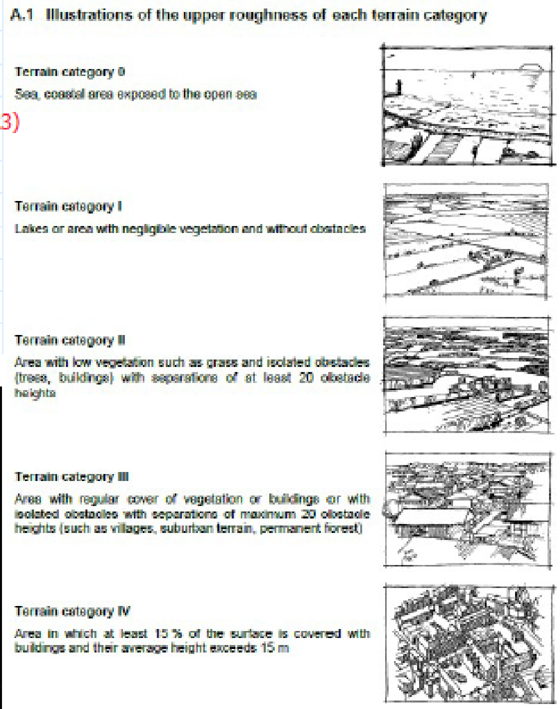


Table 4.1 — Terrain categories and terrain parameters

	Terrain category	z_0 m	z_{min} m
0	Sea or coastal area exposed to the open sea	0,003	1
I	Lakes or flat and horizontal area with negligible vegetation and without obstacles	0,01	1
II	Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights	0,05	2
III	Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)	0,3	5
IV	Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m	1,0	10

NOTE: The terrain categories are illustrated in A.1.



A.1 Illustrations of the upper roughness of each terrain category

Terrain category 0
Sea, coastal area exposed to the open sea

Terrain category I
Lakes or area with negligible vegetation and without obstacles

Terrain category II
Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights

Terrain category III
Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)

Terrain category IV
Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m

Terrain factor
$$K_r := \left\| \begin{array}{l} \text{if } Z_0 \le 0.003\ m \\ \quad \| 0.18 \\ \text{else} \\ \quad \left\| 0.19 \cdot \left(\dfrac{Z_0}{0.05\ m} \right)^{0.07} \right. \end{array} \right\| = 0.215$$

Terrain roughness
$$C_r := \left\| \begin{array}{l} \text{if } Z_{min} \le Z \le Z_{max} \\ \quad \left\| K_r \cdot \ln\left(\dfrac{Z}{Z_0}\right) \right. \\ \text{else if } Z \le Z_{min} \\ \quad \left\| K_r \cdot \ln\left(\dfrac{Z_{min}}{Z_0}\right) \right. \end{array} \right\| = 0.606$$

Expression (4.4)

$$c_r(z) = k_r \cdot \ln\left(\frac{z}{z_0}\right) \quad \text{for} \quad z_{min} \le z \le z_{max}$$
$$c_r(z) = c_r(z_{min}) \quad \text{for} \quad z \le z_{min}$$

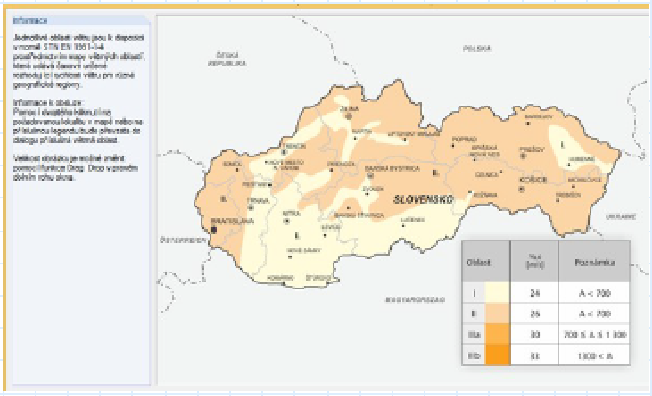
Turbulance factor $K := 1$

Ortography factor $C_o := 1$

Basic wind velocity $v_b := 24\ \frac{m}{s}$

Basic wind pressure $q_b := 360\ Pa$

Air density $\rho := 1.25\ \frac{kg}{m^3}$



Mean wind velocity $v_m := C_r \cdot C_o \cdot v_b = 14.543\ \frac{m}{s}$ $\quad v_m(z) = c_r(z) \cdot c_o(z) \cdot v_b$ Expression (4.3)

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Wind turbulence

$$I_v := \left| \begin{array}{l} \text{if } Z_{min} \le Z \le Z_{max} \\ \quad \left\| \dfrac{K}{C_o \cdot \ln\left(\dfrac{Z}{Z_0}\right)} \right. \\ \text{else if } Z \le Z_{min} \\ \quad \left\| \dfrac{K}{C_o \cdot \ln\left(\dfrac{Z_{min}}{Z_0}\right)} \right. \end{array} \right. = 0.355$$

Expression (4.7)

$$I_v(z) = \frac{\sigma_v}{v_m(z)} = \frac{k_l}{c_o(z) \cdot \ln(z / z_0)} \quad \text{for} \quad z_{min} \le z \le z_{max}$$

$$I_v(z) = I_v(z_{min}) \quad \text{for} \quad z < z_{min}$$

Peak velocity pressure

$$q_p := \left(1 + 7 \cdot I_v\right) \cdot \frac{1}{2} \cdot \rho \cdot v_m{}^2 = 461.109 \; Pa$$

External pressure coefficient

$$Ce := \frac{q_p}{q_b} = 1.28$$

Wind Calculation on the Walls in Direction 1 (0 °) - Lower Unit

SFS EN 1991-1-1 - 5-7.2.2(p. 24-37)

Height of the building $h_{w1} := 4.895 \; m$

Wall length imposed to wind $b_{w1} := 7.4 \; m$

Wall length parallel to wind $d_{w1} := 6.55 \; m$

Elevation $e_1 := min\left(b_{w1}, 2 \cdot h_{w1}\right) = 7.4 \; m$

Ratio $\dfrac{h_{w1}}{d_{w1}} = 0.747$

Length of zone D $D_1 := b_{w1} = 7.4 \; m$

Length of zone E $E_1 := b_{w1} = 7.4 \; m$

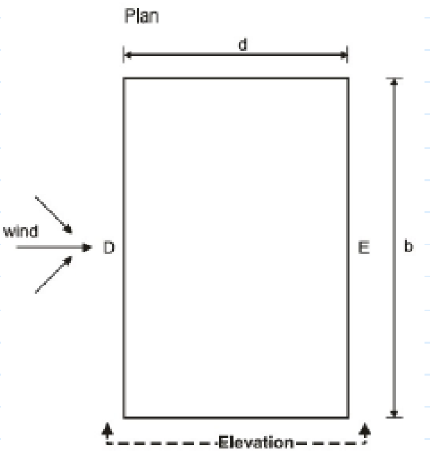


Figure (7.5)

Length of zone A

$$A_1 := \left| \begin{array}{l} \text{if } e_1 < d_{w1} \\ \quad \left\| \dfrac{e_1}{5} \right. \\ \text{else if } e_1 \ge d_{w1} \\ \quad \left\| \dfrac{e_1}{5} \right. \\ \text{else if } e_1 \ge 5 \cdot d_{w1} \\ \quad \left\| d_{w1} \right. \end{array} \right. = 1.48 \; m$$

Length of zone B

$$B_1 := \left| \begin{array}{l} \text{if } e_1 < d_{w1} \\ \quad \left\| \dfrac{4}{5} \cdot e_1 \right. \\ \text{else if } e_1 \ge d_{w1} \\ \quad \left\| d_{w1} - \dfrac{e_1}{5} \right. \\ \text{else if } e_1 \ge 5 \cdot d_{w1} \\ \quad \left\| 0 \; m \right. \end{array} \right. = 5.07 \; m$$

Length of zone C

$$C_1 := \left| \begin{array}{l} \text{if } e_1 < d_{w1} \\ \quad \left\| d_{w1} - e_1 \right. \\ \text{else if } e_1 \ge d_{w1} \\ \quad \left\| 0 \; m \right. \\ \text{else if } e_1 \ge 5 \cdot d_{w1} \\ \quad \left\| 0 \; m \right. \end{array} \right. = 0 \; m$$

Figure (7.5)

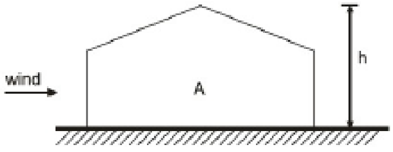


Figure (7.5)

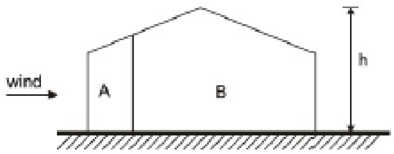
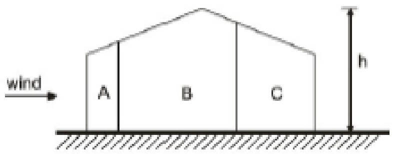


Figure (7.5)



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Areas of zones for wind on the wall

Zone A	Zone B	Zone C	Zone D	Zone E
$A_{area.1} := A_1 \cdot h_{w1}$	$B_{area.1} := B_1 \cdot h_{w1}$	$C_{area.1} := C_1 \cdot h_{w1}$	$D_{area.1} := D_1 \cdot h_{w1}$	$E_{area.1} := E_1 \cdot h_{w1}$
$A_{area.1} = 7.245\ m^2$	$B_{area.1} = 24.818\ m^2$	$C_{area.1} = 0\ m^2$	$D_{area.1} = 36.223\ m^2$	$E_{area.1} = 36.223\ m^2$

Internal pressure coefficients

Negative $C_{pi1} := 0.2$

Positive $C_{pi2} := -0.3$

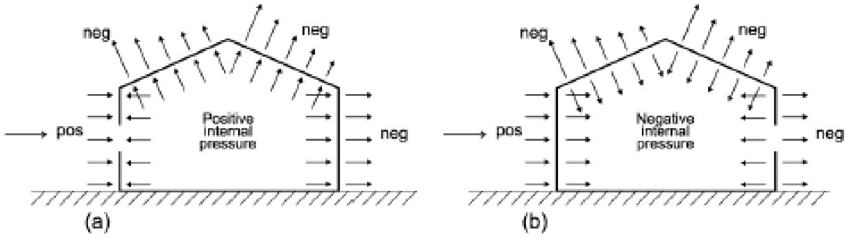

Figure (5.1)

External pressure coefficients

Table 7.1 — Recommended values of external pressure coefficients for vertical walls of rectangular plan buildings

Zone	A		B		C		D		E	
h/d	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,7	
1	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,5	
≤ 0,25	-1,2	-1,4	-0,8	-1,1	-0,5		+0,7	+1,0	-0,3	

For zones with area of less than $10\ m^2$, we use $C_{pe.1}$, for the rest $C_{pe.10}$!!!

$ZoneA_1 := -1.4$ $ZoneB_1 := -0.8$

$ZoneD_1 := 0.8$ $ZoneE_1 := -0.5$

External pressure values for the zones

$$\begin{bmatrix} C_{peA.1} \\ C_{peB.1} \\ C_{peD.1} \\ C_{peE.1} \end{bmatrix} := \begin{bmatrix} ZoneA_1 \\ ZoneB_1 \\ ZoneD_1 \\ ZoneE_1 \end{bmatrix} = \begin{bmatrix} -1.4 \\ -0.8 \\ 0.8 \\ -0.5 \end{bmatrix}$$

Total pressure coefficient at zone A

$$C_{pA.1} := \left\| \begin{array}{l} \text{if } ZoneA_1 < 0 \\ \quad \left\| C_{peA.1} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peA.1} - C_{pi2} \right. \end{array} \right. = -1.6$$

Total pressure coefficient at zone B

$$C_{pB.1} := \left\| \begin{array}{l} \text{if } ZoneB_1 < 0 \\ \quad \left\| C_{peB.1} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peB.1} - C_{pi2} \right. \end{array} \right. = -1$$

Total pressure coefficient at zone D

$$C_{pD.1} := \left\| \begin{array}{l} \text{if } ZoneD_1 < 0 \\ \quad \left\| C_{peD.1} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peD.1} - C_{pi2} \right. \end{array} \right. = 1.1$$

Total pressure coefficient at zone E

$$C_{pE.1} := \left\| \begin{array}{l} \text{if } ZoneE_1 < 0 \\ \quad \left\| C_{peE.1} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peE.1} - C_{pi2} \right. \end{array} \right. = -0.7$$

Wind pressure for each zone in direction 1 (0 °)

$$\begin{bmatrix} W_{A.1} \\ W_{B.1} \\ W_{D.1} \\ W_{E.1} \end{bmatrix} := \begin{bmatrix} C_{pA.1} \cdot q_p \\ C_{pB.1} \cdot q_p \\ C_{pD.1} \cdot q_p \\ C_{pE.1} \cdot q_p \end{bmatrix} = \begin{bmatrix} -737.775 \\ -461.109 \\ 507.22 \\ -322.777 \end{bmatrix} Pa$$

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Wind Calculation on the Walls in Direction 2 (90°) - Lower Unit

SFS EN 1991-1-1 - 5-7.2.2(p. 24-37)

Height of the building $h_{w2} := 4.895\ m$

Wall length imposed to wind $b_{w2} := 6.55\ m$

Wall length parallel to wind $d_{w2} := 7.4\ m$

Elevation $e_2 := min\left(b_{w2}, 2 \cdot h_{w2}\right) = 6.55\ m$

Ratio $\dfrac{h_{w2}}{d_{w2}} = 0.661$

Length of zone D $D_2 := b_{w2} = 6.55\ m$

Length of zone E $E_2 := b_{w2} = 6.55\ m$

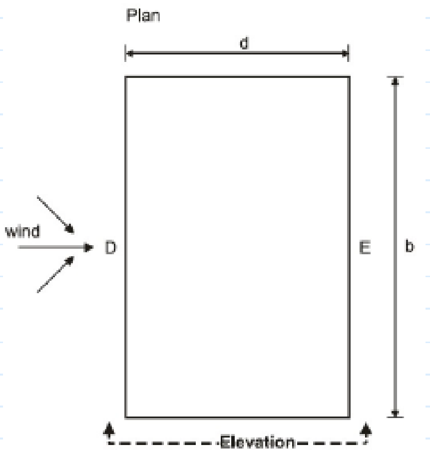


Figure (7.5)

Length of zone A

$$A_2 := \begin{array}{|l} \text{if } e_2 < d_{w2} \\ \quad \left\| \dfrac{e_2}{5} \right. \\ \text{else if } e_2 \geq d_{w2} \\ \quad \left\| \dfrac{e_2}{5} \right. \\ \text{else if } e_2 \geq 5 \cdot d_{w2} \\ \quad \| d_{w2} \end{array} = 1.31\ m$$

Length of zone B

$$B_2 := \begin{array}{|l} \text{if } e_2 < d_{w2} \\ \quad \left\| \dfrac{4}{5} \cdot e_2 \right. \\ \text{else if } e_2 \geq d_{w2} \\ \quad \left\| d_{w2} - \dfrac{e_2}{5} \right. \\ \text{else if } e_2 \geq 5 \cdot d_{w2} \\ \quad \| 0\ m \end{array} = 5.24\ m$$

Length of zone C

$$C_2 := \begin{array}{|l} \text{if } e_2 < d_{w2} \\ \quad \| d_{w2} - e_2 \\ \text{else if } e_2 \geq d_{w2} \\ \quad \| 0\ m \\ \text{else if } e_2 \geq 5 \cdot d_{w2} \\ \quad \| 0\ m \end{array} = 0.85\ m$$

Figure (7.5)

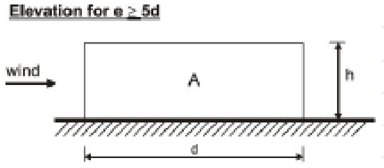

Elevation for e ≥ 5d

Figure (7.5)

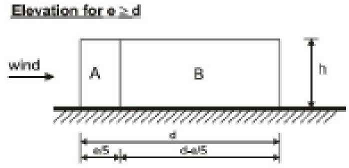
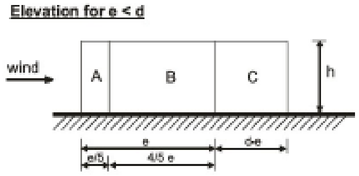

Elevation for e ≥ d

Figure (7.5)


Elevation for e < d

Areas of zones for wind on the wall

Zone A

$A_{area.2} := A_2 \cdot h_{w2}$

$A_{area.2} = 6.412\ m^2$

Zone B

$B_{area.2} := B_2 \cdot h_{w2}$

$B_{area.2} = 25.65\ m^2$

Zone C

$C_{area.2} := C_2 \cdot h_{w2}$

$C_{area.2} = 4.161\ m^2$

Zone D

$D_{area.2} := D_2 \cdot h_{w2}$

$D_{area.2} = 32.062\ m^2$

Zone E

$E_{area.2} := E_2 \cdot h_{w2}$

$E_{area.2} = 32.062\ m^2$

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External pressure coefficients

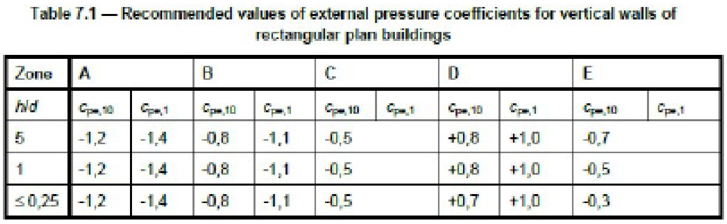

Table 7.1 — Recommended values of external pressure coefficients for vertical walls of rectangular plan buildings

Zone	A		B		C		D		E	
h/d	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,7	
1	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,5	
≤ 0,25	-1,2	-1,4	-0,8	-1,1	-0,5		+0,7	+1,0	-0,3	

For zones with area of less than $10\ m^2$, we use $C_{pe.1}$, for the rest $C_{pe.10}$!!!

$ZoneA_2 := -1.4$ $ZoneB_2 := -0.8$

$ZoneC_2 := -0.5$ $ZoneD_2 := 0.8$

$ZoneE_2 := -0.5$

External pressure values for the zones

$$\begin{bmatrix} C_{peA.2} \\ C_{peB.2} \\ C_{peC.2} \\ C_{peD.2} \\ C_{peE.2} \end{bmatrix} := \begin{bmatrix} ZoneA_2 \\ ZoneB_2 \\ ZoneC_2 \\ ZoneD_2 \\ ZoneE_2 \end{bmatrix} = \begin{bmatrix} -1.4 \\ -0.8 \\ -0.5 \\ 0.8 \\ -0.5 \end{bmatrix}$$

Total pressure coefficient at zone A

$$C_{pA.2} := \left\| \begin{array}{l} \text{if } ZoneA_2 < 0 \\ \quad \| C_{peA.2} - C_{pi1} \\ \text{else} \\ \quad \| C_{peA.2} - C_{pi2} \end{array} \right\| = -1.6$$

Total pressure coefficient at zone B

$$C_{pB.2} := \left\| \begin{array}{l} \text{if } ZoneB_2 < 0 \\ \quad \| C_{peB.2} - C_{pi1} \\ \text{else} \\ \quad \| C_{peB.2} - C_{pi2} \end{array} \right\| = -1$$

Total pressure coefficient at zone C

$$C_{pC.2} := \left\| \begin{array}{l} \text{if } ZoneC_2 < 0 \\ \quad \| C_{peC.2} - C_{pi1} \\ \text{else} \\ \quad \| C_{peC.2} - C_{pi2} \end{array} \right\| = -0.7$$

Total pressure coefficient at zone D

$$C_{pD.2} := \left\| \begin{array}{l} \text{if } ZoneD_2 < 0 \\ \quad \| C_{peD.2} - C_{pi1} \\ \text{else} \\ \quad \| C_{peD.2} - C_{pi2} \end{array} \right\| = 1.1$$

Total pressure coefficient at zone E

$$C_{pE.2} := \left\| \begin{array}{l} \text{if } ZoneE_2 < 0 \\ \quad \| C_{peE.2} - C_{pi1} \\ \text{else} \\ \quad \| C_{peE.2} - C_{pi2} \end{array} \right\| = -0.7$$

Wind pressure for each zone in direction 2 (90°)

$$\begin{bmatrix} W_{A.2} \\ W_{B.2} \\ W_{C.2} \\ W_{D.2} \\ W_{E.2} \end{bmatrix} := \begin{bmatrix} C_{pA.2} \cdot q_p \\ C_{pB.2} \cdot q_p \\ C_{pC.2} \cdot q_p \\ C_{pD.2} \cdot q_p \\ C_{pE.2} \cdot q_p \end{bmatrix} = \begin{bmatrix} -737.775 \\ -461.109 \\ -322.777 \\ 507.22 \\ -322.777 \end{bmatrix} Pa$$

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Wind Calculation on the Roof in Direction 1 (0 °) - Lower Unit

SFS EN 1991-1-1 - 5-7.2.2(p. 24-37)

Wind direction 0 degrees

Direction of Wind $DirecW = 0$

Height of the building $h_{w0} := 4.895\ m$

Wind direction $b_{w0} := 7.4\ m$

Crosswind direction $d_{w0} := 6.91\ m$

Elevation $e_0 := min\left(b_{w0}, 2 \cdot h_{w0}\right) = 7.4\ m$

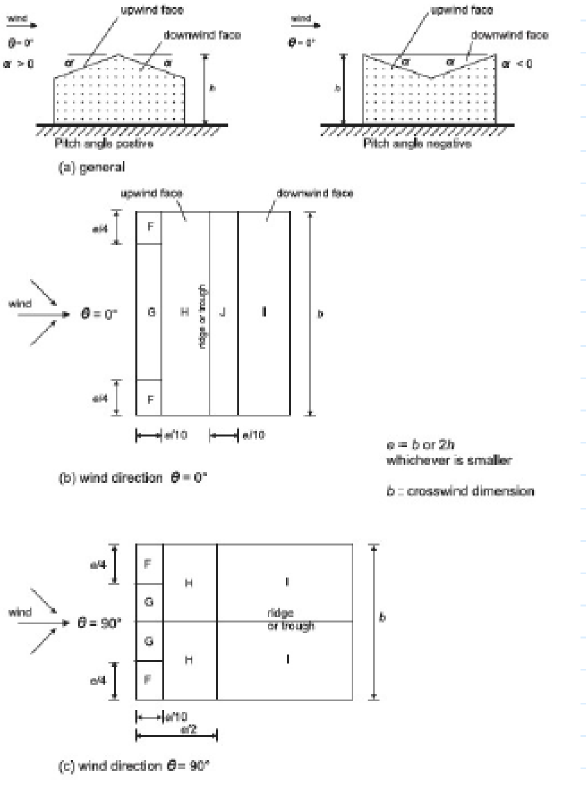

Figure 7.8 — Key for duopitch roofs

Zones for wind direcetion 0 degrees

Zone F length in y-direction $Fy_0 := \frac{e_0}{4} = 1.85\ m$

Zone F length in x-direction $Fx_0 := \frac{e_0}{10} = 0.74\ m$

Zone G length in y-direction $Gy_0 := b_{w0} - 2\left(\frac{e_0}{4}\right) = 3.7\ m$

Zone G length in x-direction $Gx_0 := \frac{e_0}{10} = 0.74\ m$

Zone H length in y-direction $Hy_0 := b_{w0} = 7.4\ m$

Zone H length in x-direction $Hx_0 := \frac{d_{w0}}{2} - \frac{e_0}{10} = 2.715\ m$

Zone J length in y-direction $Jy_0 := b_{w0} = 7.4\ m$

Zone J length in x-direction $Jx_0 := \frac{e_0}{10} = 0.74\ m$

Zone I length in y-direction $Iy_0 := b_{w0} = 7.4\ m$

Zone I length in x-direction $Ix_0 := \frac{d_{w0}}{2} - \frac{e_0}{10} = 2.715\ m$

Area of zones for wind direction 0 degrees

Zone F	Zone G	Zone H	Zone I	Zone J
$A_{F.0} := Fy_0 \cdot Fx_0$	$A_{G.0} := Gy_0 \cdot Gx_0$	$A_{H.0} := Hy_0 \cdot Hx_0$	$A_{I.0} := Iy_0 \cdot Ix_0$	$A_{J.0} := Jy_0 \cdot Jx_0$
$A_{F.0} = 1.369\ m^2$	$A_{G.0} = 2.738\ m^2$	$A_{H.0} = 20.091\ m^2$	$A_{I.0} = 20.091\ m^2$	$A_{J.0} = 5.476\ m^2$

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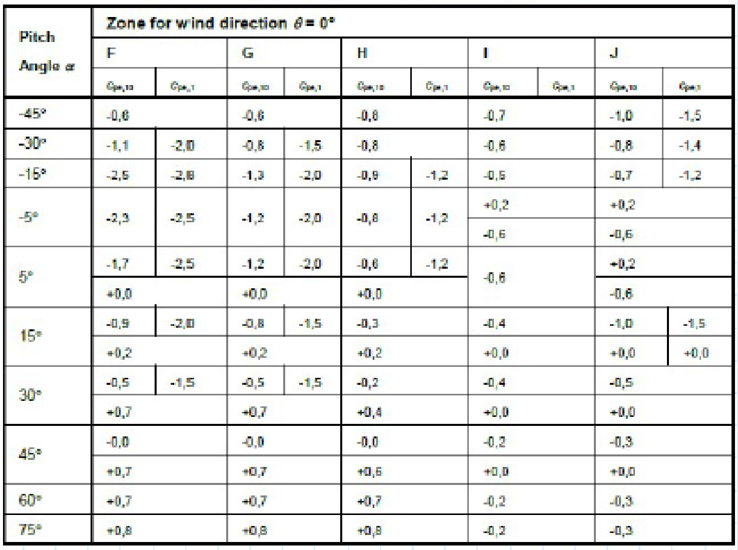
External pressure coefficients

Table 7.4a — External pressure coefficients for duopitch roofs



Pitch Angle α	Zone for wind direction θ = 0°									
	F		G		H		I		J	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
-45°	-0,6		-0,6		-0,8		-0,7		-1,0	-1,5
-30°	-1,1	-2,0	-0,8	-1,5	-0,8		-0,6		-0,8	-1,4
-15°	-2,5	-2,8	-1,3	-2,0	-0,9	-1,2	-0,5		-0,7	-1,2
-5°	-2,3	-2,5	-1,2	-2,0	-0,8	-1,2	+0,2		+0,2	
							-0,6		-0,6	
5°	-1,7	-2,5	-1,2	-2,0	-0,6	-1,2	-0,6		+0,2	
	+0,0		+0,0		+0,0				-0,6	
15°	-0,9	-2,0	-0,8	-1,5	-0,3		-0,4		-1,0	-1,5
	+0,2		+0,2		+0,2		+0,0		+0,0	+0,0
30°	-0,5	-1,5	-0,5	-1,5	-0,2		-0,4		-0,5	
	+0,7		+0,7		+0,4		+0,0		+0,0	
45°	-0,0		-0,0		-0,0		-0,2		-0,3	
	+0,7		+0,7		+0,6		+0,0		+0,0	
60°	+0,7		+0,7		+0,7		-0,2		-0,3	
75°	+0,8		+0,8		+0,8		-0,2		-0,3	

For zones with area of less than $10\ m^2$, we use $C_{pe.1}$, for the rest $C_{pe.10}$!!!

Case A for Zones

$ZoneF_{0.a} := 0.7$

$ZoneG_{0.a} := 0.7$

$ZoneH_{0.a} := 0.4$

$ZoneI_{0.a} := 0$

$ZoneJ_{0.a} := 0$

Case B for Zones

$ZoneF_{0.b} := -1.5$

$ZoneG_{0.b} := -1.5$

$ZoneH_{0.b} := -0.2$

$ZoneI_{0.b} := -0.4$

$ZoneJ_{0.b} := -0.5$

External pressure values for the zones

$$\begin{bmatrix} C_{peF.0.a} \\ C_{peG.0.a} \\ C_{peH.0.a} \\ C_{peI.0.a} \\ C_{peJ.0.a} \end{bmatrix} := \begin{bmatrix} ZoneF_{0.a} \\ ZoneG_{0.a} \\ ZoneH_{0.a} \\ ZoneI_{0.a} \\ ZoneJ_{0.a} \end{bmatrix} = \begin{bmatrix} 0.7 \\ 0.7 \\ 0.4 \\ 0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} C_{peF.0.b} \\ C_{peG.0.b} \\ C_{peH.0.b} \\ C_{peI.0.b} \\ C_{peJ.0.b} \end{bmatrix} := \begin{bmatrix} ZoneF_{0.b} \\ ZoneG_{0.b} \\ ZoneH_{0.b} \\ ZoneI_{0.b} \\ ZoneJ_{0.b} \end{bmatrix} = \begin{bmatrix} -1.5 \\ -1.5 \\ -0.2 \\ -0.4 \\ -0.5 \end{bmatrix}$$

Total pressure coefficient at zone F

$$C_{pF.0.a} := \left\| \begin{array}{l} \text{if } ZoneF_{0.a} < 0 \\ \quad \left\| C_{peF.0.a} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peF.0.a} - C_{pi2} \right. \end{array} \right. = 1$$

$$C_{pF.0.b} := \left\| \begin{array}{l} \text{if } ZoneF_{0.b} < 0 \\ \quad \left\| C_{peF.0.b} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peF.0.b} - C_{pi2} \right. \end{array} \right. = -1.7$$

Total pressure coefficient at zone G

$$C_{pG.0.a} := \left\| \begin{array}{l} \text{if } ZoneG_{0.a} < 0 \\ \quad \left\| C_{peG.0.a} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peG.0.a} - C_{pi2} \right. \end{array} \right. = 1$$

$$C_{pG.0.b} := \left\| \begin{array}{l} \text{if } ZoneG_{0.b} < 0 \\ \quad \left\| C_{peG.0.b} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peG.0.b} - C_{pi2} \right. \end{array} \right. = -1.7$$

Total pressure coefficient at zone H

$$C_{pH.0.a} := \left\| \begin{array}{l} \text{if } ZoneH_{0.a} < 0 \\ \quad \left\| C_{peH.0.a} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peH.0.a} - C_{pi2} \right. \end{array} \right. = 0.7$$

$$C_{pH.0.b} := \left\| \begin{array}{l} \text{if } ZoneH_{0.b} < 0 \\ \quad \left\| C_{peH.0.b} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peH.0.b} - C_{pi2} \right. \end{array} \right. = -0.4$$

Total pressure coefficient at zone I

$$C_{pI.0.a} := \left\| \begin{array}{l} \text{if } ZoneI_{0.a} < 0 \\ \quad \left\| C_{peI.0.a} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peI.0.a} - C_{pi2} \right. \end{array} \right. = 0.3$$

$$C_{pI.0.b} := \left\| \begin{array}{l} \text{if } ZoneI_{0.b} < 0 \\ \quad \left\| C_{peI.0.b} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peI.0.b} - C_{pi2} \right. \end{array} \right. = -0.6$$

Total pressure coefficient at zone J

$$C_{pJ.0.a} := \left\| \begin{array}{l} \text{if } ZoneJ_{0.a} < 0 \\ \quad \left\| C_{peJ.0.a} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peJ.0.a} - C_{pi2} \right. \end{array} \right. = 0.3$$

$$C_{pJ.0.b} := \left\| \begin{array}{l} \text{if } ZoneJ_{0.b} < 0 \\ \quad \left\| C_{peJ.0.b} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peJ.0.b} - C_{pi2} \right. \end{array} \right. = -0.7$$

Wind pressure for each zone in direction 1 (0 °)

$$\begin{bmatrix} W_{F.0.a} \\ W_{G.0.a} \\ W_{H.0.a} \\ W_{I.0.a} \\ W_{J.0.a} \end{bmatrix} := \begin{bmatrix} C_{pF.0.a} \cdot q_p \\ C_{pG.0.a} \cdot q_p \\ C_{pH.0.a} \cdot q_p \\ C_{pI.0.a} \cdot q_p \\ C_{pJ.0.a} \cdot q_p \end{bmatrix} = \begin{bmatrix} 461.109 \\ 461.109 \\ 322.777 \\ 138.333 \\ 138.333 \end{bmatrix} Pa$$

$$\begin{bmatrix} W_{F.0.b} \\ W_{G.0.b} \\ W_{H.0.b} \\ W_{I.0.b} \\ W_{J.0.b} \end{bmatrix} := \begin{bmatrix} C_{pF.0.b} \cdot q_p \\ C_{pG.0.b} \cdot q_p \\ C_{pH.0.b} \cdot q_p \\ C_{pI.0.b} \cdot q_p \\ C_{pJ.0.b} \cdot q_p \end{bmatrix} = \begin{bmatrix} -783.886 \\ -783.886 \\ -184.444 \\ -276.666 \\ -322.777 \end{bmatrix} Pa$$

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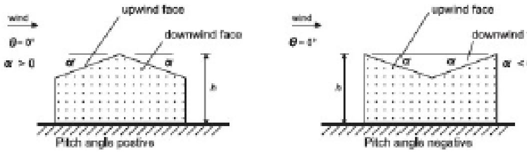
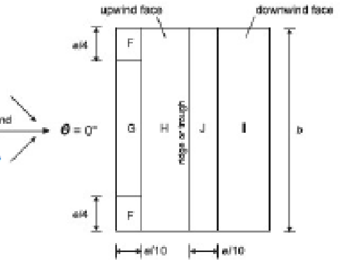
Wind Calculation on the Roof in Direction 2 (90°) - Higher Unit

SFS EN 1991-1-1 - 7.2.5(p.43-46)



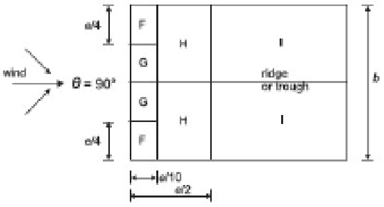
(a) general



(b) wind direction θ = 0°

e = b or 2h
whichever is smaller

b : crosswind dimension



(c) wind direction θ = 90°

Figure 7.8 — Key for duopitch roofs

Wind direction 90 degrees

Direction of Wind $DirecW = 90$

Height of the building $h_{w90} := 4.895\ m$

Wind direction $b_{w90} := 6.91\ m$

Crosswind direction $d_{w90} := 7.4\ m$

Elevation $e_{90} := min\left(b_{w90}, 2 \cdot d_{w90}\right) = 6.91\ m$

Zones for wind direction 90 degrees

Zone F length in y-direction $Fy_{90} := \frac{e_{90}}{4} = 1.728\ m$

Zone F length in x-direction $Fx_{90} := \frac{e_{90}}{10} = 0.691\ m$

Zone G length in y-direction $Gy_{90} := \frac{b_{w90}}{2} - \left(\frac{e_{90}}{4}\right) = 1.728\ m$

Zone G length in x-direction $Gx_{90} := \frac{e_{90}}{10} = 0.691\ m$

Zone H length in y-direction $Hy_{90} := \frac{b_{w90}}{2} = 3.455\ m$

Zone H length in x-direction $Hx_{90} := \frac{e_{90}}{2} - \frac{e_{90}}{10} = 2.764\ m$

Zone I length in y-direction $Iy_{90} := \frac{b_{w90}}{2} = 3.455\ m$

Zone I length in x-direction $Ix_{90} := d_{w90} - \frac{e_{90}}{2} = 3.945\ m$

Area of zones for wind direction 90 degrees

Zone F	Zone G	Zone H	Zone I
$A_{F.90} := Fy_{90} \cdot Fx_{90}$	$A_{G.90} := Gy_{90} \cdot Gx_{90}$	$A_{H.90} := Hy_{90} \cdot Hx_{90}$	$A_{I.90} := Iy_{90} \cdot Ix_{90}$
$A_{F.90} = 1.194\ m^2$	$A_{G.90} = 1.194\ m^2$	$A_{H.90} = 9.55\ m^2$	$A_{I.90} = 13.63\ m^2$

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External pressure coefficients

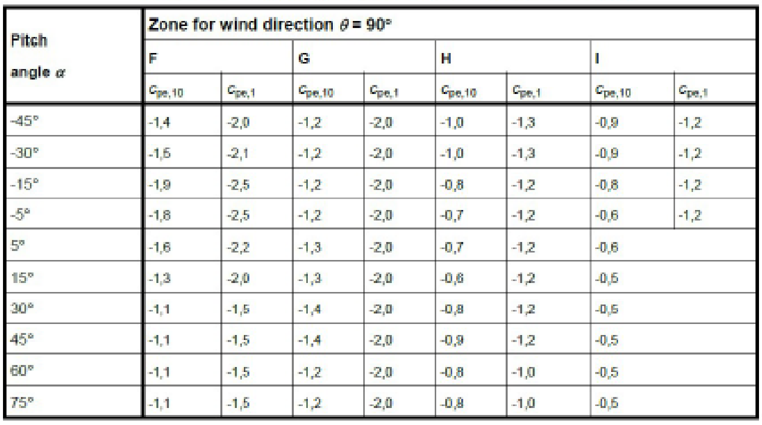

Table 7.4b — External pressure coefficients for duopitch roofs

Pitch angle α	Zone for wind direction θ = 90°							
	F		G		H		I	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
-45°	-1,4	-2,0	-1,2	-2,0	-1,0	-1,3	-0,9	-1,2
-30°	-1,5	-2,1	-1,2	-2,0	-1,0	-1,3	-0,9	-1,2
-15°	-1,9	-2,5	-1,2	-2,0	-0,8	-1,2	-0,8	-1,2
-5°	-1,8	-2,5	-1,2	-2,0	-0,7	-1,2	-0,6	-1,2
5°	-1,6	-2,2	-1,3	-2,0	-0,7	-1,2	-0,6	
15°	-1,3	-2,0	-1,3	-2,0	-0,6	-1,2	-0,5	
30°	-1,1	-1,5	-1,4	-2,0	-0,8	-1,2	-0,5	
45°	-1,1	-1,5	-1,4	-2,0	-0,9	-1,2	-0,5	
60°	-1,1	-1,5	-1,2	-2,0	-0,8	-1,0	-0,5	
75°	-1,1	-1,5	-1,2	-2,0	-0,8	-1,0	-0,5	

$ZoneF_{90} := -1.5$ $ZoneH_{90} := -1.2$

$ZoneG_{90} := -2.0$ $ZoneI_{90} := -0.5$

External pressure values for the zones

$$\begin{bmatrix} C_{peF.90} \\ C_{peG.90} \\ C_{peH.90} \\ C_{peI.90} \end{bmatrix} := \begin{bmatrix} ZoneF_{90} \\ ZoneG_{90} \\ ZoneH_{90} \\ ZoneI_{90} \end{bmatrix} = \begin{bmatrix} -1.5 \\ -2 \\ -1.2 \\ -0.5 \end{bmatrix}$$

For zones with area of less than $10\ m^2$, we use $C_{pe.1}$, for the rest $C_{pe.10}$!!!

Total pressure coefficient at zone F

$$C_{pF.90} := \left\| \begin{array}{l} \text{if } ZoneF_{90} < 0 \\ \quad \left\| C_{peF.90} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peF.90} - C_{pi2} \right. \end{array} \right. = -1.7$$

Total pressure coefficient at zone G

$$C_{pG.90} := \left\| \begin{array}{l} \text{if } ZoneG_{90} < 0 \\ \quad \left\| C_{peG.90} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peG.90} - C_{pi2} \right. \end{array} \right. = -2.2$$

Total pressure coefficient at zone H

$$C_{pH.90} := \left\| \begin{array}{l} \text{if } ZoneH_{90} < 0 \\ \quad \left\| C_{peH.90} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peH.90} - C_{pi2} \right. \end{array} \right. = -1.4$$

Total pressure coefficient at zone I

$$C_{pI.90} := \left\| \begin{array}{l} \text{if } ZoneI_{90} < 0 \\ \quad \left\| C_{peI.90} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peI.90} - C_{pi2} \right. \end{array} \right. = -0.7$$

Wind pressure for each zone in direction 2 (90°)

$$\begin{bmatrix} W_{F.90} \\ W_{G.90} \\ W_{H.90} \\ W_{I.90} \end{bmatrix} := \begin{bmatrix} C_{pF.90} \cdot q_p \\ C_{pG.90} \cdot q_p \\ C_{pH.90} \cdot q_p \\ C_{pI.90} \cdot q_p \end{bmatrix} = \begin{bmatrix} -783.886 \\ -1.014 \cdot 10^3 \\ -645.553 \\ -322.777 \end{bmatrix} Pa$$

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Wind Load - Finland - Higher Unit

Peak Velocity Calculation

SFS EN 1991-1-1 - 4.3-4.5(p. 19-23)

Height of the structure $Z := 5.37\ m$

Roughness length and min. height $\begin{bmatrix} Z_0 \\ Z_{min} \end{bmatrix} :=$ Terrain category: III

Maximum height $Z_{max} := 200\ m$

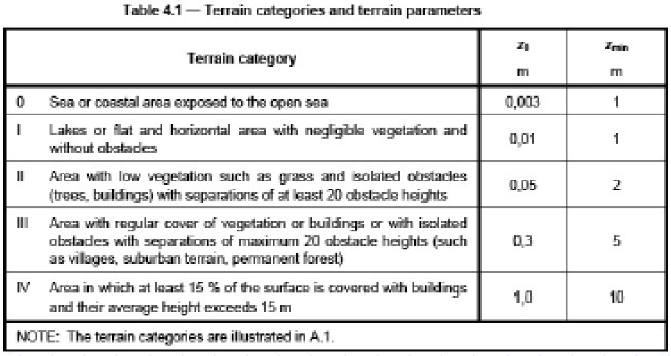
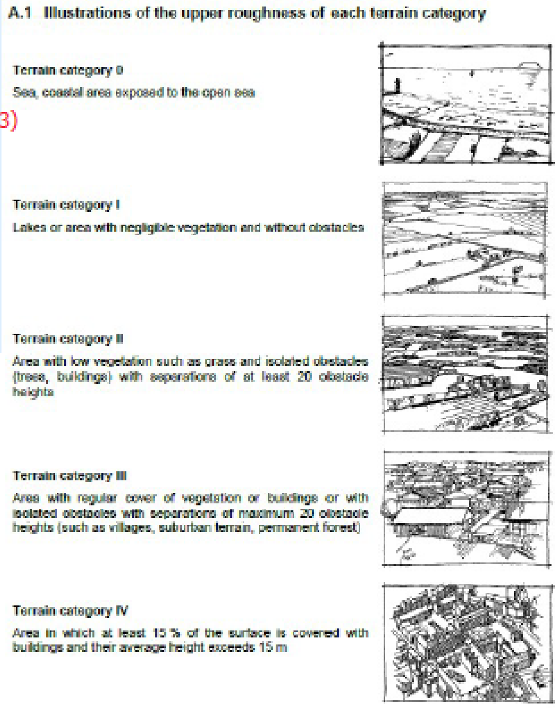


Table 4.1 — Terrain categories and terrain parameters

Terrain category		z_0 m	z_{min} m
0	Sea or coastal area exposed to the open sea	0,003	1
I	Lakes or flat and horizontal area with negligible vegetation and without obstacles	0,01	1
II	Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights	0,05	2
III	Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)	0,3	5
IV	Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m	1,0	10

NOTE: The terrain categories are illustrated in A.1.



A.1 Illustrations of the upper roughness of each terrain category

Terrain category 0
Sea, coastal area exposed to the open sea

Terrain category I
Lakes or area with negligible vegetation and without obstacles

Terrain category II
Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights

Terrain category III
Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)

Terrain category IV
Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m

Terrain factor

$$K_r := \begin{vmatrix} \text{if } Z_0 \le 0.003\ m \\ \quad \| 0.18 \\ \text{else} \\ \quad \left\| 0.19 \cdot \left(\dfrac{Z_0}{0.05\ m} \right)^{0.07} \right. \end{vmatrix} = 0.215$$

Terrain roughness

$$C_r := \begin{vmatrix} \text{if } Z_{min} \le Z \le Z_{max} \\ \quad \left\| K_r \cdot \ln\left(\dfrac{Z}{Z_0} \right) \right. \\ \text{else if } Z \le Z_{min} \\ \quad \left\| K_r \cdot \ln\left(\dfrac{Z_{min}}{Z_0} \right) \right. \end{vmatrix} = 0.621$$

Expression (4.4)

$$c_r(z) = k_r \cdot \ln\left(\frac{z}{z_0}\right) \quad \text{for} \quad z_{min} \le z \le z_{max}$$

$$c_r(z) = c_r(z_{min}) \quad \text{for} \quad z \le z_{min}$$

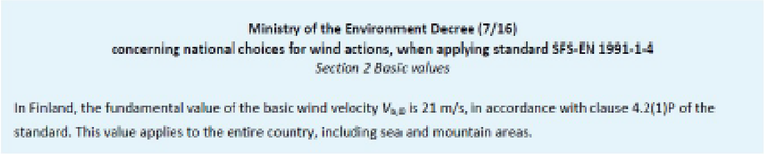
Turbulance factor $K := 1$

Ortography factor $C_o := 1$

Basic wind velocity $v_b := 21\ \dfrac{m}{s}$

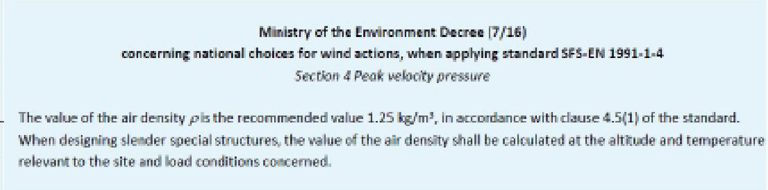
Basic wind pressure $q_b := 276\ Pa$

Air density $\rho := 1.25\ \dfrac{kg}{m^3}$



Ministry of the Environment Decree (7/16)
concerning national choices for wind actions, when applying standard SFS-EN 1991-1-4
Section 2 Basic values

In Finland, the fundamental value of the basic wind velocity $V_{b,0}$ is 21 m/s, in accordance with clause 4.2(1)P of the standard. This value applies to the entire country, including sea and mountain areas.



Ministry of the Environment Decree (7/16)
concerning national choices for wind actions, when applying standard SFS-EN 1991-1-4
Section 4 Peak velocity pressure

The value of the air density ρ is the recommended value 1.25 kg/m³, in accordance with clause 4.5(1) of the standard. When designing slender special structures, the value of the air density shall be calculated at the altitude and temperature relevant to the site and load conditions concerned.

Mean wind velocity $v_m := C_r \cdot C_o \cdot v_b = 13.048\ \dfrac{m}{s}$

$$v_m(z) = c_r(z) \cdot c_o(z) \cdot v_b$$

Expression (4.3)

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Wind turbulence

$$I_v := \begin{cases} \text{if } Z_{min} \le Z \le Z_{max} \\ \quad \dfrac{K}{C_o \cdot \ln\left(\dfrac{Z}{Z_0}\right)} \\ \text{else if } Z \le Z_{min} \\ \quad \dfrac{K}{C_o \cdot \ln\left(\dfrac{Z_{min}}{Z_0}\right)} \end{cases} = 0.347$$

Expression (4.7)

$I_v(z) = \frac{\sigma_v}{v_m(z)} = \frac{k_I}{c_o(z) \cdot \ln(z/z_0)}$ for $z_{min} \le z \le z_{max}$

$I_v(z) = I_v(z_{min})$ for $z < z_{min}$

Peak velocity pressure $q_p := (1 + 7 \cdot I_v) \cdot \frac{1}{2} \cdot \rho \cdot {v_m}^2 = 364.629\ Pa$

External pressure coefficient $Ce := \frac{q_p}{q_b} = 1.32$

Wind Calculation on the Walls in Direction 1 (0 °) - Higher Unit

SFS EN 1991-1-1 - 5-7.2.2(p. 24-37)

Height of the building $h_{w1} := 5.37\ m$

Wall length imposed to wind $b_{w1} := 14\ m$

Wall length parallel to wind $d_{w1} := 8.6\ m$

Elevation $e_1 := min(b_{w1}, 2 \cdot h_{w1}) = 10.74\ m$

Ratio $\frac{h_{w1}}{d_{w1}} = 0.624$

Length of zone D $D_1 := b_{w1} = 14\ m$

Length of zone E $E_1 := b_{w1} = 14\ m$

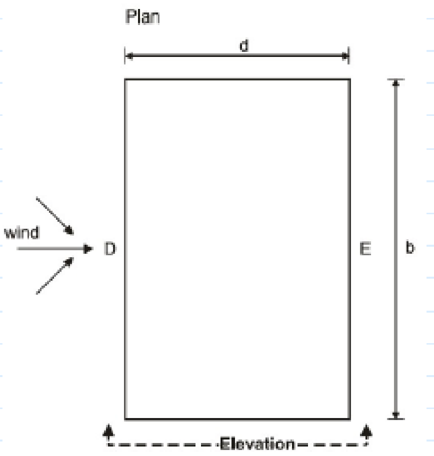


Figure (7.5)

Length of zone A

$$A_1 := \begin{cases} \text{if } e_1 < d_{w1} \\ \quad \dfrac{e_1}{5} \\ \text{else if } e_1 \ge d_{w1} \\ \quad \dfrac{e_1}{5} \\ \text{else if } e_1 \ge 5 \cdot d_{w1} \\ \quad d_{w1} \end{cases} = 2.148\ m$$

Length of zone B

$$B_1 := \begin{cases} \text{if } e_1 < d_{w1} \\ \quad \dfrac{4}{5} \cdot e_1 \\ \text{else if } e_1 \ge d_{w1} \\ \quad d_{w1} - \dfrac{e_1}{5} \\ \text{else if } e_1 \ge 5 \cdot d_{w1} \\ \quad 0\ m \end{cases} = 6.452\ m$$

Length of zone C

$$C_1 := \begin{cases} \text{if } e_1 < d_{w1} \\ \quad d_{w1} - e_1 \\ \text{else if } e_1 \ge d_{w1} \\ \quad 0\ m \\ \text{else if } e_1 \ge 5 \cdot d_{w1} \\ \quad 0\ m \end{cases} = 0\ m$$

Figure (7.5)

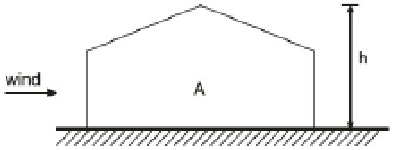


Figure (7.5)

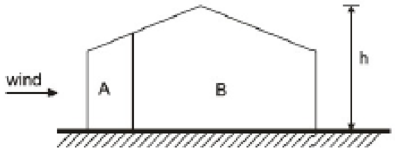
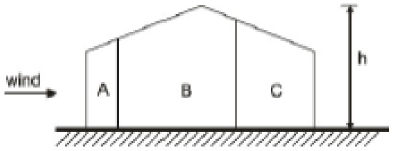


Figure (7.5)



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Areas of zones for wind on the wall

Zone A	**Zone B**	**Zone C**	**Zone D**	**Zone E**
$A_{area.1} := A_1 \cdot h_{w1}$	$B_{area.1} := B_1 \cdot h_{w1}$	$C_{area.1} := C_1 \cdot h_{w1}$	$D_{area.1} := D_1 \cdot h_{w1}$	$E_{area.1} := E_1 \cdot h_{w1}$
$A_{area.1} = 11.535\ m^2$	$B_{area.1} = 34.647\ m^2$	$C_{area.1} = 0\ m^2$	$D_{area.1} = 75.18\ m^2$	$E_{area.1} = 75.18\ m^2$

Internal pressure coefficients

Negative $C_{pi1} := 0.2$

Positive $C_{pi2} := -0.3$

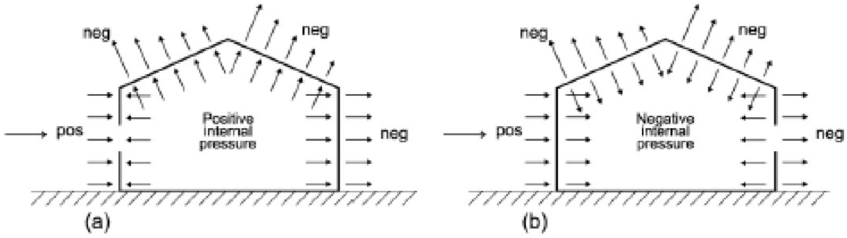

Figure (5.1)

External pressure coefficients

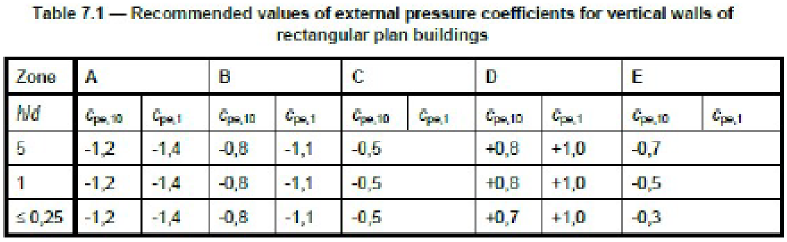

Table 7.1 — Recommended values of external pressure coefficients for vertical walls of rectangular plan buildings

Zone	A		B		C		D		E	
h/d	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,7	
1	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,5	
≤ 0,25	-1,2	-1,4	-0,8	-1,1	-0,5		+0,7	+1,0	-0,3	

For zones with area of less than $10\ m^2$, we use $C_{pe.1}$, for the rest $C_{pe.10}$!!!

$ZoneA_1 := -1.2$ $ZoneB_1 := -0.8$

$ZoneD_1 := 0.8$ $ZoneE_1 := -0.5$

External pressure values for the zones

$$\begin{bmatrix} C_{peA.1} \\ C_{peB.1} \\ C_{peD.1} \\ C_{peE.1} \end{bmatrix} := \begin{bmatrix} ZoneA_1 \\ ZoneB_1 \\ ZoneD_1 \\ ZoneE_1 \end{bmatrix} = \begin{bmatrix} -1.2 \\ -0.8 \\ 0.8 \\ -0.5 \end{bmatrix}$$

Total pressure coefficient at zone A

$$C_{pA.1} := \left\| \begin{array}{l} \text{if } ZoneA_1 < 0 \\ \quad \| C_{peA.1} - C_{pi1} \\ \text{else} \\ \quad \| C_{peA.1} - C_{pi2} \end{array} \right. = -1.4$$

Total pressure coefficient at zone B

$$C_{pB.1} := \left\| \begin{array}{l} \text{if } ZoneB_1 < 0 \\ \quad \| C_{peB.1} - C_{pi1} \\ \text{else} \\ \quad \| C_{peB.1} - C_{pi2} \end{array} \right. = -1$$

Total pressure coefficient at zone D

$$C_{pD.1} := \left\| \begin{array}{l} \text{if } ZoneD_1 < 0 \\ \quad \| C_{peD.1} - C_{pi1} \\ \text{else} \\ \quad \| C_{peD.1} - C_{pi2} \end{array} \right. = 1.1$$

Total pressure coefficient at zone E

$$C_{pE.1} := \left\| \begin{array}{l} \text{if } ZoneE_1 < 0 \\ \quad \| C_{peE.1} - C_{pi1} \\ \text{else} \\ \quad \| C_{peE.1} - C_{pi2} \end{array} \right. = -0.7$$

Wind pressure for each zone in direction 1 (0°)

$$\begin{bmatrix} W_{A.1} \\ W_{B.1} \\ W_{D.1} \\ W_{E.1} \end{bmatrix} := \begin{bmatrix} C_{pA.1} \cdot q_p \\ C_{pB.1} \cdot q_p \\ C_{pD.1} \cdot q_p \\ C_{pE.1} \cdot q_p \end{bmatrix} = \begin{bmatrix} -510.48 \\ -364.629 \\ 401.091 \\ -255.24 \end{bmatrix} Pa$$

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Wind Calculation on the Walls in Direction 2 (90 °) - Higher Unit

SFS EN 1991-1-1 - 5-7.2.2(p. 24-37)

Height of the building $h_{w2} := 5.37\ m$

Wall length imposed to wind $b_{w2} := 8.6\ m$

Wall length parallel to wind $d_{w2} := 14\ m$

Elevation $e_2 := min\left(b_{w2}, 2 \cdot h_{w2}\right) = 8.6\ m$

Ratio $\frac{h_{w2}}{d_{w2}} = 0.384$

Length of zone D $D_2 := b_{w2} = 8.6\ m$

Length of zone E $E_2 := b_{w2} = 8.6\ m$

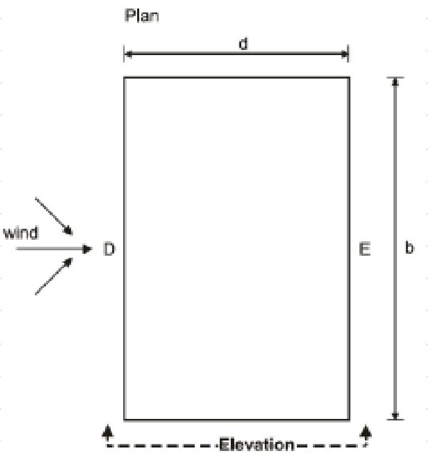


Figure (7.5)

Length of zone A

$$A_2 := \begin{cases} \frac{e_2}{5} & \text{if } e_2 < d_{w2} \\ \frac{e_2}{5} & \text{else if } e_2 \ge d_{w2} \\ d_{w2} & \text{else if } e_2 \ge 5 \cdot d_{w2} \end{cases} = 1.72\ m$$

Length of zone B

$$B_2 := \begin{cases} \frac{4}{5} \cdot e_2 & \text{if } e_2 < d_{w2} \\ d_{w2} - \frac{e_2}{5} & \text{else if } e_2 \ge d_{w2} \\ 0\ m & \text{else if } e_2 \ge 5 \cdot d_{w2} \end{cases} = 6.88\ m$$

Length of zone C

$$C_2 := \begin{cases} d_{w2} - e_2 & \text{if } e_2 < d_{w2} \\ 0\ m & \text{else if } e_2 \ge d_{w2} \\ 0\ m & \text{else if } e_2 \ge 5 \cdot d_{w2} \end{cases} = 5.4\ m$$

Figure (7.5)

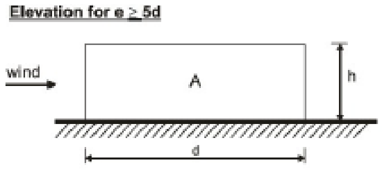


Figure (7.5)

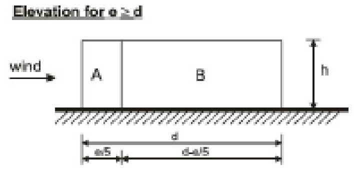
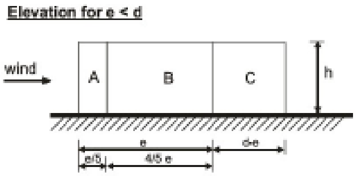


Figure (7.5)



Areas of zones for wind on the wall

Zone A	Zone B	Zone C	Zone D	Zone E
$A_{area.2} := A_2 \cdot h_{w2}$	$B_{area.2} := B_2 \cdot h_{w2}$	$C_{area.2} := C_2 \cdot h_{w2}$	$D_{area.2} := D_2 \cdot h_{w2}$	$E_{area.2} := E_2 \cdot h_{w2}$
$A_{area.2} = 9.236\ m^2$	$B_{area.2} = 36.946\ m^2$	$C_{area.2} = 28.998\ m^2$	$D_{area.2} = 46.182\ m^2$	$E_{area.2} = 46.182\ m^2$

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External pressure coefficients

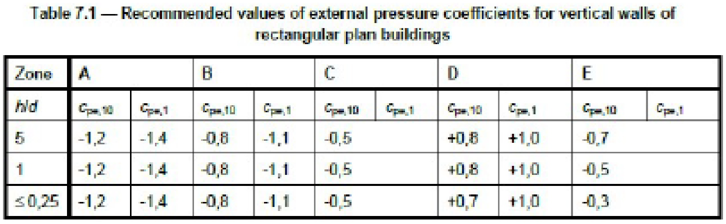


Table 7.1 — Recommended values of external pressure coefficients for vertical walls of rectangular plan buildings

Zone	A		B		C		D		E	
h/d	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,7	
1	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,5	
≤0,25	-1,2	-1,4	-0,8	-1,1	-0,5		+0,7	+1,0	-0,3	

For zones with area of less than $10\ m^2$, we use $C_{pe.1}$, for the rest $C_{pe.10}$!!!

$ZoneA_2 := -1.2$ $\quad ZoneB_2 := -0.8$

$ZoneC_2 := -0.5$ $\quad ZoneD_2 := 0.8$

$ZoneE_2 := -0.5$

External pressure values for the zones

$$\begin{bmatrix} C_{peA.2} \\ C_{peB.2} \\ C_{peC.2} \\ C_{peD.2} \\ C_{peE.2} \end{bmatrix} := \begin{bmatrix} ZoneA_2 \\ ZoneB_2 \\ ZoneC_2 \\ ZoneD_2 \\ ZoneE_2 \end{bmatrix} = \begin{bmatrix} -1.2 \\ -0.8 \\ -0.5 \\ 0.8 \\ -0.5 \end{bmatrix}$$

Total pressure coefficient at zone A

$$C_{pA.2} := \begin{array}{|l} \text{if } ZoneA_2 < 0 \\ \quad \| C_{peA.2} - C_{pi1} \\ \text{else} \\ \quad \| C_{peA.2} - C_{pi2} \end{array} = -1.4$$

Total pressure coefficient at zone B

$$C_{pB.2} := \begin{array}{|l} \text{if } ZoneB_2 < 0 \\ \quad \| C_{peB.2} - C_{pi1} \\ \text{else} \\ \quad \| C_{peB.2} - C_{pi2} \end{array} = -1$$

Total pressure coefficient at zone C

$$C_{pC.2} := \begin{array}{|l} \text{if } ZoneC_2 < 0 \\ \quad \| C_{peC.2} - C_{pi1} \\ \text{else} \\ \quad \| C_{peC.2} - C_{pi2} \end{array} = -0.7$$

Total pressure coefficient at zone D

$$C_{pD.2} := \begin{array}{|l} \text{if } ZoneD_2 < 0 \\ \quad \| C_{peD.2} - C_{pi1} \\ \text{else} \\ \quad \| C_{peD.2} - C_{pi2} \end{array} = 1.1$$

Total pressure coefficient at zone E

$$C_{pE.2} := \begin{array}{|l} \text{if } ZoneE_2 < 0 \\ \quad \| C_{peE.2} - C_{pi1} \\ \text{else} \\ \quad \| C_{peE.2} - C_{pi2} \end{array} = -0.7$$

Wind pressure for each zone in direction 2 (90°)

$$\begin{bmatrix} W_{A.2} \\ W_{B.2} \\ W_{C.2} \\ W_{D.2} \\ W_{E.2} \end{bmatrix} := \begin{bmatrix} C_{pA.2} \cdot q_p \\ C_{pB.2} \cdot q_p \\ C_{pC.2} \cdot q_p \\ C_{pD.2} \cdot q_p \\ C_{pE.2} \cdot q_p \end{bmatrix} = \begin{bmatrix} -510.48 \\ -364.629 \\ -255.24 \\ 401.091 \\ -255.24 \end{bmatrix} Pa$$

Wind Calculation on the Roof in Direction 1 (0 °) - Higher Unit

SFS EN 1991-1-1 - 7.2.5(p.43-46)

Wind direction 0 degrees

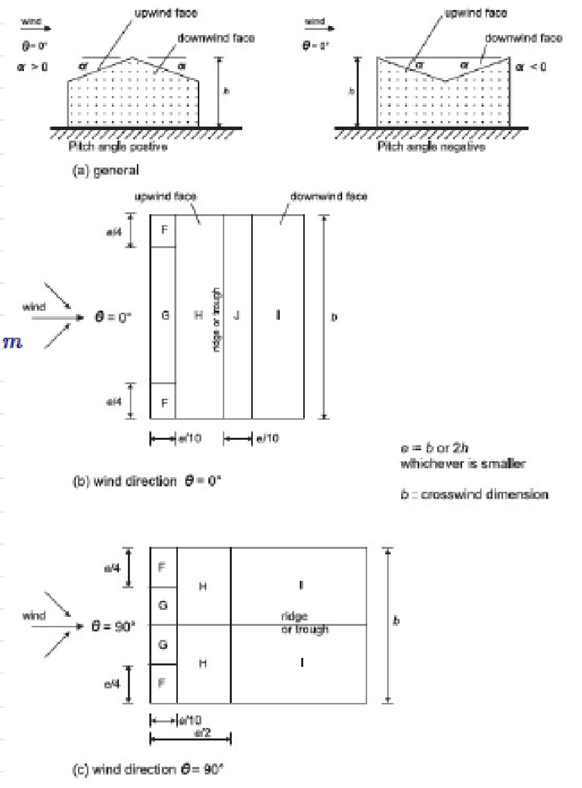


Figure 7.8 — Key for duopitch roofs

Direction of Wind $DirecW = 0$

Height of the building $h_{w0} := 5.37\ m$

Wind direction $b_{w0} := 14.36\ m$

Crosswind direction $d_{w0} := 8.96\ m$

Elevation $e_0 := min\left(b_{w0}, 2 \cdot h_{w0}\right) = 10.74\ m$

Zones for wind direcetion 0 degrees

Zone F length in y-direction $Fy_0 := \frac{e_0}{4} = 2.685\ m$

Zone F length in x-direction $Fx_0 := \frac{e_0}{10} = 1.074\ m$

Zone G length in y-direction $Gy_0 := b_{w0} - 2\left(\frac{e_0}{4}\right) = 8.99\ m$

Zone G length in x-direction $Gx_0 := \frac{e_0}{10} = 1.074\ m$

Zone H length in y-direction $Hy_0 := b_{w0} = 14.36\ m$

Zone H length in x-direction $Hx_0 := \frac{d_{w0}}{2} - \frac{e_0}{10} = 3.406\ m$

Zone J length in y-direction $Jy_0 := b_{w0} = 14.36\ m$

Zone J length in x-direction $Jx_0 := \frac{e_0}{10} = 1.074\ m$

Zone I length in y-direction $Iy_0 := b_{w0} = 14.36\ m$

Zone I length in x-direction $Ix_0 := \frac{d_{w0}}{2} - \frac{e_0}{10} = 3.406\ m$

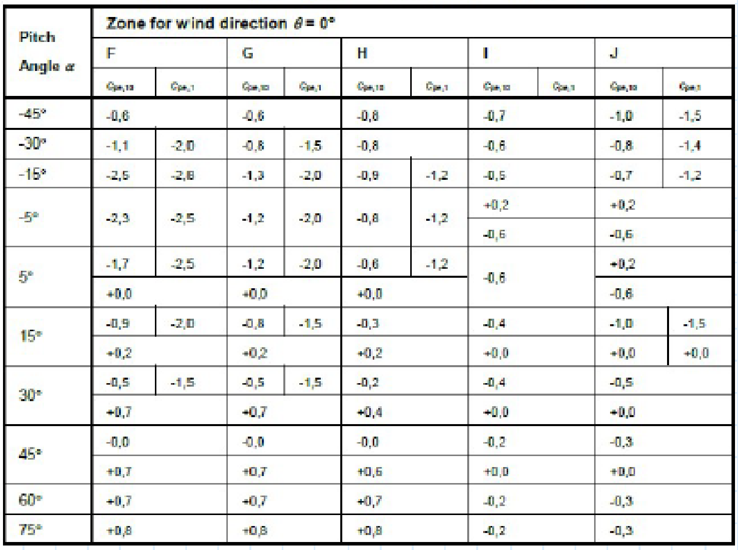
Area of zones for wind direction 0 degrees

Zone F	Zone G	Zone H	Zone I	Zone J
$A_{F.0} := Fy_0 \cdot Fx_0$	$A_{G.0} := Gy_0 \cdot Gx_0$	$A_{H.0} := Hy_0 \cdot Hx_0$	$A_{I.0} := Iy_0 \cdot Ix_0$	$A_{J.0} := Jy_0 \cdot Jx_0$
$A_{F.0} = 2.884\ m^2$	$A_{G.0} = 9.655\ m^2$	$A_{H.0} = 48.91\ m^2$	$A_{I.0} = 48.91\ m^2$	$A_{J.0} = 15.423\ m^2$

Non-Commercial Use Only

External pressure coefficients

Table 7.4a — External pressure coefficients for duopitch roofs



Pitch Angle α	Zone for wind direction θ = 0°									
	F		G		H		I		J	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
-45°	-0,6		-0,6		-0,8		-0,7		-1,0	-1,5
-30°	-1,1	-2,0	-0,8	-1,5	-0,8		-0,6		-0,8	-1,4
-15°	-2,5	-2,8	-1,3	-2,0	-0,9	-1,2	-0,5		-0,7	-1,2
-5°	-2,3	-2,5	-1,2	-2,0	-0,8	-1,2	+0,2		+0,2	
							-0,6		-0,6	
5°	-1,7	-2,5	-1,2	-2,0	-0,6	-1,2	-0,6		+0,2	
	+0,0		+0,0		+0,0				-0,6	
15°	-0,9	-2,0	-0,8	-1,5	-0,3		-0,4		-1,0	-1,5
	+0,2		+0,2		+0,2		+0,0		+0,0	+0,0
30°	-0,5	-1,5	-0,5	-1,5	-0,2		-0,4		-0,5	
	+0,7		+0,7		+0,4		+0,0		+0,0	
45°	-0,0		-0,0		-0,0		-0,2		-0,3	
	+0,7		+0,7		+0,6		+0,0		+0,0	
60°	+0,7		+0,7		+0,7		-0,2		-0,3	
75°	+0,8		+0,8		+0,8		-0,2		-0,3	

For zones with area of less than $10\ m^2$, we use $C_{pe.1}$, for the rest $C_{pe.10}$!!!

Case A for Zones

$ZoneF_{0.a} := 0.7$

$ZoneG_{0.a} := 0.7$

$ZoneH_{0.a} := 0.4$

$ZoneI_{0.a} := 0$

$ZoneJ_{0.a} := 0$

Case B for Zones

$ZoneF_{0.b} := -1.5$

$ZoneG_{0.b} := -1.5$

$ZoneH_{0.b} := -0.2$

$ZoneI_{0.b} := -0.4$

$ZoneJ_{0.b} := -0.5$

External pressure values for the zones

$$\begin{bmatrix} C_{peF.0.a} \\ C_{peG.0.a} \\ C_{peH.0.a} \\ C_{peI.0.a} \\ C_{peJ.0.a} \end{bmatrix} := \begin{bmatrix} ZoneF_{0.a} \\ ZoneG_{0.a} \\ ZoneH_{0.a} \\ ZoneI_{0.a} \\ ZoneJ_{0.a} \end{bmatrix} = \begin{bmatrix} 0.7 \\ 0.7 \\ 0.4 \\ 0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} C_{peF.0.b} \\ C_{peG.0.b} \\ C_{peH.0.b} \\ C_{peI.0.b} \\ C_{peJ.0.b} \end{bmatrix} := \begin{bmatrix} ZoneF_{0.b} \\ ZoneG_{0.b} \\ ZoneH_{0.b} \\ ZoneI_{0.b} \\ ZoneJ_{0.b} \end{bmatrix} = \begin{bmatrix} -1.5 \\ -1.5 \\ -0.2 \\ -0.4 \\ -0.5 \end{bmatrix}$$

Total pressure coefficient at zone F

$$C_{pF.0.a} := \left\| \begin{array}{l} \text{if } ZoneF_{0.a} < 0 \\ \quad \| C_{peF.0.a} - C_{pi1} \\ \text{else} \\ \quad \| C_{peF.0.a} - C_{pi2} \end{array} \right. = 1$$

$$C_{pF.0.b} := \left\| \begin{array}{l} \text{if } ZoneF_{0.b} < 0 \\ \quad \| C_{peF.0.b} - C_{pi1} \\ \text{else} \\ \quad \| C_{peF.0.b} - C_{pi2} \end{array} \right. = -1.7$$

Total pressure coefficient at zone G

$$C_{pG.0.a} := \left\| \begin{array}{l} \text{if } ZoneG_{0.a} < 0 \\ \quad \| C_{peG.0.a} - C_{pi1} \\ \text{else} \\ \quad \| C_{peG.0.a} - C_{pi2} \end{array} \right. = 1$$

$$C_{pG.0.b} := \left\| \begin{array}{l} \text{if } ZoneG_{0.b} < 0 \\ \quad \| C_{peG.0.b} - C_{pi1} \\ \text{else} \\ \quad \| C_{peG.0.b} - C_{pi2} \end{array} \right. = -1.7$$

Total pressure coefficient at zone H

$$C_{pH.0.a} := \left\| \begin{array}{l} \text{if } ZoneH_{0.a} < 0 \\ \quad \| C_{peH.0.a} - C_{pi1} \\ \text{else} \\ \quad \| C_{peH.0.a} - C_{pi2} \end{array} \right. = 0.7$$

$$C_{pH.0.b} := \left\| \begin{array}{l} \text{if } ZoneH_{0.b} < 0 \\ \quad \| C_{peH.0.b} - C_{pi1} \\ \text{else} \\ \quad \| C_{peH.0.b} - C_{pi2} \end{array} \right. = -0.4$$

Total pressure coefficient at zone I

$$C_{pI.0.a} := \left\| \begin{array}{l} \text{if } ZoneI_{0.a} < 0 \\ \quad \| C_{peI.0.a} - C_{pi1} \\ \text{else} \\ \quad \| C_{peI.0.a} - C_{pi2} \end{array} \right. = 0.3$$

$$C_{pI.0.b} := \left\| \begin{array}{l} \text{if } ZoneI_{0.b} < 0 \\ \quad \| C_{peI.0.b} - C_{pi1} \\ \text{else} \\ \quad \| C_{peI.0.b} - C_{pi2} \end{array} \right. = -0.6$$

Total pressure coefficient at zone J

$$C_{pJ.0.a} := \left\| \begin{array}{l} \text{if } ZoneJ_{0.a} < 0 \\ \quad \| C_{peJ.0.a} - C_{pi1} \\ \text{else} \\ \quad \| C_{peJ.0.a} - C_{pi2} \end{array} \right. = 0.3$$

$$C_{pJ.0.b} := \left\| \begin{array}{l} \text{if } ZoneJ_{0.b} < 0 \\ \quad \| C_{peJ.0.b} - C_{pi1} \\ \text{else} \\ \quad \| C_{peJ.0.b} - C_{pi2} \end{array} \right. = -0.7$$

Wind pressure for each zone in direction 1 (0 °)

$$\begin{bmatrix} W_{F.0.a} \\ W_{G.0.a} \\ W_{H.0.a} \\ W_{I.0.a} \\ W_{J.0.a} \end{bmatrix} := \begin{bmatrix} C_{pF.0.a} \cdot q_p \\ C_{pG.0.a} \cdot q_p \\ C_{pH.0.a} \cdot q_p \\ C_{pI.0.a} \cdot q_p \\ C_{pJ.0.a} \cdot q_p \end{bmatrix} = \begin{bmatrix} 364.629 \\ 364.629 \\ 255.24 \\ 109.389 \\ 109.389 \end{bmatrix} Pa$$

$$\begin{bmatrix} W_{F.0.b} \\ W_{G.0.b} \\ W_{H.0.b} \\ W_{I.0.b} \\ W_{J.0.b} \end{bmatrix} := \begin{bmatrix} C_{pF.0.b} \cdot q_p \\ C_{pG.0.b} \cdot q_p \\ C_{pH.0.b} \cdot q_p \\ C_{pI.0.b} \cdot q_p \\ C_{pJ.0.b} \cdot q_p \end{bmatrix} = \begin{bmatrix} -619.869 \\ -619.869 \\ -145.851 \\ -218.777 \\ -255.24 \end{bmatrix} Pa$$

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Wind Calculation on the Roof in Direction 2 (90 °) - Higher Unit

SFS EN 1991-1-1 - 7.2.5(p.43-46)

Wind direction 90 degrees

Direction of Wind $DirecW = 90$

Height of the building $h_{w90} := 5.37\ m$

Wind direction $b_{w90} := 8.96\ m$

Crosswind direction $d_{w90} := 14.36\ m$

Elevation $e_{90} := min\left(b_{w90}, 2 \cdot d_{w90}\right) = 8.96\ m$

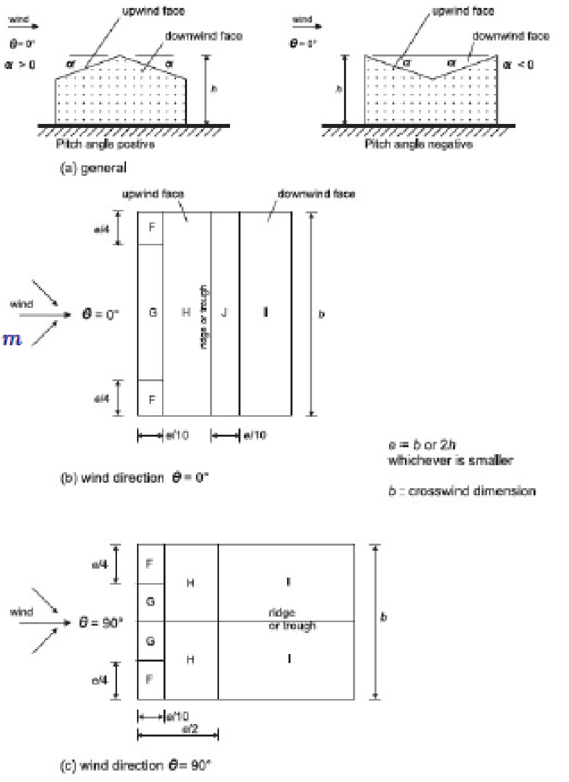

Figure 7.8 — Key for duopitch roofs

Zones for wind direction 90 degrees

Zone F length in y-direction $Fy_{90} := \frac{e_{90}}{4} = 2.24\ m$

Zone F length in x-direction $Fx_{90} := \frac{e_{90}}{10} = 0.896\ m$

Zone G length in y-direction $Gy_{90} := \frac{b_{w90}}{2} - \left(\frac{e_{90}}{4}\right) = 2.24\ m$

Zone G length in x-direction $Gx_{90} := \frac{e_{90}}{10} = 0.896\ m$

Zone H length in y-direction $Hy_{90} := \frac{b_{w90}}{2} = 4.48\ m$

Zone H length in x-direction $Hx_{90} := \frac{e_{90}}{2} - \frac{e_{90}}{10} = 3.584\ m$

Zone I length in y-direction $Iy_{90} := \frac{b_{w90}}{2} = 4.48\ m$

Zone I length in x-direction $Ix_{90} := d_{w90} - \frac{e_{90}}{2} = 9.88\ m$

Area of zones for wind direction 90 degrees

Zone F	Zone G	Zone H	Zone I
$A_{F.90} := Fy_{90} \cdot Fx_{90}$	$A_{G.90} := Gy_{90} \cdot Gx_{90}$	$A_{H.90} := Hy_{90} \cdot Hx_{90}$	$A_{I.90} := Iy_{90} \cdot Ix_{90}$
$A_{F.90} = 2.007\ m^2$	$A_{G.90} = 2.007\ m^2$	$A_{H.90} = 16.056\ m^2$	$A_{I.90} = 44.262\ m^2$

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External pressure coefficients

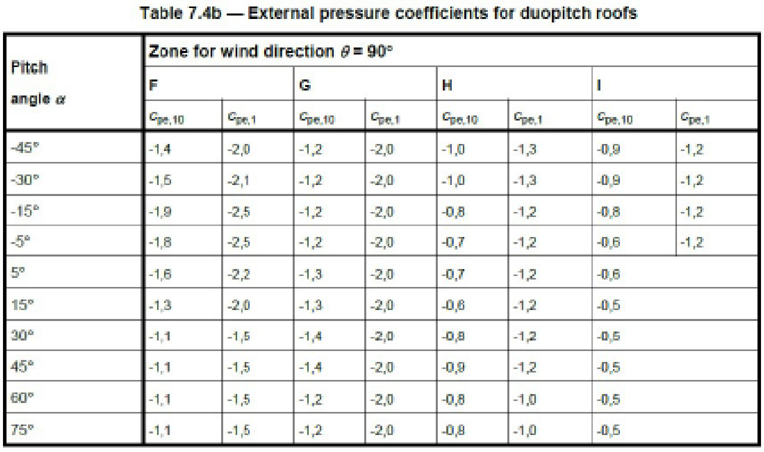

Table 7.4b — External pressure coefficients for duopitch roofs

Pitch angle α	Zone for wind direction $\theta = 90°$							
	F		G		H		I	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
-45°	-1,4	-2,0	-1,2	-2,0	-1,0	-1,3	-0,9	-1,2
-30°	-1,5	-2,1	-1,2	-2,0	-1,0	-1,3	-0,9	-1,2
-15°	-1,9	-2,5	-1,2	-2,0	-0,8	-1,2	-0,8	-1,2
-5°	-1,8	-2,5	-1,2	-2,0	-0,7	-1,2	-0,6	-1,2
5°	-1,6	-2,2	-1,3	-2,0	-0,7	-1,2	-0,6	
15°	-1,3	-2,0	-1,3	-2,0	-0,6	-1,2	-0,5	
30°	-1,1	-1,5	-1,4	-2,0	-0,8	-1,2	-0,5	
45°	-1,1	-1,5	-1,4	-2,0	-0,9	-1,2	-0,5	
60°	-1,1	-1,5	-1,2	-2,0	-0,8	-1,0	-0,5	
75°	-1,1	-1,5	-1,2	-2,0	-0,8	-1,0	-0,5	

$ZoneF_{90} := -1.5$ $\quad ZoneH_{90} := -0.8$

$ZoneG_{90} := -1.2$ $\quad ZoneI_{90} := -0.5$

External pressure values for the zones

$$\begin{bmatrix} C_{peF.90} \\ C_{peG.90} \\ C_{peH.90} \\ C_{peI.90} \end{bmatrix} := \begin{bmatrix} ZoneF_{90} \\ ZoneG_{90} \\ ZoneH_{90} \\ ZoneI_{90} \end{bmatrix} = \begin{bmatrix} -1.5 \\ -1.2 \\ -0.8 \\ -0.5 \end{bmatrix}$$

For zones with area of less than $10\ m^2$, we use $C_{pe.1}$, for the rest $C_{pe.10}$!!!

Total pressure coefficient at zone F

$$C_{pF.90} := \begin{array}{|l} \text{if } ZoneF_{90} < 0 \\ \quad \| C_{peF.90} - C_{pi1} \\ \text{else} \\ \quad \| C_{peF.90} - C_{pi2} \end{array} = -1.7$$

Total pressure coefficient at zone G

$$C_{pG.90} := \begin{array}{|l} \text{if } ZoneG_{90} < 0 \\ \quad \| C_{peG.90} - C_{pi1} \\ \text{else} \\ \quad \| C_{peG.90} - C_{pi2} \end{array} = -1.4$$

Total pressure coefficient at zone H

$$C_{pH.90} := \begin{array}{|l} \text{if } ZoneH_{90} < 0 \\ \quad \| C_{peH.90} - C_{pi1} \\ \text{else} \\ \quad \| C_{peH.90} - C_{pi2} \end{array} = -1$$

Total pressure coefficient at zone I

$$C_{pI.90} := \begin{array}{|l} \text{if } ZoneI_{90} < 0 \\ \quad \| C_{peI.90} - C_{pi1} \\ \text{else} \\ \quad \| C_{peI.90} - C_{pi2} \end{array} = -0.7$$

Wind pressure for each zone in direction 2 (90°)

$$\begin{bmatrix} W_{F.90} \\ W_{G.90} \\ W_{H.90} \\ W_{I.90} \end{bmatrix} := \begin{bmatrix} C_{pF.90} \cdot q_p \\ C_{pG.90} \cdot q_p \\ C_{pH.90} \cdot q_p \\ C_{pI.90} \cdot q_p \end{bmatrix} = \begin{bmatrix} -619.869 \\ -510.48 \\ -364.629 \\ -255.24 \end{bmatrix} Pa$$

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Wind Load - Finland - Lower Unit

Peak Velocity Calculation

SFS EN 1991-1-1 - 4.3-4.5(p. 19-23)

Height of the structure $Z := 4.895\ m$

Roughness length and min. height $\begin{bmatrix} Z_0 \\ Z_{min} \end{bmatrix} :=$ Terrain category: III

Maximum height $Z_{max} := 200\ m$

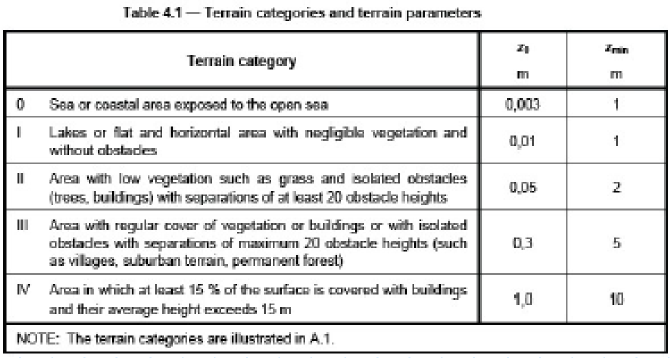
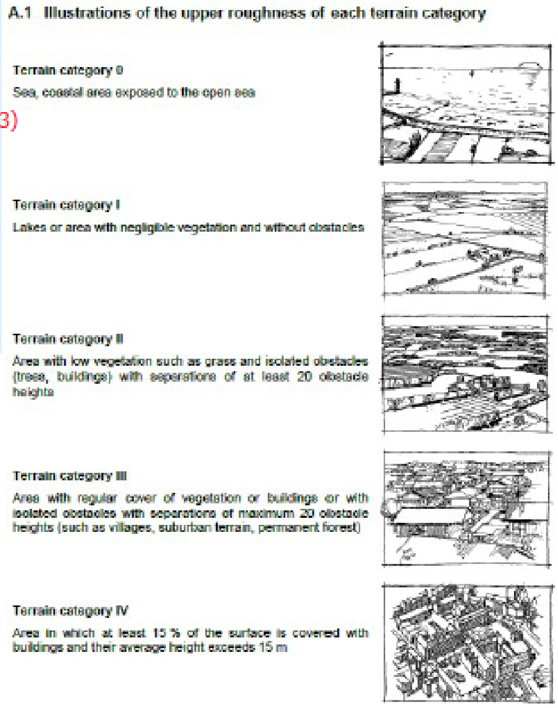


Table 4.1 — Terrain categories and terrain parameters

Terrain category		z_0 m	z_{min} m
0	Sea or coastal area exposed to the open sea	0,003	1
I	Lakes or flat and horizontal area with negligible vegetation and without obstacles	0,01	1
II	Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights	0,05	2
III	Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)	0,3	5
IV	Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m	1,0	10

NOTE: The terrain categories are illustrated in A.1.



A.1 Illustrations of the upper roughness of each terrain category

Terrain category 0

Sea, coastal area exposed to the open sea

Terrain category I

Lakes or area with negligible vegetation and without obstacles

Terrain category II

Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights

Terrain category III

Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)

Terrain category IV

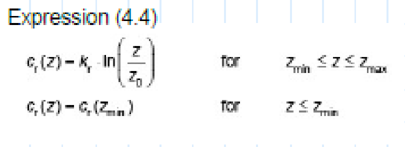
Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m

Terrain factor

$$K_r := \left\| \begin{array}{l} \text{if } Z_0 \le 0.003\ m \\ \quad \| \ 0.18 \\ \text{else} \\ \quad \| \ 0.19 \cdot \left(\dfrac{Z_0}{0.05\ m}\right)^{0.07} \end{array} \right\| = 0.215$$

Terrain roughness

$$C_r := \left\| \begin{array}{l} \text{if } Z_{min} \le Z \le Z_{max} \\ \quad \| \ K_r \cdot \ln\left(\dfrac{Z}{Z_0}\right) \\ \text{else if } Z \le Z_{min} \\ \quad \| \ K_r \cdot \ln\left(\dfrac{Z_{min}}{Z_0}\right) \end{array} \right\| = 0.606$$



Expression (4.4)

$$c_r(z) = k_r \cdot \ln\left(\frac{z}{z_0}\right) \quad \text{for} \quad z_{min} \le z \le z_{max}$$

$$c_r(z) = c_r(z_{min}) \quad \text{for} \quad z \le z_{min}$$

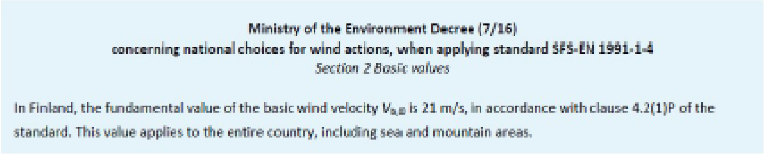
Turbulance factor $K := 1$

Ortography factor $C_o := 1$

Basic wind velocity $v_b := 21\ \dfrac{m}{s}$

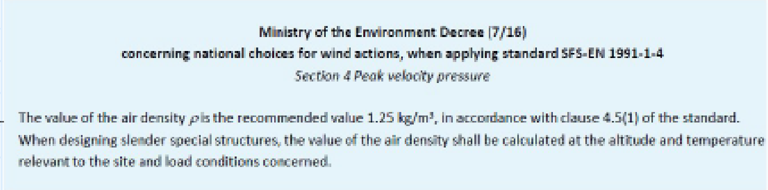
Basic wind pressure $q_b := 276\ Pa$

Air density $\rho := 1.25\ \dfrac{kg}{m^3}$



Ministry of the Environment Decree (7/16)
concerning national choices for wind actions, when applying standard SFS-EN 1991-1-4
Section 2 Basic values

In Finland, the fundamental value of the basic wind velocity $V_{b,0}$ is 21 m/s, in accordance with clause 4.2(1)P of the standard. This value applies to the entire country, including sea and mountain areas.



Ministry of the Environment Decree (7/16)
concerning national choices for wind actions, when applying standard SFS-EN 1991-1-4
Section 4 Peak velocity pressure

The value of the air density ρ is the recommended value 1.25 kg/m³, in accordance with clause 4.5(1) of the standard. When designing slender special structures, the value of the air density shall be calculated at the altitude and temperature relevant to the site and load conditions concerned.

Mean wind velocity $v_m := C_r \cdot C_o \cdot v_b = 12.726\ \dfrac{m}{s}$

$$v_m(z) = c_r(z) \cdot c_o(z) \cdot v_b$$ Expression (4.3)

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Wind turbulence

$$I_v := \begin{array}{|l} \text{if } Z_{min} \le Z \le Z_{max} \\ \quad \left\| \dfrac{K}{C_o \cdot \ln\left(\dfrac{Z}{Z_0}\right)} \right. \\ \text{else if } Z \le Z_{min} \\ \quad \left\| \dfrac{K}{C_o \cdot \ln\left(\dfrac{Z_{min}}{Z_0}\right)} \right. \end{array} = 0.355$$

Expression (4.7)

$$I_v(z) = \frac{\sigma_v}{v_m(z)} = \frac{k_l}{c_o(z) \cdot \ln(z/z_0)} \quad \text{for} \quad z_{min} \le z \le z_{max}$$

$$I_v(z) = I_v(z_{min}) \quad \text{for} \quad z < z_{min}$$

Peak velocity pressure

$$q_p := \left(1 + 7 \cdot I_v\right) \cdot \frac{1}{2} \cdot \rho \cdot {v_m}^2 = 353.037\ Pa$$

External pressure coefficient

$$Ce := \frac{q_p}{q_b} = 1.28$$

Wind Calculation on the Walls in Direction 1 (0 °) - Lower Unit

SFS EN 1991-1-1 - 5-7.2.2(p. 24-37)

Height of the building $h_{w1} := 4.895\ m$

Wall length imposed to wind $b_{w1} := 7.4\ m$

Wall length parallel to wind $d_{w1} := 6.55\ m$

Elevation $e_1 := min\left(b_{w1}, 2 \cdot h_{w1}\right) = 7.4\ m$

Ratio $\dfrac{h_{w1}}{d_{w1}} = 0.747$

Length of zone D $D_1 := b_{w1} = 7.4\ m$

Length of zone E $E_1 := b_{w1} = 7.4\ m$

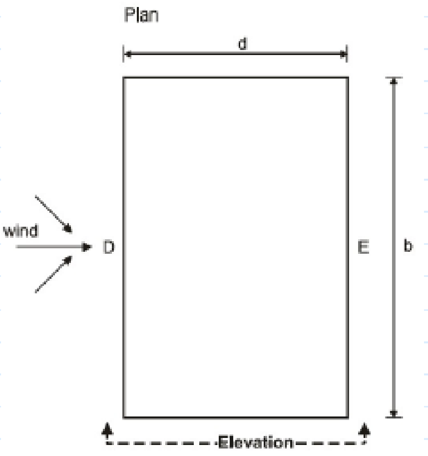


Figure (7.5)

Length of zone A

$$A_1 := \begin{array}{|l} \text{if } e_1 < d_{w1} \\ \quad \left\| \dfrac{e_1}{5} \right. \\ \text{else if } e_1 \ge d_{w1} \\ \quad \left\| \dfrac{e_1}{5} \right. \\ \text{else if } e_1 \ge 5 \cdot d_{w1} \\ \quad \| d_{w1} \end{array} = 1.48\ m$$

Length of zone B

$$B_1 := \begin{array}{|l} \text{if } e_1 < d_{w1} \\ \quad \left\| \dfrac{4}{5} \cdot e_1 \right. \\ \text{else if } e_1 \ge d_{w1} \\ \quad \left\| d_{w1} - \dfrac{e_1}{5} \right. \\ \text{else if } e_1 \ge 5 \cdot d_{w1} \\ \quad \| 0\ m \end{array} = 5.07\ m$$

Length of zone C

$$C_1 := \begin{array}{|l} \text{if } e_1 < d_{w1} \\ \quad \| d_{w1} - e_1 \\ \text{else if } e_1 \ge d_{w1} \\ \quad \| 0\ m \\ \text{else if } e_1 \ge 5 \cdot d_{w1} \\ \quad \| 0\ m \end{array} = 0\ m$$

Figure (7.5)

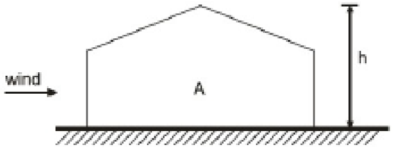


Figure (7.5)

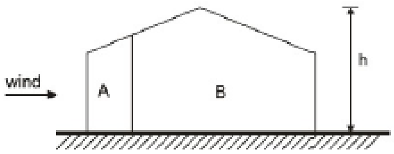
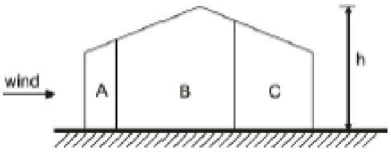


Figure (7.5)



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Areas of zones for wind on the wall

Zone A	**Zone B**	**Zone C**	**Zone D**	**Zone E**
$A_{area.1} := A_1 \cdot h_{w1}$	$B_{area.1} := B_1 \cdot h_{w1}$	$C_{area.1} := C_1 \cdot h_{w1}$	$D_{area.1} := D_1 \cdot h_{w1}$	$E_{area.1} := E_1 \cdot h_{w1}$
$A_{area.1} = 7.245\ m^2$	$B_{area.1} = 24.818\ m^2$	$C_{area.1} = 0\ m^2$	$D_{area.1} = 36.223\ m^2$	$E_{area.1} = 36.223\ m^2$

Internal pressure coefficients

Negative $C_{pi1} := 0.2$

Positive $C_{pi2} := -0.3$

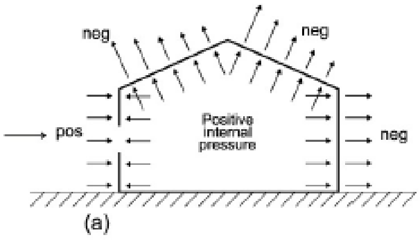

Figure (5.1)

External pressure coefficients

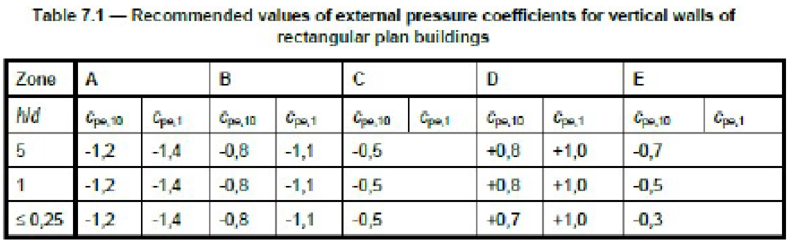

Table 7.1 — Recommended values of external pressure coefficients for vertical walls of rectangular plan buildings

Zone	A		B		C		D		E	
h/d	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,7	
1	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,5	
≤ 0,25	-1,2	-1,4	-0,8	-1,1	-0,5		+0,7	+1,0	-0,3	

For zones with area of less than $10\ m^2$, we use $C_{pe.1}$, for the rest $C_{pe.10}$!!!

$ZoneA_1 := -1.4$ $ZoneB_1 := -0.8$

$ZoneD_1 := 0.8$ $ZoneE_1 := -0.5$

External pressure values for the zones

$$\begin{bmatrix} C_{peA.1} \\ C_{peB.1} \\ C_{peD.1} \\ C_{peE.1} \end{bmatrix} := \begin{bmatrix} ZoneA_1 \\ ZoneB_1 \\ ZoneD_1 \\ ZoneE_1 \end{bmatrix} = \begin{bmatrix} -1.4 \\ -0.8 \\ 0.8 \\ -0.5 \end{bmatrix}$$

Total pressure coefficient at zone A

$$C_{pA.1} := \left\| \begin{array}{l} \text{if } ZoneA_1 < 0 \\ \quad \| C_{peA.1} - C_{pi1} \\ \text{else} \\ \quad \| C_{peA.1} - C_{pi2} \end{array} \right. = -1.6$$

Total pressure coefficient at zone B

$$C_{pB.1} := \left\| \begin{array}{l} \text{if } ZoneB_1 < 0 \\ \quad \| C_{peB.1} - C_{pi1} \\ \text{else} \\ \quad \| C_{peB.1} - C_{pi2} \end{array} \right. = -1$$

Total pressure coefficient at zone D

$$C_{pD.1} := \left\| \begin{array}{l} \text{if } ZoneD_1 < 0 \\ \quad \| C_{peD.1} - C_{pi1} \\ \text{else} \\ \quad \| C_{peD.1} - C_{pi2} \end{array} \right. = 1.1$$

Total pressure coefficient at zone E

$$C_{pE.1} := \left\| \begin{array}{l} \text{if } ZoneE_1 < 0 \\ \quad \| C_{peE.1} - C_{pi1} \\ \text{else} \\ \quad \| C_{peE.1} - C_{pi2} \end{array} \right. = -0.7$$

Wind pressure for each zone in direction 1 (0°)

$$\begin{bmatrix} W_{A.1} \\ W_{B.1} \\ W_{D.1} \\ W_{E.1} \end{bmatrix} := \begin{bmatrix} C_{pA.1} \cdot q_p \\ C_{pB.1} \cdot q_p \\ C_{pD.1} \cdot q_p \\ C_{pE.1} \cdot q_p \end{bmatrix} = \begin{bmatrix} -564.859 \\ -353.037 \\ 388.341 \\ -247.126 \end{bmatrix} Pa$$

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Wind Calculation on the Walls in Direction 2 (90°) - Lower Unit

SFS EN 1991-1-1 - 5-7.2.2(p. 24-37)

Height of the building $h_{w2} := 4.895\ m$

Wall length imposed to wind $b_{w2} := 6.55\ m$

Wall length parallel to wind $d_{w2} := 7.4\ m$

Elevation $e_2 := min\left(b_{w2}, 2 \cdot h_{w2}\right) = 6.55\ m$

Ratio $\frac{h_{w2}}{d_{w2}} = 0.661$

Length of zone D $D_2 := b_{w2} = 6.55\ m$

Length of zone E $E_2 := b_{w2} = 6.55\ m$

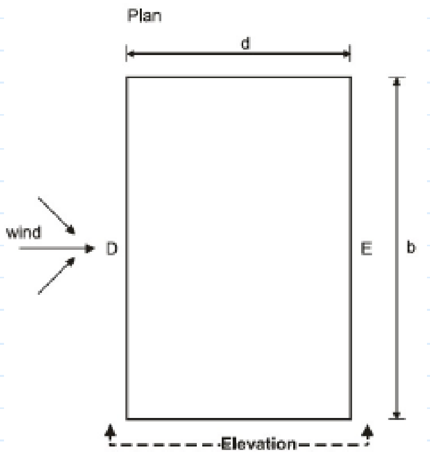


Figure (7.5)

Length of zone A

$$A_2 := \left| \begin{array}{l} \text{if } e_2 < d_{w2} \\ \quad \left\| \frac{e_2}{5} \right. \\ \text{else if } e_2 \geq d_{w2} \\ \quad \left\| \frac{e_2}{5} \right. \\ \text{else if } e_2 \geq 5 \cdot d_{w2} \\ \quad \left\| d_{w2} \right. \end{array} \right. = 1.31\ m$$

Length of zone B

$$B_2 := \left| \begin{array}{l} \text{if } e_2 < d_{w2} \\ \quad \left\| \frac{4}{5} \cdot e_2 \right. \\ \text{else if } e_2 \geq d_{w2} \\ \quad \left\| d_{w2} - \frac{e_2}{5} \right. \\ \text{else if } e_2 \geq 5 \cdot d_{w2} \\ \quad \left\| 0\ m \right. \end{array} \right. = 5.24\ m$$

Length of zone C

$$C_2 := \left| \begin{array}{l} \text{if } e_2 < d_{w2} \\ \quad \left\| d_{w2} - e_2 \right. \\ \text{else if } e_2 \geq d_{w2} \\ \quad \left\| 0\ m \right. \\ \text{else if } e_2 \geq 5 \cdot d_{w2} \\ \quad \left\| 0\ m \right. \end{array} \right. = 0.85\ m$$

Figure (7.5)

Elevation for e ≥ 5d

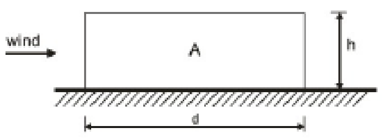


Figure (7.5)

Elevation for e ≥ d

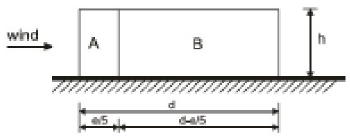
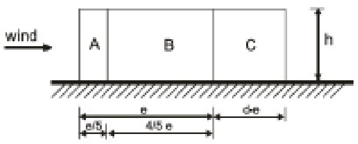


Figure (7.5)

Elevation for e < d



Areas of zones for wind on the wall

Zone A

$A_{area.2} := A_2 \cdot h_{w2}$

$A_{area.2} = 6.412\ m^2$

Zone B

$B_{area.2} := B_2 \cdot h_{w2}$

$B_{area.2} = 25.65\ m^2$

Zone C

$C_{area.2} := C_2 \cdot h_{w2}$

$C_{area.2} = 4.161\ m^2$

Zone D

$D_{area.2} := D_2 \cdot h_{w2}$

$D_{area.2} = 32.062\ m^2$

Zone E

$E_{area.2} := E_2 \cdot h_{w2}$

$E_{area.2} = 32.062\ m^2$

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External pressure coefficients

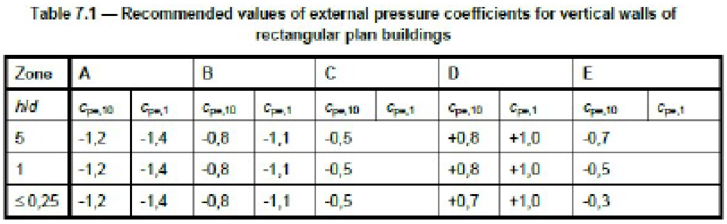

Table 7.1 — Recommended values of external pressure coefficients for vertical walls of rectangular plan buildings

Zone	A		B		C		D		E	
h/d	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,7	
1	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,5	
≤ 0,25	-1,2	-1,4	-0,8	-1,1	-0,5		+0,7	+1,0	-0,3	

For zones with area of less than $10\ m^2$, we use $C_{pe.1}$, for the rest $C_{pe.10}$!!!

$ZoneA_2 := -1.4$ $\quad ZoneB_2 := -0.8$

$ZoneC_2 := -0.5$ $\quad ZoneD_2 := 0.8$

$ZoneE_2 := -0.5$

External pressure values for the zones

$$\begin{bmatrix} C_{peA.2} \\ C_{peB.2} \\ C_{peC.2} \\ C_{peD.2} \\ C_{peE.2} \end{bmatrix} := \begin{bmatrix} ZoneA_2 \\ ZoneB_2 \\ ZoneC_2 \\ ZoneD_2 \\ ZoneE_2 \end{bmatrix} = \begin{bmatrix} -1.4 \\ -0.8 \\ -0.5 \\ 0.8 \\ -0.5 \end{bmatrix}$$

Total pressure coefficient at zone A

$$C_{pA.2} := \left\| \begin{array}{l} \text{if } ZoneA_2 < 0 \\ \quad \| C_{peA.2} - C_{pi1} \\ \text{else} \\ \quad \| C_{peA.2} - C_{pi2} \end{array} \right. = -1.6$$

Total pressure coefficient at zone B

$$C_{pB.2} := \left\| \begin{array}{l} \text{if } ZoneB_2 < 0 \\ \quad \| C_{peB.2} - C_{pi1} \\ \text{else} \\ \quad \| C_{peB.2} - C_{pi2} \end{array} \right. = -1$$

Total pressure coefficient at zone C

$$C_{pC.2} := \left\| \begin{array}{l} \text{if } ZoneC_2 < 0 \\ \quad \| C_{peC.2} - C_{pi1} \\ \text{else} \\ \quad \| C_{peC.2} - C_{pi2} \end{array} \right. = -0.7$$

Total pressure coefficient at zone D

$$C_{pD.2} := \left\| \begin{array}{l} \text{if } ZoneD_2 < 0 \\ \quad \| C_{peD.2} - C_{pi1} \\ \text{else} \\ \quad \| C_{peD.2} - C_{pi2} \end{array} \right. = 1.1$$

Total pressure coefficient at zone E

$$C_{pE.2} := \left\| \begin{array}{l} \text{if } ZoneE_2 < 0 \\ \quad \| C_{peE.2} - C_{pi1} \\ \text{else} \\ \quad \| C_{peE.2} - C_{pi2} \end{array} \right. = -0.7$$

Wind pressure for each zone in direction 2 (90°)

$$\begin{bmatrix} W_{A.2} \\ W_{B.2} \\ W_{C.2} \\ W_{D.2} \\ W_{E.2} \end{bmatrix} := \begin{bmatrix} C_{pA.2} \cdot q_p \\ C_{pB.2} \cdot q_p \\ C_{pC.2} \cdot q_p \\ C_{pD.2} \cdot q_p \\ C_{pE.2} \cdot q_p \end{bmatrix} = \begin{bmatrix} -564.859 \\ -353.037 \\ -247.126 \\ 388.341 \\ -247.126 \end{bmatrix} Pa$$

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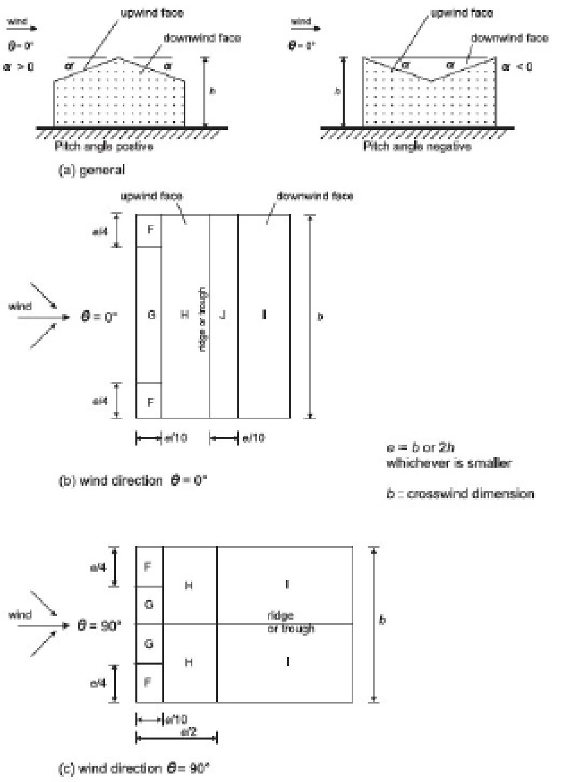
Wind Calculation on the Roof in Direction 1 (0 °) - Lower Unit

SFS EN 1991-1-1 - 7.2.5(p.43-46)

Wind direction 0 degrees

Direction of Wind	$DirecW = 0$
Height of the building	$h_{w0} := 4.895\ m$
Wind direction	$b_{w0} := 7.4\ m$
Crosswind direction	$d_{w0} := 6.91\ m$
Elevation	$e_0 := min\left(b_{w0}, 2 \cdot h_{w0}\right) = 7.4\ m$



(a) general

(b) wind direction θ = 0°

(c) wind direction θ = 90°

Figure 7.8 — Key for duopitch roofs

Zones for wind direcetion 0 degrees

Zone F length in y-direction	$Fy_0 := \frac{e_0}{4} = 1.85\ m$
Zone F length in x-direction	$Fx_0 := \frac{e_0}{10} = 0.74\ m$
Zone G length in y-direction	$Gy_0 := b_{w0} - 2\left(\frac{e_0}{4}\right) = 3.7\ m$
Zone G length in x-direction	$Gx_0 := \frac{e_0}{10} = 0.74\ m$
Zone H length in y-direction	$Hy_0 := b_{w0} = 7.4\ m$
Zone H length in x-direction	$Hx_0 := \frac{d_{w0}}{2} - \frac{e_0}{10} = 2.715\ m$
Zone J length in y-direction	$Jy_0 := b_{w0} = 7.4\ m$
Zone J length in x-direction	$Jx_0 := \frac{e_0}{10} = 0.74\ m$
Zone I length in y-direction	$Iy_0 := b_{w0} = 7.4\ m$
Zone I length in x-direction	$Ix_0 := \frac{d_{w0}}{2} - \frac{e_0}{10} = 2.715\ m$

Area of zones for wind direction 0 degrees

Zone F	**Zone G**	**Zone H**	**Zone I**	**Zone J**
$A_{F.0} := Fy_0 \cdot Fx_0$	$A_{G.0} := Gy_0 \cdot Gx_0$	$A_{H.0} := Hy_0 \cdot Hx_0$	$A_{I.0} := Iy_0 \cdot Ix_0$	$A_{J.0} := Jy_0 \cdot Jx_0$
$A_{F.0} = 1.369\ m^2$	$A_{G.0} = 2.738\ m^2$	$A_{H.0} = 20.091\ m^2$	$A_{I.0} = 20.091\ m^2$	$A_{J.0} = 5.476\ m^2$

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External pressure coefficients

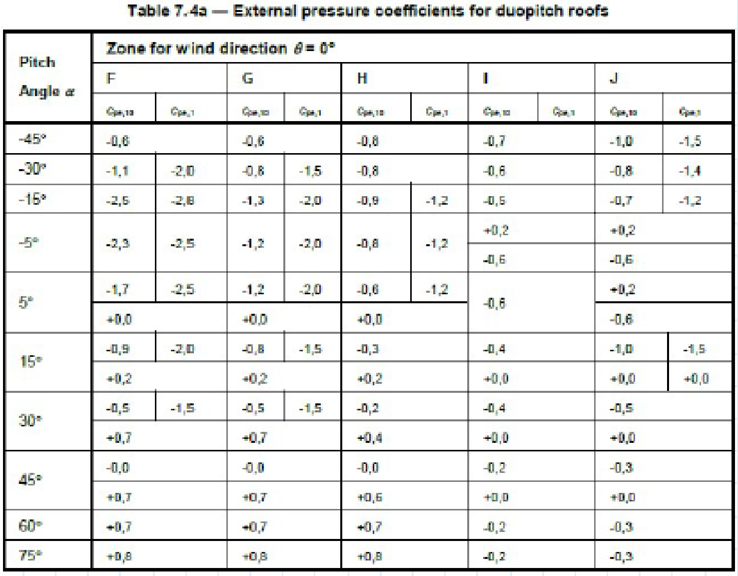

Table 7.4a — External pressure coefficients for duopitch roofs

Pitch Angle α	Zone for wind direction $\theta = 0°$									
	F		G		H		I		J	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
-45°	-0,6		-0,6		-0,8		-0,7		-1,0	-1,5
-30°	-1,1	-2,0	-0,8	-1,5	-0,8		-0,6		-0,8	-1,4
-15°	-2,5	-2,8	-1,3	-2,0	-0,9	-1,2	-0,5		-0,7	-1,2
-5°	-2,3	-2,5	-1,2	-2,0	-0,8	-1,2	+0,2		+0,2	
							-0,6		-0,6	
5°	-1,7	-2,5	-1,2	-2,0	-0,6	-1,2	-0,6		+0,2	
	+0,0		+0,0		+0,0				-0,6	
15°	-0,9	-2,0	-0,8	-1,5	-0,3		-0,4		-1,0	-1,5
	+0,2		+0,2		+0,2		+0,0		+0,0	+0,0
30°	-0,5	-1,5	-0,5	-1,5	-0,2		-0,4		-0,5	
	+0,7		+0,7		+0,4		+0,0		+0,0	
45°	-0,0		-0,0		-0,0		-0,2		-0,3	
	+0,7		+0,7		+0,6		+0,0		+0,0	
60°	+0,7		+0,7		+0,7		-0,2		-0,3	
75°	+0,8		+0,8		+0,8		-0,2		-0,3	

For zones with area of less than $10\ m^2$, we use $C_{pe.1}$, for the rest $C_{pe.10}$!!!

Case A for Zones

$ZoneF_{0.a} := 0.7$

$ZoneG_{0.a} := 0.7$

$ZoneH_{0.a} := 0.4$

$ZoneI_{0.a} := 0$

$ZoneJ_{0.a} := 0$

Case B for Zones

$ZoneF_{0.b} := -1.5$

$ZoneG_{0.b} := -1.5$

$ZoneH_{0.b} := -0.2$

$ZoneI_{0.b} := -0.4$

$ZoneJ_{0.b} := -0.5$

External pressure values for the zones

$$\begin{bmatrix} C_{peF.0.a} \\ C_{peG.0.a} \\ C_{peH.0.a} \\ C_{peI.0.a} \\ C_{peJ.0.a} \end{bmatrix} := \begin{bmatrix} ZoneF_{0.a} \\ ZoneG_{0.a} \\ ZoneH_{0.a} \\ ZoneI_{0.a} \\ ZoneJ_{0.a} \end{bmatrix} = \begin{bmatrix} 0.7 \\ 0.7 \\ 0.4 \\ 0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} C_{peF.0.b} \\ C_{peG.0.b} \\ C_{peH.0.b} \\ C_{peI.0.b} \\ C_{peJ.0.b} \end{bmatrix} := \begin{bmatrix} ZoneF_{0.b} \\ ZoneG_{0.b} \\ ZoneH_{0.b} \\ ZoneI_{0.b} \\ ZoneJ_{0.b} \end{bmatrix} = \begin{bmatrix} -1.5 \\ -1.5 \\ -0.2 \\ -0.4 \\ -0.5 \end{bmatrix}$$

Total pressure coefficient at zone F

$$C_{pF.0.a} := \begin{cases} \text{if } ZoneF_{0.a} < 0 \\ \quad C_{peF.0.a} - C_{pi1} \\ \text{else} \\ \quad C_{peF.0.a} - C_{pi2} \end{cases} = 1$$

$$C_{pF.0.b} := \begin{cases} \text{if } ZoneF_{0.b} < 0 \\ \quad C_{peF.0.b} - C_{pi1} \\ \text{else} \\ \quad C_{peF.0.b} - C_{pi2} \end{cases} = -1.7$$

Total pressure coefficient at zone G

$$C_{pG.0.a} := \begin{cases} \text{if } ZoneG_{0.a} < 0 \\ \quad C_{peG.0.a} - C_{pi1} \\ \text{else} \\ \quad C_{peG.0.a} - C_{pi2} \end{cases} = 1$$

$$C_{pG.0.b} := \begin{cases} \text{if } ZoneG_{0.b} < 0 \\ \quad C_{peG.0.b} - C_{pi1} \\ \text{else} \\ \quad C_{peG.0.b} - C_{pi2} \end{cases} = -1.7$$

Total pressure coefficient at zone H

$$C_{pH.0.a} := \begin{cases} \text{if } ZoneH_{0.a} < 0 \\ \quad C_{peH.0.a} - C_{pi1} \\ \text{else} \\ \quad C_{peH.0.a} - C_{pi2} \end{cases} = 0.7$$

$$C_{pH.0.b} := \begin{cases} \text{if } ZoneH_{0.b} < 0 \\ \quad C_{peH.0.b} - C_{pi1} \\ \text{else} \\ \quad C_{peH.0.b} - C_{pi2} \end{cases} = -0.4$$

Total pressure coefficient at zone I

$$C_{pI.0.a} := \begin{cases} \text{if } ZoneI_{0.a} < 0 \\ \quad C_{peI.0.a} - C_{pi1} \\ \text{else} \\ \quad C_{peI.0.a} - C_{pi2} \end{cases} = 0.3$$

$$C_{pI.0.b} := \begin{cases} \text{if } ZoneI_{0.b} < 0 \\ \quad C_{peI.0.b} - C_{pi1} \\ \text{else} \\ \quad C_{peI.0.b} - C_{pi2} \end{cases} = -0.6$$

Total pressure coefficient at zone J

$$C_{pJ.0.a} := \begin{cases} \text{if } ZoneJ_{0.a} < 0 \\ \quad C_{peJ.0.a} - C_{pi1} \\ \text{else} \\ \quad C_{peJ.0.a} - C_{pi2} \end{cases} = 0.3$$

$$C_{pJ.0.b} := \begin{cases} \text{if } ZoneJ_{0.b} < 0 \\ \quad C_{peJ.0.b} - C_{pi1} \\ \text{else} \\ \quad C_{peJ.0.b} - C_{pi2} \end{cases} = -0.7$$

Wind pressure for each zone in direction 1 (0°)

$$\begin{bmatrix} W_{F.0.a} \\ W_{G.0.a} \\ W_{H.0.a} \\ W_{I.0.a} \\ W_{J.0.a} \end{bmatrix} := \begin{bmatrix} C_{pF.0.a} \cdot q_p \\ C_{pG.0.a} \cdot q_p \\ C_{pH.0.a} \cdot q_p \\ C_{pI.0.a} \cdot q_p \\ C_{pJ.0.a} \cdot q_p \end{bmatrix} = \begin{bmatrix} 353.037 \\ 353.037 \\ 247.126 \\ 105.911 \\ 105.911 \end{bmatrix} Pa$$

$$\begin{bmatrix} W_{F.0.b} \\ W_{G.0.b} \\ W_{H.0.b} \\ W_{I.0.b} \\ W_{J.0.b} \end{bmatrix} := \begin{bmatrix} C_{pF.0.b} \cdot q_p \\ C_{pG.0.b} \cdot q_p \\ C_{pH.0.b} \cdot q_p \\ C_{pI.0.b} \cdot q_p \\ C_{pJ.0.b} \cdot q_p \end{bmatrix} = \begin{bmatrix} -600.163 \\ -600.163 \\ -141.215 \\ -211.822 \\ -247.126 \end{bmatrix} Pa$$

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Wind Calculation on the Roof in Direction 2 (90 °) - Higher Unit

SFS EN 1991-1-1 - 7.2.5(p.43-46)

Wind direction 90 degrees

Direction of Wind $DirecW = 90$

Height of the building $h_{w90} := 4.895\ m$

Wind direction $b_{w90} := 6.91\ m$

Crosswind direction $d_{w90} := 7.4\ m$

Elevation $e_{90} := min\left(b_{w90}, 2 \cdot d_{w90}\right) = 6.91\ m$

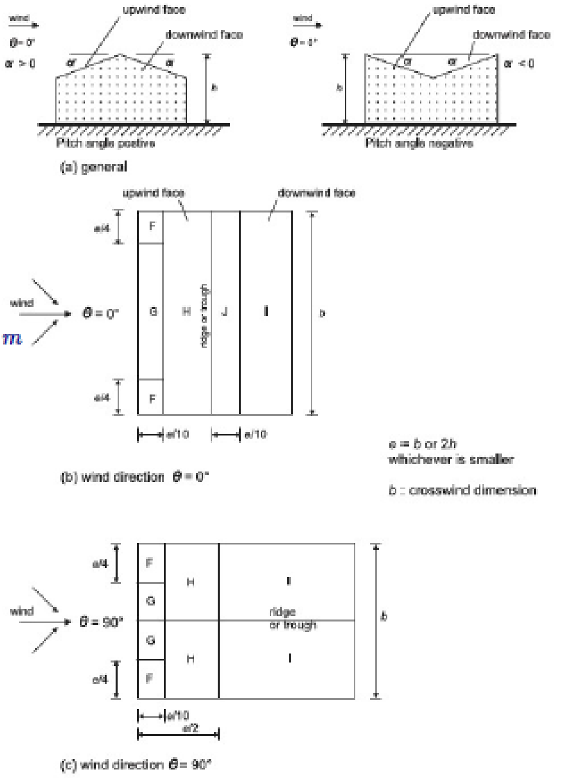

Figure 7.8 — Key for duopitch roofs

Zones for wind direction 90 degrees

Zone F length in y-direction $Fy_{90} := \frac{e_{90}}{4} = 1.728\ m$

Zone F length in x-direction $Fx_{90} := \frac{e_{90}}{10} = 0.691\ m$

Zone G length in y-direction $Gy_{90} := \frac{b_{w90}}{2} - \left(\frac{e_{90}}{4}\right) = 1.728\ m$

Zone G length in x-direction $Gx_{90} := \frac{e_{90}}{10} = 0.691\ m$

Zone H length in y-direction $Hy_{90} := \frac{b_{w90}}{2} = 3.455\ m$

Zone H length in x-direction $Hx_{90} := \frac{e_{90}}{2} - \frac{e_{90}}{10} = 2.764\ m$

Zone I length in y-direction $Iy_{90} := \frac{b_{w90}}{2} = 3.455\ m$

Zone I length in x-direction $Ix_{90} := d_{w90} - \frac{e_{90}}{2} = 3.945\ m$

Area of zones for wind direction 90 degrees

Zone F	**Zone G**	**Zone H**	**Zone I**
$A_{F.90} := Fy_{90} \cdot Fx_{90}$	$A_{G.90} := Gy_{90} \cdot Gx_{90}$	$A_{H.90} := Hy_{90} \cdot Hx_{90}$	$A_{I.90} := Iy_{90} \cdot Ix_{90}$
$A_{F.90} = 1.194\ m^2$	$A_{G.90} = 1.194\ m^2$	$A_{H.90} = 9.55\ m^2$	$A_{I.90} = 13.63\ m^2$

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External pressure coefficients

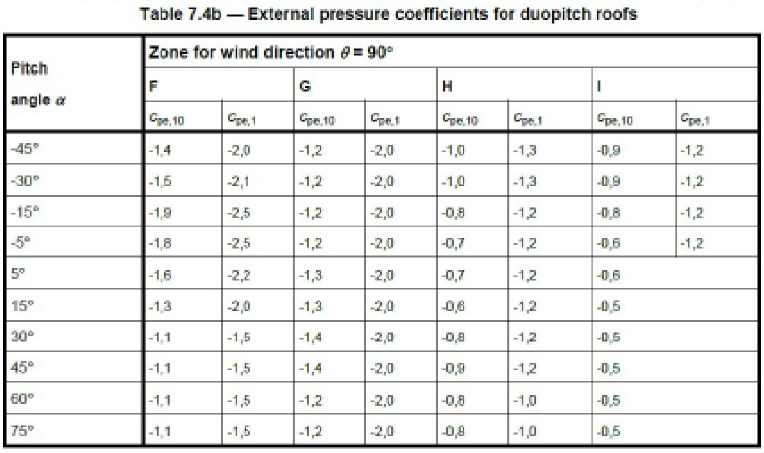

Table 7.4b — External pressure coefficients for duopitch roofs

Pitch angle α	Zone for wind direction θ = 90°							
	F		G		H		I	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
-45°	-1,4	-2,0	-1,2	-2,0	-1,0	-1,3	-0,9	-1,2
-30°	-1,5	-2,1	-1,2	-2,0	-1,0	-1,3	-0,9	-1,2
-15°	-1,9	-2,5	-1,2	-2,0	-0,8	-1,2	-0,8	-1,2
-5°	-1,8	-2,5	-1,2	-2,0	-0,7	-1,2	-0,6	-1,2
5°	-1,6	-2,2	-1,3	-2,0	-0,7	-1,2	-0,6	
15°	-1,3	-2,0	-1,3	-2,0	-0,6	-1,2	-0,5	
30°	-1,1	-1,5	-1,4	-2,0	-0,8	-1,2	-0,5	
45°	-1,1	-1,5	-1,4	-2,0	-0,9	-1,2	-0,5	
60°	-1,1	-1,5	-1,2	-2,0	-0,8	-1,0	-0,5	
75°	-1,1	-1,5	-1,2	-2,0	-0,8	-1,0	-0,5	

$ZoneF_{90} := -1.5$ $\quad ZoneH_{90} := -1.2$

$ZoneG_{90} := -2.0$ $\quad ZoneI_{90} := -0.5$

External pressure values for the zones

$$\begin{bmatrix} C_{peF.90} \\ C_{peG.90} \\ C_{peH.90} \\ C_{peI.90} \end{bmatrix} := \begin{bmatrix} ZoneF_{90} \\ ZoneG_{90} \\ ZoneH_{90} \\ ZoneI_{90} \end{bmatrix} = \begin{bmatrix} -1.5 \\ -2 \\ -1.2 \\ -0.5 \end{bmatrix}$$

For zones with area of less than $10\ m^2$, we use $C_{pe.1}$, for the rest $C_{pe.10}$!!!

Total pressure coefficient at zone F

$$C_{pF.90} := \left\| \begin{array}{l} \text{if } ZoneF_{90} < 0 \\ \quad \left\| C_{peF.90} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peF.90} - C_{pi2} \right. \end{array} \right. = -1.7$$

Total pressure coefficient at zone G

$$C_{pG.90} := \left\| \begin{array}{l} \text{if } ZoneG_{90} < 0 \\ \quad \left\| C_{peG.90} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peG.90} - C_{pi2} \right. \end{array} \right. = -2.2$$

Total pressure coefficient at zone H

$$C_{pH.90} := \left\| \begin{array}{l} \text{if } ZoneH_{90} < 0 \\ \quad \left\| C_{peH.90} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peH.90} - C_{pi2} \right. \end{array} \right. = -1.4$$

Total pressure coefficient at zone I

$$C_{pI.90} := \left\| \begin{array}{l} \text{if } ZoneI_{90} < 0 \\ \quad \left\| C_{peI.90} - C_{pi1} \right. \\ \text{else} \\ \quad \left\| C_{peI.90} - C_{pi2} \right. \end{array} \right. = -0.7$$

Wind pressure for each zone in direction 2 (90°)

$$\begin{bmatrix} W_{F.90} \\ W_{G.90} \\ W_{H.90} \\ W_{I.90} \end{bmatrix} := \begin{bmatrix} C_{pF.90} \cdot q_p \\ C_{pG.90} \cdot q_p \\ C_{pH.90} \cdot q_p \\ C_{pI.90} \cdot q_p \end{bmatrix} = \begin{bmatrix} -600.163 \\ -776.681 \\ -494.252 \\ -247.126 \end{bmatrix} Pa$$

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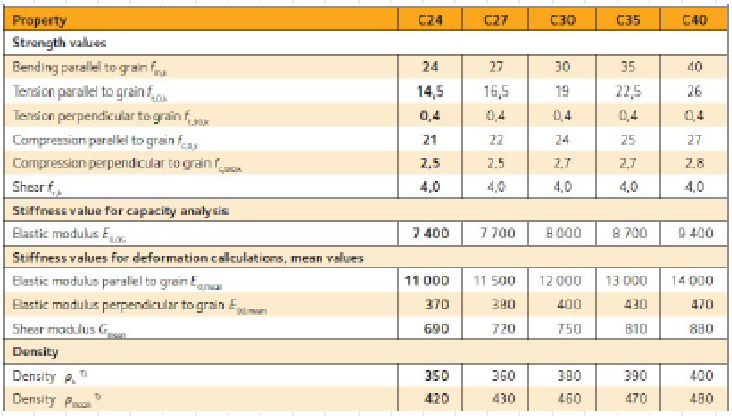
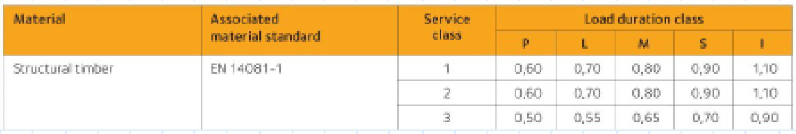
Timber Roof Calculations

Bending parallel to grain	$f_{m.k} := 24\ MPa$
Tension parallel to grain	$f_{t.0.k} := 14.5\ MPa$
Tension perpendicular to grain	$f_{t.90.k} := 0.4\ MPa$
Compression parallel to grain	$f_{c.0.k} := 21\ MPa$
Compression perpendicular to grain	$f_{c.90.k} := 2.5\ MPa$
Shear	$f_{v.k} := 4\ MPa$
Elastic modulus	$E_{0.05} := 7400\ MPa$
Shear modulus	$G_{0.05} := 690\ MPa$
Partial coefficient for material	$\gamma_M := 1.3$
Service class	$sc := 2$
Strength modification factor	$k_{mod} := 0.9$

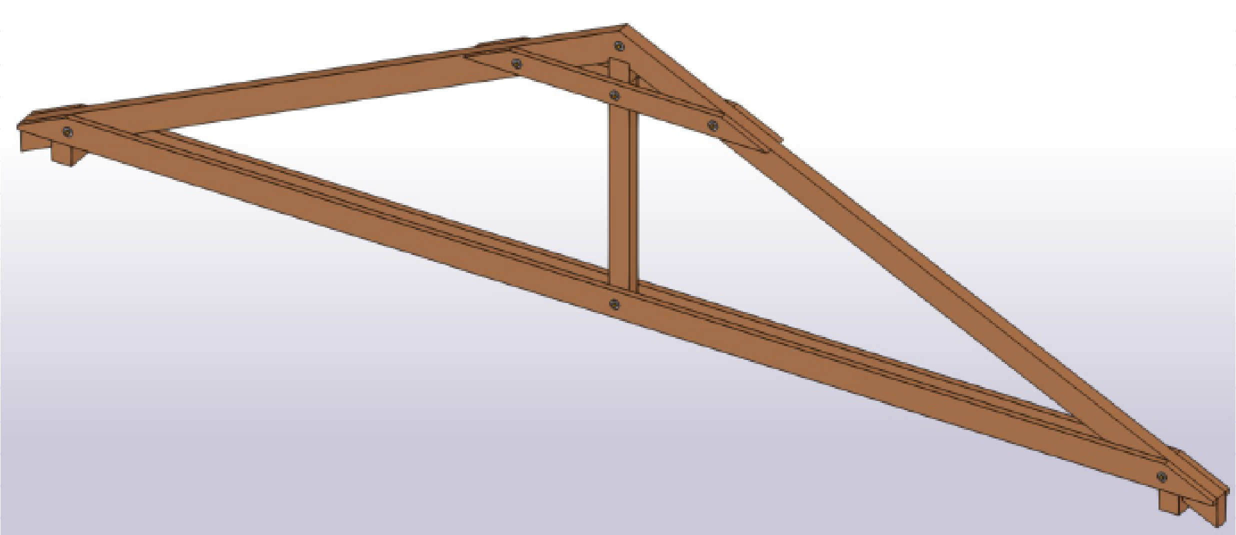


Property	C24	C27	C30	C35	C40
Strength values					
Bending parallel to grain $f_{m,k}$	**24**	27	30	35	40
Tension parallel to grain $f_{t,0,k}$	**14,5**	16,5	19	22,5	26
Tension perpendicular to grain $f_{t,90,k}$	**0,4**	0,4	0,4	0,4	0,4
Compression parallel to grain $f_{c,0,k}$	**21**	22	24	25	27
Compression perpendicular to grain $f_{c,90,k}$	**2,5**	2,5	2,7	2,7	2,8
Shear $f_{v,k}$	**4,0**	4,0	4,0	4,0	4,0
Stiffness value for capacity analysis					
Elastic modulus $E_{0,05}$	**7 400**	7 700	8 000	8 700	9 400
Stiffness values for deformation calculations, mean values					
Elastic modulus parallel to grain $E_{0,mean}$	**11 000**	11 500	12 000	13 000	14 000
Elastic modulus perpendicular to grain $E_{90,mean}$	**370**	380	400	430	470
Shear modulus G_{mean}	**690**	720	750	810	880
Density					
Density ρ_k [1)]	**350**	360	380	390	400
Density ρ_{mean} [1)]	**420**	430	460	470	480



Material	Associated material standard	Service class	Load duration class				
			P	L	M	S	I
Structural timber	EN 14081-1	1	0,60	0,70	0,80	0,90	1,10
		2	0,60	0,70	0,80	0,90	1,10
		3	0,50	0,55	0,65	0,70	0,90

Visual Representation of a Collar Tie Roof Element



The structural design procedure was carried out using the Dlubal RFEM finite element software environment. The generation of load combinations was based on Eurocode and corresponding Finnish/Slovak National Annex provisions. For the classification of load cases and the automatic creation of load combinations, EN 1990 (together with SFS 2010-09/STN 2010-11) was adopted through the Combination Wizard. The load definitions themselves were established via the Load Wizard in accordance with EN 1991 and its Finnish/Slovak National Annex (SFS 2016-12/STN 2016-01). For the verification of timber elements, the design setup was configured according to EN 1995 (Eurocode 5) in conjunction with the Finnish/Slovak National Annex (SFS 2016-12/STN 2019-12).

The governing ultimate limit state (ULS) combinations were formulated in accordance with Equation 6.10 for Slovakia and Equation 6.10a and Equation 6.10b for Finland from EN 1990. RFEM was employed to automatically evaluate all formulations, and the most unfavourable internal force effects from the entire envelope of combinations were retained for design verification.

The resulting maximum design values of axial force (NEd), shear force (VEd), and bending moment (MEd) were extracted for each structural element under consideration.

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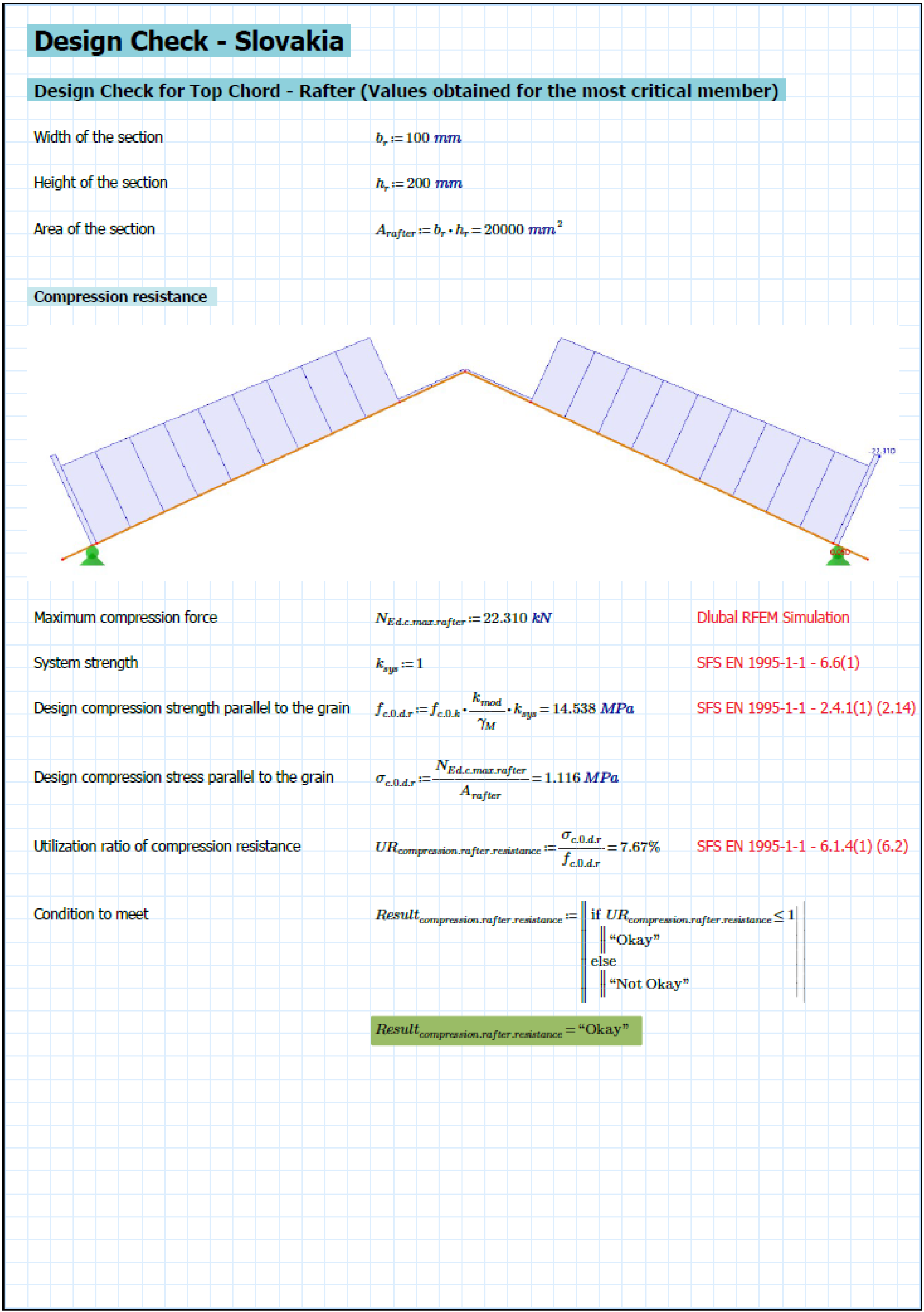

Design Check - Slovakia

Design Check for Top Chord - Rafter (Values obtained for the most critical member)

Width of the section $b_r := 100\ mm$

Height of the section $h_r := 200\ mm$

Area of the section $A_{rafter} := b_r \cdot h_r = 20000\ mm^2$

Compression resistance

Maximum compression force $N_{Ed.c.max.rafter} := 22.310\ kN$ Dlubal RFEM Simulation

System strength $k_{sys} := 1$ SFS EN 1995-1-1 - 6.6(1)

Design compression strength parallel to the grain $f_{c.0.d.r} := f_{c.0.k} \cdot \frac{k_{mod}}{\gamma_M} \cdot k_{sys} = 14.538\ MPa$ SFS EN 1995-1-1 - 2.4.1(1) (2.14)

Design compression stress parallel to the grain $\sigma_{c.0.d.r} := \frac{N_{Ed.c.max.rafter}}{A_{rafter}} = 1.116\ MPa$

Utilization ratio of compression resistance $UR_{compression.rafter.resistance} := \frac{\sigma_{c.0.d.r}}{f_{c.0.d.r}} = 7.67\%$ SFS EN 1995-1-1 - 6.1.4(1) (6.2)

Condition to meet $Result_{compression.rafter.resistance} :=$

```
if UR_compression.rafter.resistance ≤ 1
    "Okay"
else
    "Not Okay"
```

$Result_{compression.rafter.resistance} = \text{“Okay”}$

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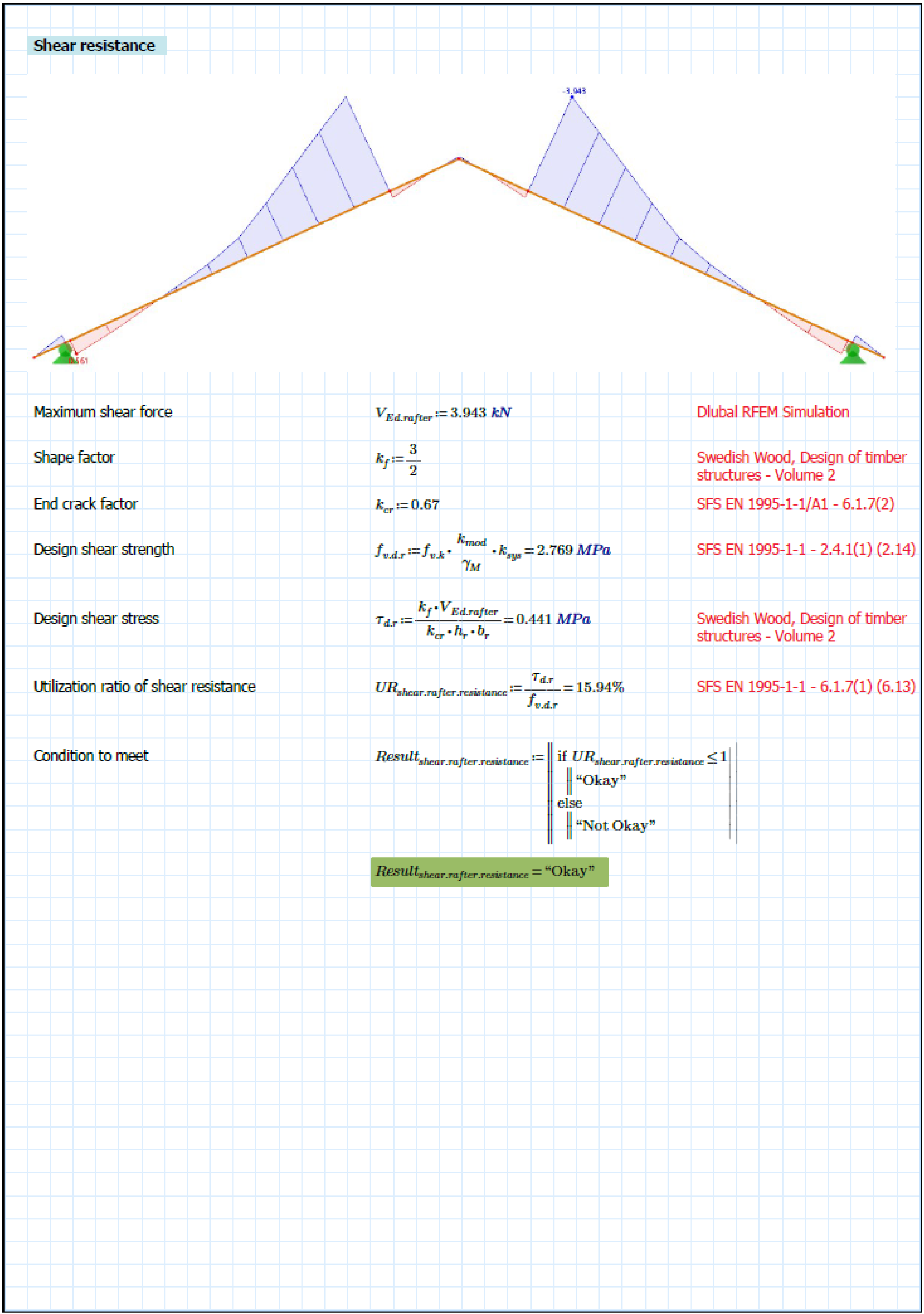

Shear resistance

Maximum shear force	$V_{Ed.rafter} := 3.943\ kN$	Dlubal RFEM Simulation
Shape factor	$k_f := \frac{3}{2}$	Swedish Wood, Design of timber structures - Volume 2
End crack factor	$k_{cr} := 0.67$	SFS EN 1995-1-1/A1 - 6.1.7(2)
Design shear strength	$f_{v.d.r} := f_{v.k} \cdot \frac{k_{mod}}{\gamma_M} \cdot k_{sys} = 2.769\ MPa$	SFS EN 1995-1-1 - 2.4.1(1) (2.14)
Design shear stress	$\tau_{d.r} := \frac{k_f \cdot V_{Ed.rafter}}{k_{cr} \cdot h_r \cdot b_r} = 0.441\ MPa$	Swedish Wood, Design of timber structures - Volume 2
Utilization ratio of shear resistance	$UR_{shear.rafter.resistance} := \frac{\tau_{d.r}}{f_{v.d.r}} = 15.94\%$	SFS EN 1995-1-1 - 6.1.7(1) (6.13)

Condition to meet

```
Result_shear.rafter.resistance := || if UR_shear.rafter.resistance ≤ 1
                                  ||   || "Okay"
                                  || else
                                  ||   || "Not Okay"
```

$Result_{shear.rafter.resistance} = \text{“Okay”}$

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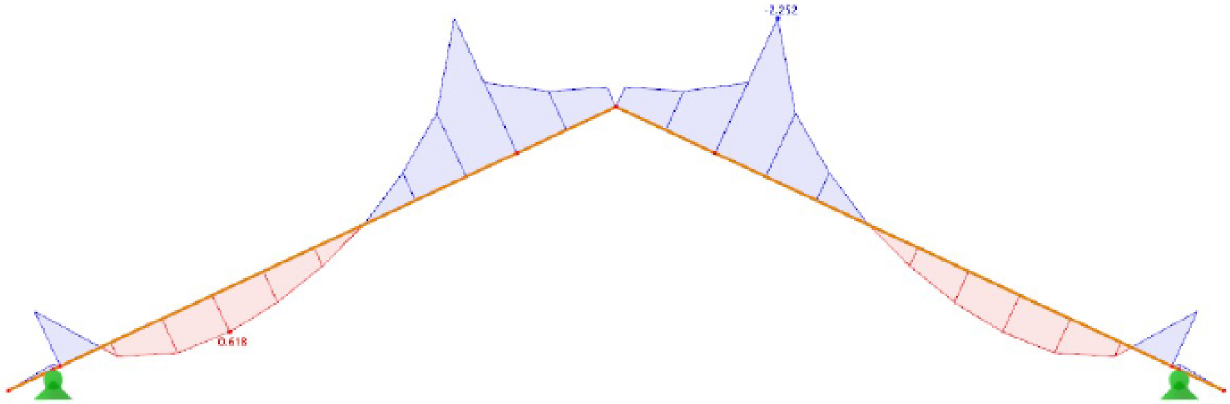
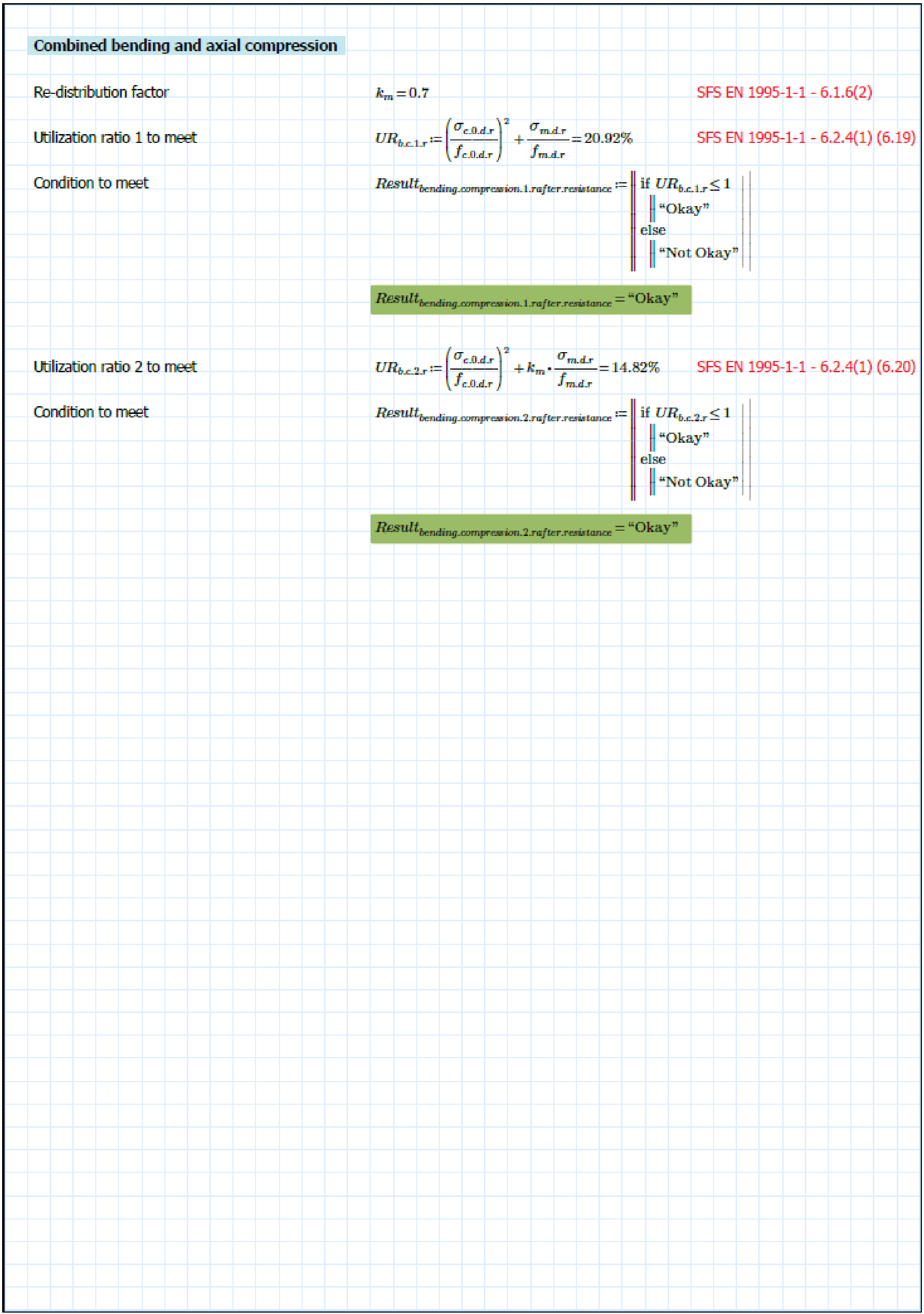
Bending resistance



Maximum bending moment	$M_{Ed.rafter} := 2.252\ kN \cdot m$	Dlubal RFEM Simulation
System strength	$k_{sys} = 1$	SFS EN 1995-1-1 - 6.6(1)
Re-distribution factor	$k_m := 0.7$	SFS EN 1995-1-1 - 6.1.6(2)
Elastic section modulus about y-y	$W_{y.r} := \frac{b_r \cdot {h_r}^2}{6} = \left(6.667 \cdot 10^5\right)\ mm^3$	
Design bending strength	$f_{m.d.r} := f_{m.k} \cdot \frac{k_{mod}}{\gamma_M} \cdot k_{sys} = 16.615\ MPa$	SFS EN 1995-1-1 - 2.4.1(1) (2.14)
Design bending stress	$\sigma_{m.d.r} := \frac{M_{Ed.rafter}}{W_{y.r}} = 3.378\ MPa$	
Utilization ratio of bending resistance	$UR_{bending.rafter.resistance} := \max\left(\frac{\sigma_{m.d.r}}{f_{m.d.r}}, k_m \cdot \frac{\sigma_{m.d.r}}{f_{m.d.r}}\right) = 20.33\%$	SFS EN 1995-1-1 - 6.1.6(1) (6.11/6.12)
Condition to meet	$Result_{bending.rafter.resistance} := \begin{array}{l} \text{if } UR_{bending.rafter.resistance} \le 1 \\ \quad \text{“Okay”} \\ \text{else} \\ \quad \text{“Not Okay”} \end{array}$	

$Result_{bending.rafter.resistance} = \text{“Okay”}$

Non-Commercial Use Only



Combined bending and axial compression

Re-distribution factor $k_m = 0.7$ SFS EN 1995-1-1 - 6.1.6(2)

Utilization ratio 1 to meet $UR_{b.c.1.r} := \left(\frac{\sigma_{c.0.d.r}}{f_{c.0.d.r}}\right)^2 + \frac{\sigma_{m.d.r}}{f_{m.d.r}} = 20.92\%$ SFS EN 1995-1-1 - 6.2.4(1) (6.19)

Condition to meet

$$Result_{bending.compression.1.rafter.resistance} := \begin{array}{l} \text{if } UR_{b.c.1.r} \le 1 \\ \quad \text{“Okay”} \\ \text{else} \\ \quad \text{“Not Okay”} \end{array}$$

$Result_{bending.compression.1.rafter.resistance} = \text{“Okay”}$

Utilization ratio 2 to meet $UR_{b.c.2.r} := \left(\frac{\sigma_{c.0.d.r}}{f_{c.0.d.r}}\right)^2 + k_m \cdot \frac{\sigma_{m.d.r}}{f_{m.d.r}} = 14.82\%$ SFS EN 1995-1-1 - 6.2.4(1) (6.20)

Condition to meet

$$Result_{bending.compression.2.rafter.resistance} := \begin{array}{l} \text{if } UR_{b.c.2.r} \le 1 \\ \quad \text{“Okay”} \\ \text{else} \\ \quad \text{“Not Okay”} \end{array}$$

$Result_{bending.compression.2.rafter.resistance} = \text{“Okay”}$

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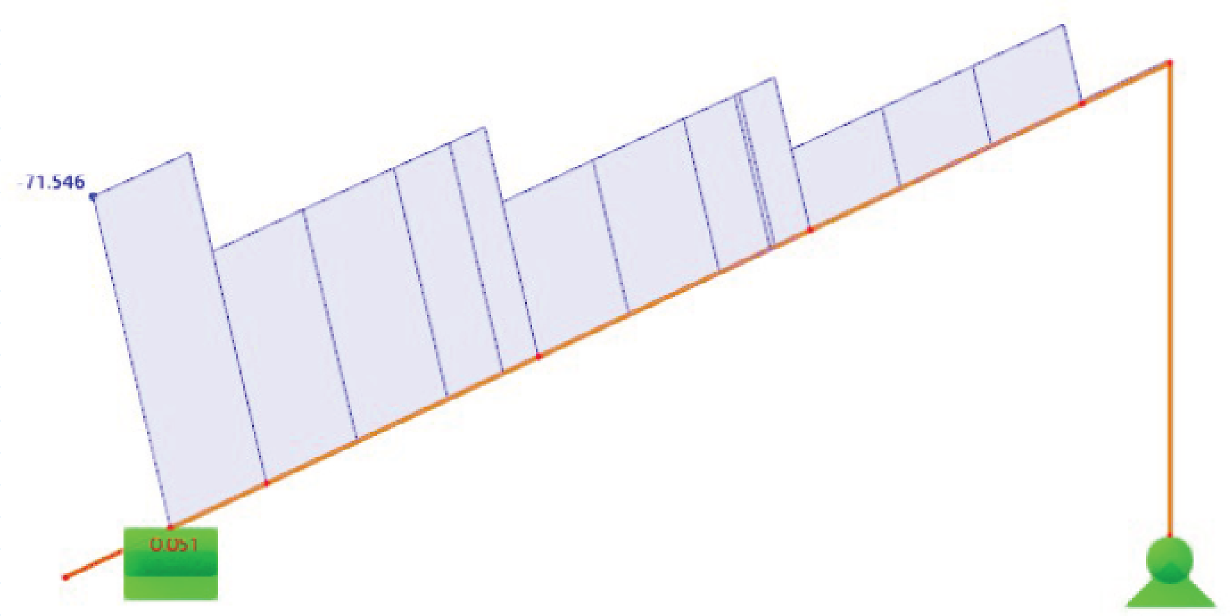
Design Check for Top Chord - Hip Rafter (Values obtained for the most critical member)

Width of the section $b_h := 150\ mm$

Height of the section $h_h := 200\ mm$

Area of the section $A_{hiprafter} := b_h \cdot h_h = 30000\ mm^2$

Compression resistance



Maximum compression force $N_{Ed.c.max.hiprafter} := 71.546\ kN$ Dlubal RFEM Simulation

System strength $k_{sys} = 1$ SFS EN 1995-1-1 - 6.6(1)

Design compression strength parallel to the grain $f_{c.0.d.h} := f_{c.0.k} \cdot \frac{k_{mod}}{\gamma_M} \cdot k_{sys} = 14.538\ MPa$ SFS EN 1995-1-1 - 2.4.1(1) (2.14)

Design compression stress parallel to the grain $\sigma_{c.0.d.h} := \frac{N_{Ed.c.max.hiprafter}}{A_{hiprafter}} = 2.385\ MPa$

Utilization ratio of compression resistance $UR_{compression.hiprafter.resistance} := \frac{\sigma_{c.0.d.h}}{f_{c.0.d.h}} = 16.4\%$ SFS EN 1995-1-1 - 6.1.4(1) (6.2)

Condition to meet

$$Result_{compression.hiprafter.resistance} := \begin{array}{|l} \text{if } UR_{compression.hiprafter.resistance} \le 1 \\ \quad \text{"Okay"} \\ \text{else} \\ \quad \text{"Not Okay"} \end{array}$$

$Result_{compression.hiprafter.resistance} = \text{"Okay"}$

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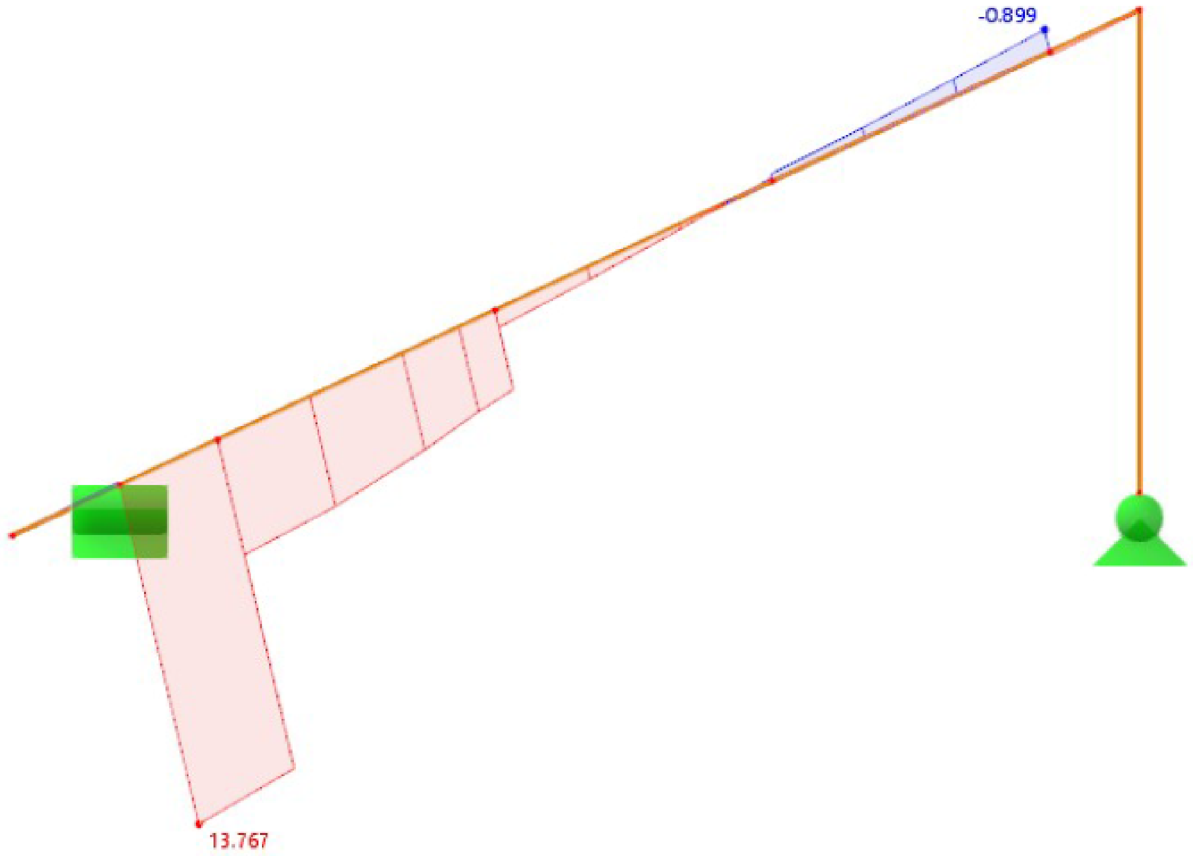
Shear resistance



Maximum shear force	$V_{Ed.hiprafter} := 13.767\ kN$	Dlubal RFEM Simulation
Shape factor	$k_f = 1.5$	Swedish Wood, Design of timber structures - Volume 2
End crack factor	$k_{cr} = 0.67$	STN EN 1995-1-1/NA - 6.1.7(2)
Design shear strength	$f_{v.d.h} := f_{v.k} \cdot \frac{k_{mod}}{\gamma_M} \cdot k_{sys} = 2.769\ MPa$	SFS EN 1995-1-1 - 2.4.1(1) (2.14)
Design shear stress	$\tau_{d.h} := \frac{k_f \cdot V_{Ed.hiprafter}}{k_{cr} \cdot h_h \cdot b_h} = 1.027\ MPa$	Swedish Wood, Design of timber structures - Volume 2
Utilization ratio of shear resistance	$UR_{shear.hiprafter.resistance} := \frac{\tau_{d.h}}{f_{v.d.h}} = 37.1\%$	SFS EN 1995-1-1 - 6.1.7(1) (6.13)
Condition to meet	$Result_{shear.hiprafter.resistance} := \left\| \begin{array}{l} \text{if } UR_{shear.hiprafter.resistance} \le 1 \\ \quad \text{"Okay"} \\ \text{else} \\ \quad \text{"Not Okay"} \end{array} \right.$	

$Result_{shear.hiprafter.resistance} = \text{"Okay"}$

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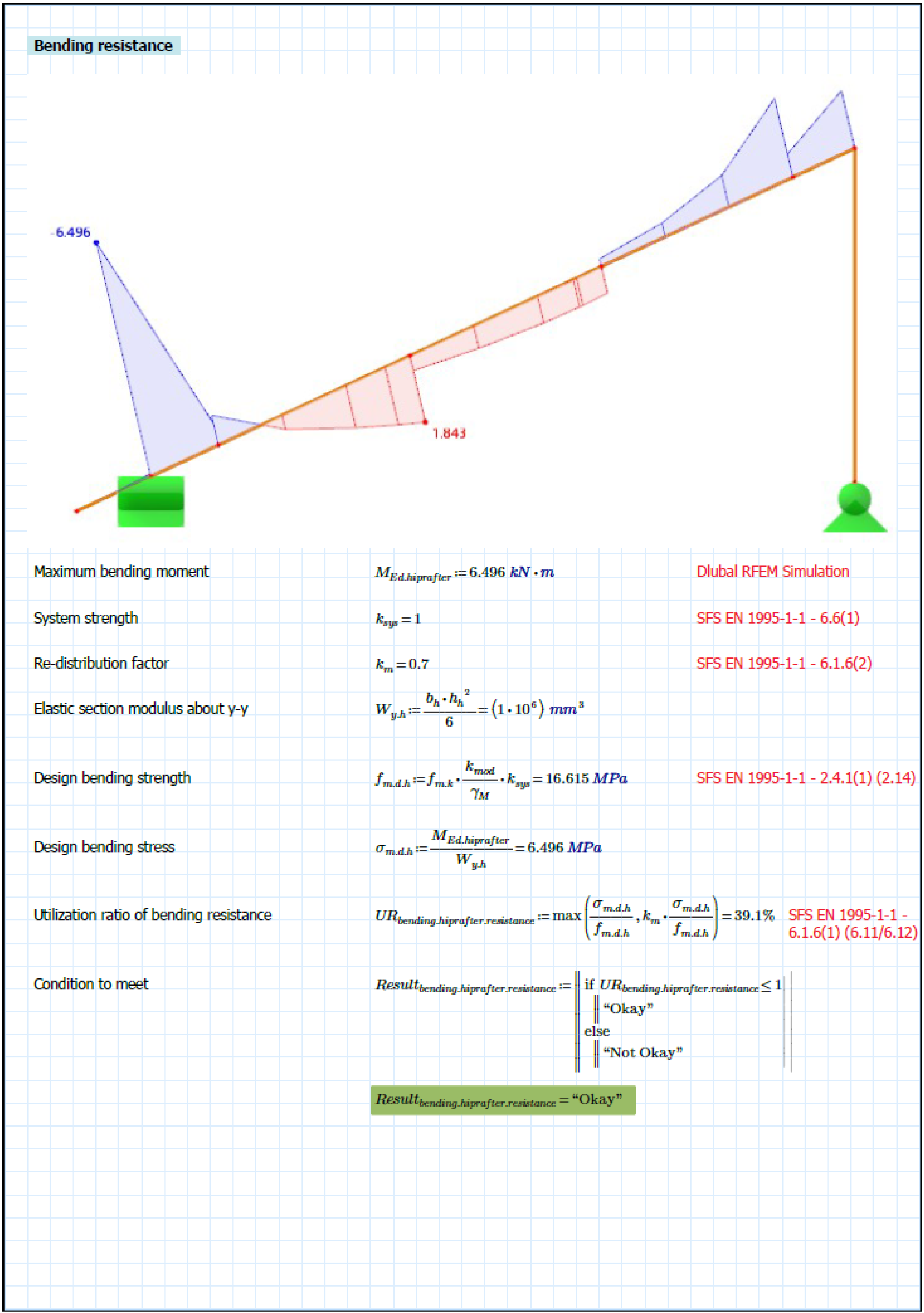

Bending resistance

Maximum bending moment	$M_{Ed.hiprafter} := 6.496\ kN \cdot m$	Dlubal RFEM Simulation
System strength	$k_{sys} = 1$	SFS EN 1995-1-1 - 6.6(1)
Re-distribution factor	$k_m = 0.7$	SFS EN 1995-1-1 - 6.1.6(2)
Elastic section modulus about y-y	$W_{y.h} := \frac{b_h \cdot h_h^{2}}{6} = \left(1 \cdot 10^{6}\right)\ mm^{3}$	
Design bending strength	$f_{m.d.h} := f_{m.k} \cdot \frac{k_{mod}}{\gamma_M} \cdot k_{sys} = 16.615\ MPa$	SFS EN 1995-1-1 - 2.4.1(1) (2.14)
Design bending stress	$\sigma_{m.d.h} := \frac{M_{Ed.hiprafter}}{W_{y.h}} = 6.496\ MPa$	
Utilization ratio of bending resistance	$UR_{bending.hiprafter.resistance} := \max\left(\frac{\sigma_{m.d.h}}{f_{m.d.h}}, k_m \cdot \frac{\sigma_{m.d.h}}{f_{m.d.h}}\right) = 39.1\%$	SFS EN 1995-1-1 - 6.1.6(1) (6.11/6.12)
Condition to meet	$Result_{bending.hiprafter.resistance} :=$ if $UR_{bending.hiprafter.resistance} \le 1$ “Okay” else “Not Okay”	

$Result_{bending.hiprafter.resistance} =$ “Okay”

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Combined bending and axial compression

Re-distribution factor $k_m = 0.7$ SFS EN 1995-1-1 - 6.1.6(2)

Utilization ratio 1 to meet $UR_{b.c.1.h} := \left(\frac{\sigma_{c.0.d.h}}{f_{c.0.d.h}}\right)^2 + \frac{\sigma_{m.d.h}}{f_{m.d.h}} = 41.79\%$ SFS EN 1995-1-1 - 6.2.4(1) (6.19)

Condition to meet $Result_{bending.compression.1.hiprafter.resistance} :=$

```
if UR_b.c.1.h ≤ 1
    "Okay"
else
    "Not Okay"
```

$Result_{bending.compression.1.hiprafter.resistance} =$ "Okay"

Utilization ratio 2 to meet $UR_{b.c.2.h} := \left(\frac{\sigma_{c.0.d.h}}{f_{c.0.d.h}}\right)^2 + k_m \cdot \frac{\sigma_{m.d.h}}{f_{m.d.h}} = 30.06\%$ SFS EN 1995-1-1 - 6.2.4(1) (6.20)

Condition to meet $Result_{bending.compression.2.hiprafter.resistance} :=$

```
if UR_b.c.2.h ≤ 1
    "Okay"
else
    "Not Okay"
```

$Result_{bending.compression.2.hiprafter.resistance} =$ "Okay"

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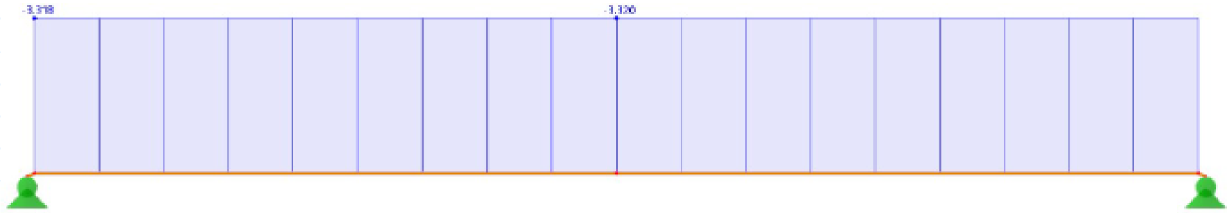
Design Check for Bottom Chord - Rafter Tie (Values obtained for the most critical member)

Width of the section $b_t := 50\ mm$

Height of the section $h_t := 200\ mm$

Area of the section $A_{raftertie} := b_t \cdot h_t = 10000\ mm^2$

Compression resistance



Maximum compression force $N_{Ed.c.max.raftertie} := 3.320\ kN$ Dlubal RFEM Simulation

System strength $k_{sys} = 1$ SFS EN 1995-1-1 - 6.6(1)

Design compression strength parallel to the grain $f_{c.0.d.t} := f_{c.0.k} \cdot \dfrac{k_{mod}}{\gamma_M} \cdot k_{sys} = 14.538\ MPa$ SFS EN 1995-1-1 - 2.4.1(1) (2.14)

Design compression stress parallel to the grain $\sigma_{c.0.d.t} := \dfrac{N_{Ed.c.max.raftertie}}{A_{raftertie}} = 0.332\ MPa$

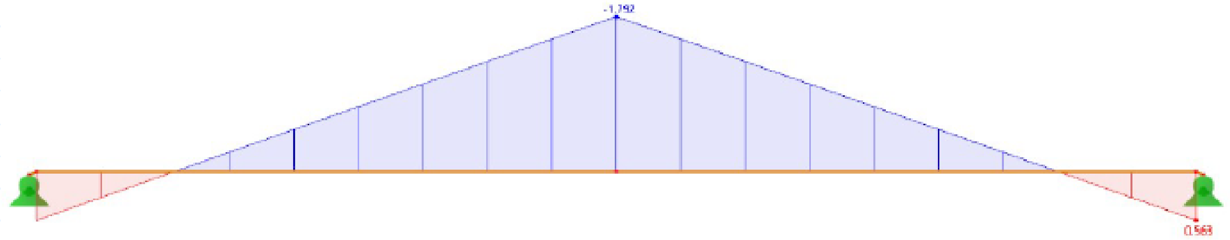
Utilization ratio of compression resistance $UR_{compression.raftertie.resistance} := \dfrac{\sigma_{c.0.d.t}}{f_{c.0.d.t}} = 2.28\%$ SFS EN 1995-1-1 - 6.1.4(1) (6.2)

Condition to meet

$$Result_{compression.raftertie.resistance} := \left\| \begin{array}{l} \text{if } UR_{compression.raftertie.resistance} \le 1 \\ \quad \left\| \text{“Okay”} \right. \\ \text{else} \\ \quad \left\| \text{“Not Okay”} \right. \end{array} \right.$$

$Result_{compression.raftertie.resistance} = \text{“Okay”}$

Shear resistance



Maximum shear force $V_{Ed.raftertie} := 1.792\ kN$ Dlubal RFEM Simulation

Shape factor $k_f = 1.5$ Swedish Wood, Design of timber structures - Volume 2

End crack factor $k_{cr} = 0.67$ STN EN 1995-1-1/NA - 6.1.7(2)

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Design shear strength $f_{v.d.t} := f_{v.k} \cdot \frac{k_{mod}}{\gamma_M} \cdot k_{sys} = 2.769 \ MPa$ SFS EN 1995-1-1 - 2.4.1(1) (2.14)

Design shear stress $\tau_{d.t} := \frac{k_f \cdot V_{Ed.raftertie}}{k_{cr} \cdot h_t \cdot b_t} = 0.401 \ MPa$ Swedish Wood, Design of timber structures - Volume 2

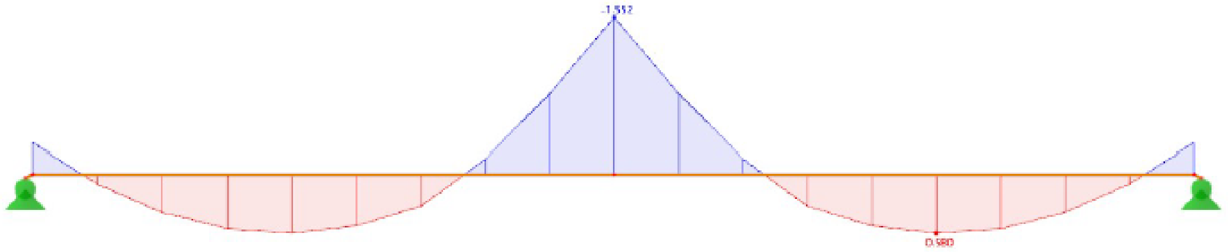
Utilization ratio of shear resistance $UR_{shear.raftertie.resistance} := \frac{\tau_{d.t}}{f_{v.d.t}} = 14.49\%$ SFS EN 1995-1-1 - 6.1.7(1) (6.13)

Condition to meet

$$Result_{shear.raftertie.resistance} := \left\| \begin{array}{l} \text{if } UR_{shear.raftertie.resistance} \le 1 \\ \quad \left\| \text{“Okay”} \right. \\ \text{else} \\ \quad \left\| \text{“Not Okay”} \right. \end{array} \right.$$

$Result_{shear.raftertie.resistance} = \text{“Okay”}$

Bending resistance



Maximum bending moment $M_{Ed.raftertie} := 1.552 \ kN \cdot m$ Dlubal RFEM Simulation

System strength $k_{sys} = 1$ SFS EN 1995-1-1 - 6.6(1)

Re-distribution factor $k_m = 0.7$ SFS EN 1995-1-1 - 6.1.6(2)

Elastic section modulus about y-y $W_{y.t} := \frac{b_t \cdot h_t^2}{6} = \left(3.333 \cdot 10^5\right) \ mm^3$

Design bending strength $f_{m.d.t} := f_{m.k} \cdot \frac{k_{mod}}{\gamma_M} \cdot k_{sys} = 16.615 \ MPa$ SFS EN 1995-1-1 - 2.4.1(1) (2.14)

Design bending stress $\sigma_{m.d.t} := \frac{M_{Ed.raftertie}}{W_{y.t}} = 4.656 \ MPa$

Utilization ratio of bending resistance $UR_{bending.raftertie.resistance} := \max\left(\frac{\sigma_{m.d.t}}{f_{m.d.t}}, k_m \cdot \frac{\sigma_{m.d.t}}{f_{m.d.t}}\right) = 28.02\%$ SFS EN 1995-1-1 - 6.1.6(1) (6.11/6.12)

Condition to meet

$$Result_{bending.raftertie.resistance} := \left\| \begin{array}{l} \text{if } UR_{bending.raftertie.resistance} \le 1 \\ \quad \left\| \text{“Okay”} \right. \\ \text{else} \\ \quad \left\| \text{“Not Okay”} \right. \end{array} \right.$$

$Result_{bending.raftertie.resistance} = \text{“Okay”}$

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Combined bending and axial compression

Re-distribution factor $k_m = 0.7$ SFS EN 1995-1-1 - 6.1.6(2)

Utilization ratio 1 to meet $UR_{b.c.1.t} := \left(\frac{\sigma_{c.0.d.t}}{f_{c.0.d.t}}\right)^2 + \frac{\sigma_{m.d.t}}{f_{m.d.t}} = 28.07\%$ SFS EN 1995-1-1 - 6.2.4(1) (6.19)

Condition to meet

$$Result_{bending.compression.1.raftertie.resistance} := \begin{array}{l} \text{if } UR_{b.c.1.t} \le 1 \\ \quad \text{“Okay”} \\ \text{else} \\ \quad \text{“Not Okay”} \end{array}$$

$Result_{bending.compression.1.raftertie.resistance} = \text{“Okay”}$

Utilization ratio 2 to meet $UR_{b.c.2.t} := \left(\frac{\sigma_{c.0.d.t}}{f_{c.0.d.t}}\right)^2 + k_m \cdot \frac{\sigma_{m.d.t}}{f_{m.d.t}} = 19.67\%$ SFS EN 1995-1-1 - 6.2.4(1) (6.20)

Condition to meet

$$Result_{bending.compression.2.raftertie.resistance} := \begin{array}{l} \text{if } UR_{b.c.2.t} \le 1 \\ \quad \text{“Okay”} \\ \text{else} \\ \quad \text{“Not Okay”} \end{array}$$

$Result_{bending.compression.2.raftertie.resistance} = \text{“Okay”}$

Lateral torsional buckling resistance

Length of the beam $L_t := 8.195\ m$

Efective length factor $l_{ef.t} := 0.9$ SFS EN 1995-1-1 - 6.3.3(3) Table 6.1

Coefficient $\beta_c := 0.2$ SFS EN 1995-1-1 - 6.3.2(1) (6.29)

Second moment of inertia $I_{z.t} := \frac{b_t \cdot h_t^3}{12} = (3.333 \cdot 10^7)\ mm^4$

Torsional moment of inertia $I_{tor.t} := \frac{b_t^3 \cdot h_t}{3} \cdot \left(1 - 0.58 \cdot \frac{b_t}{h_t}\right) = (7.125 \cdot 10^6)\ mm^4$

Elastic section modulus $W_{y.t} = (3.333 \cdot 10^5)\ mm^3$

Critical bending stress $\sigma_{m.crit.t} := \frac{\pi \cdot \sqrt{E_{0.05} \cdot I_{z.t} \cdot G_{0.05} \cdot I_{tor.t}}}{l_{ef.t} \cdot L_t \cdot W_{y.t}} = 44.5\ MPa$ SFS EN 1995-1-1 - 6.3.3(2) (6.31)

Relative slenderness - If $\lambda_{rel.m.t} \le 0.75$, no LTB $\lambda_{rel.m.t} := \sqrt{\frac{f_{m.k}}{\sigma_{m.crit.t}}} = 0.734$ SFS EN 1995-1-1 - 6.3.3(2) (6.30)

Critical bending parameter $k_{crit} := 1$ SFS EN 1995-1-1 - 6.3.3(5)

Slenderness ratio $\lambda_{z.t} := \frac{L_t \cdot l_{ef.t}}{\frac{b_t}{\sqrt{12}}} = 510.99$

Relative slenderness ratio $\lambda_{rel.z.t} := \frac{\lambda_{z.t}}{\pi} \cdot \sqrt{\frac{f_{c.0.k}}{E_{0.05}}} = 8.665$ SFS EN 1995-1-1 - 6.3.2(1) (6.21)

Factor $k_{z.t} := 0.5\ \left(1 + \beta_c \cdot \left(\lambda_{rel.z.t} - 0.3\right) + \lambda_{rel.z.t}^{\ 2}\right) = 38.9$ SFS EN 1995-1-1 - 6.3.2(3) (6.23)

Bending moment and axial compression expression $\left(\frac{\sigma_{m.d.t}}{k_{crit} \cdot f_{m.d.t}}\right)^2 + \frac{\sigma_{c.0.d.t}}{k_{z.t} \cdot f_{c.0.d.t}} \le 1 = 1$ SFS EN 1995-1-1 - 6.3.3(6) (6.35)

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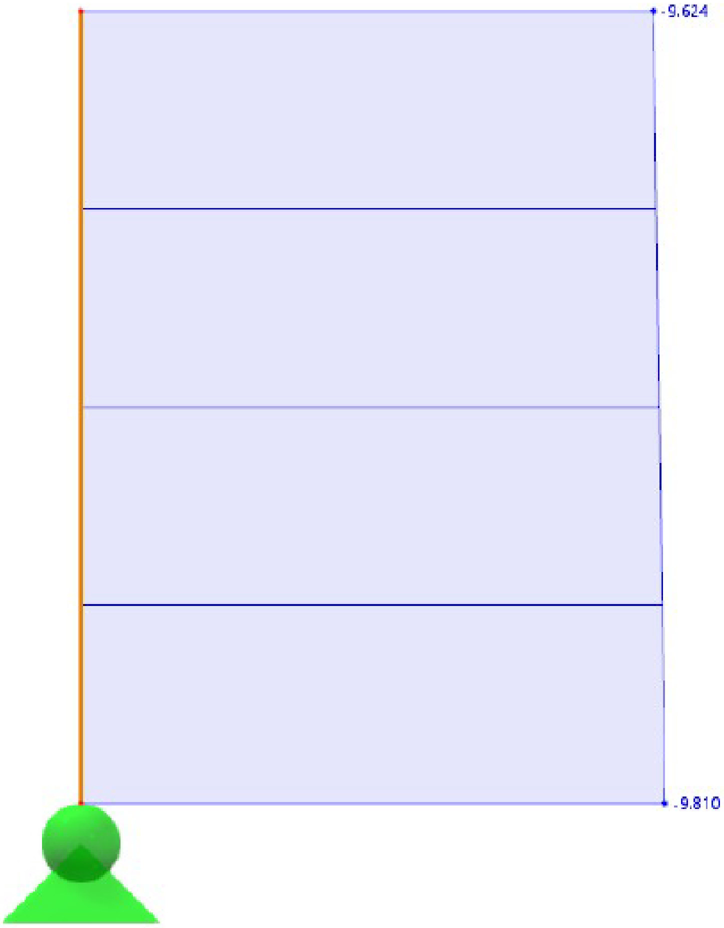
Design Check for Vertical Member - Column

Compression resistance



Width of the section $b_c := 150\ mm$

Height of the section $h_c := 150\ mm$

Area of the section $A_{column} := b_c \cdot h_c = 22500\ mm^2$

Maximum compression force	$N_{Ed.c.max.column} := 9.810\ kN$	Dlubal RFEM Simulation
System strength	$k_{sys} = 1$	SFS EN 1995-1-1 - 6.6(1)
Design compression strength parallel to the grain	$f_{c.0.d.c} := f_{c.0.k} \cdot \frac{k_{mod}}{\gamma_M} \cdot k_{sys} = 14.538\ MPa$	SFS EN 1995-1-1 - 2.4.1(1) (2.14)
Design compression stress parallel to the grain	$\sigma_{c.0.d.c} := \frac{N_{Ed.c.max.column}}{A_{column}} = 0.436\ MPa$	
Utilization ratio of compression resistance	$UR_{compression.column.resistance} := \frac{\sigma_{c.0.d.c}}{f_{c.0.d.c}} = 3\%$	SFS EN 1995-1-1 - 6.1.4(1) (6.2)
Condition to meet	$Result_{compression.column.resistance} := \begin{array}{l} \text{if } UR_{compression.column.resistance} \le 1 \\ \quad \text{“Okay”} \\ \text{else} \\ \quad \text{“Not Okay”} \end{array}$	

$Result_{compression.column.resistance} = \text{“Okay”}$

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Buckling resistance

Buckling coefficient	$k := 1$	
Section length	$L_c := 1.225\ m$	
Curvature coefficient	$\beta_c = 0.2$	SFS EN 1995-1-1 - 6.3.2(1) (6.29)
Effective length	$L_{e.y.c} := k \cdot L_c = 1.225\ m$	
Slenderness ratio	$\lambda_{y.c} := \dfrac{L_{e.y.c}}{\dfrac{h_c}{\sqrt{12}}} = 28.29$	
Relative slenderness ratio	$\lambda_{rel.y.c} := \dfrac{\lambda_{y.c}}{\pi} \cdot \sqrt{\dfrac{f_{c.0.k}}{E_{0.05}}} = 0.48$	SFS EN 1995-1-1 - 6.3.2(1) (6.21)
Factor	$k_{y.c} := 0.5\left(1 + \beta_c \cdot \left(\lambda_{rel.y.c} - 0.3\right) + {\lambda_{rel.y.c}}^2\right) = 0.63$	SFS EN 1995-1-1 - 6.3.2(1) (6.27)
Instability factor	$k_{c.y.c} := \dfrac{1}{k_{y.c} + \sqrt{{k_{y.c}}^2 - {\lambda_{rel.y.c}}^2}} = 0.956$	SFS EN 1995-1-1 - 6.3.2(1) (6.25)
Utilization ratio of compression resistance	$UR_{buckling.column.resistance} := \dfrac{\sigma_{c.0.d.c}}{f_{c.0.d.c} \cdot k_{c.y.c}} = 3.14\%$	SFS EN 1995-1-1 - 6.3.2(3) (6.23)
Condition to meet	$Result_{buckling.column.resistance} :=$ if $UR_{buckling.column.resistance} \leq 1$ "Okay" else "Not Okay"	
	$Result_{buckling.column.resistance} =$ "Okay"	

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Connections for Rafter and Ties

Maximum axial force	$F := 22.310\ kN$	
Thickness of the timber side member	$t_1 := 50\ mm$	
Thickness of the timber middle member	$t_2 := 150\ mm$	
Total penetration depth for the nail	$t := 100\ mm$	
Bolt diameter (mm) - pre-drilled hole	$d_b := 16$	
Nail diameter (mm) - no pre-drilled hole	$d_n := 4$	
Ultimate tensile strength of bolt (MPa)	$f_{ub} := 800$	
Ultimate tensile strength of nail (MPa)	$f_{un} := 600$	
Characteristic density of wood	$\rho_k := 350$	

Strength parameters for the bolt

The yield moment of the bolt	$M_{y.Rk.b} := \left(0.3 \cdot f_{ub} \cdot {d_b}^{2.6}\right) \cdot 1 \cdot N \cdot mm = 324.28\ N \cdot m$	SFS EN 1995-1-1 - 8.5.1.1(1) (8.30)
Embeded strength parallel to grain direction	$f_{h.0.k.b} := \left(\left(0.082 \cdot \left(1 - 0.01 \cdot d_b\right)\right) \cdot \rho_k\right) \cdot 1 \cdot MPa = 24.11\ MPa$	SFS EN 1995-1-1 - 8.5.1.1(2) (8.32)

Shear capacity for the bolt

Area of washer	$D_{washer} := 68\ mm$	
Area of the washer	$A_{s.washer} := \pi \cdot \dfrac{\left({D_{washer}}^2 - {d_b}^2\right)}{4} = \left(3.43 \cdot 10^3\right)\ mm^2$	
Widthdrawal capacity of a bolt	$F_{ax.Rk.b} := 3 \cdot f_{c.90.k} \cdot A_{s.washer} = 25.73\ kN$	SFS EN 1995-1-1 - 8.5.2(2)
Characteristic embedment strength	$f_{h.1.k.b} := f_{h.0.k.b} = 24.11\ MPa$	SFS EN 1995-1-1 - 8.2.2(1)
Characteristic embedment strength	$f_{h.2.k.b} := f_{h.0.k.b} = 24.11\ MPa$	SFS EN 1995-1-1 - 8.2.2(1)
Embeded strength ratio	$\beta_{s.b} := \dfrac{f_{h.2.k.b}}{f_{h.1.k.b}} = 1$	SFS EN 1995-1-1 - 8.2.2(1) (8.8)

ALL BELOW -> SFS EN 1995-1-1 - 8.2.2(1) (8.7)

Shear capacity - double shear - mode g	$F_{v.Rk.g.b} := f_{h.1.k.b} \cdot t_1 \cdot d_b = 19.29\ kN$
Shear capacity - double shear - mode h	$F_{v.Rk.h.b} := 0.5 \cdot f_{h.2.k.b} \cdot t_2 \cdot d_b = 28.93\ kN$
Shear capacity - double shear - mode j	$F_{v.Rk.j.b} := 1.05 \cdot \dfrac{f_{h.1.k.b} \cdot t_1 \cdot d_b}{2 + \beta_{s.b}} \cdot \left(\sqrt{2 \cdot \beta_{s.b} \cdot \left(1 + \beta_{s.b}\right) + \dfrac{4 \cdot \beta_{s.b} \cdot \left(2 + \beta_{s.b}\right) \cdot M_{y.Rk.b}}{f_{h.1.k.b} \cdot {t_1}^2 \cdot d_b}} - \beta_{s.b}\right) + \dfrac{F_{ax.Rk.b}}{4} = 24.34\ kN$
Shear capacity - double shear - mode k	$F_{v.Rk.k.b} := 1.15 \cdot \sqrt{\dfrac{2 \cdot \beta_{s.b}}{1 + \beta_{s.b}}} \cdot \sqrt{2 \cdot M_{y.Rk.b} \cdot f_{h.1.k.b} \cdot d_b} + \dfrac{F_{ax.Rk.b}}{4} = 24.62\ kN$
Shear capacity per shear plane	$F_{v.Rk.b} := min\left(F_{v.Rk.g.b}, F_{v.Rk.h.b}, F_{v.Rk.j.b}, F_{v.Rk.k.b}\right) = 19.29\ kN$

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Strength parameters for the nail

The yield moment of the nail $M_{y.Rk.n} := \left(0.3 \cdot f_{un} \cdot d_n^{\ 2.6}\right) \cdot 1 \cdot N \cdot mm = 6.62\ N \cdot m$ SFS EN 1995-1-1 - 8.3.1.1(4) (8.14)

Embeded strength parallel to grain direction $f_{h.0.k.n} := \left(0.082 \cdot \rho_k\right) \cdot d_n^{\ -0.3} \cdot 1 \cdot MPa = 18.93\ MPa$ SFS EN 1995-1-1 - 8.3.1.1(5) (8.15)

Shear capacity for the nail

Characteristic pointside withdraval strength $f_{ax.k} := 20 \cdot 10^{-6} \cdot \rho_k^{\ 2} \cdot 1\ MPa = 2.45\ MPa$ SFS EN 1995-1-1 - 8.3.2(6) (8.25)

Characteristic headside pull-through strength $f_{head.k} := 70 \cdot 10^{-6} \cdot \rho_k^{\ 2} \cdot 1\ MPa = 8.58\ MPa$ SFS EN 1995-1-1 - 8.3.2(6) (8.26)

Pointside penetration length $t_{pen} := 50\ mm$ SFS EN 1995-1-1 - 8.3.2(4)

Nail head diameter $d_h := 8\ mm$ SFS EN 1995-1-1 - 8.3.2(4)

Widthdrawal capacity of a nail $F_{ax.Rk.n} := min\left(\begin{bmatrix} f_{ax.k} \cdot d_n \cdot t_{pen} \\ f_{ax.k} \cdot d_n \cdot t_1 + f_{head.k} \cdot d_h^{\ 2} \end{bmatrix}\right) = 0.49\ kN$ SFS EN 1995-1-1 - 8.3.2(4) (6.24)

Characteristic embedment strength $f_{h.1.k.n} := f_{h.0.k.n} = 18.93\ MPa$ SFS EN 1995-1-1 - 8.2.2(1)

Characteristic embedment strength $f_{h.2.k.n} := f_{h.0.k.n} = 18.93\ MPa$ SFS EN 1995-1-1 - 8.2.2(1)

Embeded strength ratio $\beta_{s.n} := \frac{f_{h.2.k.n}}{f_{h.1.k.n}} = 1$ SFS EN 1995-1-1 - 8.2.2(1) (8.8)

ALL BELOW -> SFS EN 1995-1-1 - 8.2.2(1) (8.6)

Shear capacity - single shear - mode a $F_{v.Rk.a.n} := f_{h.1.k.n} \cdot t_1 \cdot d_n = 3.79\ kN$

Shear capacity - single shear - mode b $F_{v.Rk.b.n} := f_{h.2.k.n} \cdot t_{pen} \cdot d_n = 3.79\ kN$

Shear capacity - single shear - mode c

$$F_{v.Rk.c.n} := \frac{f_{h.1.k.n} \cdot t_1 \cdot d_n}{1 + \beta_{s.n}} \cdot \left(\sqrt{\beta_{s.n} + 2 \cdot \beta_{s.n}^{\ 2} \cdot \left(1 + \frac{t_{pen}}{t_1} + \left(\frac{t_{pen}}{t_1}\right)^2\right) + \beta_{s.n}^{\ 3} \cdot \left(\frac{t_{pen}}{t_1}\right)^2} - \beta_{s.n} \cdot \left(1 + \frac{t_{pen}}{t_1}\right)\right) + \frac{F_{ax.Rk.n}}{4} = 1.69\ kN$$

Shear capacity - single shear - mode d

$$F_{v.Rk.d.n} := 1.05 \cdot \frac{f_{h.1.k.n} \cdot t_1 \cdot d_n}{2 + \beta_{s.n}} \cdot \left(\sqrt{2 \cdot \beta_{s.n} \cdot \left(1 + \beta_{s.n}\right) + \frac{4 \cdot \beta_{s.n} \cdot \left(2 + \beta_{s.n}\right) \cdot M_{y.Rk.n}}{f_{h.1.k.n} \cdot t_1^{\ 2} \cdot d_n}} - \beta_{s.n}\right) + \frac{F_{ax.Rk.n}}{4} = 2.57\ kN$$

Shear capacity - single shear - mode e

$$F_{v.Rk.e.n} := 1.05 \cdot \frac{f_{h.1.k.n} \cdot t_{pen} \cdot d_n}{2 + \beta_{s.n}} \cdot \left(\sqrt{2 \cdot \beta_{s.n} \cdot \left(1 + \beta_{s.n}\right) + \frac{4 \cdot \beta_{s.n} \cdot \left(1 + 2 \cdot \beta_{s.n}\right) \cdot M_{y.Rk.n}}{f_{h.1.k.n} \cdot t_{pen}^{\ 2} \cdot d_n}} - \beta_{s.n}\right) + \frac{F_{ax.Rk.n}}{4} = 2.57\ kN$$

Shear capacity - single shear - mode f $F_{v.Rk.f.n} := 1.15 \cdot \sqrt{\frac{2 \cdot \beta_{s.n}}{1 + \beta_{s.n}}} \cdot \sqrt{2 \cdot M_{y.Rk.n} \cdot f_{h.1.k.n} \cdot d_n} + \frac{F_{ax.Rk.n}}{4} = 1.27\ kN$

Shear capacity $F_{v.Rk.n} := min\left(F_{v.Rk.a.n}, F_{v.Rk.b.n}, F_{v.Rk.c.n}, F_{v.Rk.d.n}, F_{v.Rk.e.n}, F_{v.Rk.e.n}\right) = 1.69\ kN$

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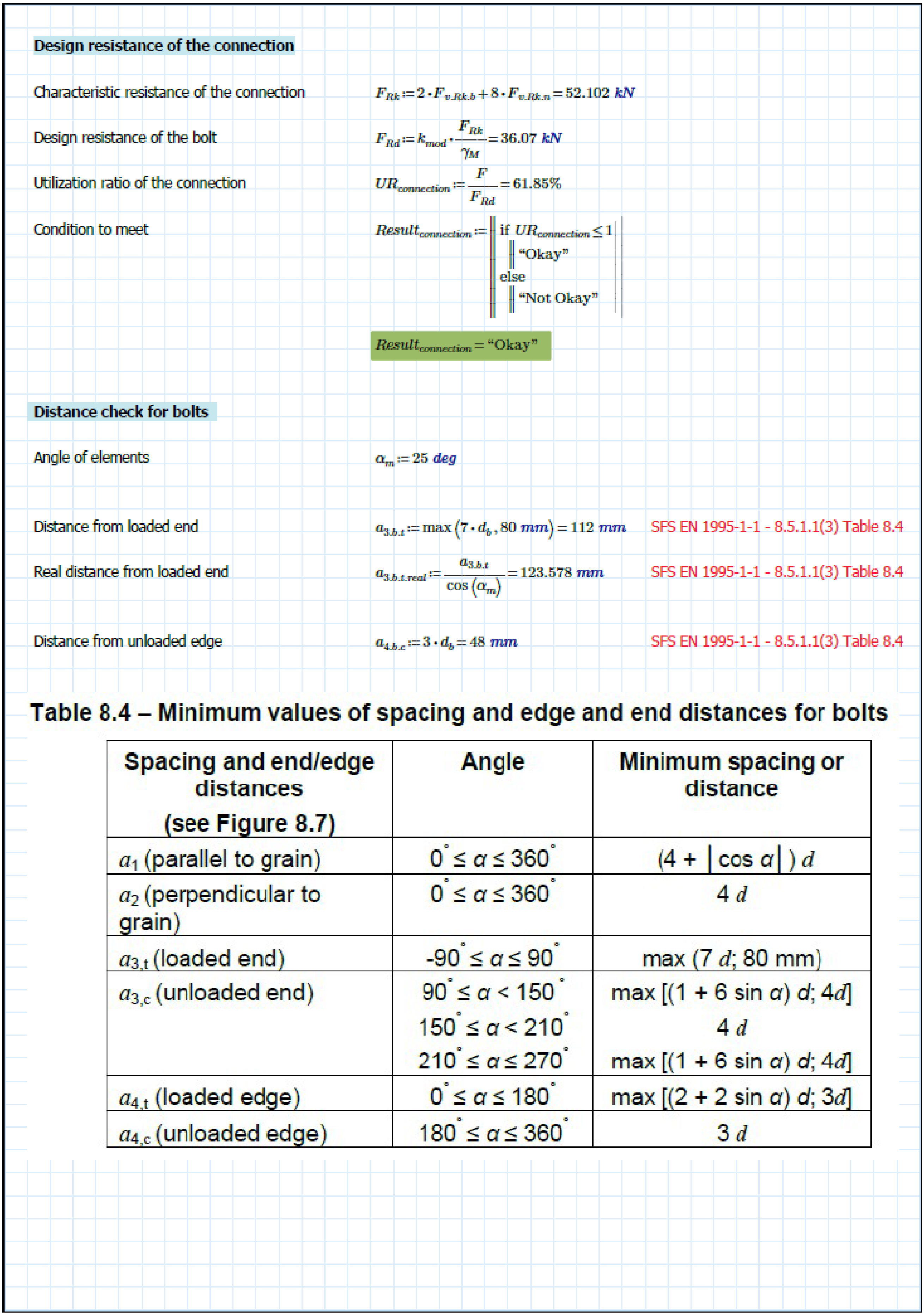

Design resistance of the connection

Characteristic resistance of the connection $F_{Rk} := 2 \cdot F_{v.Rk.b} + 8 \cdot F_{v.Rk.n} = 52.102\ kN$

Design resistance of the bolt $F_{Rd} := k_{mod} \cdot \frac{F_{Rk}}{\gamma_M} = 36.07\ kN$

Utilization ratio of the connection $UR_{connection} := \frac{F}{F_{Rd}} = 61.85\%$

Condition to meet $Result_{connection} :=$ if $UR_{connection} \le 1$ "Okay" else "Not Okay"

$Result_{connection} = \text{"Okay"}$

Distance check for bolts

Angle of elements $\alpha_m := 25\ deg$

Distance from loaded end $a_{3.b.t} := \max(7 \cdot d_b, 80\ mm) = 112\ mm$ SFS EN 1995-1-1 - 8.5.1.1(3) Table 8.4

Real distance from loaded end $a_{3.b.t.real} := \frac{a_{3.b.t}}{\cos(\alpha_m)} = 123.578\ mm$ SFS EN 1995-1-1 - 8.5.1.1(3) Table 8.4

Distance from unloaded edge $a_{4.b.c} := 3 \cdot d_b = 48\ mm$ SFS EN 1995-1-1 - 8.5.1.1(3) Table 8.4

Table 8.4 – Minimum values of spacing and edge and end distances for bolts

Spacing and end/edge distances (see Figure 8.7)	Angle	Minimum spacing or distance
a_1 (parallel to grain)	$0^\circ \le \alpha \le 360^\circ$	$(4 + \lvert\cos\alpha\rvert)\ d$
a_2 (perpendicular to grain)	$0^\circ \le \alpha \le 360^\circ$	$4\ d$
$a_{3,t}$ (loaded end)	$-90^\circ \le \alpha \le 90^\circ$	max (7 d; 80 mm)
$a_{3,c}$ (unloaded end)	$90^\circ \le \alpha < 150^\circ$ $150^\circ \le \alpha < 210^\circ$ $210^\circ \le \alpha \le 270^\circ$	max [(1 + 6 sin α) d; 4d] 4 d max [(1 + 6 sin α) d; 4d]
$a_{4,t}$ (loaded edge)	$0^\circ \le \alpha \le 180^\circ$	max [(2 + 2 sin α) d; 3d]
$a_{4,c}$ (unloaded edge)	$180^\circ \le \alpha \le 360^\circ$	$3\ d$

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Distance check for nails

Angle of elements $\alpha_m = 25\ deg$

Distance parallel to the grain $a_{1.n} := (5 + 7 \cdot \cos(\alpha_m)) \cdot d_n = 45.38\ mm$ SFS EN 1995-1-1 - 8.3.1.2(5) Table 8.2

Real distance parallel to the grain $a_{1.n.real} := \frac{a_{1.n}}{\cos(\alpha_m)} = 50.07\ mm$ SFS EN 1995-1-1 - 8.3.1.2(5) Table 8.2

Distance perpendicular to the grain $a_{2.n} := 5 \cdot d_n = 20\ mm$ SFS EN 1995-1-1 - 8.3.1.2(5) Table 8.2

Distance from loaded end $a_{3.n.t} := (10 + 5 \cdot \cos(\alpha_m)) \cdot d_n = 58.13\ mm$ SFS EN 1995-1-1 - 8.3.1.2(5) Table 8.2

Real distance from loaded end $a_{3.n.t.real} := \frac{a_{3.n.t}}{\cos(\alpha_m)} = 64.14\ mm$ SFS EN 1995-1-1 - 8.3.1.2(5) Table 8.2

Distance from unloaded edge $a_{4.n.c} := 5 \cdot d_n = 20\ mm$ SFS EN 1995-1-1 - 8.3.1.2(5) Table 8.2

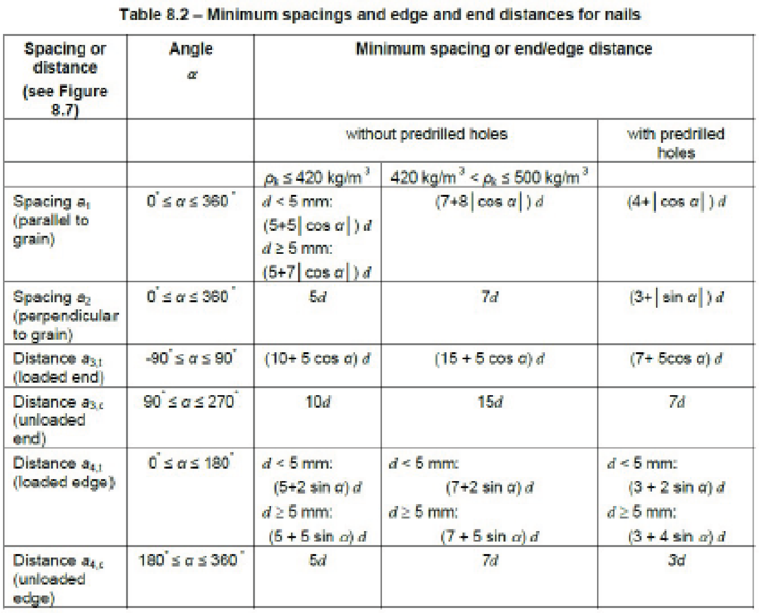
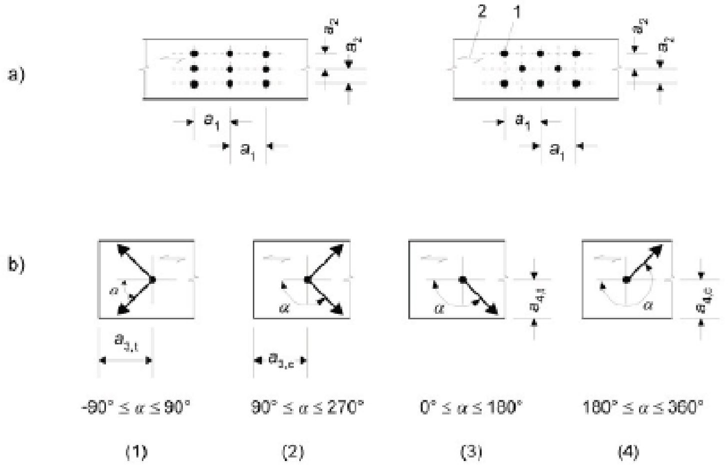


Table 8.2 – Minimum spacings and edge and end distances for nails

Spacing or distance (see Figure 8.7)	Angle α	Minimum spacing or end/edge distance		
		without predrilled holes		with predrilled holes
		$\rho_k \le 420$ kg/m^3	420 kg/m^3 $< \rho_k \le 500$ kg/m^3	
Spacing a_1 (parallel to grain)	$0^\circ \le \alpha \le 360^\circ$	$d < 5$ mm: $(5+5\|\cos\alpha\|)\,d$ $d \ge 5$ mm: $(5+7\|\cos\alpha\|)\,d$	$(7+8\|\cos\alpha\|)\,d$	$(4+\|\cos\alpha\|)\,d$
Spacing a_2 (perpendicular to grain)	$0^\circ \le \alpha \le 360^\circ$	$5d$	$7d$	$(3+\|\sin\alpha\|)\,d$
Distance $a_{3,t}$ (loaded end)	$-90^\circ \le \alpha \le 90^\circ$	$(10+5\cos\alpha)\,d$	$(15+5\cos\alpha)\,d$	$(7+5\cos\alpha)\,d$
Distance $a_{3,c}$ (unloaded end)	$90^\circ \le \alpha \le 270^\circ$	$10d$	$15d$	$7d$
Distance $a_{4,t}$ (loaded edge)	$0^\circ \le \alpha \le 180^\circ$	$d < 5$ mm: $(5+2\sin\alpha)\,d$ $d \ge 5$ mm: $(5+5\sin\alpha)\,d$	$d < 5$ mm: $(7+2\sin\alpha)\,d$ $d \ge 5$ mm: $(7+5\sin\alpha)\,d$	$d < 5$ mm: $(3+2\sin\alpha)\,d$ $d \ge 5$ mm: $(3+4\sin\alpha)\,d$
Distance $a_{4,c}$ (unloaded edge)	$180^\circ \le \alpha \le 360^\circ$	$5d$	$7d$	$3d$



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Design Check - Finland

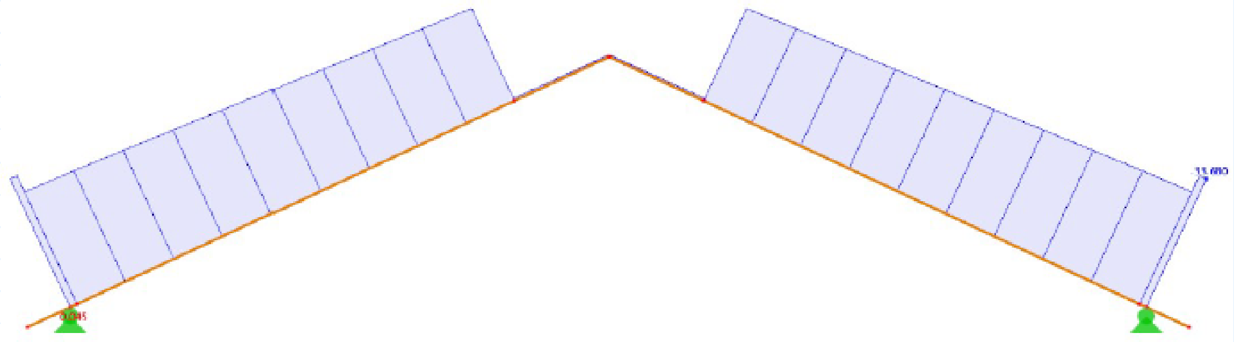
Design Check for Top Chord - Rafter (Values obtained for the most critical member)

Width of the section $b_r := 100\ mm$

Height of the section $h_r := 200\ mm$

Area of the section $A_{rafter} := b_r \cdot h_r = 20000\ mm^2$

Compression resistance



Maximum compression force $N_{Ed.c.max.rafter} := 33.680\ kN$ Dlubal RFEM Simulation

System strength $k_{sys} := 1$ SFS EN 1995-1-1 - 6.6(1)

Design compression strength parallel to the grain $f_{c.0.d.r} := f_{c.0.k} \cdot \frac{k_{mod}}{\gamma_M} \cdot k_{sys} = 14.538\ MPa$ SFS EN 1995-1-1 - 2.4.1(1) (2.14)

Design compression stress parallel to the grain $\sigma_{c.0.d.r} := \frac{N_{Ed.c.max.rafter}}{A_{rafter}} = 1.684\ MPa$

Utilization ratio of compression resistance $UR_{compression.rafter.resistance} := \frac{\sigma_{c.0.d.r}}{f_{c.0.d.r}} = 11.58\%$ SFS EN 1995-1-1 - 6.1.4(1) (6.2)

Condition to meet

```
Result_compression.rafter.resistance := | if UR_compression.rafter.resistance ≤ 1
                                        |   ‖ "Okay"
                                        | else
                                        |   ‖ "Not Okay"
```

$Result_{compression.rafter.resistance} = \text{“Okay”}$

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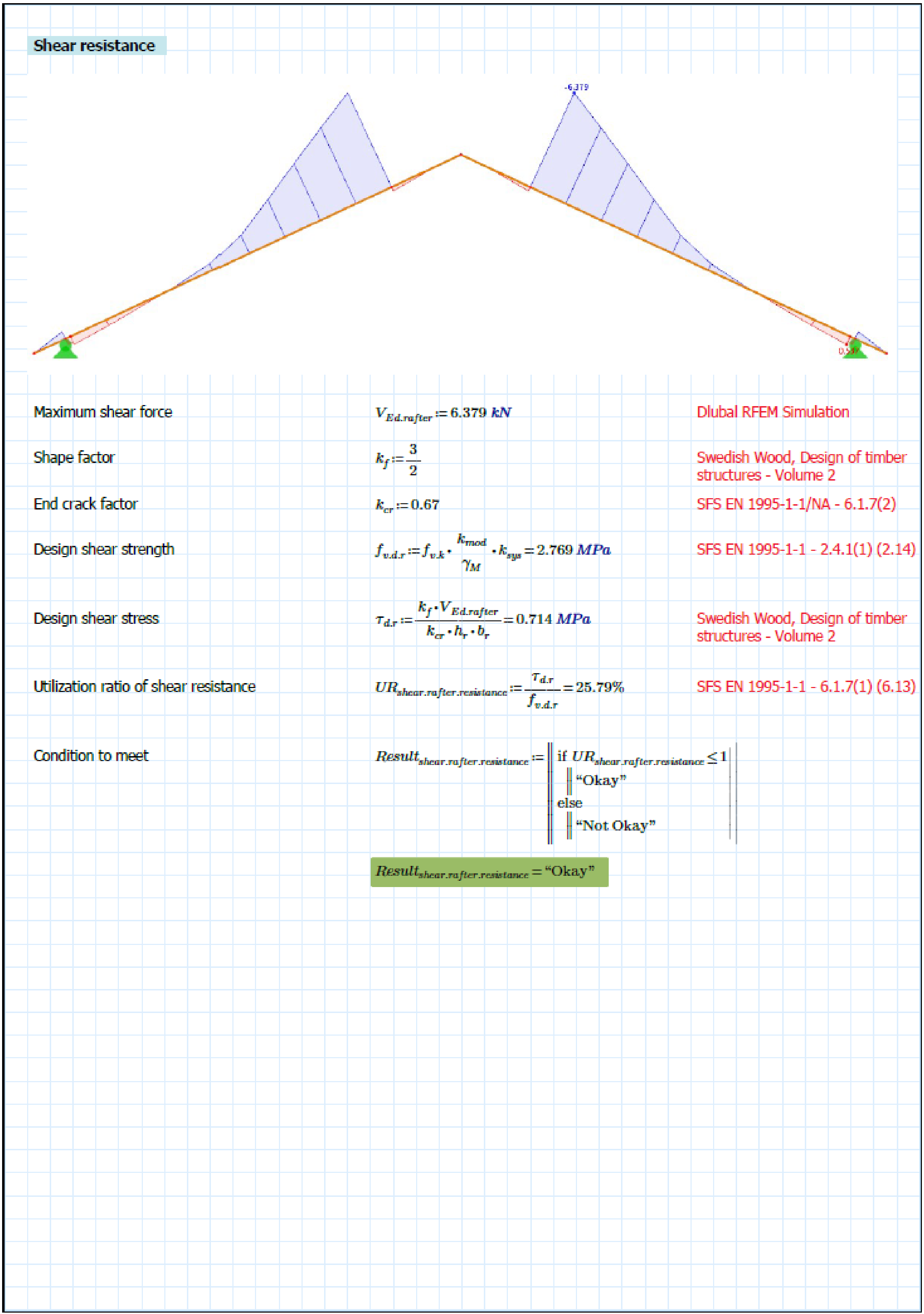

Shear resistance

Maximum shear force $V_{Ed.rafter} := 6.379\ kN$ Dlubal RFEM Simulation

Shape factor $k_f := \frac{3}{2}$ Swedish Wood, Design of timber structures - Volume 2

End crack factor $k_{cr} := 0.67$ SFS EN 1995-1-1/NA - 6.1.7(2)

Design shear strength $f_{v.d.r} := f_{v.k} \cdot \frac{k_{mod}}{\gamma_M} \cdot k_{sys} = 2.769\ MPa$ SFS EN 1995-1-1 - 2.4.1(1) (2.14)

Design shear stress $\tau_{d.r} := \frac{k_f \cdot V_{Ed.rafter}}{k_{cr} \cdot h_r \cdot b_r} = 0.714\ MPa$ Swedish Wood, Design of timber structures - Volume 2

Utilization ratio of shear resistance $UR_{shear.rafter.resistance} := \frac{\tau_{d.r}}{f_{v.d.r}} = 25.79\%$ SFS EN 1995-1-1 - 6.1.7(1) (6.13)

Condition to meet

```
Result_shear.rafter.resistance := if UR_shear.rafter.resistance ≤ 1
                                      "Okay"
                                   else
                                      "Not Okay"
```

$Result_{shear.rafter.resistance} = \text{"Okay"}$

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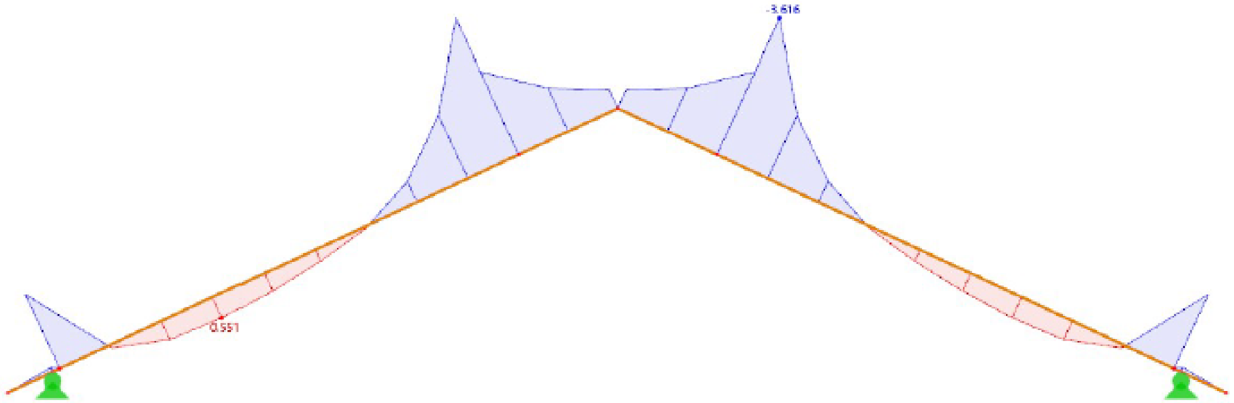
Bending resistance



Maximum bending moment	$M_{Ed.rafter} := 3.616\ kN \cdot m$	Dlubal RFEM Simulation
Re-distribution factor	$k_m := 0.7$	SFS EN 1995-1-1 - 6.1.6(2)
System strength	$k_{sys} = 1$	SFS EN 1995-1-1 - 6.6(1)
Elastic section modulus about y-y	$W_{y.r} := \frac{b_r \cdot {h_r}^2}{6} = \left(6.667 \cdot 10^5\right)\ mm^3$	
Design bending strength	$f_{m.d.r} := f_{m.k} \cdot \frac{k_{mod}}{\gamma_M} \cdot k_{sys} = 16.615\ MPa$	SFS EN 1995-1-1 - 2.4.1(1) (2.14)
Design bending stress	$\sigma_{m.d.r} := \frac{M_{Ed.rafter}}{W_{y.r}} = 5.424\ MPa$	
Utilization ratio of bending resistance	$UR_{bending.rafter.resistance} := \max\left(\frac{\sigma_{m.d.r}}{f_{m.d.r}}, k_m \cdot \frac{\sigma_{m.d.r}}{f_{m.d.r}}\right) = 32.64\%$	SFS EN 1995-1-1 - 6.1.6(1) (6.11/6.12)

Condition to meet

```
Result_bending.rafter.resistance := ‖ if UR_bending.rafter.resistance ≤ 1
                                    ‖   ‖ "Okay"
                                    ‖ else
                                    ‖   ‖ "Not Okay"
```

$Result_{bending.rafter.resistance} = \text{“Okay”}$

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Combined bending and axial compression

Re-distribution factor $k_m = 0.7$ SFS EN 1995-1-1 - 6.1.6(2)

Utilization ratio 1 to meet $UR_{b.c.1.r} := \left(\frac{\sigma_{c.0.d.r}}{f_{c.0.d.r}}\right)^2 + \frac{\sigma_{m.d.r}}{f_{m.d.r}} = 33.99\%$ SFS EN 1995-1-1 - 6.2.4(1) (6.19)

Condition to meet

```
Result_bending.compression.1.rafter.resistance := if UR_b.c.1.r ≤ 1
                                                     "Okay"
                                                  else
                                                     "Not Okay"
```

$Result_{bending.compression.1.rafter.resistance} = \text{"Okay"}$

Utilization ratio 2 to meet $UR_{b.c.2.r} := \left(\frac{\sigma_{c.0.d.r}}{f_{c.0.d.r}}\right)^2 + k_m \cdot \frac{\sigma_{m.d.r}}{f_{m.d.r}} = 24.19\%$ SFS EN 1995-1-1 - 6.2.4(1) (6.20)

Condition to meet

```
Result_bending.compression.2.rafter.resistance := if UR_b.c.2.r ≤ 1
                                                     "Okay"
                                                  else
                                                     "Not Okay"
```

$Result_{bending.compression.2.rafter.resistance} = \text{"Okay"}$

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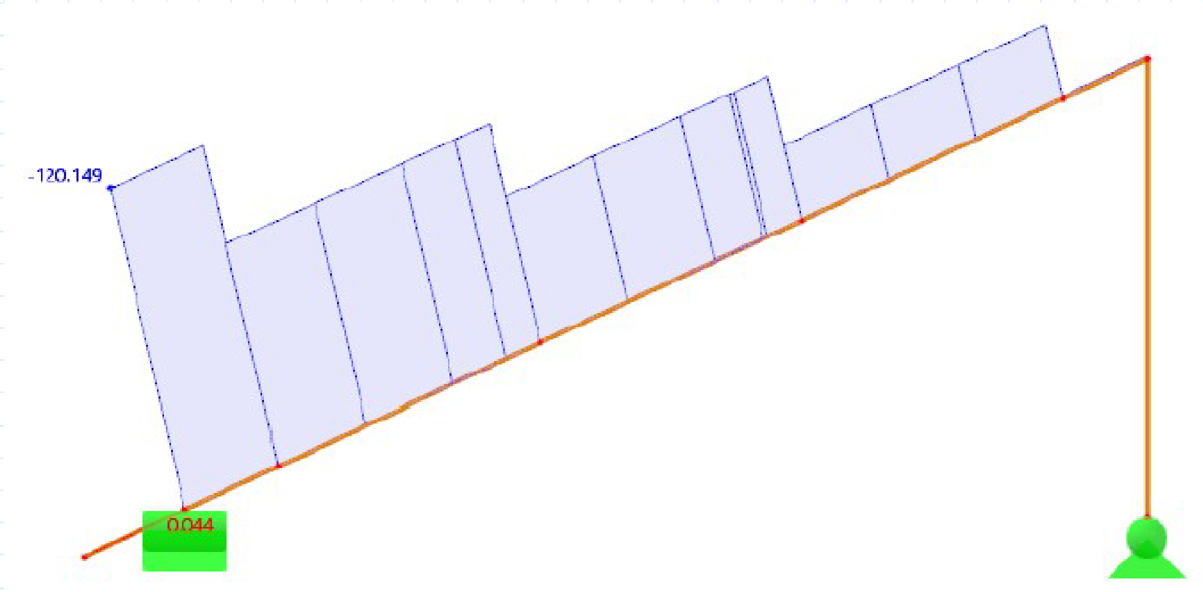
Design Check for Top Chord - Hip Rafter (Values obtained for the most critical member)

Width of the section	$b_h := 150\ mm$
Height of the section	$h_h := 200\ mm$
Area of the section	$A_{hiprafter} := b_h \cdot h_h = 30000\ mm^2$

Compression resistance



Maximum compression force	$N_{Ed.c.max.hiprafter} := 120.149\ kN$	Dlubal RFEM Simulation
System strength	$k_{sys} = 1$	SFS EN 1995-1-1 - 6.6(1)
Design compression strength parallel to the grain	$f_{c.0.d.h} := f_{c.0.k} \cdot \frac{k_{mod}}{\gamma_M} \cdot k_{sys} = 14.538\ MPa$	SFS EN 1995-1-1 - 2.4.1(1) (2.14)
Design compression stress parallel to the grain	$\sigma_{c.0.d.h} := \frac{N_{Ed.c.max.hiprafter}}{A_{hiprafter}} = 4.005\ MPa$	
Utilization ratio of compression resistance	$UR_{compression.hiprafter.resistance} := \frac{\sigma_{c.0.d.h}}{f_{c.0.d.h}} = 27.55\%$	SFS EN 1995-1-1 - 6.1.4(1) (6.2)
Condition to meet	$Result_{compression.hiprafter.resistance} := \left\| \begin{array}{l} \text{if } UR_{compression.hiprafter.resistance} \le 1 \\ \quad \left\| \text{“Okay”} \right. \\ \text{else} \\ \quad \left\| \text{“Not Okay”} \right. \end{array} \right.$	

$Result_{compression.hiprafter.resistance} = \text{“Okay”}$

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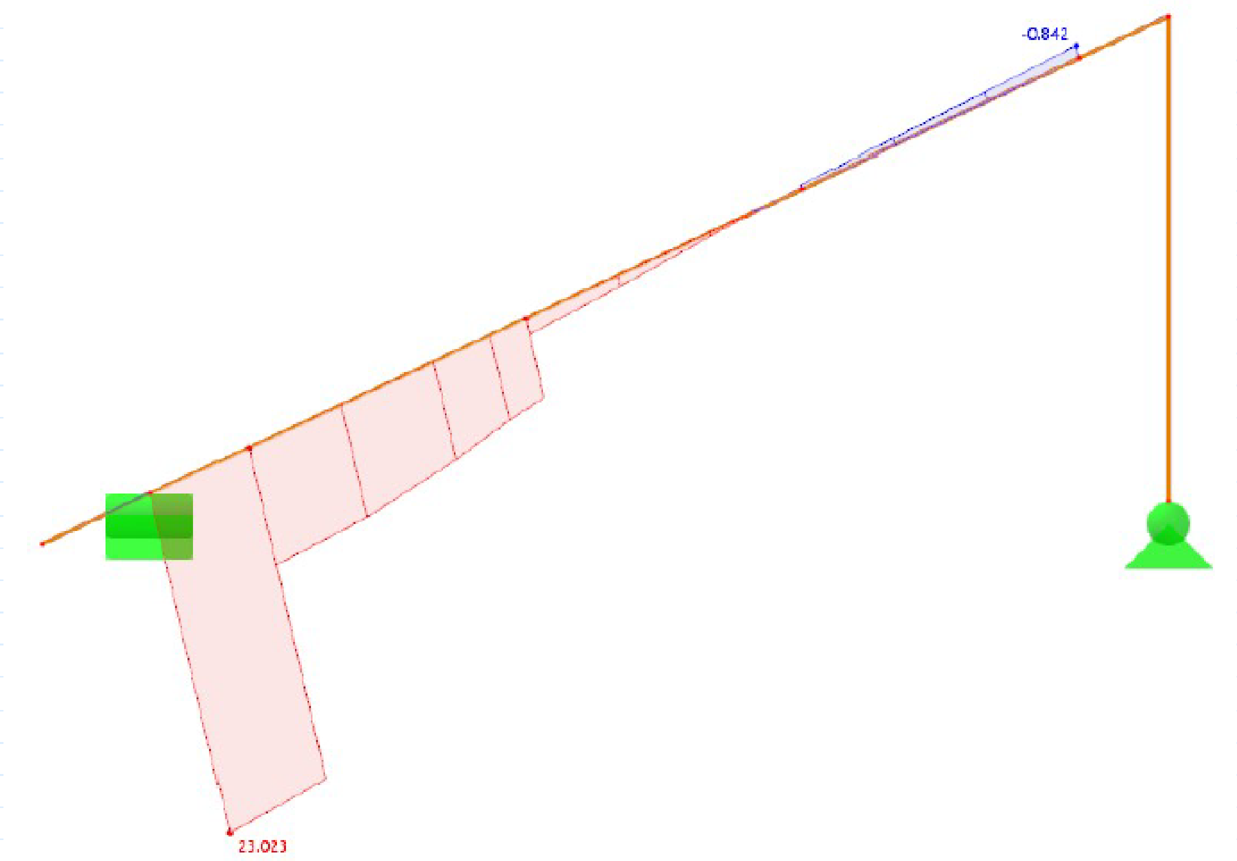
Shear resistance



Maximum shear force	$V_{Ed.hiprafter} := 23.023\ kN$	Dlubal RFEM Simulation
Shape factor	$k_f = 1.5$	Swedish Wood, Design of timber structures - Volume 2
End crack factor	$k_{cr} = 0.67$	SFS EN 1995-1-1/NA - 6.1.7(2)
Design shear strength	$f_{v.d.h} := f_{v.k} \cdot \frac{k_{mod}}{\gamma_M} \cdot k_{sys} = 2.769\ MPa$	SFS EN 1995-1-1 - 2.4.1(1) (2.14)
Design shear stress	$\tau_{d.h} := \frac{k_f \cdot V_{Ed.hiprafter}}{k_{cr} \cdot h_h \cdot b_h} = 1.718\ MPa$	Swedish Wood, Design of timber structures - Volume 2
Utilization ratio of shear resistance	$UR_{shear.hiprafter.resistance} := \frac{\tau_{d.h}}{f_{v.d.h}} = 62.04\%$	SFS EN 1995-1-1 - 6.1.7(1) (6.13)
Condition to meet	$Result_{shear.hiprafter.resistance} := \begin{array}{l} \text{if } UR_{shear.hiprafter.resistance} \le 1 \\ \quad \text{“Okay”} \\ \text{else} \\ \quad \text{“Not Okay”} \end{array}$	

$Result_{shear.hiprafter.resistance} = \text{“Okay”}$

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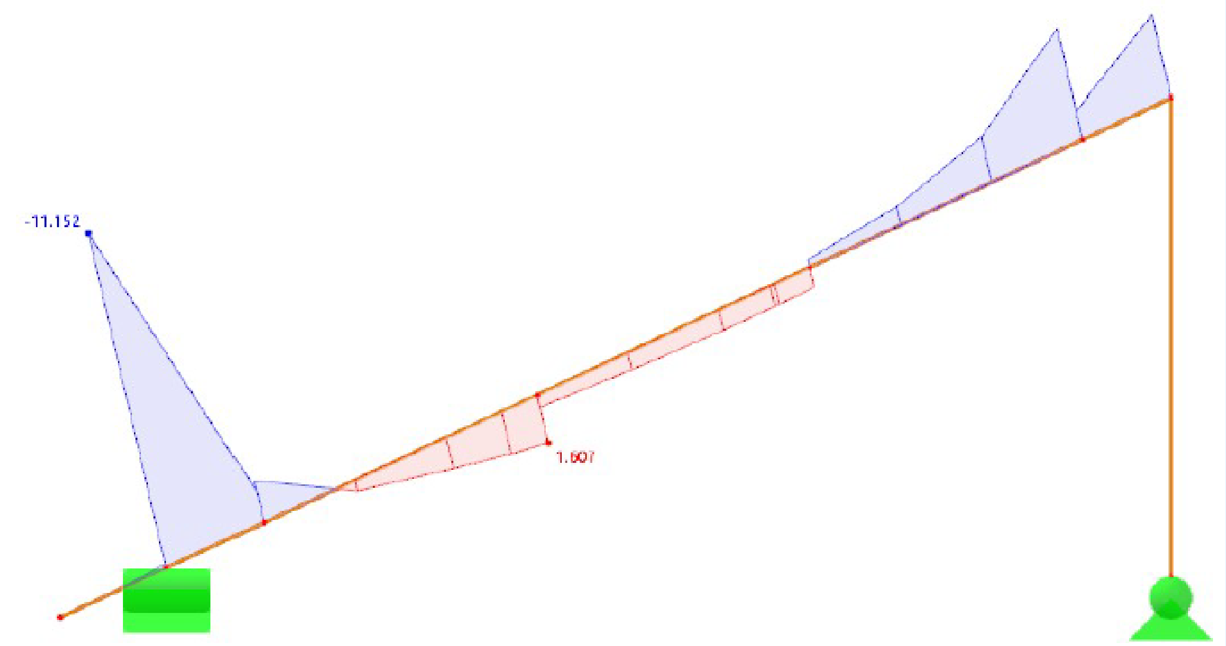
Bending resistance



Maximum bending moment	$M_{Ed.hiprafter} := 11.152\ kN \cdot m$	Dlubal RFEM Simulation
System strength	$k_{sys} = 1$	SFS EN 1995-1-1 - 6.6(1)
Re-distribution factor	$k_m = 0.7$	SFS EN 1995-1-1 - 6.1.6(2)
Elastic section modulus about y-y	$W_{y.h} := \frac{b_h \cdot h_h^{\ 2}}{6} = \left(1 \cdot 10^6\right)\ mm^3$	
Design bending strength	$f_{m.d.h} := f_{m.k} \cdot \frac{k_{mod}}{\gamma_M} \cdot k_{sys} = 16.615\ MPa$	SFS EN 1995-1-1 - 2.4.1(1) (2.14)
Design bending stress	$\sigma_{m.d.h} := \frac{M_{Ed.hiprafter}}{W_{y.h}} = 11.152\ MPa$	
Utilization ratio of bending resistance	$UR_{bending.hiprafter.resistance} := \max\left(\frac{\sigma_{m.d.h}}{f_{m.d.h}}, k_m \cdot \frac{\sigma_{m.d.h}}{f_{m.d.h}}\right) = 67.12\%$	SFS EN 1995-1-1 - 6.1.6(1) (6.11/6.12)
Condition to meet	$Result_{bending.hiprafter.resistance} := \begin{array}{l} \text{if } UR_{bending.hiprafter.resistance} \le 1 \\ \quad \text{“Okay”} \\ \text{else} \\ \quad \text{“Not Okay”} \end{array}$	

$Result_{bending.hiprafter.resistance} = \text{“Okay”}$

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Combined bending and axial compression

Re-distribution factor $k_m = 0.7$ SFS EN 1995-1-1 - 6.1.6(2)

Utilization ratio 1 to meet

$$UR_{b.c.1.h} := \left(\frac{\sigma_{c.0.d.h}}{f_{c.0.d.h}}\right)^2 + \frac{\sigma_{m.d.h}}{f_{m.d.h}} = 74.71\%$$

SFS EN 1995-1-1 - 6.2.4(1) (6.19)

Condition to meet

$$Result_{bending.compression.1.hiprafter.resistance} := \left\| \begin{array}{l} \text{if } UR_{b.c.1.h} \le 1 \\ \quad \left\| \text{“Okay”} \right. \\ \text{else} \\ \quad \left\| \text{“Not Okay”} \right. \end{array} \right.$$

$$Result_{bending.compression.1.hiprafter.resistance} = \text{“Okay”}$$

Utilization ratio 2 to meet

$$UR_{b.c.2.h} := \left(\frac{\sigma_{c.0.d.h}}{f_{c.0.d.h}}\right)^2 + k_m \cdot \frac{\sigma_{m.d.h}}{f_{m.d.h}} = 54.57\%$$

SFS EN 1995-1-1 - 6.2.4(1) (6.20)

Condition to meet

$$Result_{bending.compression.2.hiprafter.resistance} := \left\| \begin{array}{l} \text{if } UR_{b.c.2.h} \le 1 \\ \quad \left\| \text{“Okay”} \right. \\ \text{else} \\ \quad \left\| \text{“Not Okay”} \right. \end{array} \right.$$

$$Result_{bending.compression.2.hiprafter.resistance} = \text{“Okay”}$$

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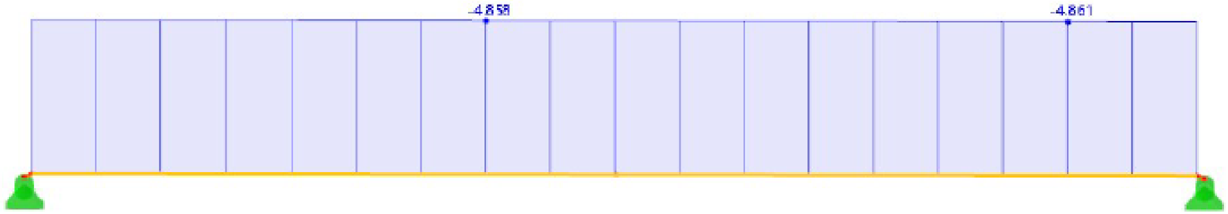
Design Check for Bottom Chord - Rafter Tie (Values obtained for the most critical member)

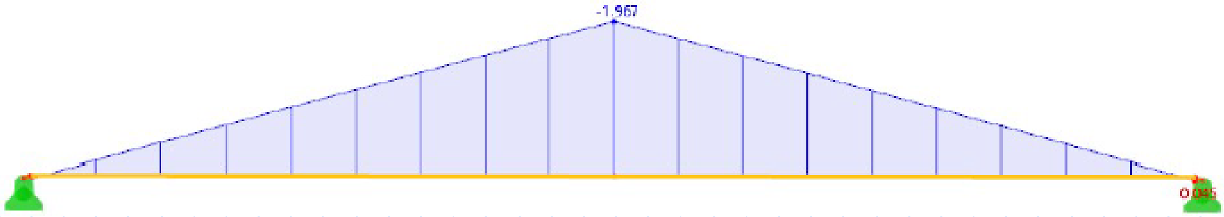
Width of the section	$b_t := 50\ mm$	
Height of the section	$h_t := 200\ mm$	
Area of the section	$A_{raftertie} := b_t \cdot h_t = 10000\ mm^2$	

Compression resistance



Maximum compression force	$N_{Ed.c.max.raftertie} := 4.861\ kN$	Dlubal RFEM Simulation
System strength	$k_{sys} = 1$	SFS EN 1995-1-1 - 6.6(1)
Design compression strength parallel to the grain	$f_{c.0.d.t} := f_{c.0.k} \cdot \dfrac{k_{mod}}{\gamma_M} \cdot k_{sys} = 14.538\ MPa$	SFS EN 1995-1-1 - 2.4.1(1) (2.14)
Design compression stress parallel to the grain	$\sigma_{c.0.d.t} := \dfrac{N_{Ed.c.max.raftertie}}{A_{raftertie}} = 0.486\ MPa$	
Utilization ratio of compression resistance	$UR_{compression.raftertie.resistance} := \dfrac{\sigma_{c.0.d.t}}{f_{c.0.d.t}} = 3.34\%$	SFS EN 1995-1-1 - 6.1.4(1) (6.2)
Condition to meet	$Result_{compression.raftertie.resistance} := \begin{cases} \text{if } UR_{compression.raftertie.resistance} \le 1 \\ \quad \text{"Okay"} \\ \text{else} \\ \quad \text{"Not Okay"} \end{cases}$	
	$Result_{compression.raftertie.resistance} = \text{"Okay"}$	

Shear resistance



Maximum shear force	$V_{Ed.raftertie} := 1.967\ kN$	Dlubal RFEM Simulation
Shape factor	$k_f = 1.5$	Swedish Wood, Design of timber structures - Volume 2
End crack factor	$k_{cr} = 0.67$	SFS EN 1995-1-1/NA - 6.1.7(2)

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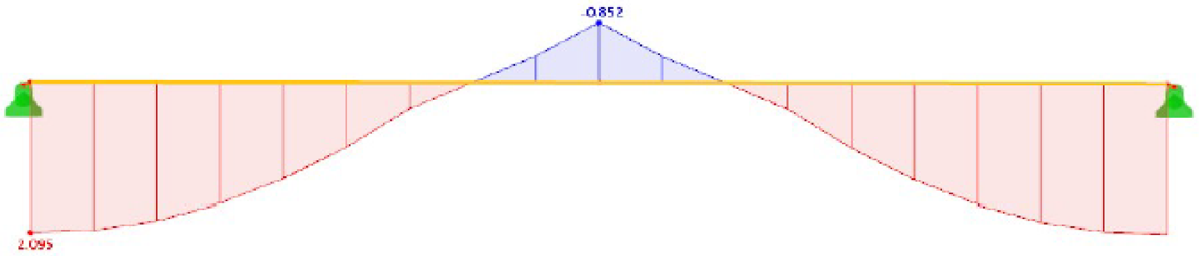
Design shear strength	$f_{v.d.t} := f_{v.k} \cdot \frac{k_{mod}}{\gamma_M} \cdot k_{sys} = 2.769\ MPa$	SFS EN 1995-1-1 - 2.4.1(1) (2.14)
Design shear stress	$\tau_{d.t} := \frac{k_f \cdot V_{Ed.raftertie}}{k_{cr} \cdot h_t \cdot b_t} = 0.44\ MPa$	Swedish Wood, Design of timber structures - Volume 2
Utilization ratio of shear resistance	$UR_{shear.raftertie.resistance} := \frac{\tau_{d.t}}{f_{v.d.t}} = 15.9\%$	SFS EN 1995-1-1 - 6.1.7(1) (6.13)
Condition to meet	$Result_{shear.raftertie.resistance} := \left\| \begin{array}{l} \text{if } UR_{shear.raftertie.resistance} \le 1 \\ \quad \| \text{“Okay”} \\ \text{else} \\ \quad \| \text{“Not Okay”} \end{array} \right\|$	
	$Result_{shear.raftertie.resistance} = \text{“Okay”}$	

Bending resistance



Maximum bending moment	$M_{Ed.raftertie} := 2.095\ kN \cdot m$	Dlubal RFEM Simulation
System strength	$k_{sys} = 1$	SFS EN 1995-1-1 - 6.6(1)
Re-distribution factor	$k_m = 0.7$	SFS EN 1995-1-1 - 6.1.6(2)
Elastic section modulus about y-y	$W_{y.t} := \frac{b_t \cdot h_t^{\ 2}}{6} = \left(3.333 \cdot 10^5\right)\ mm^3$	
Design bending strength	$f_{m.d.t} := f_{m.k} \cdot \frac{k_{mod}}{\gamma_M} \cdot k_{sys} = 16.615\ MPa$	SFS EN 1995-1-1 - 2.4.1(1) (2.14)
Design bending stress	$\sigma_{m.d.t} := \frac{M_{Ed.raftertie}}{W_{y.t}} = 6.285\ MPa$	
Utilization ratio of bending resistance	$UR_{bending.raftertie.resistance} := \max\left(\frac{\sigma_{m.d.t}}{f_{m.d.t}}, k_m \cdot \frac{\sigma_{m.d.t}}{f_{m.d.t}}\right) = 37.83\%$	SFS EN 1995-1-1 - 6.1.6(1) (6.11/6.12)
Condition to meet	$Result_{bending.raftertie.resistance} := \left\| \begin{array}{l} \text{if } UR_{bending.raftertie.resistance} \le 1 \\ \quad \| \text{“Okay”} \\ \text{else} \\ \quad \| \text{“Not Okay”} \end{array} \right\|$	
	$Result_{bending.raftertie.resistance} = \text{“Okay”}$	

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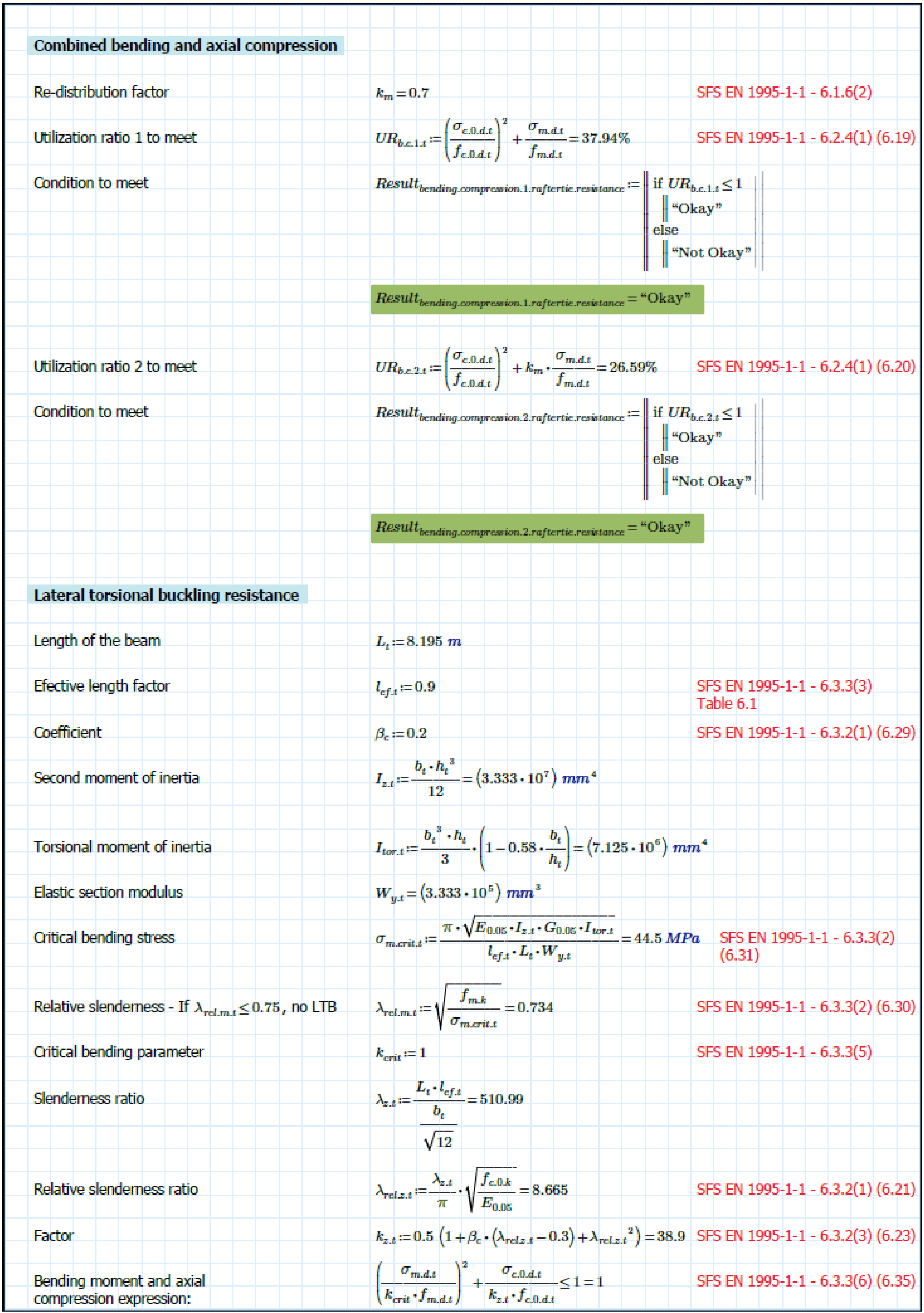

Combined bending and axial compression

Re-distribution factor	$k_m = 0.7$	SFS EN 1995-1-1 - 6.1.6(2)
Utilization ratio 1 to meet	$UR_{b.c.1.t} := \left(\frac{\sigma_{c.0.d.t}}{f_{c.0.d.t}}\right)^2 + \frac{\sigma_{m.d.t}}{f_{m.d.t}} = 37.94\%$	SFS EN 1995-1-1 - 6.2.4(1) (6.19)
Condition to meet	$Result_{bending.compression.1.raftertie.resistance} :=$ if $UR_{b.c.1.t} \le 1$ "Okay" else "Not Okay"	
	$Result_{bending.compression.1.raftertie.resistance} =$ "Okay"	
Utilization ratio 2 to meet	$UR_{b.c.2.t} := \left(\frac{\sigma_{c.0.d.t}}{f_{c.0.d.t}}\right)^2 + k_m \cdot \frac{\sigma_{m.d.t}}{f_{m.d.t}} = 26.59\%$	SFS EN 1995-1-1 - 6.2.4(1) (6.20)
Condition to meet	$Result_{bending.compression.2.raftertie.resistance} :=$ if $UR_{b.c.2.t} \le 1$ "Okay" else "Not Okay"	
	$Result_{bending.compression.2.raftertie.resistance} =$ "Okay"	

Lateral torsional buckling resistance

Length of the beam	$L_t := 8.195\ m$	
Efective length factor	$l_{ef.t} := 0.9$	SFS EN 1995-1-1 - 6.3.3(3) Table 6.1
Coefficient	$\beta_c := 0.2$	SFS EN 1995-1-1 - 6.3.2(1) (6.29)
Second moment of inertia	$I_{z.t} := \frac{b_t \cdot h_t^3}{12} = \left(3.333 \cdot 10^7\right)\ mm^4$	
Torsional moment of inertia	$I_{tor.t} := \frac{b_t^3 \cdot h_t}{3} \cdot \left(1 - 0.58 \cdot \frac{b_t}{h_t}\right) = \left(7.125 \cdot 10^6\right)\ mm^4$	
Elastic section modulus	$W_{y.t} = \left(3.333 \cdot 10^5\right)\ mm^3$	
Critical bending stress	$\sigma_{m.crit.t} := \frac{\pi \cdot \sqrt{E_{0.05} \cdot I_{z.t} \cdot G_{0.05} \cdot I_{tor.t}}}{l_{ef.t} \cdot L_t \cdot W_{y.t}} = 44.5\ MPa$	SFS EN 1995-1-1 - 6.3.3(2) (6.31)
Relative slenderness - If $\lambda_{rel.m.t} \le 0.75$, no LTB	$\lambda_{rel.m.t} := \sqrt{\frac{f_{m.k}}{\sigma_{m.crit.t}}} = 0.734$	SFS EN 1995-1-1 - 6.3.3(2) (6.30)
Critical bending parameter	$k_{crit} := 1$	SFS EN 1995-1-1 - 6.3.3(5)
Slenderness ratio	$\lambda_{z.t} := \frac{L_t \cdot l_{ef.t}}{\frac{b_t}{\sqrt{12}}} = 510.99$	
Relative slenderness ratio	$\lambda_{rel.z.t} := \frac{\lambda_{z.t}}{\pi} \cdot \sqrt{\frac{f_{c.0.k}}{E_{0.05}}} = 8.665$	SFS EN 1995-1-1 - 6.3.2(1) (6.21)
Factor	$k_{z.t} := 0.5\ \left(1 + \beta_c \cdot \left(\lambda_{rel.z.t} - 0.3\right) + \lambda_{rel.z.t}^2\right) = 38.9$	SFS EN 1995-1-1 - 6.3.2(3) (6.23)
Bending moment and axial compression expression:	$\left(\frac{\sigma_{m.d.t}}{k_{crit} \cdot f_{m.d.t}}\right)^2 + \frac{\sigma_{c.0.d.t}}{k_{z.t} \cdot f_{c.0.d.t}} \le 1 = 1$	SFS EN 1995-1-1 - 6.3.3(6) (6.35)

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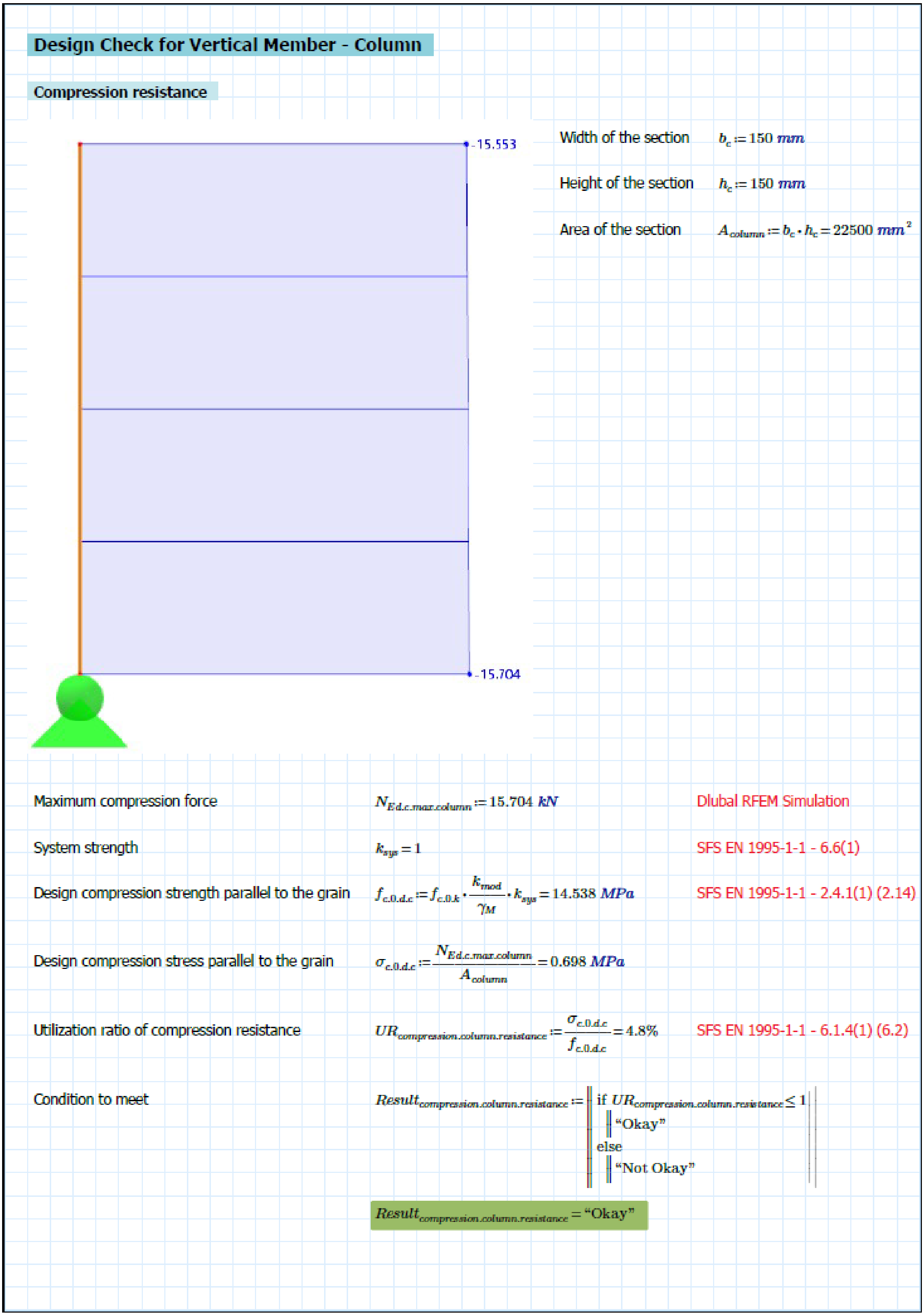

Design Check for Vertical Member - Column

Compression resistance

Width of the section $b_c := 150\ mm$

Height of the section $h_c := 150\ mm$

Area of the section $A_{column} := b_c \cdot h_c = 22500\ mm^2$

Maximum compression force	$N_{Ed.c.max.column} := 15.704\ kN$	Dlubal RFEM Simulation
System strength	$k_{sys} = 1$	SFS EN 1995-1-1 - 6.6(1)
Design compression strength parallel to the grain	$f_{c.0.d.c} := f_{c.0.k} \cdot \frac{k_{mod}}{\gamma_M} \cdot k_{sys} = 14.538\ MPa$	SFS EN 1995-1-1 - 2.4.1(1) (2.14)
Design compression stress parallel to the grain	$\sigma_{c.0.d.c} := \frac{N_{Ed.c.max.column}}{A_{column}} = 0.698\ MPa$	
Utilization ratio of compression resistance	$UR_{compression.column.resistance} := \frac{\sigma_{c.0.d.c}}{f_{c.0.d.c}} = 4.8\%$	SFS EN 1995-1-1 - 6.1.4(1) (6.2)
Condition to meet	$Result_{compression.column.resistance} :=$ if $UR_{compression.column.resistance} \le 1$ "Okay" else "Not Okay"	

$Result_{compression.column.resistance} =$ "Okay"

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Buckling resistance

Buckling coefficient	$k := 1$	
Section length	$L_c := 1.225\ m$	
Curvature coefficient	$\beta_c = 0.2$	SFS EN 1995-1-1 - 6.3.2(1) (6.29)
Effective length	$L_{e.y.c} := k \cdot L_c = 1.225\ m$	
Slenderness ratio	$\lambda_{y.c} := \dfrac{L_{e.y.c}}{\dfrac{h_c}{\sqrt{12}}} = 28.29$	
Relative slenderness ratio	$\lambda_{rel.y.c} := \dfrac{\lambda_{y.c}}{\pi} \cdot \sqrt{\dfrac{f_{c.0.k}}{E_{0.05}}} = 0.48$	SFS EN 1995-1-1 - 6.3.2(1) (6.21)
Factor	$k_{y.c} := 0.5\left(1 + \beta_c \cdot \left(\lambda_{rel.y.c} - 0.3\right) + {\lambda_{rel.y.c}}^2\right) = 0.63$	SFS EN 1995-1-1 - 6.3.2(1) (6.27)
Instability factor	$k_{c.y.c} := \dfrac{1}{k_{y.c} + \sqrt{{k_{y.c}}^2 - {\lambda_{rel.y.c}}^2}} = 0.956$	SFS EN 1995-1-1 - 6.3.2(1) (6.25)
Utilization ratio of compression resistance	$UR_{buckling.column.resistance} := \dfrac{\sigma_{c.0.d.c}}{f_{c.0.d.c} \cdot k_{c.y.c}} = 5.02\%$	SFS EN 1995-1-1 - 6.3.2(3) (6.23)
Condition to meet	$Result_{buckling.column.resistance} := \left\Vert \begin{array}{l} \text{if } UR_{buckling.column.resistance} \le 1 \\ \quad \Vert \text{“Okay”} \\ \text{else} \\ \quad \Vert \text{“Not Okay”} \end{array} \right.$	
	$Result_{buckling.column.resistance} = \text{“Okay”}$	

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Connections for Rafter and Ties

Maximum axial force $F := 33.680\ kN$

Thickness of the timber side member $t_1 := 50\ mm$

Thickness of the timber middle member $t_2 := 150\ mm$

Total penetration depth for the nail $t := 100\ mm$

Bolt diameter (mm) - pre-drilled hole $d_b := 16$

Nail diameter (mm) - no pre-drilled hole $d_n := 4$

Ultimate tensile strength of bolt (MPa) $f_{ub} := 800$

Ultimate tensile strength of nail (MPa) $f_{un} := 600$

Characteristic density of wood $\rho_k := 350$

Strength parameters for the bolt

The yield moment of the bolt $M_{y.Rk.b} := \left(0.3 \cdot f_{ub} \cdot d_b^{\,2.6}\right) \cdot 1 \cdot N \cdot mm = 324.28\ N \cdot m$ SFS EN 1995-1-1 - 8.5.1.1(1) (8.30)

Embeded strength parallel to grain direction $f_{h.0.k.b} := \left(\left(0.082 \cdot \left(1 - 0.01 \cdot d_b\right)\right) \cdot \rho_k\right) \cdot 1 \cdot MPa = 24.11\ MPa$ SFS EN 1995-1-1 - 8.5.1.1(2) (8.32)

Shear capacity for the bolt

Area of washer $D_{washer} := 68\ mm$

Area of the washer $A_{s.washer} := \pi \cdot \frac{\left(D_{washer}^{\,2} - d_b^{\,2}\right)}{4} = \left(3.43 \cdot 10^3\right)\ mm^2$

Widthdrawal capacity of a bolt $F_{ax.Rk.b} := 3 \cdot f_{c.90.k} \cdot A_{s.washer} = 25.73\ kN$ SFS EN 1995-1-1 - 8.5.2(2)

Characteristic embedment strength $f_{h.1.k.b} := f_{h.0.k.b} = 24.11\ MPa$ SFS EN 1995-1-1 - 8.2.2(1)

Characteristic embedment strength $f_{h.2.k.b} := f_{h.0.k.b} = 24.11\ MPa$ SFS EN 1995-1-1 - 8.2.2(1)

Embeded strength ratio $\beta_{s.b} := \frac{f_{h.2.k.b}}{f_{h.1.k.b}} = 1$ SFS EN 1995-1-1 - 8.2.2(1) (8.8)

ALL BELOW -> SFS EN 1995-1-1 - 8.2.2(1) (8.7)

Shear capacity - double shear - mode g $F_{v.Rk.g.b} := f_{h.1.k.b} \cdot t_1 \cdot d_b = 19.29\ kN$

Shear capacity - double shear - mode h $F_{v.Rk.h.b} := 0.5 \cdot f_{h.2.k.b} \cdot t_2 \cdot d_b = 28.93\ kN$

Shear capacity - double shear - mode j

$$F_{v.Rk.j.b} := 1.05 \cdot \frac{f_{h.1.k.b} \cdot t_1 \cdot d_b}{2 + \beta_{s.b}} \cdot \left(\sqrt{2 \cdot \beta_{s.b} \cdot \left(1 + \beta_{s.b}\right) + \frac{4 \cdot \beta_{s.b} \cdot \left(2 + \beta_{s.b}\right) \cdot M_{y.Rk.b}}{f_{h.1.k.b} \cdot t_1^{\,2} \cdot d_b}} - \beta_{s.b}\right) + \frac{F_{ax.Rk.b}}{4} = 24.34\ kN$$

Shear capacity - double shear - mode k $F_{v.Rk.k.b} := 1.15 \cdot \sqrt{\frac{2 \cdot \beta_{s.b}}{1 + \beta_{s.b}}} \cdot \sqrt{2 \cdot M_{y.Rk.b} \cdot f_{h.1.k.b} \cdot d_b} + \frac{F_{ax.Rk.b}}{4} = 24.62\ kN$

Shear capacity per shear plane $F_{v.Rk.b} := min\left(F_{v.Rk.g.b}, F_{v.Rk.h.b}, F_{v.Rk.j.b}, F_{v.Rk.k.b}\right) = 19.29\ kN$

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Strength parameters for the nail

The yield moment of the nail

$$M_{y.Rk.n} := \left(0.3 \cdot f_{un} \cdot d_n^{2.6}\right) \cdot 1 \cdot N \cdot mm = 6.62\ N \cdot m$$

SFS EN 1995-1-1 - 8.3.1.1(4) (8.14)

Embeded strength parallel to grain direction

$$f_{h.0.k.n} := \left(0.082 \cdot \rho_k\right) \cdot d_n^{-0.3} \cdot 1 \cdot MPa = 18.93\ MPa$$

SFS EN 1995-1-1 - 8.3.1.1(5) (8.15)

Shear capacity for the nail

Characteristic pointside withdraval strength

$$f_{ax.k} := 20 \cdot 10^{-6} \cdot \rho_k^{2} \cdot 1\ MPa = 2.45\ MPa$$

SFS EN 1995-1-1 - 8.3.2(6) (8.25)

Characteristic headside pull-through strength

$$f_{head.k} := 70 \cdot 10^{-6} \cdot \rho_k^{2} \cdot 1\ MPa = 8.58\ MPa$$

SFS EN 1995-1-1 - 8.3.2(6) (8.26)

Pointside penetration length

$$t_{pen} := 50\ mm$$

SFS EN 1995-1-1 - 8.3.2(4)

Nail head diameter

$$d_h := 8\ mm$$

SFS EN 1995-1-1 - 8.3.2(4)

Widthdrawal capacity of a nail

$$F_{ax.Rk.n} := min\left(\begin{bmatrix} f_{ax.k} \cdot d_n \cdot t_{pen} \\ f_{ax.k} \cdot d_n \cdot t_1 + f_{head.k} \cdot d_h^{2} \end{bmatrix}\right) = 0.49\ kN$$

SFS EN 1995-1-1 - 8.3.2(4) (6.24)

Characteristic embedment strength

$$f_{h.1.k.n} := f_{h.0.k.n} = 18.93\ MPa$$

SFS EN 1995-1-1 - 8.2.2(1)

Characteristic embedment strength

$$f_{h.2.k.n} := f_{h.0.k.n} = 18.93\ MPa$$

SFS EN 1995-1-1 - 8.2.2(1)

Embeded strength ratio

$$\beta_{s.n} := \frac{f_{h.2.k.n}}{f_{h.1.k.n}} = 1$$

SFS EN 1995-1-1 - 8.2.2(1) (8.8)

ALL BELOW -> SFS EN 1995-1-1 - 8.2.2(1) (8.6)

Shear capacity - single shear - mode a

$$F_{v.Rk.a.n} := f_{h.1.k.n} \cdot t_1 \cdot d_n = 3.79\ kN$$

Shear capacity - single shear - mode b

$$F_{v.Rk.b.n} := f_{h.2.k.n} \cdot t_{pen} \cdot d_n = 3.79\ kN$$

Shear capacity - single shear - mode c

$$F_{v.Rk.c.n} := \frac{f_{h.1.k.n} \cdot t_1 \cdot d_n}{1 + \beta_{s.n}} \cdot \left(\sqrt{\beta_{s.n} + 2 \cdot \beta_{s.n}^{2} \cdot \left(1 + \frac{t_{pen}}{t_1} + \left(\frac{t_{pen}}{t_1}\right)^{2}\right) + \beta_{s.n}^{3} \cdot \left(\frac{t_{pen}}{t_1}\right)^{2}} - \beta_{s.n} \cdot \left(1 + \frac{t_{pen}}{t_1}\right)\right) + \frac{F_{ax.Rk.n}}{4} = 1.69\ kN$$

Shear capacity - single shear - mode d

$$F_{v.Rk.d.n} := 1.05 \cdot \frac{f_{h.1.k.n} \cdot t_1 \cdot d_n}{2 + \beta_{s.n}} \cdot \left(\sqrt{2 \cdot \beta_{s.n} \cdot \left(1 + \beta_{s.n}\right) + \frac{4 \cdot \beta_{s.n} \cdot \left(2 + \beta_{s.n}\right) \cdot M_{y.Rk.n}}{f_{h.1.k.n} \cdot t_1^{2} \cdot d_n}} - \beta_{s.n}\right) + \frac{F_{ax.Rk.n}}{4} = 2.57\ kN$$

Shear capacity - single shear - mode e

$$F_{v.Rk.e.n} := 1.05 \cdot \frac{f_{h.1.k.n} \cdot t_{pen} \cdot d_n}{2 + \beta_{s.n}} \cdot \left(\sqrt{2 \cdot \beta_{s.n} \cdot \left(1 + \beta_{s.n}\right) + \frac{4 \cdot \beta_{s.n} \cdot \left(1 + 2 \cdot \beta_{s.n}\right) \cdot M_{y.Rk.n}}{f_{h.1.k.n} \cdot t_{pen}^{2} \cdot d_n}} - \beta_{s.n}\right) + \frac{F_{ax.Rk.n}}{4} = 2.57\ kN$$

Shear capacity - single shear - mode f

$$F_{v.Rk.f.n} := 1.15 \cdot \sqrt{\frac{2 \cdot \beta_{s.n}}{1 + \beta_{s.n}}} \cdot \sqrt{2 \cdot M_{y.Rk.n} \cdot f_{h.1.k.n} \cdot d_n} + \frac{F_{ax.Rk.n}}{4} = 1.27\ kN$$

Shear capacity

$$F_{v.Rk.n} := min\left(F_{v.Rk.a.n}, F_{v.Rk.b.n}, F_{v.Rk.c.n}, F_{v.Rk.d.n}, F_{v.Rk.e.n}, F_{v.Rk.e.n}\right) = 1.69\ kN$$

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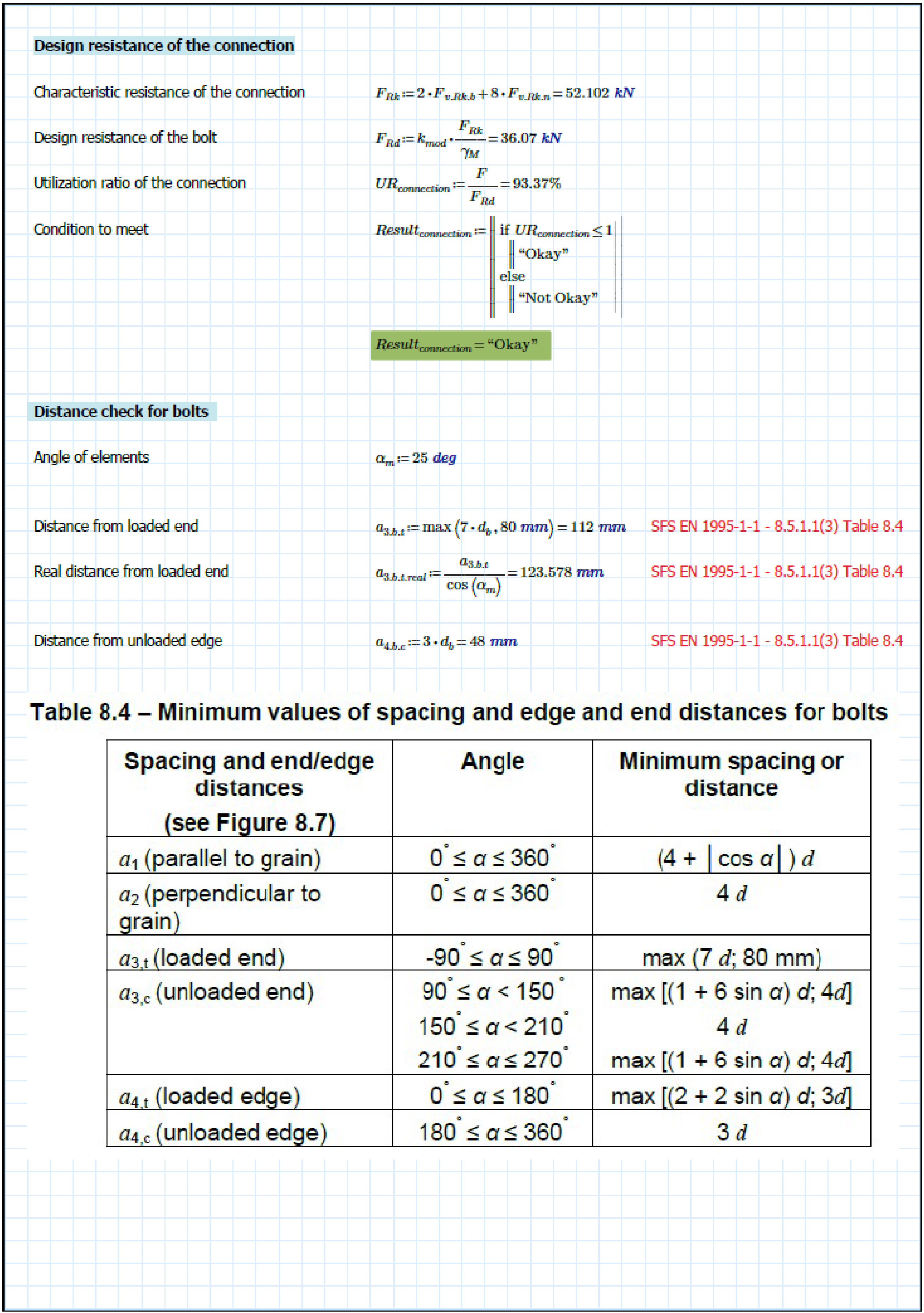

Design resistance of the connection

Characteristic resistance of the connection $F_{Rk} := 2 \cdot F_{v.Rk.b} + 8 \cdot F_{v.Rk.n} = 52.102\ kN$

Design resistance of the bolt $F_{Rd} := k_{mod} \cdot \dfrac{F_{Rk}}{\gamma_M} = 36.07\ kN$

Utilization ratio of the connection $UR_{connection} := \dfrac{F}{F_{Rd}} = 93.37\%$

Condition to meet

$$Result_{connection} := \left\| \begin{array}{l} \text{if } UR_{connection} \le 1 \\ \quad \left\| \text{“Okay”} \right. \\ \text{else} \\ \quad \left\| \text{“Not Okay”} \right. \end{array} \right.$$

$Result_{connection} = \text{“Okay”}$

Distance check for bolts

Angle of elements $\alpha_m := 25\ deg$

Distance from loaded end $a_{3.b.t} := \max\left(7 \cdot d_b, 80\ mm\right) = 112\ mm$ SFS EN 1995-1-1 - 8.5.1.1(3) Table 8.4

Real distance from loaded end $a_{3.b.t.real} := \dfrac{a_{3.b.t}}{\cos\left(\alpha_m\right)} = 123.578\ mm$ SFS EN 1995-1-1 - 8.5.1.1(3) Table 8.4

Distance from unloaded edge $a_{4.b.c} := 3 \cdot d_b = 48\ mm$ SFS EN 1995-1-1 - 8.5.1.1(3) Table 8.4

Table 8.4 – Minimum values of spacing and edge and end distances for bolts

Spacing and end/edge distances (see Figure 8.7)	Angle	Minimum spacing or distance
a_1 (parallel to grain)	$0^\circ \le \alpha \le 360^\circ$	$(4 + \lvert\cos \alpha\rvert)\ d$
a_2 (perpendicular to grain)	$0^\circ \le \alpha \le 360^\circ$	$4\ d$
$a_{3,t}$ (loaded end)	$-90^\circ \le \alpha \le 90^\circ$	max (7 d; 80 mm)
$a_{3,c}$ (unloaded end)	$90^\circ \le \alpha < 150^\circ$ $150^\circ \le \alpha < 210^\circ$ $210^\circ \le \alpha \le 270^\circ$	max [(1 + 6 sin α) d; 4d] 4 d max [(1 + 6 sin α) d; 4d]
$a_{4,t}$ (loaded edge)	$0^\circ \le \alpha \le 180^\circ$	max [(2 + 2 sin α) d; 3d]
$a_{4,c}$ (unloaded edge)	$180^\circ \le \alpha \le 360^\circ$	3 d

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Distance check for nails

Angle of elements $\alpha_m = 25 \, deg$

Distance parallel to the grain $a_{1.n} := \left(5 + 7 \cdot \cos\left(\alpha_m\right)\right) \cdot d_n = 45.38 \, mm$ SFS EN 1995-1-1 - 8.3.1.2(5) Table 8.2

Real distance parallel to the grain $a_{1.n.real} := \dfrac{a_{1.n}}{\cos\left(\alpha_m\right)} = 50.07 \, mm$ SFS EN 1995-1-1 - 8.3.1.2(5) Table 8.2

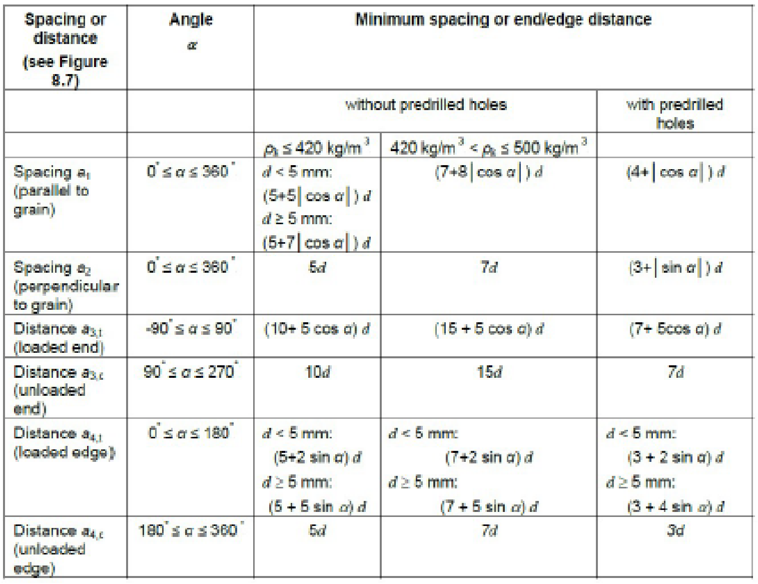
Distance perpendicular to the grain $a_{2.n} := 5 \cdot d_n = 20 \, mm$ SFS EN 1995-1-1 - 8.3.1.2(5) Table 8.2

Distance from loaded end $a_{3.n.t} := \left(10 + 5 \cdot \cos\left(\alpha_m\right)\right) \cdot d_n = 58.13 \, mm$ SFS EN 1995-1-1 - 8.3.1.2(5) Table 8.2

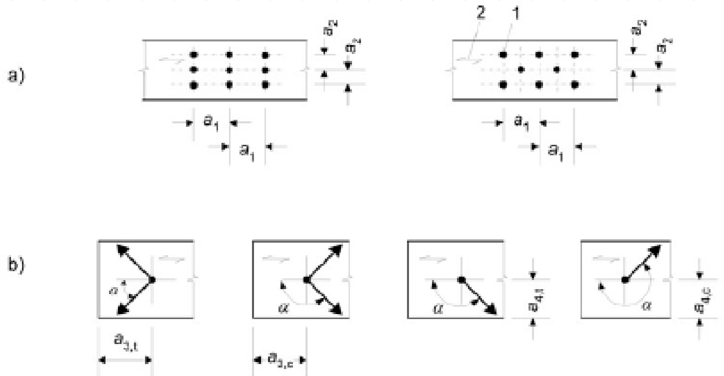
Real distance from loaded end $a_{3.n.t.real} := \dfrac{a_{3.n.t}}{\cos\left(\alpha_m\right)} = 64.14 \, mm$ SFS EN 1995-1-1 - 8.3.1.2(5) Table 8.2

Distance from unloaded edge $a_{4.n.c} := 5 \cdot d_n = 20 \, mm$ SFS EN 1995-1-1 - 8.3.1.2(5) Table 8.2

Table 8.2 – Minimum spacings and edge and end distances for nails



Spacing or distance (see Figure 8.7)	Angle α	Minimum spacing or end/edge distance		
		without predrilled holes		with predrilled holes
		$\rho_k \leq 420$ kg/m^3	420 kg/m^3 < $\rho_k \leq 500$ kg/m^3	
Spacing a_1 (parallel to grain)	$0^\circ \leq \alpha \leq 360^\circ$	d < 5 mm: $(5+5\lvert\cos\alpha\rvert)\,d$ $d \geq 5$ mm: $(5+7\lvert\cos\alpha\rvert)\,d$	$(7+8\lvert\cos\alpha\rvert)\,d$	$(4+\lvert\cos\alpha\rvert)\,d$
Spacing a_2 (perpendicular to grain)	$0^\circ \leq \alpha \leq 360^\circ$	$5d$	$7d$	$(3+\lvert\sin\alpha\rvert)\,d$
Distance $a_{3,t}$ (loaded end)	$-90^\circ \leq \alpha \leq 90^\circ$	$(10+5\cos\alpha)\,d$	$(15+5\cos\alpha)\,d$	$(7+5\cos\alpha)\,d$
Distance $a_{3,c}$ (unloaded end)	$90^\circ \leq \alpha \leq 270^\circ$	$10d$	$15d$	$7d$
Distance $a_{4,t}$ (loaded edge)	$0^\circ \leq \alpha \leq 180^\circ$	d < 5 mm: $(5+2\sin\alpha)\,d$ $d \geq 5$ mm: $(5+5\sin\alpha)\,d$	d < 5 mm: $(7+2\sin\alpha)\,d$ $d \geq 5$ mm: $(7+5\sin\alpha)\,d$	d < 5 mm: $(3+2\sin\alpha)\,d$ $d \geq 5$ mm: $(3+4\sin\alpha)\,d$
Distance $a_{4,c}$ (unloaded edge)	$180^\circ \leq \alpha \leq 360^\circ$	$5d$	$7d$	$3d$



$-90^\circ \leq \alpha \leq 90^\circ$ (1)

$90^\circ \leq \alpha \leq 270^\circ$ (2)

$0^\circ \leq \alpha \leq 180^\circ$ (3)

$180^\circ \leq \alpha \leq 360^\circ$ (4)

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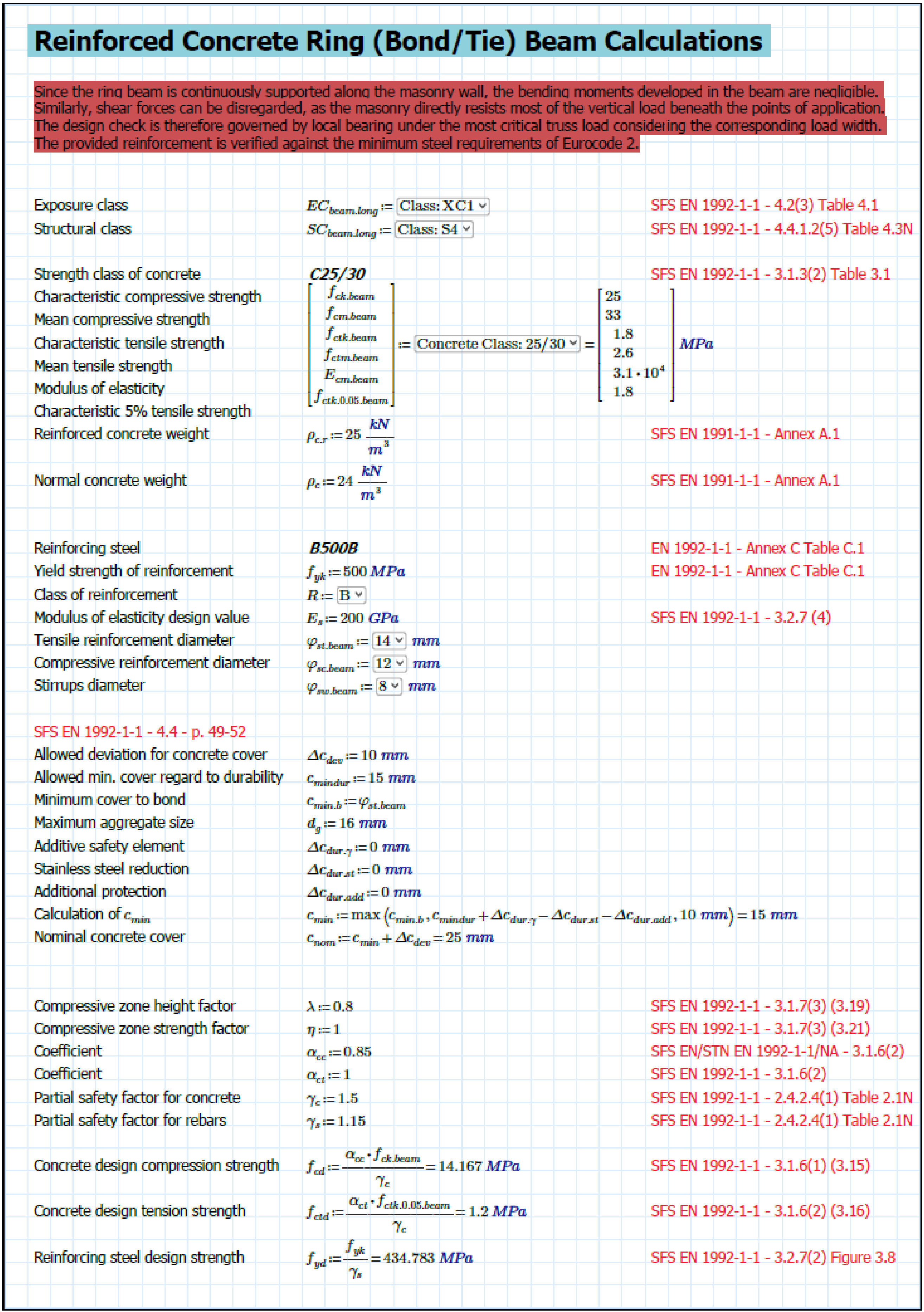

Reinforced Concrete Ring (Bond/Tie) Beam Calculations

Since the ring beam is continuously supported along the masonry wall, the bending moments developed in the beam are negligible. Similarly, shear forces can be disregarded, as the masonry directly resists most of the vertical load beneath the points of application. The design check is therefore governed by local bearing under the most critical truss load considering the corresponding load width. The provided reinforcement is verified against the minimum steel requirements of Eurocode 2.

Exposure class	$EC_{beam.long} := \text{Class: XC1}$ ⌄	SFS EN 1992-1-1 - 4.2(3) Table 4.1
Structural class	$SC_{beam.long} := \text{Class: S4}$ ⌄	SFS EN 1992-1-1 - 4.4.1.2(5) Table 4.3N
Strength class of concrete	***C25/30***	SFS EN 1992-1-1 - 3.1.3(2) Table 3.1
Characteristic compressive strength Mean compressive strength Characteristic tensile strength Mean tensile strength Modulus of elasticity Characteristic 5% tensile strength	$\begin{bmatrix} f_{ck.beam} \\ f_{cm.beam} \\ f_{ctk.beam} \\ f_{ctm.beam} \\ E_{cm.beam} \\ f_{ctk.0.05.beam} \end{bmatrix} := \text{Concrete Class: 25/30} = \begin{bmatrix} 25 \\ 33 \\ 1.8 \\ 2.6 \\ 3.1 \cdot 10^4 \\ 1.8 \end{bmatrix} MPa$	
Reinforced concrete weight	$\rho_{c.r} := 25 \ \frac{kN}{m^3}$	SFS EN 1991-1-1 - Annex A.1
Normal concrete weight	$\rho_c := 24 \ \frac{kN}{m^3}$	SFS EN 1991-1-1 - Annex A.1
Reinforcing steel	***B500B***	EN 1992-1-1 - Annex C Table C.1
Yield strength of reinforcement	$f_{yk} := 500 \ MPa$	EN 1992-1-1 - Annex C Table C.1
Class of reinforcement	$R := \text{B}$ ⌄	
Modulus of elasticity design value	$E_s := 200 \ GPa$	SFS EN 1992-1-1 - 3.2.7 (4)
Tensile reinforcement diameter	$\varphi_{st.beam} := 14$ ⌄ mm	
Compressive reinforcement diameter	$\varphi_{sc.beam} := 12$ ⌄ mm	
Stirrups diameter	$\varphi_{sw.beam} := 8$ ⌄ mm	
SFS EN 1992-1-1 - 4.4 - p. 49-52		
Allowed deviation for concrete cover	$\Delta c_{dev} := 10 \ mm$	
Allowed min. cover regard to durability	$c_{mindur} := 15 \ mm$	
Minimum cover to bond	$c_{min.b} := \varphi_{st.beam}$	
Maximum aggregate size	$d_g := 16 \ mm$	
Additive safety element	$\Delta c_{dur.\gamma} := 0 \ mm$	
Stainless steel reduction	$\Delta c_{dur.st} := 0 \ mm$	
Additional protection	$\Delta c_{dur.add} := 0 \ mm$	
Calculation of c_{min}	$c_{min} := \max\left(c_{min.b}, c_{mindur} + \Delta c_{dur.\gamma} - \Delta c_{dur.st} - \Delta c_{dur.add}, 10 \ mm\right) = 15 \ mm$	
Nominal concrete cover	$c_{nom} := c_{min} + \Delta c_{dev} = 25 \ mm$	
Compressive zone height factor	$\lambda := 0.8$	SFS EN 1992-1-1 - 3.1.7(3) (3.19)
Compressive zone strength factor	$\eta := 1$	SFS EN 1992-1-1 - 3.1.7(3) (3.21)
Coefficient	$\alpha_{cc} := 0.85$	SFS EN/STN EN 1992-1-1/NA - 3.1.6(2)
Coefficient	$\alpha_{ct} := 1$	SFS EN 1992-1-1 - 3.1.6(2)
Partial safety factor for concrete	$\gamma_c := 1.5$	SFS EN 1992-1-1 - 2.4.2.4(1) Table 2.1N
Partial safety factor for rebars	$\gamma_s := 1.15$	SFS EN 1992-1-1 - 2.4.2.4(1) Table 2.1N
Concrete design compression strength	$f_{cd} := \frac{\alpha_{cc} \cdot f_{ck.beam}}{\gamma_c} = 14.167 \ MPa$	SFS EN 1992-1-1 - 3.1.6(1) (3.15)
Concrete design tension strength	$f_{ctd} := \frac{\alpha_{ct} \cdot f_{ctk.0.05.beam}}{\gamma_c} = 1.2 \ MPa$	SFS EN 1992-1-1 - 3.1.6(2) (3.16)
Reinforcing steel design strength	$f_{yd} := \frac{f_{yk}}{\gamma_s} = 434.783 \ MPa$	SFS EN 1992-1-1 - 3.2.7(2) Figure 3.8

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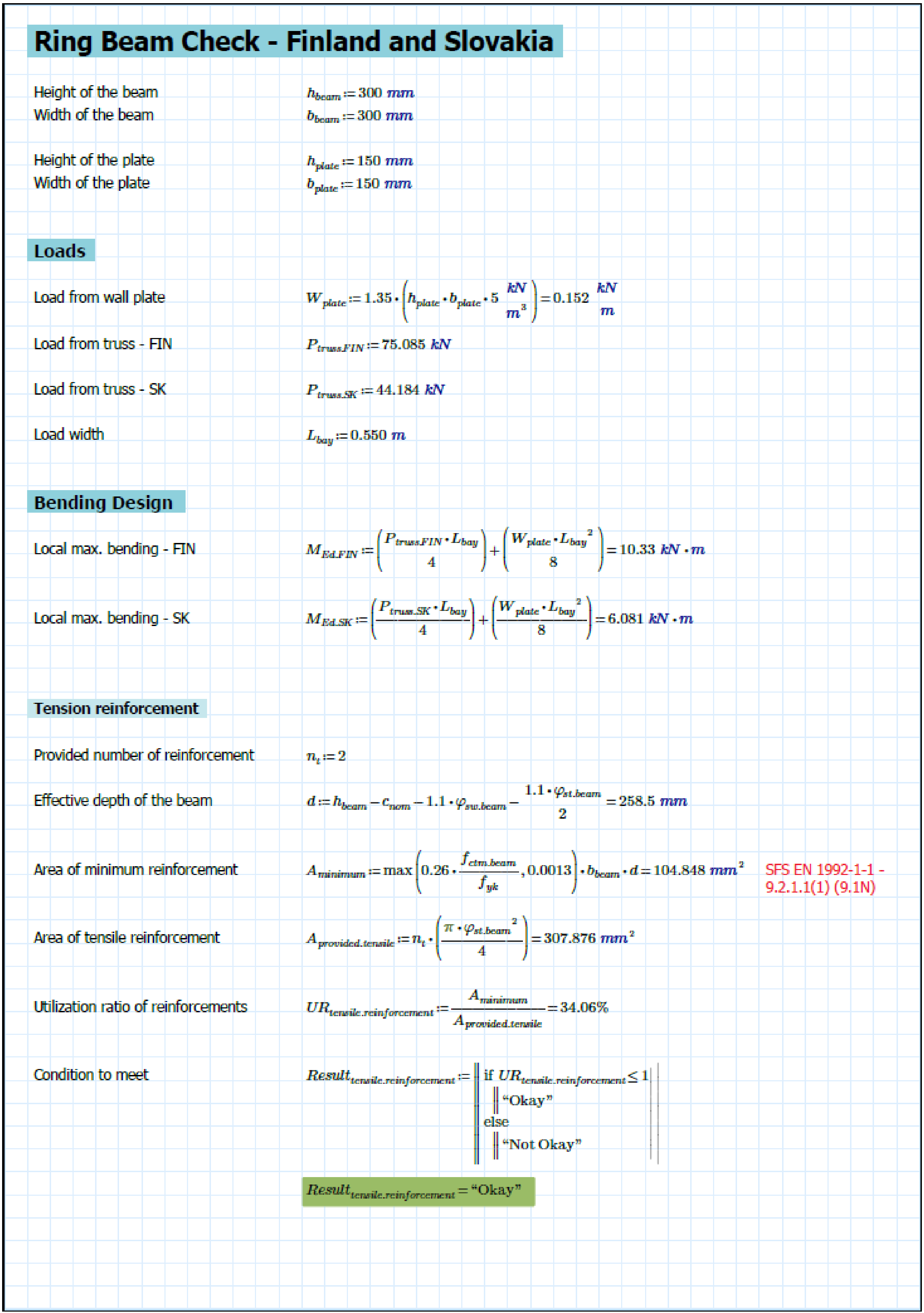

Ring Beam Check - Finland and Slovakia

Height of the beam $h_{beam} := 300\ mm$

Width of the beam $b_{beam} := 300\ mm$

Height of the plate $h_{plate} := 150\ mm$

Width of the plate $b_{plate} := 150\ mm$

Loads

Load from wall plate $W_{plate} := 1.35 \cdot \left(h_{plate} \cdot b_{plate} \cdot 5\ \frac{kN}{m^3} \right) = 0.152\ \frac{kN}{m}$

Load from truss - FIN $P_{truss.FIN} := 75.085\ kN$

Load from truss - SK $P_{truss.SK} := 44.184\ kN$

Load width $L_{bay} := 0.550\ m$

Bending Design

Local max. bending - FIN $M_{Ed.FIN} := \left(\frac{P_{truss.FIN} \cdot L_{bay}}{4} \right) + \left(\frac{W_{plate} \cdot L_{bay}^{\ 2}}{8} \right) = 10.33\ kN \cdot m$

Local max. bending - SK $M_{Ed.SK} := \left(\frac{P_{truss.SK} \cdot L_{bay}}{4} \right) + \left(\frac{W_{plate} \cdot L_{bay}^{\ 2}}{8} \right) = 6.081\ kN \cdot m$

Tension reinforcement

Provided number of reinforcement $n_t := 2$

Effective depth of the beam $d := h_{beam} - c_{nom} - 1.1 \cdot \varphi_{sw.beam} - \frac{1.1 \cdot \varphi_{st.beam}}{2} = 258.5\ mm$

Area of minimum reinforcement $A_{minimum} := \max \left(0.26 \cdot \frac{f_{ctm.beam}}{f_{yk}}, 0.0013 \right) \cdot b_{beam} \cdot d = 104.848\ mm^2$ SFS EN 1992-1-1 - 9.2.1.1(1) (9.1N)

Area of tensile reinforcement $A_{provided.tensile} := n_t \cdot \left(\frac{\pi \cdot \varphi_{st.beam}^{\ 2}}{4} \right) = 307.876\ mm^2$

Utilization ratio of reinforcements $UR_{tensile.reinforcement} := \frac{A_{minimum}}{A_{provided.tensile}} = 34.06\%$

Condition to meet $Result_{tensile.reinforcement} :=$ if $UR_{tensile.reinforcement} \le 1$
"Okay"
else
"Not Okay"

$Result_{tensile.reinforcement} =$ "Okay"

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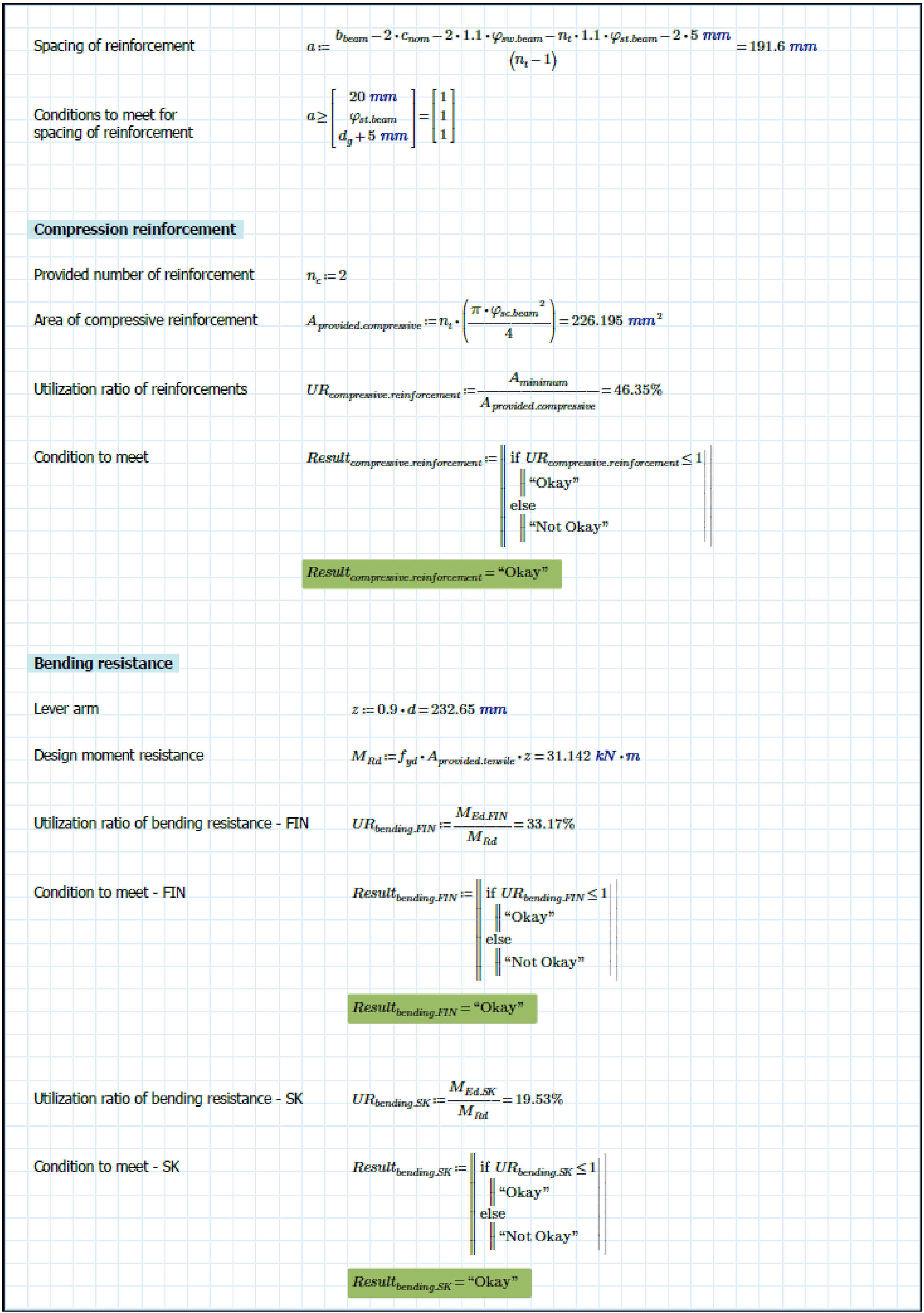

Spacing of reinforcement $a := \dfrac{b_{beam} - 2 \cdot c_{nom} - 2 \cdot 1.1 \cdot \varphi_{sw.beam} - n_t \cdot 1.1 \cdot \varphi_{st.beam} - 2 \cdot 5\ mm}{(n_t - 1)} = 191.6\ mm$

Conditions to meet for spacing of reinforcement $a \geq \begin{bmatrix} 20\ mm \\ \varphi_{st.beam} \\ d_g + 5\ mm \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$

Compression reinforcement

Provided number of reinforcement $n_c := 2$

Area of compressive reinforcement $A_{provided.compressive} := n_t \cdot \left(\dfrac{\pi \cdot \varphi_{sc.beam}^{\ 2}}{4} \right) = 226.195\ mm^2$

Utilization ratio of reinforcements $UR_{compressive.reinforcement} := \dfrac{A_{minimum}}{A_{provided.compressive}} = 46.35\%$

Condition to meet

$$Result_{compressive.reinforcement} := \left\| \begin{array}{l} \text{if } UR_{compressive.reinforcement} \leq 1 \\ \quad \| \text{“Okay”} \\ \text{else} \\ \quad \| \text{“Not Okay”} \end{array} \right.$$

$Result_{compressive.reinforcement} = \text{“Okay”}$

Bending resistance

Lever arm $z := 0.9 \cdot d = 232.65\ mm$

Design moment resistance $M_{Rd} := f_{yd} \cdot A_{provided.tensile} \cdot z = 31.142\ kN \cdot m$

Utilization ratio of bending resistance - FIN $UR_{bending.FIN} := \dfrac{M_{Ed.FIN}}{M_{Rd}} = 33.17\%$

Condition to meet - FIN

$$Result_{bending.FIN} := \left\| \begin{array}{l} \text{if } UR_{bending.FIN} \leq 1 \\ \quad \| \text{“Okay”} \\ \text{else} \\ \quad \| \text{“Not Okay”} \end{array} \right.$$

$Result_{bending.FIN} = \text{“Okay”}$

Utilization ratio of bending resistance - SK $UR_{bending.SK} := \dfrac{M_{Ed.SK}}{M_{Rd}} = 19.53\%$

Condition to meet - SK

$$Result_{bending.SK} := \left\| \begin{array}{l} \text{if } UR_{bending.SK} \leq 1 \\ \quad \| \text{“Okay”} \\ \text{else} \\ \quad \| \text{“Not Okay”} \end{array} \right.$$

$Result_{bending.SK} = \text{“Okay”}$

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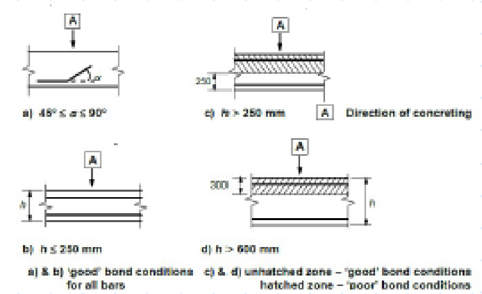
Anchorage for reinforcement

SFS EN 1992-1-1 - 8.4(p. 132-136)

Design stress of the bar $\sigma_{sd} := f_{yd} = 434.78\ MPa$

A coefficient related to the quality of the bond condition and the position of the bar during concreting $\eta_1 := 1$

A coefficient related to the bar diameter, good conditions - "Size of the rebar" $\le 32\ mm$ $\eta_2 := 1$



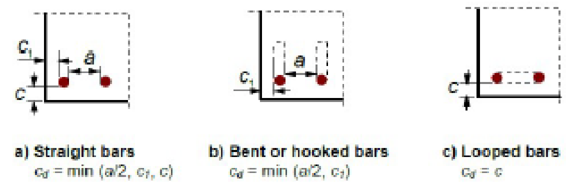
The design value of the ultimate bond stress $f_{bd} := 2.25 \cdot \eta_1 \cdot \eta_2 \cdot f_{ctd} = 2.7\ MPa$

The basic required anchorage length $l_{b.rqrd} := \dfrac{\varphi_{st.beam}}{4} \cdot \dfrac{\sigma_{sd}}{f_{bd}} = 563.61\ mm$

Value of c $c := c_{nom} - \dfrac{1}{2} \cdot \varphi_{sw.beam} = 21\ mm$

Value of c_1 $c_1 := c_{nom} - \dfrac{1}{2} \cdot \varphi_{sw.beam} = 21\ mm$

Value of c_d $c_d := min\left(\dfrac{a}{2}, c, c_1\right) = 21\ mm$



Coefficient for shape of bars - straight $\alpha_1 := 1$

Coefficient for concrete cover - straight $\alpha_2 := \max\left(0.7, min\left(1 - \dfrac{0.15 \cdot (c_d - \varphi_{st.beam})}{\varphi_{st.beam}}, 1\right)\right) = 0.925$

Simplified value $\alpha_3 := 1$

Simplified value $\alpha_4 := 0.7$

Simplified value $\alpha_5 := 1$

Minimum anchorage length $l_{b.min} := \max\left(0.3 \cdot l_{b.rqrd}, 10 \cdot \varphi_{st.beam}, 100\ mm\right) = 169.082\ mm$

Minimum required design anchorage length $l_{bd} := \max\left(\alpha_1 \cdot \alpha_2 \cdot \alpha_3 \cdot \alpha_4 \cdot \alpha_5 \cdot l_{b.rqrd}, l_{b.min}\right) = 364.94\ mm$

Design anchorage length $L_{bd} := \text{Ceil}\left(2 \cdot l_{bd}, 50\ mm\right) = 750\ mm$

Lap length for reinforcement

SFS EN 1992-1-1 - 8.7(p. 138-139)

Coefficient for lapped bars $\alpha_6 := 1.5$

Minimum lap length $l_{0.min} := \max\left(0.3 \cdot \alpha_6 \cdot l_{b.rqrd}, 15 \cdot \varphi_{st.beam}, 200\ mm\right) = 253.623\ mm$

Minimum required design lap length $l_0 := \max\left(\alpha_1 \cdot \alpha_2 \cdot \alpha_3 \cdot \alpha_4 \cdot \alpha_5 \cdot \alpha_6 \cdot l_{b.rqrd}, l_{0.min}\right) = 547.403\ mm$

Design lap length $L_0 := \text{Ceil}\left(l_0, 100\ mm\right) = 600\ mm$

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Shear Design

Local max. shear - FIN

$$V_{beam.local.FIN} := \left(\frac{P_{truss.FIN}}{2}\right) + \left(\frac{W_{plate} \cdot L_{bay}}{2}\right) = 37.58\ kN$$

Local max. shear - SK

$$V_{beam.local.SK} := \left(\frac{P_{truss.SK}}{2}\right) + \left(\frac{W_{plate} \cdot L_{bay}}{2}\right) = 22.13\ kN$$

Crushing strength of the concrete struts

Angle of concrete struts $22\ ° \le \theta \le 45\ °$

$$\theta_1 := 22\ deg$$

Crushing strength of the concrete struts

SFS EN 1992-1-1 - 6.2.3(3) (6.9)

$$V_{Rd.max.22} := \frac{0.36 \cdot f_{ck.beam} \cdot b_{beam} \cdot d \cdot \left(1 - \frac{f_{ck.beam}}{250\ MPa}\right)}{\left(\cot\left(\theta_1\right) + \tan\left(\theta_1\right)\right)} = 218.18\ kN$$

Angle of concrete struts $22\ ° \le \theta \le 45\ °$

$$\theta_2 := 45\ deg$$

Crushing strength of the concrete struts

SFS EN 1992-1-1 - 6.2.3(3) (6.9)

$$V_{Rd.max.45} := \frac{0.36 \cdot f_{ck.beam} \cdot b_{beam} \cdot d \cdot \left(1 - \frac{f_{ck.beam}}{250\ MPa}\right)}{\left(\cot\left(\theta_2\right) + \tan\left(\theta_2\right)\right)} = 314.08\ kN$$

Design crushing strength of the concrete struts

$$V_{Rd.max} := min\left(V_{Rd.max.22}, V_{Rd.max.45}\right) = 218.177\ kN$$

Utilization ratio of the crushing strength - FIN

$$UR_{cr.FIN} := \frac{V_{beam.local.FIN}}{V_{Rd.max}} = 17\%$$

Condition to meet - FIN

$$Result_{cr.FIN} := \left\| \begin{array}{l} \text{if } UR_{cr.FIN} \le 1 \\ \quad \left\| \text{“Okay”} \right. \\ \text{else} \\ \quad \left\| \text{“Not Okay”} \right. \end{array} \right.$$

$$Result_{cr.FIN} = \text{“Okay”}$$

Utilization ratio of the crushing strength - SK

$$UR_{cr.SK} := \frac{V_{beam.local.SK}}{V_{Rd.max}} = 10\%$$

Condition to meet - SK

$$Result_{cr.SK} := \left\| \begin{array}{l} \text{if } UR_{cr.SK} \le 1 \\ \quad \left\| \text{“Okay”} \right. \\ \text{else} \\ \quad \left\| \text{“Not Okay”} \right. \end{array} \right.$$

$$Result_{cr.SK} = \text{“Okay”}$$

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Shear resistance

Number of stirrups legs

$$n_{sw} := 2$$

Cross-sectional area of the shear reinforcement

$$A_{sw} := n_{sw} \cdot \pi \cdot \frac{\varphi_{sw.beam}^{2}}{4} = 100.53\ mm^{2}$$

Design spacing of stirrups

$$s_{sw} := 150\ mm$$

Shear resistance

$$V_{Rd.s} := \frac{A_{sw}}{s_{sw}} \cdot 0.78 \cdot f_{yk} \cdot d \cdot \cot\left(\theta_1\right) = 167\ kN$$

SFS EN 1992-1-1 - 6.2.3(3) (6.8)

Design shear resistance

$$V_{Rd.shear} := min\left(V_{Rd.max}, V_{Rd.s}\right) = 167.23\ kN$$

Utilization ratio for shear resistance
at support - FIN

$$UR_{shear.FIN} := \frac{V_{beam.local.FIN}}{V_{Rd.shear}} = 22.47\%$$

Condition to meet - FIN

$$Result_{shear.FIN} := \begin{array}{l} \text{if } UR_{shear.FIN} \le 1 \\ \quad \text{“Okay”} \\ \text{else} \\ \quad \text{“Not Okay”} \end{array}$$

$$Result_{shear.FIN} = \text{“Okay”}$$

Utilization ratio for shear resistance
at support - SK

$$UR_{shear.SK} := \frac{V_{beam.local.SK}}{V_{Rd.shear}} = 13.24\%$$

Condition to meet - SK

$$Result_{shear.SK} := \begin{array}{l} \text{if } UR_{shear.SK} \le 1 \\ \quad \text{“Okay”} \\ \text{else} \\ \quad \text{“Not Okay”} \end{array}$$

$$Result_{shear.SK} = \text{“Okay”}$$

Minimum shear reinforcement

Angle of the stirrups

$$\alpha_{sw} := 90\ deg$$

Shear reinforcement ratio

$$\rho_w := \frac{A_{sw}}{s_{sw} \cdot b_{beam} \cdot \sin\left(\alpha_{sw}\right)} = 0.002$$

SFS EN 1992-1-1 - 9.2.2(5) (9.4)

Minimum shear reinforcement ratio

$$\rho_{w.min} := \frac{0.08 \cdot \sqrt{\dfrac{f_{ck.beam}}{MPa}}}{\dfrac{f_{yk}}{MPa}} = 0.0008$$

SFS EN 1992-1-1 - 9.2.2(5) (9.5N)

Utilization ratio of the minimum shear
reinforcement

$$UR_{\rho w} := \frac{\rho_{w.min}}{\rho_w} = 35.81\%$$

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Condition to meet

$$Result_{pw} := \left\| \begin{array}{l} \text{if } UR_{pw} \le 1 \\ \quad \left\| \text{“Okay”} \right. \\ \text{else} \\ \quad \left\| \text{“Not Okay”} \right. \end{array} \right.$$

$$Result_{pw} = \text{“Okay”}$$

Maximum spacing

Maximum allowable longitudinal spacing $s_{l.max} := 0.75 \cdot d \cdot (1 + \cot(\alpha_{sw})) = 193.88\ mm$ SFS EN 1992-1-1 - 9.2.2(6) (9.6N)

Utilization ratio of longitudinal spacing $UR_{sl} := \frac{s_{sw}}{s_{l.max}} = 77.37\%$

Condition to meet

$$Result_{sl} := \left\| \begin{array}{l} \text{if } UR_{sl} \le 1 \\ \quad \left\| \text{“Okay”} \right. \\ \text{else} \\ \quad \left\| \text{“Not Okay”} \right. \end{array} \right.$$

$$Result_{sl} = \text{“Okay”}$$

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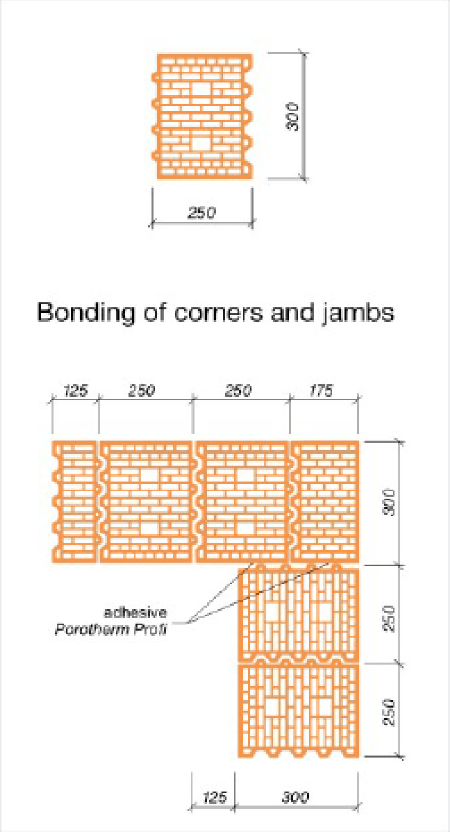
Masonry Wall Calculations

Masonry type	*CLAY*
Masonry class	*Class 2*
Masonry and mortar category	*Category A*
Masonry density	$\rho_m := 800\ \frac{kg}{m^3}$
Masonry length	$l_m := 250\ mm$
Masonry width	$w_m := 300\ mm$
Masonry height	$h_m := 249\ mm$
Mortar thickness	$t_{mo} := 1\ mm$
Wall thickness	$t_w := 300\ mm$
Wall width	$w_w := 1000\ mm$
Wall height	$h_w := 3000\ mm$
Masonry mean compressive strength (given by manufacturer)	$f_{b.o} := 12\ MPa$
Mortar compressive strength (given by manufacturer)	$f_m := 10\ MPa$
Height of the beam	$h_{beam} := 300\ mm$
Width of the beam	$b_{beam} := 300\ mm$
Height of the plate	$h_{plate} := 150\ mm$
Width of the plate	$b_{plate} := 150\ mm$

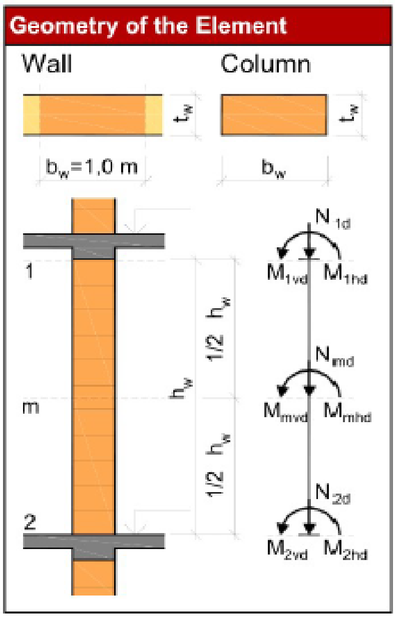


Bonding of corners and jambs

Wienerberger.sk

Porotherm 30 Profi P12 adhesive

Wienerberger.sk



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Ultimate Limit State (ULS) - Slovakia

Load from wall plate	$P_{plate} := 1.35 \cdot \left(h_{plate} \cdot b_{plate} \cdot 5 \frac{kN}{m^3}\right) = 0.152 \frac{kN}{m}$	
Load from ring beam	$P_{beam} := 1.35 \cdot \left(h_{beam} \cdot b_{beam} \cdot 25 \frac{kN}{m^3}\right) = 3.038 \frac{kN}{m}$	
Load from wind	$W_{wind} := 1.5 \cdot \left(0.507 \frac{kN}{m^2} \cdot 1\ m\right) = 0.761 \frac{kN}{m}$	
Self-weight of the masonry	$P_{masonry} := \rho_m \cdot g \cdot w_m \cdot 1\ m = 2.354 \frac{kN}{m}$	
Total load acting on top of the wall from truss	$P_{truss} := \frac{44.184\ kN}{w_w} = 44.184 \frac{kN}{m}$	
Vertical line load acting at the top of wall	$N_{1d} := \left(P_{plate} + P_{beam}\right) + P_{truss} = 47.373 \frac{kN}{m}$	
Bending moment acting at the top of wall and resulting from the eccentricity of horizontal loads	$M_{1hd} := \frac{\left(\frac{W_{wind} \cdot (0\ m)^2}{2}\right)}{w_w} = 0 \frac{kN \cdot m}{m}$	
Bending moment acting at the top of wall and resulting from the eccentricity of vertical loads	$M_{1vd} := 0 \frac{kN \cdot m}{m}$	
Vertical line load acting at the middle of wall height	$N_{md} := N_{1d} + \frac{P_{masonry} \cdot h_w \cdot 0.5}{w_w} = 50.904 \frac{kN}{m}$	
Bending moment acting at the middle of wall height and resulting from the eccentricity of horizontal loads	$M_{mhd} := \frac{\left(\frac{W_{wind} \cdot (1.5\ m)^2}{2}\right)}{w_w} = 0.856 \frac{kN \cdot m}{m}$	
Bending moment acting at the middle of wall height and resulting from the eccentricity of vertical loads	$M_{mvd} := 0 \frac{kN \cdot m}{m}$	
Vertical load acting at the bottom of wall	$N_{2d} := N_{1d} + \frac{P_{masonry} \cdot h_w}{w_w} = 54.434 \frac{kN}{m}$	
Bending moment acting at the bottom of wall and resulting from the eccentricity of horizontal loads	$M_{2hd} := \frac{\left(\frac{W_{wind} \cdot (3\ m)^2}{2}\right)}{w_w} = 3.422 \frac{kN \cdot m}{m}$	
Bending moment acting at the bottom of wall and resulting from the eccentricity of vertical loads	$M_{2vd} := 0 \frac{kN \cdot m}{m}$	
Partial safety factor	$\gamma_M := 2$	STN EN 1996-1-1/NA - Table 4.6
Material combination factor	$K := 0.7$	STN EN 1996-1-1/NA - Table 3.1
Modulus of elasticity factor	$K_E := 1000$	SFS EN 1996-1-1 - 3.7.2(2)
Shape factor (interpolated, EN772-1)	$\delta_s := \left(\frac{1.15 - 1.10}{250 - 200}\right) \cdot (249 - 200) + 1.10 = 1.149$	SFS EN 772-1 - Table A.1
Normalised masonry mean compressive strength	$f_b := \delta_s \cdot \frac{f_{b.o}}{1\ MPa} = 13.79$	SFS EN 1996-1-1 - 3.1.2(1)

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Characteristic masonry compressive strength	$f_k := \left(K \cdot f_b^{\,0.7}\right) \cdot 1\ MPa = 4.39\ MPa$	SFS EN 1996-1-1 - 3.6.1.2(2) (3.4)
Modulus of elasticity	$E := K_E \cdot f_k = 4.393\ GPa$	SFS EN 1996-1-1 - 3.7.2(2)
Design masonry compressive strength	$f_d := \frac{f_k}{\gamma_M} = 2.2\ MPa$	SFS EN 1996-1-1 - 2.4.1(1)
Reduction factor	$\rho_2 := 1$	SFS EN 1996-1-1 - 5.5.1.2(11) (5.5)
Effective height of the wall	$h_{ef} := h_w \cdot \rho_2 = 3000\ mm$	SFS EN 1996-1-1 - 5.5.1.2(10) (5.2)
Thickness coefficient	$\rho_t := 1$	SFS EN 1996-1-1 - 5.5.1.3 Table 5.1
Effective thickness of the wall	$t_{ef} := \rho_t \cdot t_w = 300\ mm$	SFS EN 1996-1-1 - 5.5.1.3(2) (5.10)
Slenderness ratio	$\lambda := \frac{h_{ef}}{t_{ef}} = 10$	SFS EN 1996-1-1 - 6.1.2.2(2)
Condition to meet	$Result_{slenderness} := \left\| \begin{array}{l} \text{if } \frac{h_{ef}}{t_{ef}} \le 27 \\ \quad \text{"Okay"} \\ \text{else} \\ \quad \text{"Not Okay"} \end{array} \right.$	STN EN 1996-1-1/NA - 5.5.1.4(2)
	$Result_{slenderness} = \text{"Okay"}$	
Eccentricity at the top of the wall from vertical loads	$e_{1ve} := \frac{M_{1vd}}{N_{1d}} = 0\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1)
Eccentricity at the top of the wall from horizontal loads	$e_{1he} := \frac{M_{1hd}}{N_{1d}} = 0\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1)
Initial eccentricity at the top of the wall	$e_{1init} := \frac{h_{ef}}{450} = 6.67\ mm$	SFS EN 1996-1-1 - 5.5.1.1(4)
Eccentricity at the top of the wall	$e_1 := e_{1ve} + e_{1he} + e_{1init} = 6.667\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1) (6.5)
Design eccentricity at the top of the wall	$e_{1d} := \left\| \begin{array}{l} \text{if } e_1 \ge 0.05 \cdot t_w \\ \quad e_1 \\ \text{else} \\ \quad 0.05 \cdot t_w \end{array} \right. = 15\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1)
Reduction factor for slenderness and eccentricity at the top of the wall	$\Phi_1 := 1 - 2 \cdot \frac{e_{1d}}{t_w} = 0.9$	SFS EN 1996-1-1 - 6.1.2.2(1) (6.4)
Design axial resistance at the top of the wall	$N_{1Rd} := \left(\Phi_1 \cdot t_w \cdot f_d\right) = 593\ \frac{kN}{m}$	SFS EN 1996-1-1 - 6.1.2.1(2) (6.2)
Utilization ratio of loads	$UR_{top} := \frac{N_{1d}}{N_{1Rd}} = 7.99\%$	SFS EN 1996-1-1 - 6.1.2.1(1) (6.1)
Condition to meet	$Result_{top} := \left\| \begin{array}{l} \text{if } UR_{top} \le 1 \\ \quad \text{"Okay"} \\ \text{else} \\ \quad \text{"Not Okay"} \end{array} \right.$	
	$Result_{top} = \text{"Okay"}$	

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Eccentricity at the middle of the wall height from vertical loads	$e_{mve} := \frac{M_{mvd}}{N_{md}} = 0\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1)
Eccentricity at the middle of the wall height from horizontal loads	$e_{mhe} := \frac{M_{mhd}}{N_{md}} = 16.81\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1)
Initial eccentricity middle of the wall height	$e_{minit} := \frac{h_{ef}}{450} = 6.67\ mm$	SFS EN 1996-1-1 - 5.5.1.1(4)
Eccentricity at the middle of the wall height	$e_m := e_{mve} + e_{mhe} + e_{minit} = 23.47\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1) (6.7)
Final creep coefficient	$\phi_{\infty} := 1$	SFS EN 1996-1-1 - 3.7.4(2)
Eccentricity due to creep	$e_k := \left\| \begin{array}{l} \text{if } \lambda \le 15 \\ \quad \| \ 0 \\ \text{else} \\ \quad \| \ 0.002 \cdot \phi_{\infty} \cdot \frac{h_{ef}}{t_{ef}} \cdot \sqrt{t_w \cdot e_m} \end{array} \right\| = 0$	SFS EN 1996-1-1 - 6.1.2.2(1) (6.8)
Eccentricity at the middle of the wall height	$e_{mk} := e_m + e_k = 23.47\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1) (6.6)
Design eccentricity at the middle of the wall height	$e_{md} := \left\| \begin{array}{l} \text{if } e_{mk} \ge 0.05 \cdot t_w \\ \quad \| \ e_{mk} \\ \text{else} \\ \quad \| \ 0.05 \cdot t_w \end{array} \right\| = 23.47\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1)
Coefficient for reduction factor	$A_1 := 1 - 2 \cdot \frac{e_{md}}{t_w} = 0.844$	SFS EN 1996-1-1 - Annex G (G.2)
Coefficient for reduction factor	$u := \frac{\frac{h_{ef}}{t_{ef}} - 2}{23 - 37 \cdot \frac{e_{md}}{t_w}} = 0.398$	SFS EN 1996-1-1 - Annex G (G.6)
Reduction factor for slenderness and eccentricity at the middle of the wall height	$\Phi_m := A_1 \cdot e^{\frac{u^2}{2}} = 0.78$	SFS EN 1996-1-1 - Annex G (G.1)
Design axial resistance at the middle of the wall height	$N_{mRd} := \left(\Phi_m \cdot t_w \cdot f_d\right) = 513.5\ \frac{kN}{m}$	SFS EN 1996-1-1 - 6.1.2.1(2) (6.2)
Utilization ratio of loads	$UR_{mid} := \frac{N_{md}}{N_{mRd}} = 9.91\%$	SFS EN 1996-1-1 - 6.1.2.1(1) (6.1)
Condition to meet	$Result_{mid} := \left\| \begin{array}{l} \text{if } UR_{mid} \le 1 \\ \quad \| \ \text{"Okay"} \\ \text{else} \\ \quad \| \ \text{"Not Okay"} \end{array} \right\|$	
	$Result_{mid} = \text{"Okay"}$	

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Eccentricity at the bottom of the wall from vertical loads	$e_{2ve} := \frac{M_{2vd}}{N_{2d}} = 0\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1)
Eccentricity at the bottom of the wall from horizontal loads	$e_{2he} := \frac{M_{2hd}}{N_{2d}} = 62.87\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1)
Initial eccentricity at the bottom of the wall	$e_{2init} := \frac{h_{ef}}{450} = 6.67\ mm$	SFS EN 1996-1-1 - 5.5.1.1(4)
Eccentricity at the bottom of the wall	$e_2 := e_{2ve} + e_{2he} + e_{2init} = 69.536\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1) (6.5)
Design eccentricity at the bottom of the wall	$e_{2d} := \left\| \begin{array}{l} \text{if } e_2 \ge 0.05 \cdot t_w \\ \quad \left\| e_2 \right. \\ \text{else} \\ \quad \left\| 0.05 \cdot t_w \right. \end{array} \right\| = 69.536\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1)
Reduction factor for slenderness and eccentricity at the bottom of the wall	$\Phi_2 := 1 - 2 \cdot \frac{e_{2d}}{t_w} = 0.54$	SFS EN 1996-1-1 - 6.1.2.2(1) (6.4)
Design axial resistance at the bottom of the wall	$N_{2Rd} := \Phi_2 \cdot t_w \cdot f_d = 353.5\ \frac{kN}{m}$	SFS EN 1996-1-1 - 6.1.2.1(2) (6.2)
Utilization ratio of loads	$UR_{bot} := \frac{N_{2d}}{N_{2Rd}} = 15.4\%$	SFS EN 1996-1-1 - 6.1.2.1(1) (6.1)
Condition to meet	$Result_{bot} := \left\| \begin{array}{l} \text{if } UR_{bot} \le 1 \\ \quad \left\| \text{“Okay”} \right. \\ \text{else} \\ \quad \left\| \text{“Not Okay”} \right. \end{array} \right\|$ $Result_{bot} = \text{“Okay”}$	
Design utilization ratio of ULS	$UR := \max\left(UR_{top}, UR_{mid}, UR_{bot}\right) = 15.4\%$	

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Ultimate Limit State (ULS) - Finland

Load from wall plate	$P_{plate} := 1.35 \cdot \left(h_{plate} \cdot b_{plate} \cdot 5 \frac{kN}{m^3}\right) = 0.152 \frac{kN}{m}$	
Load from ring beam	$P_{beam} := 1.35 \cdot \left(h_{beam} \cdot b_{beam} \cdot 25 \frac{kN}{m^3}\right) = 3.038 \frac{kN}{m}$	
Load from wind	$W_{wind} := 1.5 \cdot \left(0.388 \frac{kN}{m^2} \cdot 1\ m\right) = 0.582 \frac{kN}{m}$	
Self-weight of the masonry	$P_{masonry} := \rho_m \cdot g \cdot w_m \cdot 1\ m = 2.354 \frac{kN}{m}$	
Total load acting on top of the wall from truss	$P_{truss} := \frac{75.085\ kN}{w_w} = 75.085 \frac{kN}{m}$	
Vertical line load acting at the top of wall	$N_{1d} := \left(P_{plate} + P_{beam}\right) + P_{truss} = 78.274 \frac{kN}{m}$	
Bending moment acting at the top of wall and resulting from the eccentricity of horizontal loads	$M_{1hd} := \frac{\left(\frac{W_{wind} \cdot (0\ m)^2}{2}\right)}{w_w} = 0 \frac{kN \cdot m}{m}$	
Bending moment acting at the top of wall and resulting from the eccentricity of vertical loads	$M_{1vd} := 0 \frac{kN \cdot m}{m}$	
Vertical line load acting at the middle of wall height	$N_{md} := N_{1d} + \frac{P_{masonry} \cdot h_w \cdot 0.5}{w_w} = 81.805 \frac{kN}{m}$	
Bending moment acting at the middle of wall height and resulting from the eccentricity of horizontal loads	$M_{mhd} := \frac{\left(\frac{W_{wind} \cdot (1.5\ m)^2}{2}\right)}{w_w} = 0.655 \frac{kN \cdot m}{m}$	
Bending moment acting at the middle of wall height and resulting from the eccentricity of vertical loads	$M_{mvd} := 0 \frac{kN \cdot m}{m}$	
Vertical load acting at the bottom of wall	$N_{2d} := N_{1d} + \frac{P_{masonry} \cdot h_w}{w_w} = 85.335 \frac{kN}{m}$	
Bending moment acting at the bottom of wall and resulting from the eccentricity of horizontal loads	$M_{2hd} := \frac{\left(\frac{W_{wind} \cdot (3\ m)^2}{2}\right)}{w_w} = 2.619 \frac{kN \cdot m}{m}$	
Bending moment acting at the bottom of wall and resulting from the eccentricity of vertical loads	$M_{2vd} := 0 \frac{kN \cdot m}{m}$	
Partial safety factor	$\gamma_M := 1.8$	SFS EN 1996-1-1/NA - Table 1
Material combination factor	$K := 0.7$	SFS EN 1996-1-1/NA - Table 2
Modulus of elasticity factor	$K_E := 700$	SFS EN 1996-1-1/NA - 3.7.2(2)
Shape factor (interpolated)	$\delta_s := \left(\frac{1.15 - 1.10}{250 - 200}\right) \cdot (249 - 200) + 1.10 = 1.149$	SFS EN 772-1 - Table A.1
Normalised masonry mean compressive strength	$f_b := \delta_s \cdot \frac{f_{b.o}}{1\ MPa} = 13.79$	SFS EN 1996-1-1 - 3.1.2(1)

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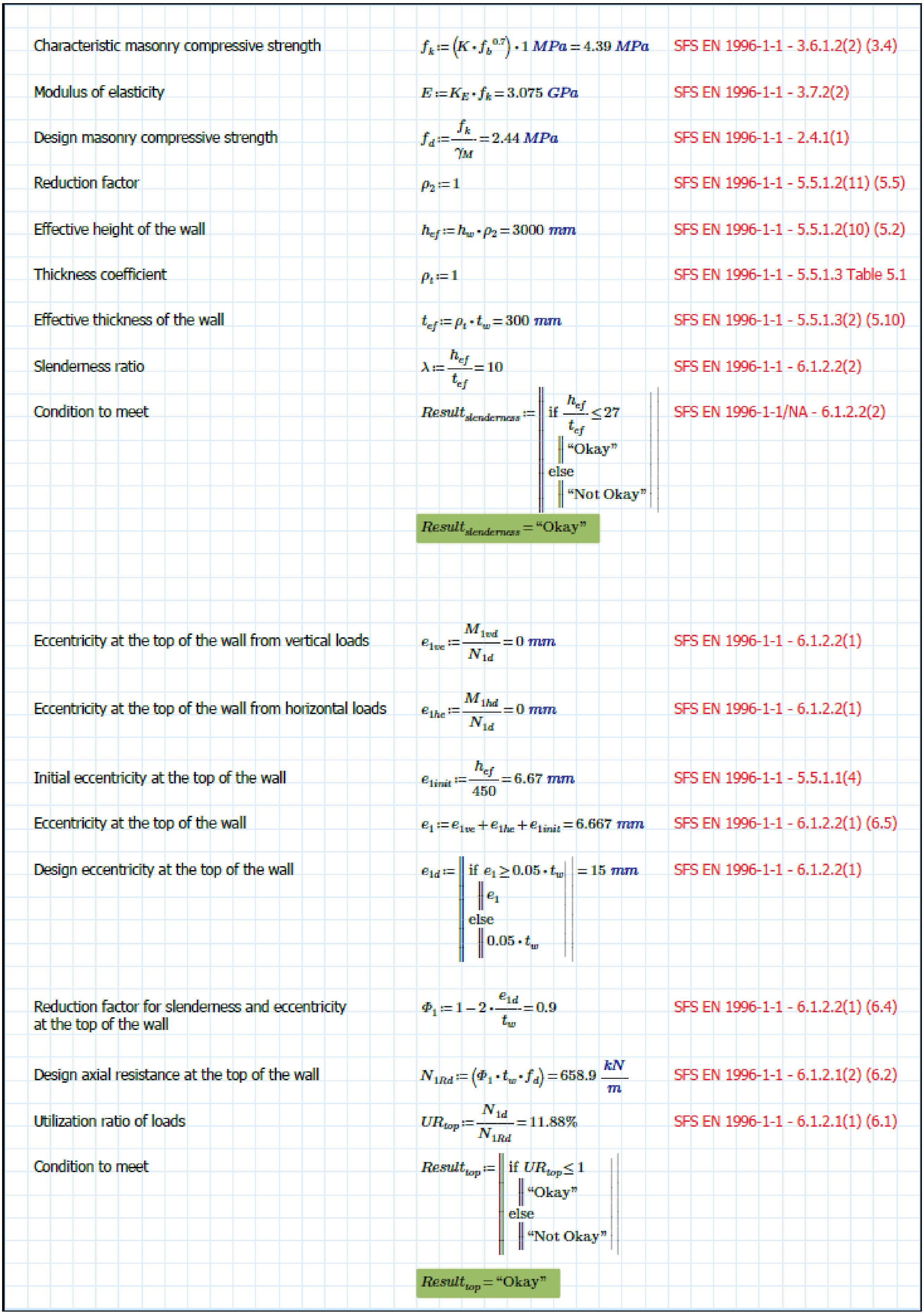

Characteristic masonry compressive strength	$f_k := \left(K \cdot f_b^{0.7}\right) \cdot 1\ MPa = 4.39\ MPa$	SFS EN 1996-1-1 - 3.6.1.2(2) (3.4)
Modulus of elasticity	$E := K_E \cdot f_k = 3.075\ GPa$	SFS EN 1996-1-1 - 3.7.2(2)
Design masonry compressive strength	$f_d := \frac{f_k}{\gamma_M} = 2.44\ MPa$	SFS EN 1996-1-1 - 2.4.1(1)
Reduction factor	$\rho_2 := 1$	SFS EN 1996-1-1 - 5.5.1.2(11) (5.5)
Effective height of the wall	$h_{ef} := h_w \cdot \rho_2 = 3000\ mm$	SFS EN 1996-1-1 - 5.5.1.2(10) (5.2)
Thickness coefficient	$\rho_t := 1$	SFS EN 1996-1-1 - 5.5.1.3 Table 5.1
Effective thickness of the wall	$t_{ef} := \rho_t \cdot t_w = 300\ mm$	SFS EN 1996-1-1 - 5.5.1.3(2) (5.10)
Slenderness ratio	$\lambda := \frac{h_{ef}}{t_{ef}} = 10$	SFS EN 1996-1-1 - 6.1.2.2(2)
Condition to meet	$Result_{slenderness} := \begin{array}{l} \text{if } \frac{h_{ef}}{t_{ef}} \le 27 \\ \quad \text{"Okay"} \\ \text{else} \\ \quad \text{"Not Okay"} \end{array}$	SFS EN 1996-1-1/NA - 6.1.2.2(2)
	$Result_{slenderness} = \text{"Okay"}$	
Eccentricity at the top of the wall from vertical loads	$e_{1ve} := \frac{M_{1vd}}{N_{1d}} = 0\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1)
Eccentricity at the top of the wall from horizontal loads	$e_{1he} := \frac{M_{1hd}}{N_{1d}} = 0\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1)
Initial eccentricity at the top of the wall	$e_{1init} := \frac{h_{ef}}{450} = 6.67\ mm$	SFS EN 1996-1-1 - 5.5.1.1(4)
Eccentricity at the top of the wall	$e_1 := e_{1ve} + e_{1he} + e_{1init} = 6.667\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1) (6.5)
Design eccentricity at the top of the wall	$e_{1d} := \begin{array}{l} \text{if } e_1 \ge 0.05 \cdot t_w \\ \quad e_1 \\ \text{else} \\ \quad 0.05 \cdot t_w \end{array} = 15\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1)
Reduction factor for slenderness and eccentricity at the top of the wall	$\Phi_1 := 1 - 2 \cdot \frac{e_{1d}}{t_w} = 0.9$	SFS EN 1996-1-1 - 6.1.2.2(1) (6.4)
Design axial resistance at the top of the wall	$N_{1Rd} := \left(\Phi_1 \cdot t_w \cdot f_d\right) = 658.9\ \frac{kN}{m}$	SFS EN 1996-1-1 - 6.1.2.1(2) (6.2)
Utilization ratio of loads	$UR_{top} := \frac{N_{1d}}{N_{1Rd}} = 11.88\%$	SFS EN 1996-1-1 - 6.1.2.1(1) (6.1)
Condition to meet	$Result_{top} := \begin{array}{l} \text{if } UR_{top} \le 1 \\ \quad \text{"Okay"} \\ \text{else} \\ \quad \text{"Not Okay"} \end{array}$	
	$Result_{top} = \text{"Okay"}$	

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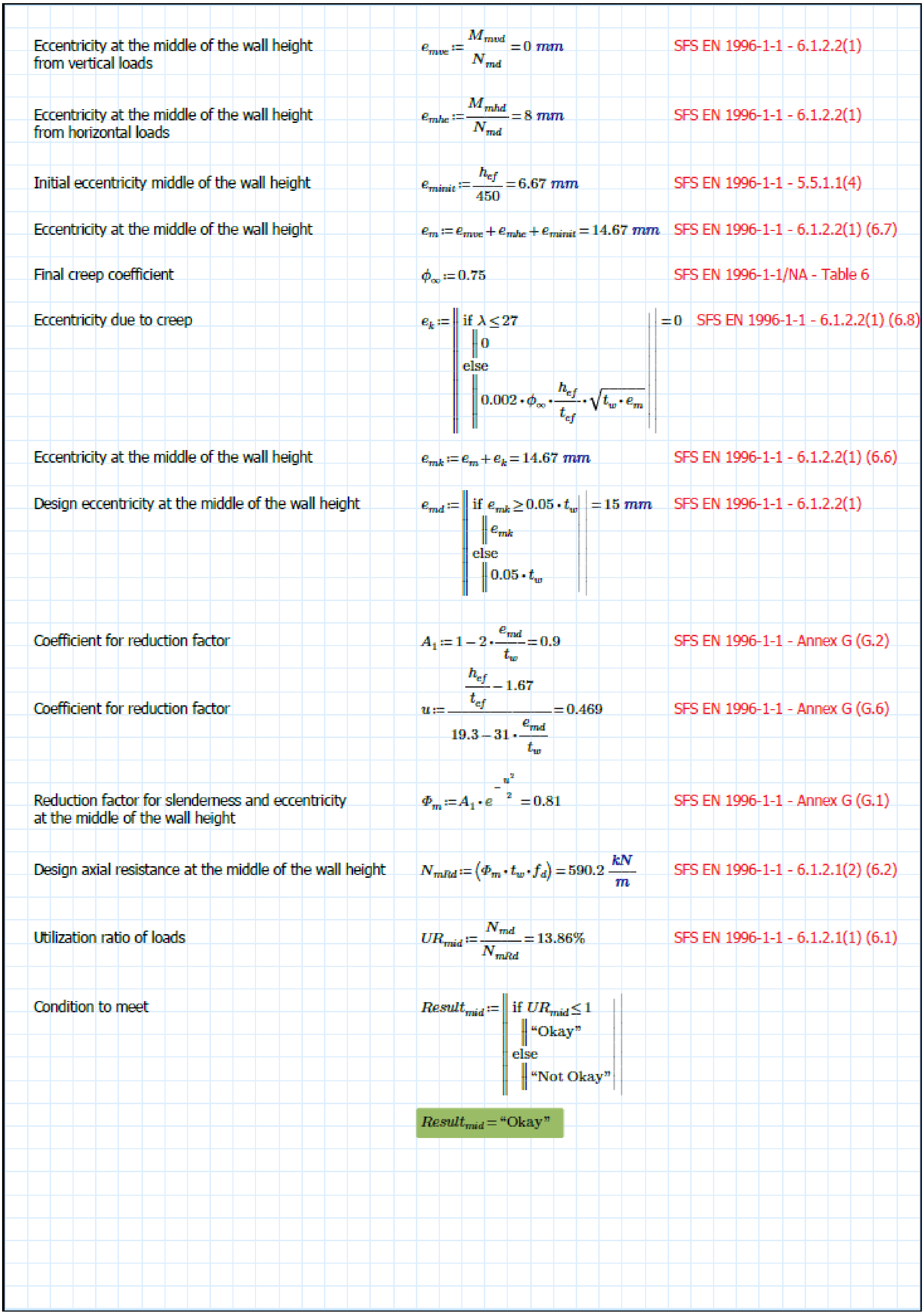

Eccentricity at the middle of the wall height from vertical loads	$e_{mve} := \frac{M_{mvd}}{N_{md}} = 0\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1)
Eccentricity at the middle of the wall height from horizontal loads	$e_{mhe} := \frac{M_{mhd}}{N_{md}} = 8\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1)
Initial eccentricity middle of the wall height	$e_{minit} := \frac{h_{ef}}{450} = 6.67\ mm$	SFS EN 1996-1-1 - 5.5.1.1(4)
Eccentricity at the middle of the wall height	$e_m := e_{mve} + e_{mhe} + e_{minit} = 14.67\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1) (6.7)
Final creep coefficient	$\phi_\infty := 0.75$	SFS EN 1996-1-1/NA - Table 6
Eccentricity due to creep	$e_k := \begin{array}{l} \text{if } \lambda \le 27 \\ \quad 0 \\ \text{else} \\ \quad 0.002 \cdot \phi_\infty \cdot \frac{h_{ef}}{t_{ef}} \cdot \sqrt{t_w \cdot e_m} \end{array} = 0$	SFS EN 1996-1-1 - 6.1.2.2(1) (6.8)
Eccentricity at the middle of the wall height	$e_{mk} := e_m + e_k = 14.67\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1) (6.6)
Design eccentricity at the middle of the wall height	$e_{md} := \begin{array}{l} \text{if } e_{mk} \ge 0.05 \cdot t_w \\ \quad e_{mk} \\ \text{else} \\ \quad 0.05 \cdot t_w \end{array} = 15\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1)
Coefficient for reduction factor	$A_1 := 1 - 2 \cdot \frac{e_{md}}{t_w} = 0.9$	SFS EN 1996-1-1 - Annex G (G.2)
Coefficient for reduction factor	$u := \frac{\frac{h_{ef}}{t_{ef}} - 1.67}{19.3 - 31 \cdot \frac{e_{md}}{t_w}} = 0.469$	SFS EN 1996-1-1 - Annex G (G.6)
Reduction factor for slenderness and eccentricity at the middle of the wall height	$\Phi_m := A_1 \cdot e^{-\frac{u^2}{2}} = 0.81$	SFS EN 1996-1-1 - Annex G (G.1)
Design axial resistance at the middle of the wall height	$N_{mRd} := \left(\Phi_m \cdot t_w \cdot f_d\right) = 590.2\ \frac{kN}{m}$	SFS EN 1996-1-1 - 6.1.2.1(2) (6.2)
Utilization ratio of loads	$UR_{mid} := \frac{N_{md}}{N_{mRd}} = 13.86\%$	SFS EN 1996-1-1 - 6.1.2.1(1) (6.1)
Condition to meet	$Result_{mid} := \begin{array}{l} \text{if } UR_{mid} \le 1 \\ \quad \text{"Okay"} \\ \text{else} \\ \quad \text{"Not Okay"} \end{array}$	

$Result_{mid} = \text{"Okay"}$

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Eccentricity at the bottom of the wall from vertical loads	$e_{2ve} := \frac{M_{2vd}}{N_{2d}} = 0\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1)
Eccentricity at the bottom of the wall from horizontal loads	$e_{2he} := \frac{M_{2hd}}{N_{2d}} = 30.69\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1)
Initial eccentricity at the bottom of the wall	$e_{2init} := \frac{h_{ef}}{450} = 6.67\ mm$	SFS EN 1996-1-1 - 5.5.1.1(4)
Eccentricity at the bottom of the wall	$e_2 := e_{2ve} + e_{2he} + e_{2init} = 37.357\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1) (6.5)
Design eccentricity at the bottom of the wall	$e_{2d} := \left\Vert \begin{array}{l} \text{if } e_2 \geq 0.05 \cdot t_w \\ \quad \Vert\ e_2 \\ \text{else} \\ \quad \Vert\ 0.05 \cdot t_w \end{array} \right. = 37.357\ mm$	SFS EN 1996-1-1 - 6.1.2.2(1)
Reduction factor for slenderness and eccentricity at the bottom of the wall	$\Phi_2 := 1 - 2 \cdot \frac{e_{2d}}{t_w} = 0.75$	SFS EN 1996-1-1 - 6.1.2.2(1) (6.4)
Design axial resistance at the bottom of the wall	$N_{2Rd} := \Phi_2 \cdot t_w \cdot f_d = 549.8\ \frac{kN}{m}$	SFS EN 1996-1-1 - 6.1.2.1(2) (6.2)
Utilization ratio of loads	$UR_{bot} := \frac{N_{2d}}{N_{2Rd}} = 15.52\%$	SFS EN 1996-1-1 - 6.1.2.1(1) (6.1)
Condition to meet	$Result_{bot} := \left\Vert \begin{array}{l} \text{if } UR_{bot} \leq 1 \\ \quad \Vert\ \text{“Okay”} \\ \text{else} \\ \quad \Vert\ \text{“Not Okay”} \end{array} \right.$	
	$Result_{bot} = \text{“Okay”}$	
Design utilization ratio of ULS	$UR := \max\left(UR_{top}, UR_{mid}, UR_{bot}\right) = 15.52\%$	

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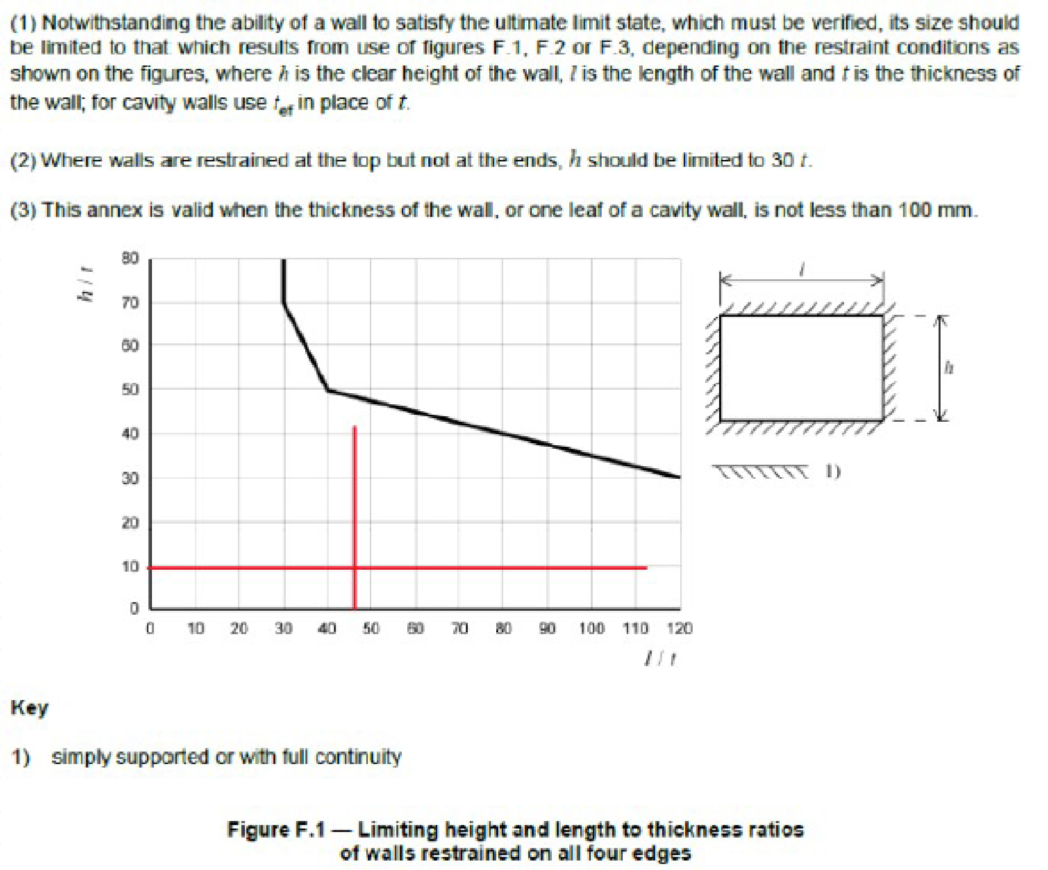
Serviceability Limit State (SLS)

Length of the longest wall $l_w := 14\ m$

Height to thickness ratio for the wall $\dfrac{h_w}{t_w} = 10$

Length to thickness ratio for the wall $\dfrac{l_w}{t_w} = 46.67$ SFS EN 1996-1-1 - Annex F



(1) Notwithstanding the ability of a wall to satisfy the ultimate limit state, which must be verified, its size should be limited to that which results from use of figures F.1, F.2 or F.3, depending on the restraint conditions as shown on the figures, where *h* is the clear height of the wall, *l* is the length of the wall and *t* is the thickness of the wall; for cavity walls use t_{ef} in place of *t*.

(2) Where walls are restrained at the top but not at the ends, *h* should be limited to 30 *t*.

(3) This annex is valid when the thickness of the wall, or one leaf of a cavity wall, is not less than 100 mm.

Key

1) simply supported or with full continuity

Figure F.1 — Limiting height and length to thickness ratios of walls restrained on all four edges

Design utilization ratio of SLS

$UR_{SLS} = Okay$

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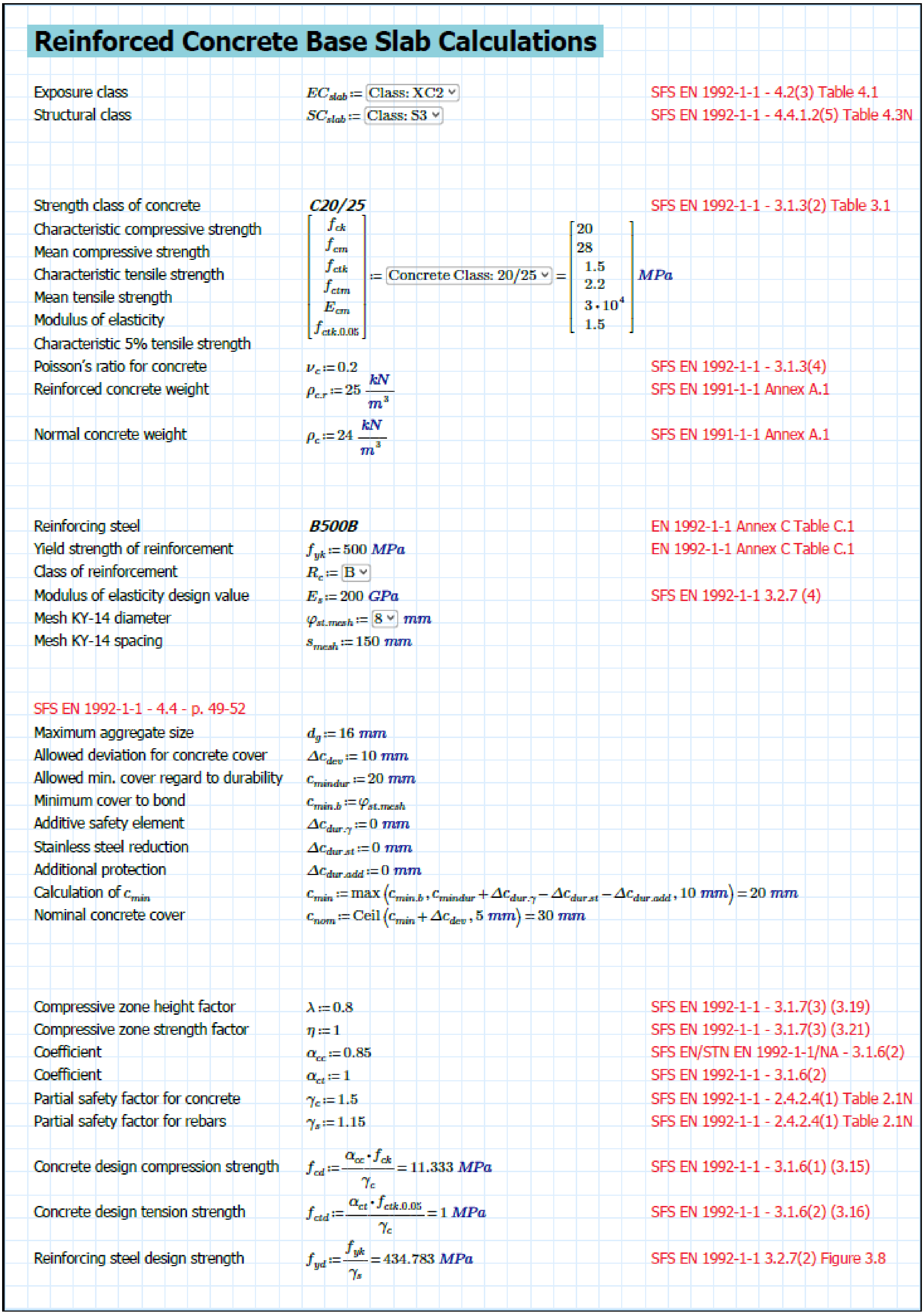

Reinforced Concrete Base Slab Calculations

Exposure class	$EC_{slab} :=$ Class: XC2 ⌄	SFS EN 1992-1-1 - 4.2(3) Table 4.1
Structural class	$SC_{slab} :=$ Class: S3 ⌄	SFS EN 1992-1-1 - 4.4.1.2(5) Table 4.3N
Strength class of concrete	***C20/25***	SFS EN 1992-1-1 - 3.1.3(2) Table 3.1
Characteristic compressive strength Mean compressive strength Characteristic tensile strength Mean tensile strength Modulus of elasticity Characteristic 5% tensile strength	$\begin{bmatrix} f_{ck} \\ f_{cm} \\ f_{ctk} \\ f_{ctm} \\ E_{cm} \\ f_{ctk.0.05} \end{bmatrix} :=$ Concrete Class: 20/25 ⌄ $= \begin{bmatrix} 20 \\ 28 \\ 1.5 \\ 2.2 \\ 3 \cdot 10^4 \\ 1.5 \end{bmatrix} MPa$	
Poisson's ratio for concrete	$\nu_c := 0.2$	SFS EN 1992-1-1 - 3.1.3(4)
Reinforced concrete weight	$\rho_{c.r} := 25 \frac{kN}{m^3}$	SFS EN 1991-1-1 Annex A.1
Normal concrete weight	$\rho_c := 24 \frac{kN}{m^3}$	SFS EN 1991-1-1 Annex A.1
Reinforcing steel	***B500B***	EN 1992-1-1 Annex C Table C.1
Yield strength of reinforcement	$f_{yk} := 500\ MPa$	EN 1992-1-1 Annex C Table C.1
Class of reinforcement	$R_c :=$ B ⌄	
Modulus of elasticity design value	$E_s := 200\ GPa$	SFS EN 1992-1-1 3.2.7 (4)
Mesh KY-14 diameter	$\varphi_{st.mesh} :=$ 8 ⌄ mm	
Mesh KY-14 spacing	$s_{mesh} := 150\ mm$	
SFS EN 1992-1-1 - 4.4 - p. 49-52		
Maximum aggregate size	$d_g := 16\ mm$	
Allowed deviation for concrete cover	$\Delta c_{dev} := 10\ mm$	
Allowed min. cover regard to durability	$c_{mindur} := 20\ mm$	
Minimum cover to bond	$c_{min.b} := \varphi_{st.mesh}$	
Additive safety element	$\Delta c_{dur.\gamma} := 0\ mm$	
Stainless steel reduction	$\Delta c_{dur.st} := 0\ mm$	
Additional protection	$\Delta c_{dur.add} := 0\ mm$	
Calculation of c_{min}	$c_{min} := \max\left(c_{min.b}, c_{mindur} + \Delta c_{dur.\gamma} - \Delta c_{dur.st} - \Delta c_{dur.add}, 10\ mm\right) = 20\ mm$	
Nominal concrete cover	$c_{nom} := \mathrm{Ceil}\left(c_{min} + \Delta c_{dev}, 5\ mm\right) = 30\ mm$	
Compressive zone height factor	$\lambda := 0.8$	SFS EN 1992-1-1 - 3.1.7(3) (3.19)
Compressive zone strength factor	$\eta := 1$	SFS EN 1992-1-1 - 3.1.7(3) (3.21)
Coefficient	$\alpha_{cc} := 0.85$	SFS EN/STN EN 1992-1-1/NA - 3.1.6(2)
Coefficient	$\alpha_{ct} := 1$	SFS EN 1992-1-1 - 3.1.6(2)
Partial safety factor for concrete	$\gamma_c := 1.5$	SFS EN 1992-1-1 - 2.4.2.4(1) Table 2.1N
Partial safety factor for rebars	$\gamma_s := 1.15$	SFS EN 1992-1-1 - 2.4.2.4(1) Table 2.1N
Concrete design compression strength	$f_{cd} := \frac{\alpha_{cc} \cdot f_{ck}}{\gamma_c} = 11.333\ MPa$	SFS EN 1992-1-1 - 3.1.6(1) (3.15)
Concrete design tension strength	$f_{ctd} := \frac{\alpha_{ct} \cdot f_{ctk.0.05}}{\gamma_c} = 1\ MPa$	SFS EN 1992-1-1 - 3.1.6(2) (3.16)
Reinforcing steel design strength	$f_{yd} := \frac{f_{yk}}{\gamma_s} = 434.783\ MPa$	SFS EN 1992-1-1 3.2.7(2) Figure 3.8

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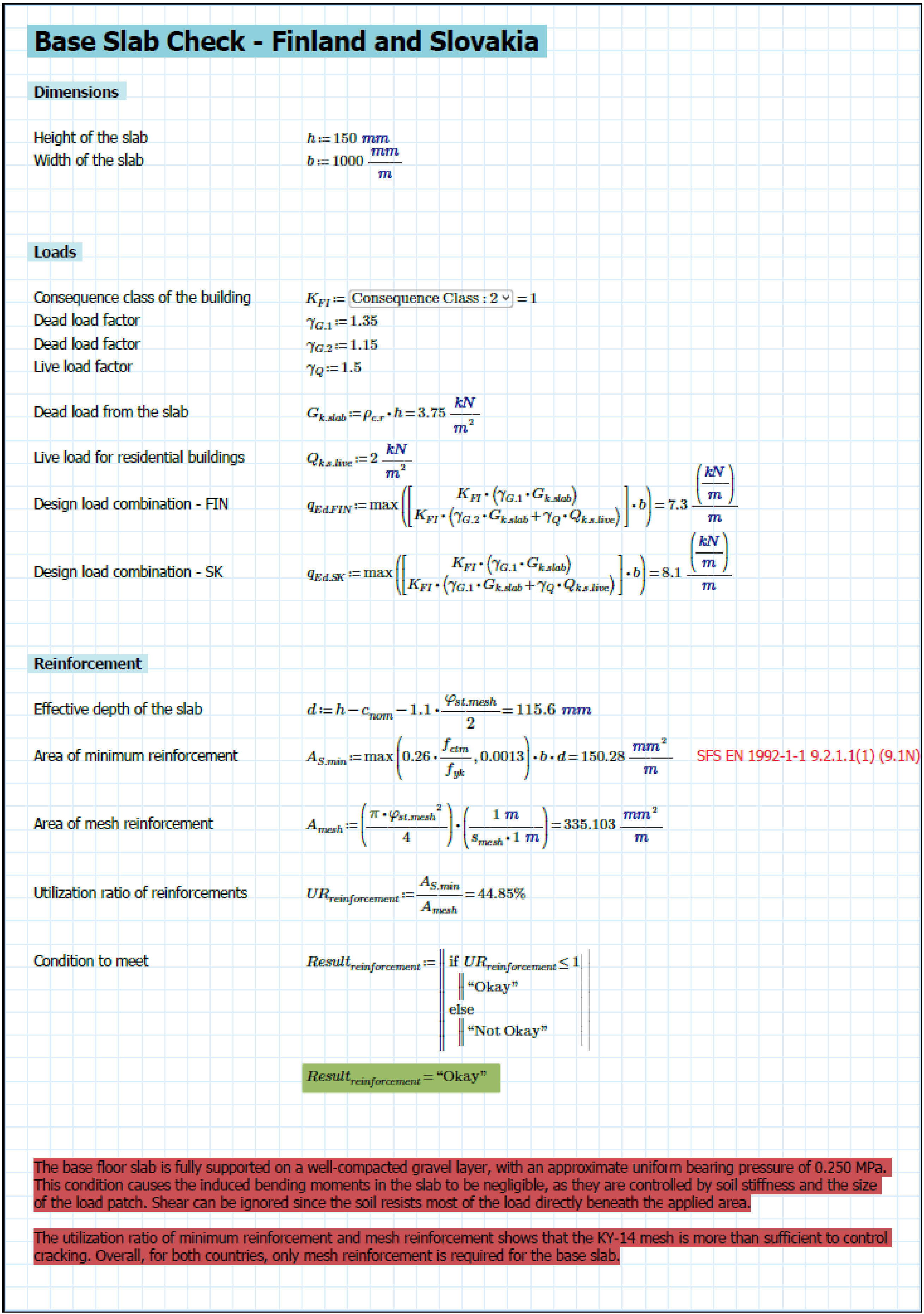

Base Slab Check - Finland and Slovakia

Dimensions

Height of the slab $h := 150\ mm$

Width of the slab $b := 1000\ \dfrac{mm}{m}$

Loads

Consequence class of the building $K_{FI} :=$ Consequence Class : 2 ▾ $= 1$

Dead load factor $\gamma_{G.1} := 1.35$

Dead load factor $\gamma_{G.2} := 1.15$

Live load factor $\gamma_Q := 1.5$

Dead load from the slab $G_{k.slab} := \rho_{c.r} \cdot h = 3.75\ \dfrac{kN}{m^2}$

Live load for residential buildings $Q_{k.s.live} := 2\ \dfrac{kN}{m^2}$

Design load combination - FIN $q_{Ed.FIN} := \max\left(\begin{bmatrix} K_{FI} \cdot \left(\gamma_{G.1} \cdot G_{k.slab}\right) \\ K_{FI} \cdot \left(\gamma_{G.2} \cdot G_{k.slab} + \gamma_Q \cdot Q_{k.s.live}\right) \end{bmatrix} \cdot b\right) = 7.3\ \dfrac{\left(\dfrac{kN}{m}\right)}{m}$

Design load combination - SK $q_{Ed.SK} := \max\left(\begin{bmatrix} K_{FI} \cdot \left(\gamma_{G.1} \cdot G_{k.slab}\right) \\ K_{FI} \cdot \left(\gamma_{G.1} \cdot G_{k.slab} + \gamma_Q \cdot Q_{k.s.live}\right) \end{bmatrix} \cdot b\right) = 8.1\ \dfrac{\left(\dfrac{kN}{m}\right)}{m}$

Reinforcement

Effective depth of the slab $d := h - c_{nom} - 1.1 \cdot \dfrac{\varphi_{st.mesh}}{2} = 115.6\ mm$

Area of minimum reinforcement $A_{S.min} := \max\left(0.26 \cdot \dfrac{f_{ctm}}{f_{yk}}, 0.0013\right) \cdot b \cdot d = 150.28\ \dfrac{mm^2}{m}$ SFS EN 1992-1-1 9.2.1.1(1) (9.1N)

Area of mesh reinforcement $A_{mesh} := \left(\dfrac{\pi \cdot \varphi_{st.mesh}^{\ 2}}{4}\right) \cdot \left(\dfrac{1\ m}{s_{mesh} \cdot 1\ m}\right) = 335.103\ \dfrac{mm^2}{m}$

Utilization ratio of reinforcements $UR_{reinforcement} := \dfrac{A_{S.min}}{A_{mesh}} = 44.85\%$

Condition to meet

```
Result_reinforcement := | if UR_reinforcement ≤ 1
                        |   || "Okay"
                        | else
                        |   || "Not Okay"
```

$Result_{reinforcement} = \text{“Okay”}$

The base floor slab is fully supported on a well-compacted gravel layer, with an approximate uniform bearing pressure of 0.250 MPa. This condition causes the induced bending moments in the slab to be negligible, as they are controlled by soil stiffness and the size of the load patch. Shear can be ignored since the soil resists most of the load directly beneath the applied area.

The utilization ratio of minimum reinforcement and mesh reinforcement shows that the KY-14 mesh is more than sufficient to control cracking. Overall, for both countries, only mesh reinforcement is required for the base slab.

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Strip Footing Calculations

Exposure class $EC_{slab} :=$ Class: XC2 ⌄

Structural class $SC_{slab} :=$ Class: S3 ⌄

Strength class of concrete ***C20/25***

Characteristic compressive strength

Mean compressive strength

Characteristic tensile strength

Mean tensile strength

Modulus of elasticity

Characteristic 5% tensile strength

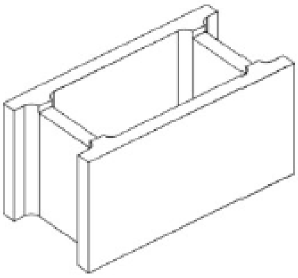
$$\begin{bmatrix} f_{ck} \\ f_{cm} \\ f_{ctk} \\ f_{ctm} \\ E_{cm} \\ f_{ctk.0.05} \end{bmatrix} := \text{Concrete Class: 20/25} \; = \begin{bmatrix} 20 \\ 28 \\ 1.5 \\ 2.2 \\ 3 \cdot 10^4 \\ 1.5 \end{bmatrix} MPa$$

Poisson's ratio for concrete $\nu_c := 0.2$

Reinforced concrete weight $\rho_{c.r} := 25 \frac{kN}{m^3}$

Normal concrete weight $\rho_c := 24 \frac{kN}{m^3}$

CMU Plinth DT15, 20, 30, 40



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Reinforcing steel ***B500B***

Yield strength of reinforcement $f_{yk} := 500\ MPa$

Class of reinforcement $R_c :=$ B ⌄

Modulus of elasticity design value $E_s := 200\ GPa$

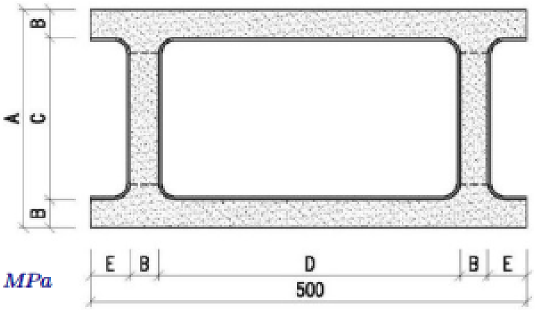
Tensile reinforcement diameter $\varphi_{st} :=$ 14 ⌄ mm

Compressive reinforcement diameter $\varphi_{sc} :=$ 12 ⌄ mm

Stirrups diameter $\varphi_{sw} :=$ 8 ⌄ mm

Geometry of the CMU Plinth

DT15, 20, 24, 30, 40



Compressive zone height factor $\lambda := 0.8$

Compressive zone strength factor $\eta := 1$

Coefficient $\alpha_{cc} := 0.85$

Coefficient $\alpha_{ct} := 1$

Partial safety factor for concrete $\gamma_c := 1.5$

Partial safety factor for rebars $\gamma_s := 1.15$

Concrete design compression strength $f_{cd} := \frac{\alpha_{cc} \cdot f_{ck}}{\gamma_c} = 11.333\ MPa$

Concrete design tension strength $f_{ctd} := \frac{\alpha_{ct} \cdot f_{ctk.0.05}}{\gamma_c} = 1\ MPa$

Reinforcing steel design strength $f_{yd} := \frac{f_{yk}}{\gamma_s} = 434.783\ MPa$

Tabel of Dimensions

[mm]	A	B	C	D	E
DT15	150	28	94	352	46
DT20	200	30	140	348	46
DT24	240	29	182	310	62
DT25	250	32	186	344	46
DT30	300	35	230	338	46
DT40	400	33	334	342	46

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Maximum aggregate size $d_g := 16\ mm$

Allowed deviation for concrete cover $\Delta c_{dev} := 30\ mm$ SFS EN/STN EN 1992-1-1/NA - 4.4.1.3(4)

Allowed min. cover regard to durability $c_{mindur} := 20\ mm$

Minimum cover to bond $c_{min.b} := \varphi_{st}$

Additive safety element $\Delta c_{dur.\gamma} := 0\ mm$

Stainless steel reduction $\Delta c_{dur.st} := 0\ mm$

Additional protection $\Delta c_{dur.add} := 0\ mm$

Calculation of c_{min} $c_{min} := \max\left(c_{min.b}, c_{mindur} + \Delta c_{dur.\gamma} - \Delta c_{dur.st} - \Delta c_{dur.add}, 10\ mm\right) = 20\ mm$

Nominal concrete cover $c_{nom} := \text{Ceil}\left(c_{min} + \Delta c_{dev}, 5\ mm\right) = 50\ mm$

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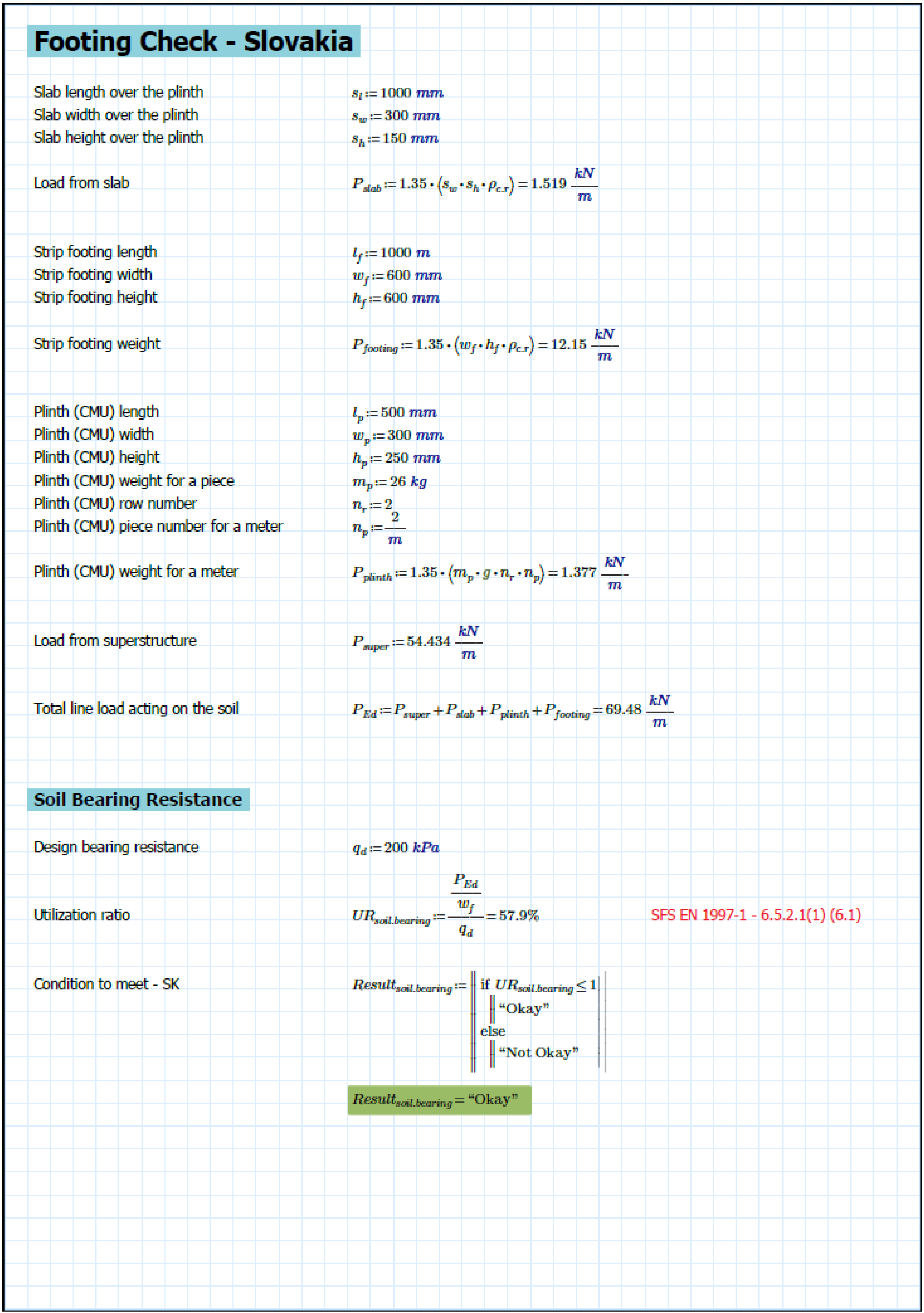

Footing Check - Slovakia

Slab length over the plinth $s_l := 1000\ mm$

Slab width over the plinth $s_w := 300\ mm$

Slab height over the plinth $s_h := 150\ mm$

Load from slab $P_{slab} := 1.35 \cdot \left(s_w \cdot s_h \cdot \rho_{c.r}\right) = 1.519\ \frac{kN}{m}$

Strip footing length $l_f := 1000\ m$

Strip footing width $w_f := 600\ mm$

Strip footing height $h_f := 600\ mm$

Strip footing weight $P_{footing} := 1.35 \cdot \left(w_f \cdot h_f \cdot \rho_{c.r}\right) = 12.15\ \frac{kN}{m}$

Plinth (CMU) length $l_p := 500\ mm$

Plinth (CMU) width $w_p := 300\ mm$

Plinth (CMU) height $h_p := 250\ mm$

Plinth (CMU) weight for a piece $m_p := 26\ kg$

Plinth (CMU) row number $n_r := 2$

Plinth (CMU) piece number for a meter $n_p := \frac{2}{m}$

Plinth (CMU) weight for a meter $P_{plinth} := 1.35 \cdot \left(m_p \cdot g \cdot n_r \cdot n_p\right) = 1.377\ \frac{kN}{m}$

Load from superstructure $P_{super} := 54.434\ \frac{kN}{m}$

Total line load acting on the soil $P_{Ed} := P_{super} + P_{slab} + P_{plinth} + P_{footing} = 69.48\ \frac{kN}{m}$

Soil Bearing Resistance

Design bearing resistance $q_d := 200\ kPa$

Utilization ratio $UR_{soil.bearing} := \frac{\frac{P_{Ed}}{w_f}}{q_d} = 57.9\%$ SFS EN 1997-1 - 6.5.2.1(1) (6.1)

Condition to meet - SK

```
Result_soil.bearing := | if UR_soil.bearing ≤ 1
                       |   | "Okay"
                       | else
                       |   | "Not Okay"
```

$Result_{soil.bearing} = \text{“Okay”}$

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Bending Design

Bending moment

$$M_{Ed} := \left(\frac{P_{Ed} \cdot {w_f}^2}{2}\right) + 3.422\ kN \cdot m = 15.928\ kN \cdot m$$

Effective depth

$$d := h_f - c_{nom} - 1.1 \cdot \varphi_{sw} - \frac{1.1 \cdot \varphi_{st}}{2} = 533.5\ mm$$

Design resistance moment

$$M_{bal} := 0.167 \cdot f_{ck} \cdot w_f \cdot d^2 = 570.383\ kN \cdot m$$

If it is Not Okay ---> Use comp. rebars

$$M_{bal} \geq M_{Ed} = 1$$

Compression force due to concrete

$$F_{CC} = 0.454 \cdot f_{ck} \cdot w_f \cdot x = \lambda \cdot x \cdot w_f \cdot f_{cd}$$

Tension force due to tension rebar

$$F_{ST} = 0.87 \cdot f_{yk} \cdot A_S = f_{yd} \cdot A_S$$

Lever arm for tensile reinforcement

$$z = d - 0.4 \cdot x$$

Moment resistance respect to concrete $M_{Ed} = F_{CC} \cdot z$

Guess Values

$$x := 1\ mm$$

Constraints

$$M_{Ed} = \lambda \cdot x \cdot w_f \cdot f_{cd} \cdot (d - 0.4 \cdot x)$$

Solver

$$x_S := \text{Find}(x)$$

Height of compression zone

$$x_S = 5.51\ mm$$

Lever arm

$$z := min(d - 0.4 \cdot x_S, 0.9 \cdot d) = 480.15\ mm$$

Area of minimum reinforcement

$$A_{S.min} := \max\left(0.26 \cdot \frac{f_{ctm}}{f_{yk}}, 0.0013\right) \cdot w_f \cdot d = 416.13\ mm^2$$

SFS EN 1992-1-1 - 9.2.1.1(1) (9.1N)

Area of required reinforcement

$$A_{S.req} := \frac{M_{Ed}}{f_{yd} \cdot z} = 76.299\ mm^2$$

Design area of reinforcement

$$A_S := \max(A_{S.req}, A_{S.min}) = 416.13\ mm^2$$

Required number of reinforcement

$$n_s := \text{ceil}\left(\frac{A_S}{\frac{\pi \cdot {\varphi_{st}}^2}{4}}\right) = 3$$

Provided area of reinforcement

$$A_{S.provided} := n_s \cdot \frac{\pi \cdot {\varphi_{st}}^2}{4} = 461.814\ mm^2$$

Utilization ratio of reinforcement

$$UR_{tensile.reinforcement} := \frac{A_S}{A_{S.provided}} = 90.11\%$$

Condition to meet

$$Result_{tensile.reinforcement} := \begin{array}{|l} \text{if } UR_{tensile.reinforcement} \leq 1 \\ \quad \| \text{“Okay”} \\ \text{else} \\ \quad \| \text{“Not Okay”} \end{array}$$

$$Result_{tensile.reinforcement} = \text{“Okay”}$$

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Spacing of reinforcement

$$a := \frac{w_f - 2 \cdot c_{nom} - 2 \cdot 1.1 \cdot \varphi_{sw} - n_s \cdot 1.1 \cdot \varphi_{st} - 2 \cdot 5\ mm}{(n_s - 1)} = 213.1\ mm$$

Conditions to meet for spacing of reinforcement

$$a \geq \begin{bmatrix} 20\ mm \\ \varphi_{st} \\ d_g + 5\ mm \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$$

Design moment resistance

$$M_{Rd} := f_{yd} \cdot A_{S.provided} \cdot z = 96.409\ kN \cdot m$$

Utilization ratio of bending resistance

$$UR_{bending} := \frac{M_{Ed}}{M_{Rd}} = 16.52\%$$

Condition to meet

$$Result_{bending} := \left\| \begin{array}{l} \text{if } UR_{bending} \leq 1 \\ \quad \left\| \text{“Okay”} \right. \\ \text{else} \\ \quad \left\| \text{“Not Okay”} \right. \end{array} \right.$$

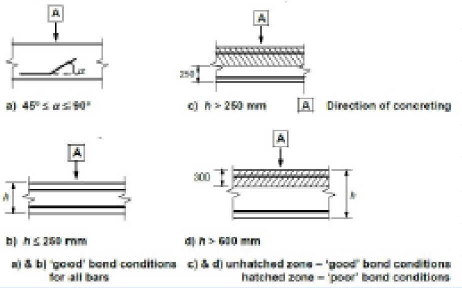
$$Result_{bending} = \text{“Okay”}$$

Anchorage for reinforcement

SFS EN 1992-1-1 - 8.4(p. 132-136)

Design stress of the bar

$$\sigma_{sd} := f_{yd} = 434.78\ MPa$$



A coefficient related to the quality of the bond condition and the position of the bar during concreting

$$\eta_1 := 1$$

A coefficient related to the bar diameter, good conditions - “Size of the rebar ” $\leq 32\ mm$

$$\eta_2 := 1$$

The design value of the bond stress

$$f_{bd} := 2.25 \cdot \eta_1 \cdot \eta_2 \cdot f_{ctd} = 2.25\ MPa$$

The basic required anchorage length

$$l_{b.rqrd} := \frac{\varphi_{st}}{4} \cdot \frac{\sigma_{sd}}{f_{bd}} = 676.33\ mm$$

Value of c

$$c_s := c_{nom} - \frac{1}{2} \cdot \varphi_{sw} = 46\ mm$$

Value of c_1

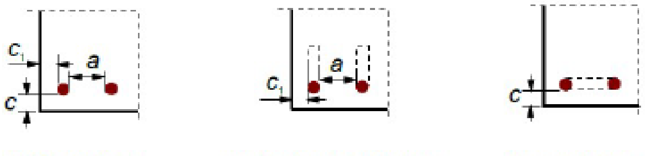
$$c_1 := c_{nom} - \frac{1}{2} \cdot \varphi_{sw} = 46\ mm$$

Value of $c_{d.s}$

$$c_{d.s} := min\left(\frac{a}{2}, c_s, c_1\right) = 46\ mm$$

Value of $c_{d.b}$

$$c_{d.b} := min\left(\frac{a}{2}, c_1\right) = 46\ mm$$



a) Straight bars
$c_d = \min(a/2, c_1, c)$

b) Bent or hooked bars
$c_d = \min(a/2, c_1)$

c) Looped bars
$c_d = c$

Coefficient for shape of bars - straight

$$\alpha_{1.s} := 1$$

Coefficient for shape of bars - bent

$$\alpha_{1.b} := 1$$

Coefficient for concrete cover - straight

$$\alpha_{2.s} := \max\left(0.7, min\left(1 - \frac{0.15 \cdot (c_{d.s} - \varphi_{st})}{\varphi_{st}}, 1\right)\right) = 0.7$$

Coefficient for concrete cover - bent

$$\alpha_{2.b} := \max\left(0.7, min\left(1 - \frac{0.15 \cdot (c_{d.b} - 3 \cdot \varphi_{st})}{\varphi_{st}}, 1\right)\right) = 0.957$$

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Simplified value $\alpha_3 := 1$

Simplified value $\alpha_4 := 0.7$

Simplified value $\alpha_5 := 1$

Minimum anchorage length $l_{b.min} := \max\left(0.3 \cdot l_{b.rqrd}, 10 \cdot \varphi_{st}, 100\ mm\right) = 202.899\ mm$

Min. required design anchorage length $l_{bd.s} := \max\left(\alpha_{1.s} \cdot \alpha_{2.s} \cdot \alpha_3 \cdot \alpha_4 \cdot \alpha_5 \cdot l_{b.rqrd}, l_{b.min}\right) = 331.4\ mm$

Design straight anchorage length $L_{bd.s} := \mathrm{Ceil}\left(2 \cdot l_{bd.s}, 50\ mm\right) = 700\ mm$

Min. required design anchorage length $l_{bd.b} := \max\left(\alpha_{1.b} \cdot \alpha_{2.b} \cdot \alpha_3 \cdot \alpha_4 \cdot \alpha_5 \cdot l_{b.rqrd}, l_{b.min}\right) = 453.14\ mm$

Design bent anchorage length $L_{bd.b} := \mathrm{Ceil}\left(2 \cdot l_{bd.b}, 50\ mm\right) = 950\ mm$

Lap length for reinforcement

SFS EN 1992-1-1 - 8.7(p. 138-139)

Coefficient for lapped bars $\alpha_6 := 1.5$

Minimum lap length $l_{0.min} := \max\left(0.3 \cdot \alpha_6 \cdot l_{b.rqrd}, 15 \cdot \varphi_{st}, 200\ mm\right) = 304.348\ mm$

Minimum required design lap length $l_{0.s} := \max\left(\alpha_{1.s} \cdot \alpha_{2.s} \cdot \alpha_3 \cdot \alpha_4 \cdot \alpha_5 \cdot \alpha_6 \cdot l_{b.rqrd}, l_{0.min}\right) = 497.101\ mm$

Design straight lap length $L_{0.s} := 600\ mm$

Minimum required design lap length $l_{0.b} := \max\left(\alpha_{1.b} \cdot \alpha_{2.b} \cdot \alpha_3 \cdot \alpha_4 \cdot \alpha_5 \cdot \alpha_6 \cdot l_{b.rqrd}, l_{0.min}\right) = 679.71\ mm$

Design bent lap length $L_{0.b} := 900\ mm$

Shear Design

Shear force $V_{Ed} := \dfrac{P_{Ed} \cdot w_f}{2} = 20.844\ kN$

Crushing strength of the concrete struts

Angle of concrete struts $22\ ° \le \theta \le 45\ °$ $\theta_1 := 22\ deg$

Crushing strength of the concrete struts

$$V_{Rd.max.22} := \frac{0.36 \cdot f_{ck} \cdot w_f \cdot d \cdot \left(1 - \dfrac{f_{ck}}{250\ MPa}\right)}{\left(\cot\left(\theta_1\right) + \tan\left(\theta_1\right)\right)} = 736.46\ kN$$

SFS EN 1992-1-1 - 6.2.3(3) (6.9)

Angle of concrete struts $22\ ° \le \theta \le 45\ °$ $\theta_2 := 45\ deg$

Crushing strength of the concrete struts

$$V_{Rd.max.45} := \frac{0.36 \cdot f_{ck} \cdot w_f \cdot d \cdot \left(1 - \dfrac{f_{ck}}{250\ MPa}\right)}{\left(\cot\left(\theta_2\right) + \tan\left(\theta_2\right)\right)} = 1060.17\ kN$$

SFS EN 1992-1-1 - 6.2.3(3) (6.9)

Design crushing strength of the concrete struts $V_{Rd.max} := \min\left(V_{Rd.max.22}, V_{Rd.max.45}\right) = 736.457\ kN$

Utilization ratio of the crushing strength $UR_{cr} := \dfrac{V_{Ed}}{V_{Rd.max}} = 3\%$

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Condition to meet

$$Result_{cr} := \left\| \begin{array}{l} \text{if } UR_{cr} \le 1 \\ \quad \| \text{"Okay"} \\ \text{else} \\ \quad \| \text{"Not Okay"} \end{array} \right.$$

$$Result_{cr} = \text{"Okay"}$$

Shear resistance

Number of stirrups legs $n_{sw} := 2$

Cross-sectional area of the shear reinforcement $A_{sw} := n_{sw} \cdot \pi \cdot \frac{\varphi_{sw}^{2}}{4} = 100.53\ mm^{2}$

Design spacing of stirrups $s_{sw} := 200\ mm$

Shear resistance $V_{Rd.s} := \frac{A_{sw}}{s_{sw}} \cdot 0.78 \cdot f_{yk} \cdot d \cdot \cot\left(\theta_1\right) = 259\ kN$ SFS EN 1992-1-1 - 6.2.3(3) (6.8)

Design shear resistance $V_{Rd.shear} := min\left(V_{Rd.max}, V_{Rd.s}\right) = 258.86\ kN$

Utilization ratio for shear resistance at support $UR_{shear} := \frac{V_{Ed}}{V_{Rd.shear}} = 8.05\%$

Condition to meet

$$Result_{shear} := \left\| \begin{array}{l} \text{if } UR_{shear} \le 1 \\ \quad \| \text{"Okay"} \\ \text{else} \\ \quad \| \text{"Not Okay"} \end{array} \right.$$

$$Result_{shear} = \text{"Okay"}$$

Minimum shear reinforcement

Angle of the stirrups $\alpha_{sw} := 90\ deg$

Shear reinforcement ratio $\rho_w := \frac{A_{sw}}{s_{sw} \cdot w_f \cdot \sin\left(\alpha_{sw}\right)} = 0.001$ SFS EN 1992-1-1 - 9.2.2(5) (9.4)

Minimum shear reinforcement ratio $\rho_{w.min} := \frac{0.08 \cdot \sqrt{\frac{f_{ck}}{MPa}}}{\frac{f_{yk}}{MPa}} = 0.0007$ SFS EN 1992-1-1 - 9.2.2(5) (9.5N)

Utilization ratio of the minimum shear reinforcement $UR_{pw} := \frac{\rho_{w.min}}{\rho_w} = 85.41\%$

Condition to meet

$$Result_{pw} := \left\| \begin{array}{l} \text{if } UR_{pw} \le 1 \\ \quad \| \text{"Okay"} \\ \text{else} \\ \quad \| \text{"Not Okay"} \end{array} \right.$$

$$Result_{pw} = \text{"Okay"}$$

Non-Commercial Use Only

Maximum spacing

Maximum allowable longitudinal spacing $s_{l.max} := 0.75 \cdot d \cdot (1 + \cot(\alpha_{sw})) = 400.13\ mm$ SFS EN 1992-1-1 - 9.2.2(6) (9.6N)

Utilization ratio of longitudinal spacing $UR_{sl} := \frac{s_{sw}}{s_{l.max}} = 49.98\%$

Condition to meet

```
$Result_{sl} :=$ if $UR_{sl} \le 1$
                     "Okay"
                 else
                     "Not Okay"
```

$Result_{sl} =$ "Okay"

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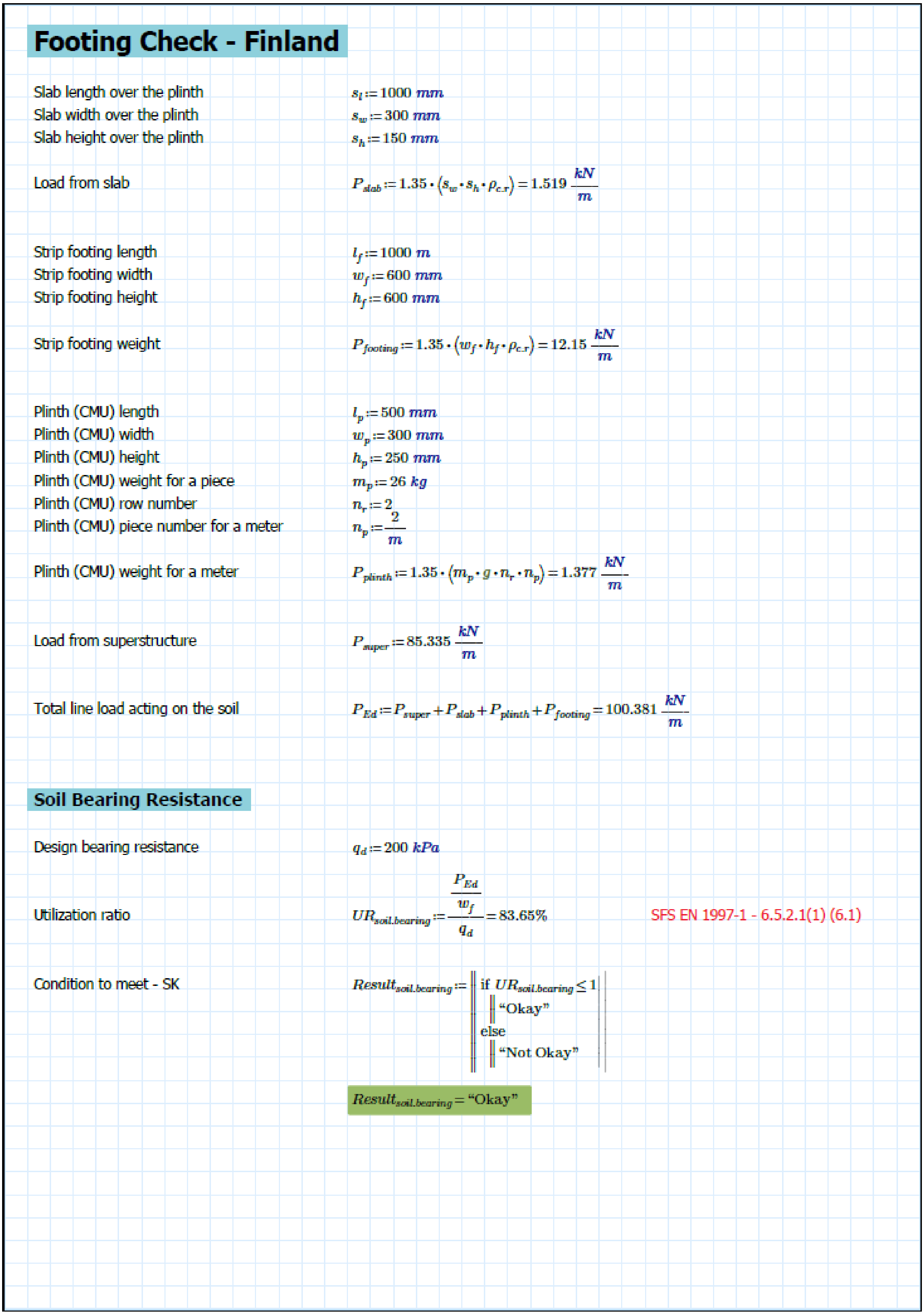

Footing Check - Finland

Slab length over the plinth	$s_l := 1000\ mm$
Slab width over the plinth	$s_w := 300\ mm$
Slab height over the plinth	$s_h := 150\ mm$
Load from slab	$P_{slab} := 1.35 \cdot (s_w \cdot s_h \cdot \rho_{c.r}) = 1.519\ \frac{kN}{m}$
Strip footing length	$l_f := 1000\ m$
Strip footing width	$w_f := 600\ mm$
Strip footing height	$h_f := 600\ mm$
Strip footing weight	$P_{footing} := 1.35 \cdot (w_f \cdot h_f \cdot \rho_{c.r}) = 12.15\ \frac{kN}{m}$
Plinth (CMU) length	$l_p := 500\ mm$
Plinth (CMU) width	$w_p := 300\ mm$
Plinth (CMU) height	$h_p := 250\ mm$
Plinth (CMU) weight for a piece	$m_p := 26\ kg$
Plinth (CMU) row number	$n_r := 2$
Plinth (CMU) piece number for a meter	$n_p := \frac{2}{m}$
Plinth (CMU) weight for a meter	$P_{plinth} := 1.35 \cdot (m_p \cdot g \cdot n_r \cdot n_p) = 1.377\ \frac{kN}{m}$
Load from superstructure	$P_{super} := 85.335\ \frac{kN}{m}$
Total line load acting on the soil	$P_{Ed} := P_{super} + P_{slab} + P_{plinth} + P_{footing} = 100.381\ \frac{kN}{m}$

Soil Bearing Resistance

Design bearing resistance	$q_d := 200\ kPa$	
Utilization ratio	$UR_{soil.bearing} := \frac{\frac{P_{Ed}}{w_f}}{q_d} = 83.65\%$	SFS EN 1997-1 - 6.5.2.1(1) (6.1)
Condition to meet - SK	$Result_{soil.bearing} := \begin{cases} \text{“Okay”} & \text{if } UR_{soil.bearing} \le 1 \\ \text{“Not Okay”} & \text{else} \end{cases}$	

$Result_{soil.bearing} = \text{“Okay”}$

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Bending Design

Bending moment $M_{Ed} := \left(\frac{P_{Ed} \cdot w_f^2}{2}\right) + 2.619\ kN \cdot m = 20.688\ kN \cdot m$

Effective depth $d := h_f - c_{nom} - 1.1 \cdot \varphi_{sw} - \frac{1.1 \cdot \varphi_{st}}{2} = 533.5\ mm$

Design resistance moment $M_{bal} := 0.167 \cdot f_{ck} \cdot w_f \cdot d^2 = 570.383\ kN \cdot m$

If it is Not Okay ---> Use comp. rebars $M_{bal} \ge M_{Ed} = 1$

Compression force due to concrete $F_{CC} = 0.454 \cdot f_{ck} \cdot w_f \cdot x = \lambda \cdot x \cdot w_f \cdot f_{cd}$

Tension force due to tension rebar $F_{ST} = 0.87 \cdot f_{yk} \cdot A_S = f_{yd} \cdot A_S$

Lever arm for tensile reinforcement $z = d - 0.4 \cdot x$

Values $x := 1\ mm$

Moment resistance respect to concrete $M_{Ed} = F_{CC} \cdot z$ Constraints $M_{Ed} = \lambda \cdot x \cdot w_f \cdot f_{cd} \cdot (d - 0.4 \cdot x)$

Solver $x_S := \text{Find}(x)$

Height of compression zone $x_S = 7.17\ mm$

Lever arm $z := min(d - 0.4 \cdot x_S, 0.9 \cdot d) = 480.15\ mm$

Area of minimum reinforcement $A_{S.min} := \max\left(0.26 \cdot \frac{f_{ctm}}{f_{yk}}, 0.0013\right) \cdot w_f \cdot d = 416.13\ mm^2$ SFS EN 1992-1-1 - 9.2.1.1(1) (9.1N)

Area of required reinforcement $A_{S.req} := \frac{M_{Ed}}{f_{yd} \cdot z} = 99.097\ mm^2$

Design area of reinforcement $A_S := \max(A_{S.req}, A_{S.min}) = 416.13\ mm^2$

Required number of reinforcement $n_s := \text{ceil}\left(\frac{A_S}{\frac{\pi \cdot \varphi_{st}^2}{4}}\right) = 3$

Provided area of reinforcement $A_{S.provided} := n_s \cdot \frac{\pi \cdot \varphi_{st}^2}{4} = 461.814\ mm^2$

Utilization ratio of reinforcement $UR_{tensile.reinforcement} := \frac{A_S}{A_{S.provided}} = 90.11\%$

Condition to meet $Result_{tensile.reinforcement} :=$ if $UR_{tensile.reinforcement} \le 1$
"Okay"
else
"Not Okay"

$Result_{tensile.reinforcement} =$ "Okay"

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Spacing of reinforcement $a := \frac{w_f - 2 \cdot c_{nom} - 2 \cdot 1.1 \cdot \varphi_{sw} - n_s \cdot 1.1 \cdot \varphi_{st} - 2 \cdot 5\ mm}{(n_s - 1)} = 213.1\ mm$

Conditions to meet for spacing of reinforcement $a \geq \begin{bmatrix} 20\ mm \\ \varphi_{st} \\ d_g + 5\ mm \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$

Design moment resistance $M_{Rd} := f_{yd} \cdot A_{S.provided} \cdot z = 96.409\ kN \cdot m$

Utilization ratio of bending resistance $UR_{bending} := \frac{M_{Ed}}{M_{Rd}} = 21.46\%$

Condition to meet

$$Result_{bending} := \begin{array}{l} \text{if } UR_{bending} \leq 1 \\ \quad \text{“Okay”} \\ \text{else} \\ \quad \text{“Not Okay”} \end{array}$$

$Result_{bending} = \text{“Okay”}$

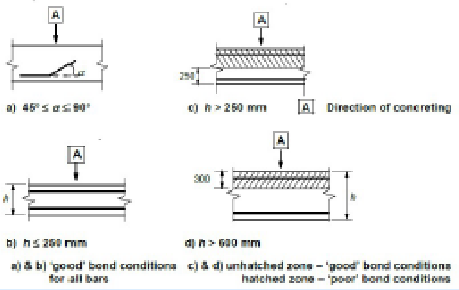
Anchorage for reinforcement

SFS EN 1992-1-1 - 8.4(p. 132-136)

Design stress of the bar $\sigma_{sd} := f_{yd} = 434.78\ MPa$

A coefficient related to the quality of the bond condition and the position of the bar during concreting $\eta_1 := 1$

A coefficient related to the bar diameter, good conditions - “Size of the rebar ” $\leq 32\ mm$ $\eta_2 := 1$



The design value of the bond stress $f_{bd} := 2.25 \cdot \eta_1 \cdot \eta_2 \cdot f_{ctd} = 2.25\ MPa$

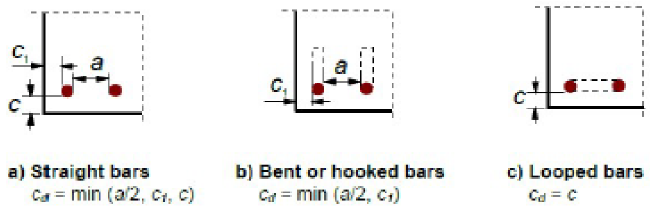
The basic required anchorage length $l_{b.rqrd} := \frac{\varphi_{st}}{4} \cdot \frac{\sigma_{sd}}{f_{bd}} = 676.33\ mm$

Value of c $c_s := c_{nom} - \frac{1}{2} \cdot \varphi_{sw} = 46\ mm$

Value of c_1 $c_1 := c_{nom} - \frac{1}{2} \cdot \varphi_{sw} = 46\ mm$

Value of $c_{d.s}$ $c_{d.s} := min\left(\frac{a}{2}, c_s, c_1\right) = 46\ mm$

Value of $c_{d.b}$ $c_{d.b} := min\left(\frac{a}{2}, c_1\right) = 46\ mm$



Coefficient for shape of bars - straight $\alpha_{1.s} := 1$

Coefficient for shape of bars - bent $\alpha_{1.b} := 1$

Coefficient for concrete cover - straight $\alpha_{2.s} := \max\left(0.7, min\left(1 - \frac{0.15 \cdot (c_{d.s} - \varphi_{st})}{\varphi_{st}}, 1\right)\right) = 0.7$

Coefficient for concrete cover - bent $\alpha_{2.b} := \max\left(0.7, min\left(1 - \frac{0.15 \cdot (c_{d.b} - 3 \cdot \varphi_{st})}{\varphi_{st}}, 1\right)\right) = 0.957$

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Simplified value $\alpha_3 := 1$

Simplified value $\alpha_4 := 0.7$

Simplified value $\alpha_5 := 1$

Minimum anchorage length $l_{b.min} := \max\left(0.3 \cdot l_{b.rqrd}, 10 \cdot \varphi_{st}, 100\ mm\right) = 202.899\ mm$

Min. required design anchorage length $l_{bd.s} := \max\left(\alpha_{1.s} \cdot \alpha_{2.s} \cdot \alpha_3 \cdot \alpha_4 \cdot \alpha_5 \cdot l_{b.rqrd}, l_{b.min}\right) = 331.4\ mm$

Design straight anchorage length $L_{bd.s} := \mathrm{Ceil}\left(2 \cdot l_{bd.s}, 50\ mm\right) = 700\ mm$

Min. required design anchorage length $l_{bd.b} := \max\left(\alpha_{1.b} \cdot \alpha_{2.b} \cdot \alpha_3 \cdot \alpha_4 \cdot \alpha_5 \cdot l_{b.rqrd}, l_{b.min}\right) = 453.14\ mm$

Design bent anchorage length $L_{bd.b} := \mathrm{Ceil}\left(2 \cdot l_{bd.b}, 50\ mm\right) = 950\ mm$

Lap length for reinforcement

SFS EN 1992-1-1 - 8.7(p. 138-139)

Coefficient for lapped bars $\alpha_6 := 1.5$

Minimum lap length $l_{0.min} := \max\left(0.3 \cdot \alpha_6 \cdot l_{b.rqrd}, 15 \cdot \varphi_{st}, 200\ mm\right) = 304.348\ mm$

Minimum required design lap length $l_{0.s} := \max\left(\alpha_{1.s} \cdot \alpha_{2.s} \cdot \alpha_3 \cdot \alpha_4 \cdot \alpha_5 \cdot \alpha_6 \cdot l_{b.rqrd}, l_{0.min}\right) = 497.101\ mm$

Design straight lap length $L_{0.s} := 600\ mm$

Minimum required design lap length $l_{0.b} := \max\left(\alpha_{1.b} \cdot \alpha_{2.b} \cdot \alpha_3 \cdot \alpha_4 \cdot \alpha_5 \cdot \alpha_6 \cdot l_{b.rqrd}, l_{0.min}\right) = 679.71\ mm$

Design bent lap length $L_{0.b} := 900\ mm$

Shear Design

Shear force $V_{Ed} := \frac{P_{Ed} \cdot w_f}{2} = 30.114\ kN$

Crushing strength of the concrete struts

Angle of concrete struts $22\ ° \le \theta \le 45\ °$ $\theta_1 := 22\ deg$

SFS EN 1992-1-1 - 6.2.3(3) (6.9)

Crushing strength of the concrete struts

$$V_{Rd.max.22} := \frac{0.36 \cdot f_{ck} \cdot w_f \cdot d \cdot \left(1 - \frac{f_{ck}}{250\ MPa}\right)}{\left(\cot\left(\theta_1\right) + \tan\left(\theta_1\right)\right)} = 736.46\ kN$$

Angle of concrete struts $22\ ° \le \theta \le 45\ °$ $\theta_2 := 45\ deg$

SFS EN 1992-1-1 - 6.2.3(3) (6.9)

Crushing strength of the concrete struts

$$V_{Rd.max.45} := \frac{0.36 \cdot f_{ck} \cdot w_f \cdot d \cdot \left(1 - \frac{f_{ck}}{250\ MPa}\right)}{\left(\cot\left(\theta_2\right) + \tan\left(\theta_2\right)\right)} = 1060.17\ kN$$

Design crushing strength of the concrete struts $V_{Rd.max} := \min\left(V_{Rd.max.22}, V_{Rd.max.45}\right) = 736.457\ kN$

Utilization ratio of the crushing strength $UR_{cr} := \frac{V_{Ed}}{V_{Rd.max}} = 4\%$

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Condition to meet

$$Result_{cr} := \begin{array}{|l} \text{if } UR_{cr} \le 1 \\ \quad \text{"Okay"} \\ \text{else} \\ \quad \text{"Not Okay"} \end{array}$$

$$Result_{cr} = \text{"Okay"}$$

Shear resistance

Number of stirrups legs $n_{sw} := 2$

Cross-sectional area of the shear reinforcement $A_{sw} := n_{sw} \cdot \pi \cdot \frac{\varphi_{sw}^{2}}{4} = 100.53\ mm^{2}$

Design spacing of stirrups $s_{sw} := 200\ mm$

Shear resistance $V_{Rd.s} := \frac{A_{sw}}{s_{sw}} \cdot 0.78 \cdot f_{yk} \cdot d \cdot \cot\left(\theta_{1}\right) = 259\ kN$ SFS EN 1992-1-1 - 6.2.3(3) (6.8)

Design shear resistance $V_{Rd.shear} := min\left(V_{Rd.max}, V_{Rd.s}\right) = 258.86\ kN$

Utilization ratio for shear resistance at support $UR_{shear} := \frac{V_{Ed}}{V_{Rd.shear}} = 11.63\%$

Condition to meet

$$Result_{shear} := \begin{array}{|l} \text{if } UR_{shear} \le 1 \\ \quad \text{"Okay"} \\ \text{else} \\ \quad \text{"Not Okay"} \end{array}$$

$$Result_{shear} = \text{"Okay"}$$

Minimum shear reinforcement

Angle of the stirrups $\alpha_{sw} := 90\ deg$

Shear reinforcement ratio $\rho_{w} := \frac{A_{sw}}{s_{sw} \cdot w_{f} \cdot \sin\left(\alpha_{sw}\right)} = 0.001$ SFS EN 1992-1-1 - 9.2.2(5) (9.4)

Minimum shear reinforcement ratio $\rho_{w.min} := \frac{0.08 \cdot \sqrt{\frac{f_{ck}}{MPa}}}{\frac{f_{yk}}{MPa}} = 0.0007$ SFS EN 1992-1-1 - 9.2.2(5) (9.5N)

Utilization ratio of the minimum shear reinforcement $UR_{pw} := \frac{\rho_{w.min}}{\rho_{w}} = 85.41\%$

Condition to meet

$$Result_{pw} := \begin{array}{|l} \text{if } UR_{pw} \le 1 \\ \quad \text{"Okay"} \\ \text{else} \\ \quad \text{"Not Okay"} \end{array}$$

$$Result_{pw} = \text{"Okay"}$$

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Maximum spacing

Maximum allowable longitudinal spacing $s_{l.max} := 0.75 \cdot d \cdot \left(1 + \cot\left(\alpha_{sw}\right)\right) = 400.13\ mm$ SFS EN 1992-1-1 - 9.2.2(6) (9.6N)

Utilization ratio of longitudinal spacing $UR_{sl} := \frac{s_{sw}}{s_{l.max}} = 49.98\%$

Condition to meet

$$Result_{sl} := \left\| \begin{array}{l} \text{if } UR_{sl} \le 1 \\ \quad \left\| \text{“Okay”} \right. \\ \text{else} \\ \quad \left\| \text{“Not Okay”} \right. \end{array} \right.$$

$Result_{sl} = \text{“Okay”}$

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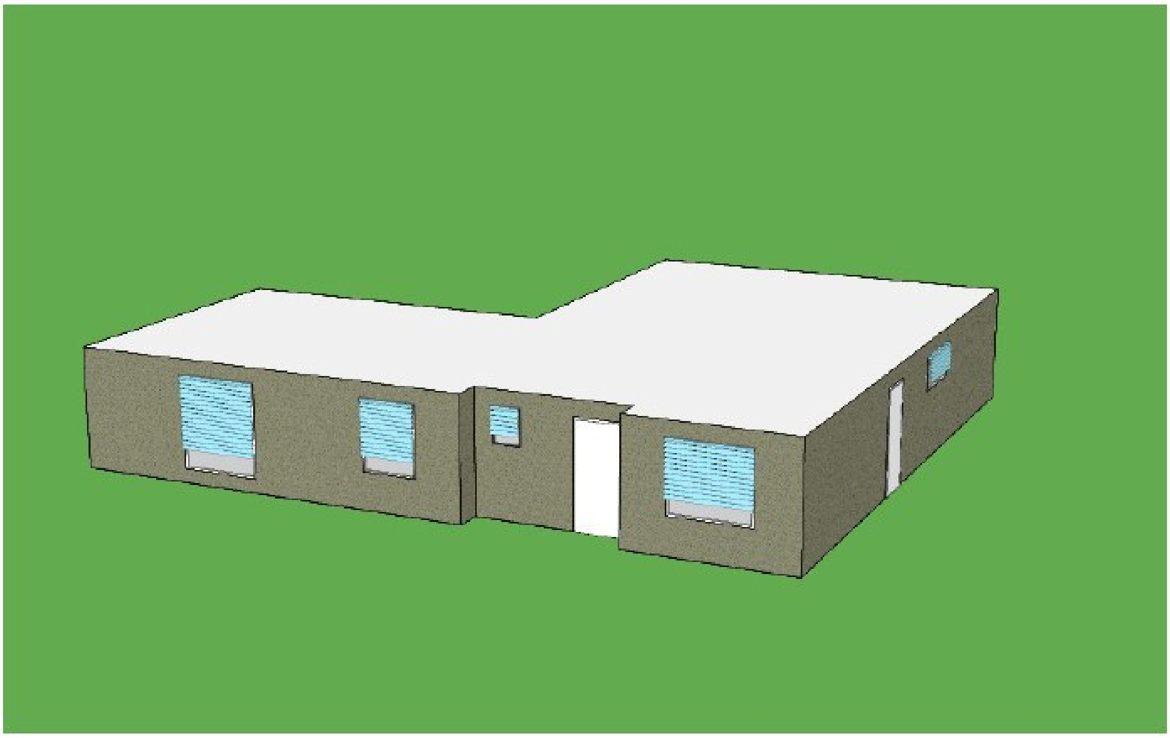
Appendix 7. Energy report

Energy Report



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Calculations for thermal insulation, moisture protection and heat protection

created on 18.9.2025 12:59

Content

	Component	U-value W/m²K	Condensate kg	TA-Attenuation	Thickness cm	Weight kg/m²	Page
1	Thesis - Ceiling - SK	0,08	-	19,4	68,11	43,8	2
2	Thesis - Ceiling - FIN	0,07	-	30,3	68,11	45,3	7
3	Thesis - Wall - SK	0,15	-	588,2	49,94	247,0	12
4	Thesis - Wall - FIN	0,12	-	833,3	56,94	248,1	17
5	Thesis - Floor - SK	0,24	-	113,6	50,08	796,9	22
6	Thesis - Floor - FIN	0,15	0,004	200,0	58,08	798,9	26

Comparison with different maximum values*

Component	GEG 2020/24 Bestand	BEG Einzelmaßn.	GEG 2023/24 Neubau	DIN 4108
Thesis - Ceiling - SK	✓	✓	✓	✓
Thesis - Ceiling - FIN	✓	✓	✓	✓
Thesis - Wall - SK	✓	✓	✓	✓
Thesis - Wall - FIN	✓	✓	✓	✓
Thesis - Floor - SK	✓	✓	✓	✓
Thesis - Floor - FIN	✓	✓	✓	✓

---

*Comparison of the U-value with den Höchstwerten aus GEG Anlage 7 (GEG 2020-2024 Bestand); den techn. Mindestanforderungen für BEG Einzelmaßnahmen; 70% des U-Werts der Referenzausführung aus GEG 2023/2024 Anlage 1 (GEG Neubau); den R-Werten aus DIN 4108-2 Tabelle 3

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Thesis - Ceiling - SK

Ceiling
created on 18.9.2025

Thermal protection

U = 0,08 W/(m²K)

STN 73 0540-2: U<0.10 W/(m²K)

excellent insufficient

Moisture proofing

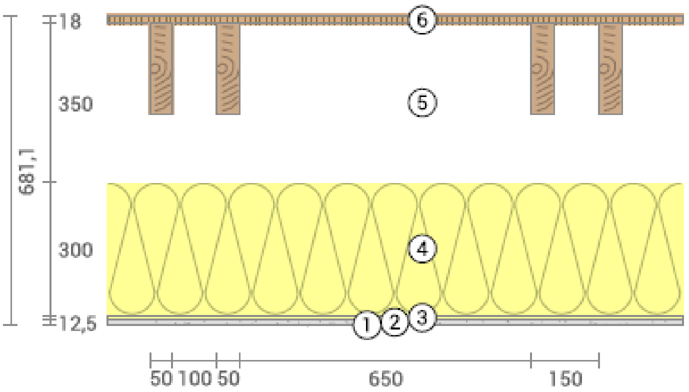
Drying reserve: 202 g/m²a
No condensate

excellent insufficient

Heat protection

Temperature amplitude damping: 19
phase shift: 11,7 h
Thermal capacity inside: 17,8 kJ/m²K

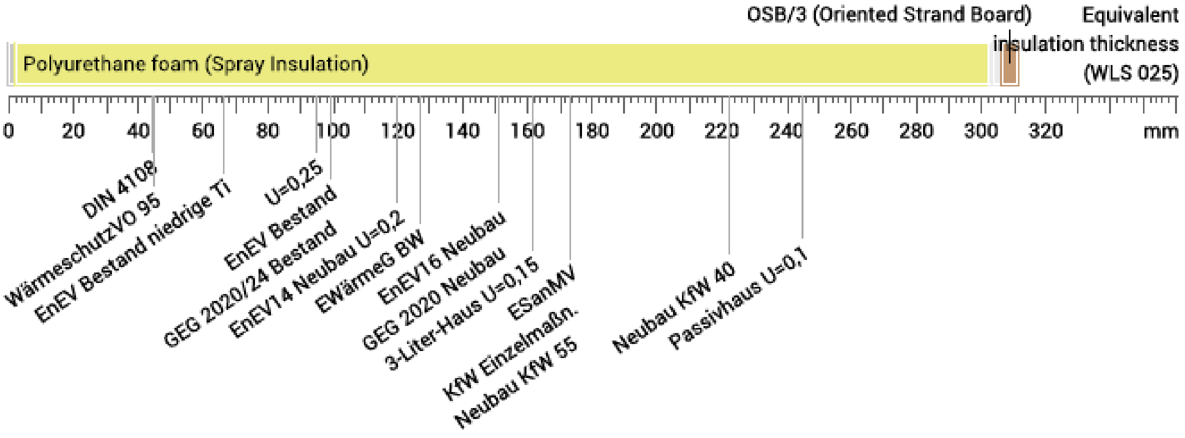
excellent insufficient



① Inner surface finish (0,1 mm)
② Gypsum board (12,5 mm)
③ Vapor barrier sd=100m
④ Polyurethane foam (300 mm)
⑤ Stationary air (350 mm)
⑥ OSB/3 (18 mm)

Impact of each layer and comparison to reference values

For the following figure, the thermal resistances of the individual layers were converted in millimeters insulation. The scale refers to an insulation of thermal conductivity 0,025 W/mK.



Inside air : 21,0°C / 50%
Non-heated room: -2,0°C / 80%
Surface temperature.: 20,8°C / -1,9°C

sd-value: 106,7 m

Thickness: 68,1 cm
Weight: 44 kg/m²
Heat capacity: 58 kJ/m²K

☑ GEG 2020/24 Bestand ☑ BEG Einzelmaßn. ☑ GEG 2023/24 Neubau ☑ DIN 4108

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*Comparison of the U-value with den Höchstwerten aus GEG Anlage 7 (GEG 2020-2024 Bestand); den techn. Mindestanforderungen für BEG Einzelmaßnahmen; 70% des U-Werts der Referenzausführung aus GEG 2023/2024 Anlage 1 (GEG Neubau); den R-Werten aus DIN 4108-2 Tabelle 3

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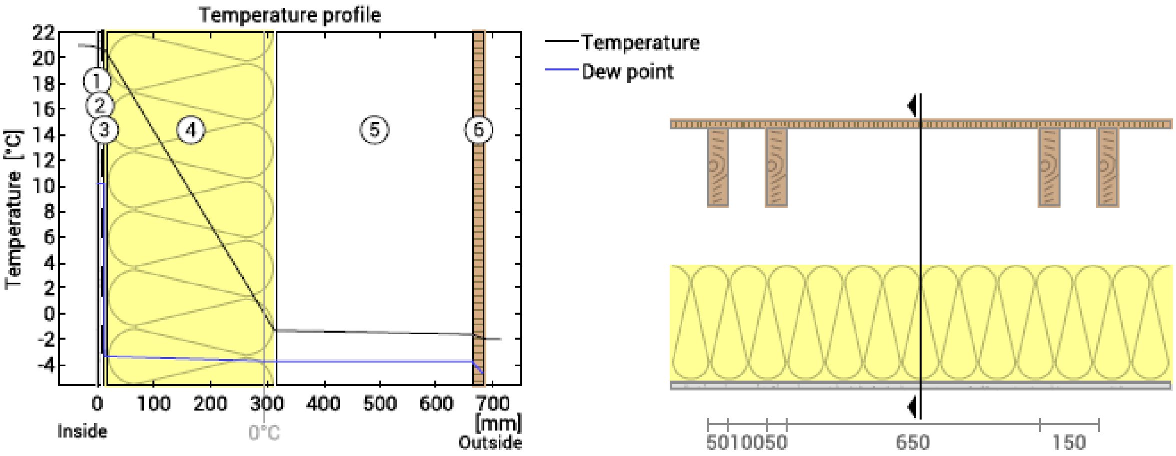
Thesis - Ceiling - SK, U=0,08 $\mathrm{W/(m^2K)}$

Temperature profile



① Inner surface finish (0,1 mm)
② Gypsum board (12,5 mm)
③ Vapor barrier sd=100m
④ Polyurethane foam (300 mm)
⑤ Stationary air (350 mm)
⑥ OSB/3 (18 mm)

Left: Temperature and dew-point temperature at the place marked in the right figure. The dew-point indicates the temperature, at which water vapour condensates. As long as the temperature of the component is everywhere above the dew point, no condensation occurs. If the curves have contact, condensation occurs at the corresponding position.
Right: The component, drawn to scale.

Layers (from inside to outside)

#		Material	λ	R	Temperatur [°C]		Weight
			[W/mK]	[m^{2}K/W]	min	max	[kg/m^2]
		Thermal contact resistance*		0,100	20,8	21,0	
1	0,01 cm	Inner surface finish (Paint)	1,000	0,000	20,8	20,8	0,1
2	1,25 cm	Gypsum board (Drywall)	0,160	0,078	20,7	20,8	11,9
3	0,05 cm	Vapor barrier sd=100m	0,220	0,002	20,7	20,7	0,1
4	30 cm	Polyurethane foam (Spray Insulation)	0,025	12,000	-1,3	20,7	9,0
5	35 cm	Stationary air (unventilated)	2,188	0,160	-1,6	-1,3	0,4
	20 cm	Spruce (Width: 5 cm)	0,130	1,538	-1,7	-1,4	5,3
	20 cm	Spruce (Width: 5 cm)	0,130	1,538	-1,7	-1,4	5,3
6	1,8 cm	OSB/3 (Oriented Strand Board)	0,107	0,168	-1,9	-1,6	11,7
		Thermal contact resistance*		0,100	-2,0	-1,9	
	68,11 cm	Whole component		12,628			43,8

*Assuming free circulating air at the inside surface.

Surface temperature inside (min / average / max): 20,8°C 20,8°C 20,8°C
Surface temperature outside (min / average / max): -1,9°C -1,9°C -1,9°C

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Moisture proofing

For the calculation of the amount of condensation water, the component was exposed to the following constant climate for 90 days: inside: 21°C und 50% Humidity; outside: -2°C und 80% Humidity (Climate according to user input).

Interior heat transfer resistance Rsi (user input deviating from DIN 4108-3):0.1 m²K/W

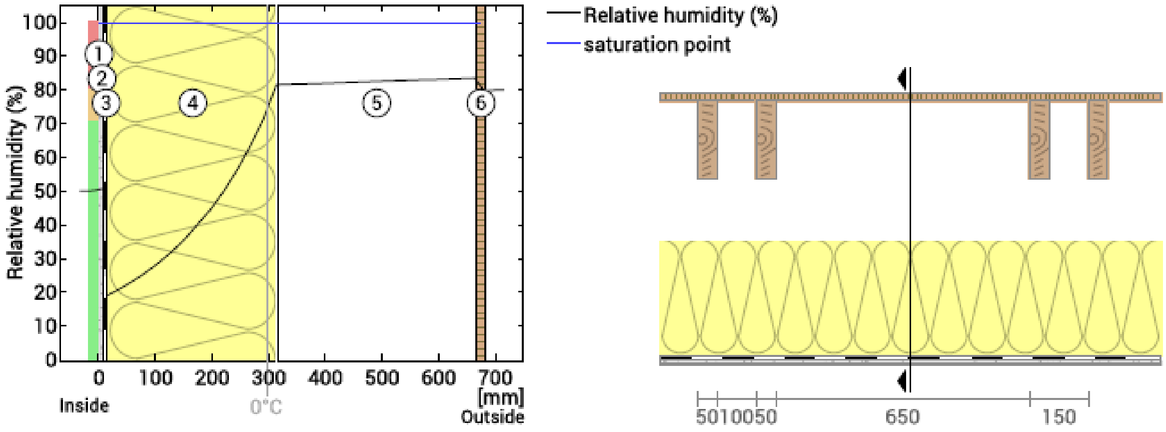
This component is free of condensate under the given climate conditions.

Drying reserve according to Ubakus 2D-FE method:	202 g/(m²a)
At least required by DIN 68800-2:	100 g/(m²a)

#		Material	sd-value [m]	Condensate [kg/m²]	[Gew.-%]	Weight [kg/m²]
1	0,01 cm	Inner surface finish (Paint)	0,10	-		0,1
2	1,25 cm	Gypsum board (Drywall)	0,09	-		11,9
3	0,05 cm	Vapor barrier sd=100m	100,00	-		0,1
4	30 cm	Polyurethane foam (Spray Insulation)	2,00	-		9,0
5	35 cm	Stationary air (unventilated)	0,01	-		0,4
	20 cm	Spruce (Width: 5 cm)	7,00	-	-	5,3
	20 cm	Spruce (Width: 5 cm)	10,00	-	-	5,3
6	1,8 cm	OSB/3 (Oriented Strand Board)	4,00	-	-	11,7
	68,11 cm	Whole component	106,66	0		43,8

Humidity

The temperature of the inside surface is 20,8 °C leading to a relative humidity on the surface of 51%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.



① Inner surface finish (0,1 mm)
② Gypsum board (12,5 mm)
③ Vapor barrier sd=100m
④ Polyurethane foam (300 mm)
⑤ Stationary air (350 mm)
⑥ OSB/3 (18 mm)

Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

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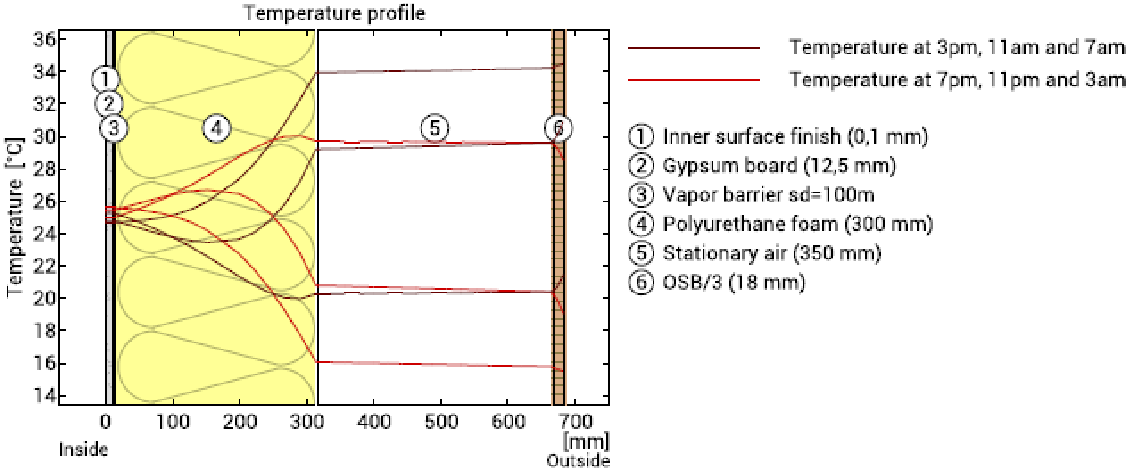
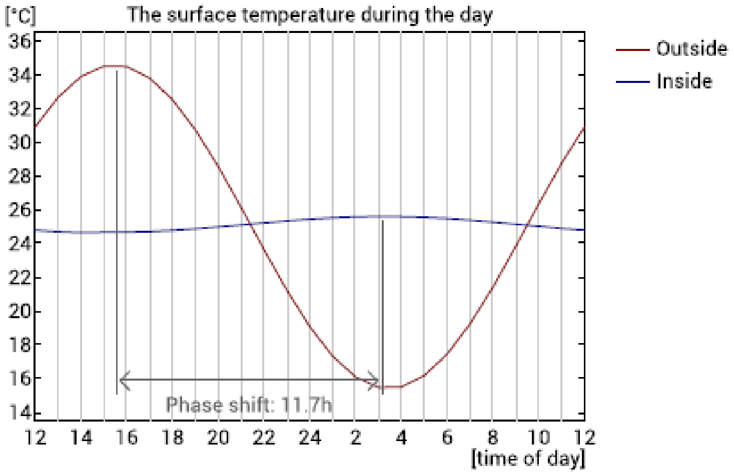
Thesis - Ceiling - SK, U=0,08 W/(m²K)

Heat protection

The following results are properties of the tested component alone and do not make any statement about the heat protection of the entire room:





Top: Temperature profile within the component at different times. From top to bottom, brown lines: at 3 pm, 11 am and 7 am and red lines at 7 pm , 11 pm and 3 am.
Bottom: Temperature on the outer (red) and inner (blue) surface in the course of a day. The arrows indicate the location of the temperature maximum values . The maximum of the inner surface temperature should preferably occur during the second half of the night.

Phase shift*	11,7 h	Heat storage capacity (whole component):	58 kJ/m²K
Amplitude attenuation **	19,4	Thermal capacity of inner layers:	17.8 kJ/m²K
TAV ***	0,052		

* The phase shift is the time in hours after which the temperature peak of the afternoon reaches the component interior.
** The amplitude attenuation describes the attenuation of the temperature wave when passing through the component. A value of 10 means that the temperature on the outside varies 10x stronger than on the inside, e.g. outside 15-35 °C, inside 24-26 °C.
***The temperature amplitude ratio TAV is the reciprocal of the attenuation: TAV = 1 / amplitude attenuation

Note: The heat protection of a room is influenced by several factors, but essentially by the direct solar radiation through windows and the total amount of heat storage capacity (including floor, interior walls and furniture). A single component usually has only a very small influence on the heat protection of the room.

The calculations presented above have been created for a 1-dimensional cross-section of the component.

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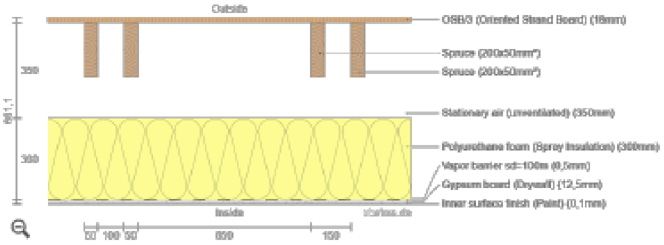
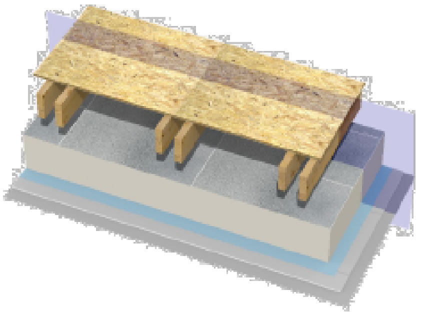
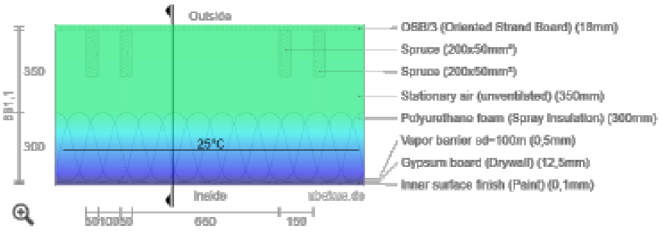
Thesis - Ceiling - SK, U=0,08 W/(m²K)

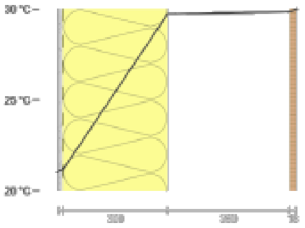
Diagrams



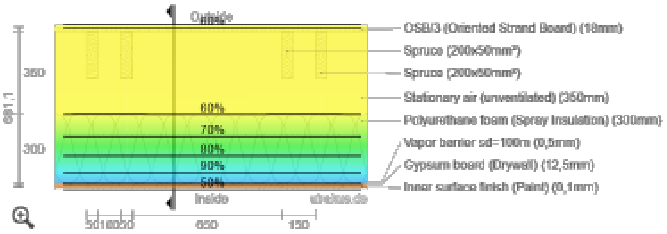


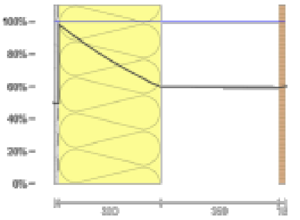
Temperature (summer)



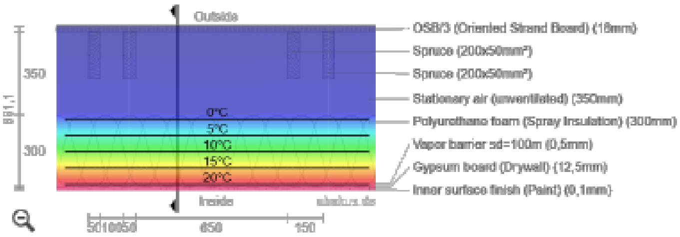


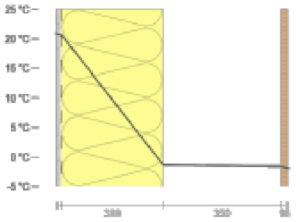
Humidity (summer)



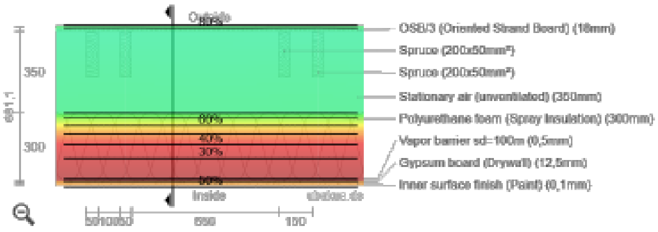


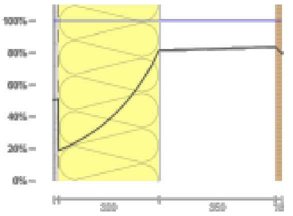
Temperature (winter)





Humidity (winter)





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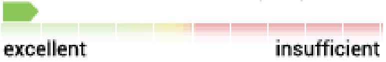
Thesis - Ceiling - FIN

Ceiling
created on 18.9.2025

Thermal protection

U = 0,07 W/(m²K)

SDK 1010/2017: U<0.07W/(m²K)

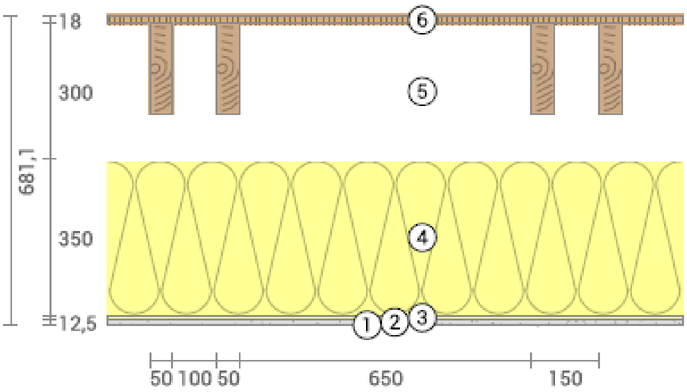


Moisture proofing

Drying reserve: 202 g/m²a
No condensate

Heat protection

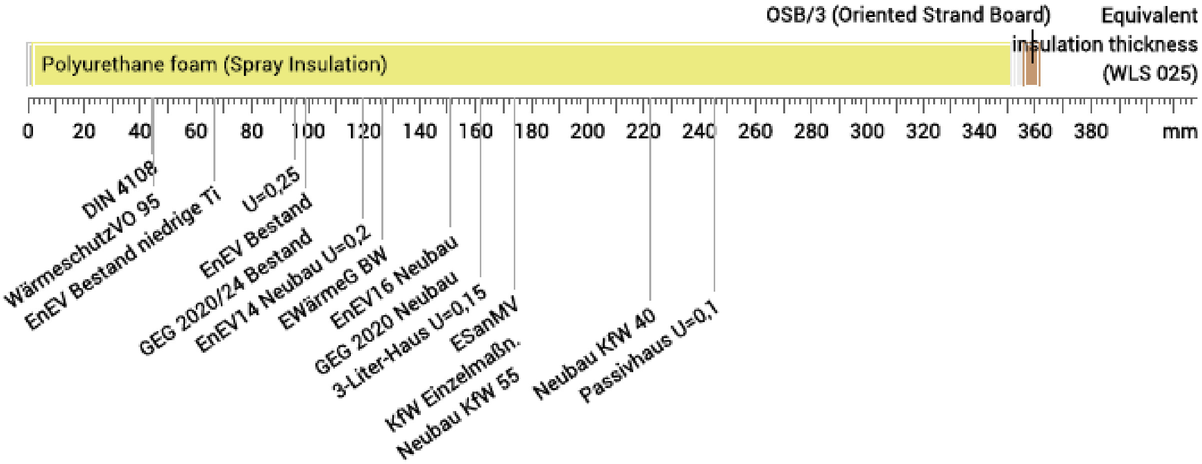
Temperature amplitude damping: 30
phase shift: 13,2 h
Thermal capacity inside: 18,9 kJ/m²K



① Inner surface finish (0,1 mm)
② Gypsum board (12,5 mm)
③ Vapor barrier sd=100m
④ Polyurethane foam (350 mm)
⑤ Stationary air (300 mm)
⑥ OSB/3 (18 mm)

Impact of each layer and comparison to reference values

For the following figure, the thermal resistances of the individual layers were converted in millimeters insulation. The scale refers to an insulation of thermal conductivity 0,025 W/mK.



Inside air : 21,0°C / 50%
Non-heated room: -10,0°C / 80%
Surface temperature.: 20,8°C / -9,9°C

sd-value: 106,7 m

Thickness: 68,1 cm
Weight: 45 kg/m²
Heat capacity: 60 kJ/m²K

☑ GEG 2020/24 Bestand ☑ BEG Einzelmaßn. ☑ GEG 2023/24 Neubau ☑ DIN 4108

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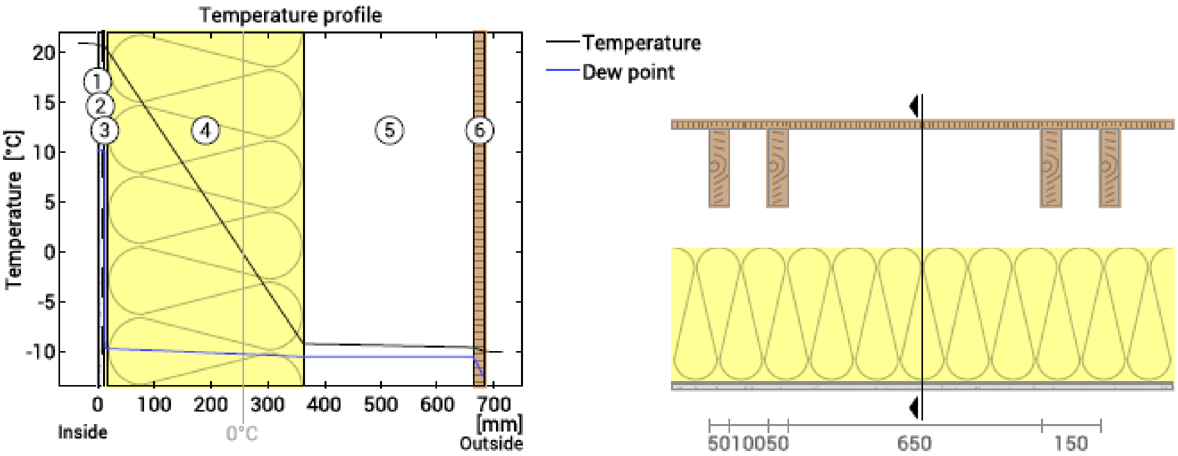
*Comparison of the U-value with den Höchstwerten aus GEG Anlage 7 (GEG 2020-2024 Bestand); den techn. Mindestanforderungen für BEG Einzelmaßnahmen; 70% des U-Werts der Referenzausführung aus GEG 2023/2024 Anlage 1 (GEG Neubau); den R-Werten aus DIN 4108-2 Tabelle 3

Thesis - Ceiling - FIN, U=0,07 W/(m²K)

Temperature profile



① Inner surface finish (0,1 mm)
② Gypsum board (12,5 mm)
③ Vapor barrier sd=100m
④ Polyurethane foam (350 mm)
⑤ Stationary air (300 mm)
⑥ OSB/3 (18 mm)

Left: Temperature and dew-point temperature at the place marked in the right figure. The dew-point indicates the temperature, at which water vapour condensates. As long as the temperature of the component is everywhere above the dew point, no condensation occurs. If the curves have contact, condensation occurs at the corresponding position.
Right: The component, drawn to scale.

Layers (from inside to outside)

#		Material	λ	R	Temperatur [°C]		Weight
			[W/mK]	[m²K/W]	min	max	[kg/m²]
		Thermal contact resistance*		0,100	20,8	21,0	
1	0,01 cm	Inner surface finish (Paint)	1,000	0,000	20,8	20,8	0,1
2	1,25 cm	Gypsum board (Drywall)	0,160	0,078	20,6	20,8	11,9
3	0,05 cm	Vapor barrier sd=100m	0,220	0,002	20,6	20,6	0,1
4	35 cm	Polyurethane foam (Spray Insulation)	0,025	14,000	-9,2	20,6	10,5
5	30 cm	Stationary air (unventilated)	1,875	0,160	-9,6	-9,2	0,3
	20 cm	Spruce (Width: 5 cm)	0,130	1,538	-9,7	-9,3	5,3
	20 cm	Spruce (Width: 5 cm)	0,130	1,538	-9,7	-9,3	5,3
6	1,8 cm	OSB/3 (Oriented Strand Board)	0,107	0,168	-9,9	-9,5	11,7
		Thermal contact resistance*		0,100	-10,0	-9,9	
	68,11 cm	Whole component		14,630			45,3

*Assuming free circulating air at the inside surface.

Surface temperature inside (min / average / max):	20,8°C	20,8°C	20,8°C
Surface temperature outside (min / average / max):	-9,9°C	-9,9°C	-9,9°C

ubakus
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Thesis - Ceiling - FIN, U=0,07 W/(m²K)

Moisture proofing

For the calculation of the amount of condensation water, the component was exposed to the following constant climate for 90 days: inside: 21°C und 50% Humidity; outside: -10°C und 80% Humidity (Climate according to user input).

Interior heat transfer resistance Rsi (user input deviating from DIN 4108-3):0.1 m²K/W

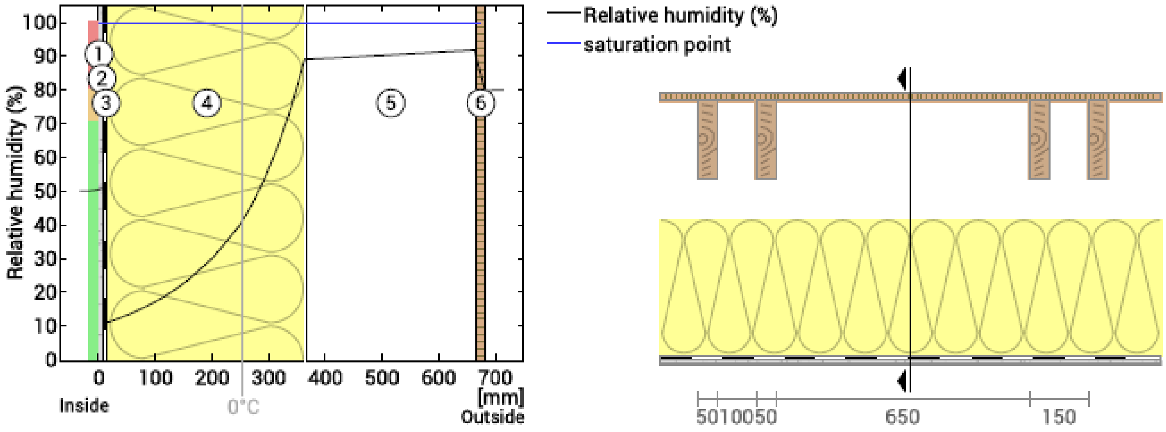
This component is free of condensate under the given climate conditions.

Drying reserve according to Ubakus 2D-FE method:	202 g/(m²a)
At least required by DIN 68800-2:	100 g/(m²a)

#		Material	sd-value [m]	Condensate [kg/m²]	[Gew.-%]	Weight [kg/m²]
1	0,01 cm	Inner surface finish (Paint)	0,10	-		0,1
2	1,25 cm	Gypsum board (Drywall)	0,09	-		11,9
3	0,05 cm	Vapor barrier sd=100m	100,00	-		0,1
4	35 cm	Polyurethane foam (Spray Insulation)	2,00	-		10,5
5	30 cm	Stationary air (unventilated)	0,01	-		0,3
	20 cm	Spruce (Width: 5 cm)	10,00	-	-	5,3
	20 cm	Spruce (Width: 5 cm)	7,00	-	-	5,3
6	1,8 cm	OSB/3 (Oriented Strand Board)	4,00	-	-	11,7
	68,11 cm	Whole component	106,66	0		45,3

Humidity

The temperature of the inside surface is 20,8 °C leading to a relative humidity on the surface of 51%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.



① Inner surface finish (0,1 mm)
② Gypsum board (12,5 mm)
③ Vapor barrier sd=100m
④ Polyurethane foam (350 mm)
⑤ Stationary air (300 mm)
⑥ OSB/3 (18 mm)

Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

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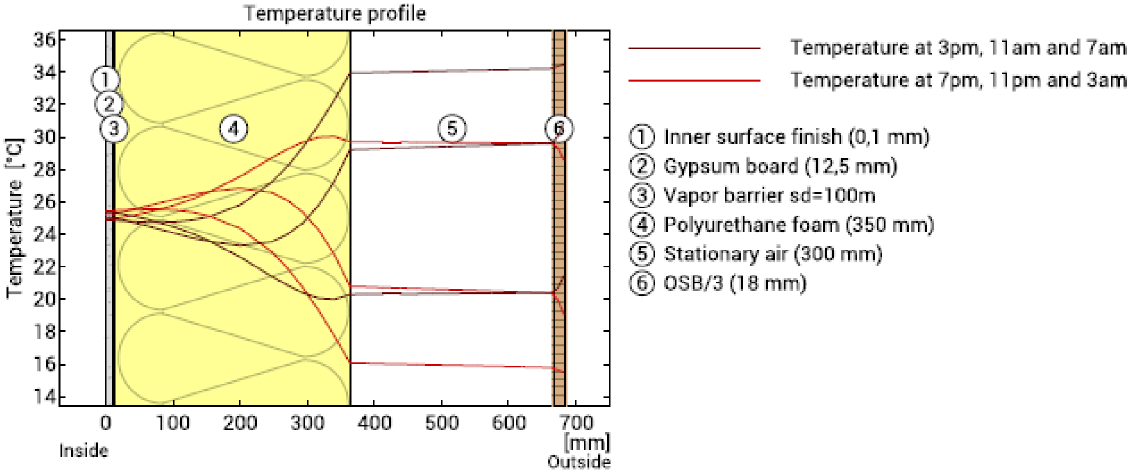
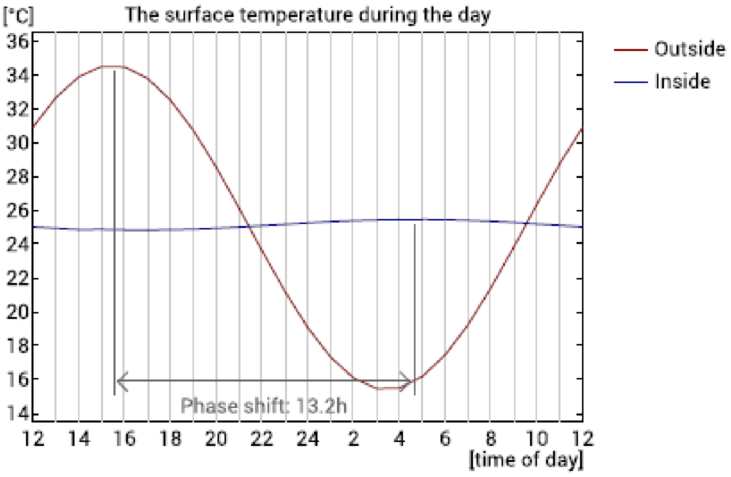
Heat protection

The following results are properties of the tested component alone and do not make any statement about the heat protection of the entire room:





Top: Temperature profile within the component at different times. From top to bottom, brown lines: at 3 pm, 11 am and 7 am and red lines at 7 pm , 11 pm and 3 am.
Bottom: Temperature on the outer (red) and inner (blue) surface in the course of a day. The arrows indicate the location of the temperature maximum values . The maximum of the inner surface temperature should preferably occur during the second half of the night.

Phase shift*	13,2 h	Heat storage capacity (whole component):	60 kJ/m²K
Amplitude attenuation **	30,3	Thermal capacity of inner layers:	18.9 kJ/m²K
TAV ***	0,033		

* The phase shift is the time in hours after which the temperature peak of the afternoon reaches the component interior.
** The amplitude attenuation describes the attenuation of the temperature wave when passing through the component. A value of 10 means that the temperature on the outside varies 10x stronger than on the inside, e.g. outside 15-35 °C, inside 24-26 °C.
***The temperature amplitude ratio TAV is the reciprocal of the attenuation: TAV = 1 / amplitude attenuation

Note: The heat protection of a room is influenced by several factors, but essentially by the direct solar radiation through windows and the total amount of heat storage capacity (including floor, interior walls and furniture). A single component usually has only a very small influence on the heat protection of the room.

The calculations presented above have been created for a 1-dimensional cross-section of the component.

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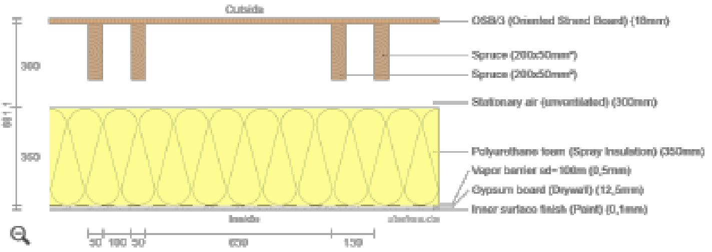
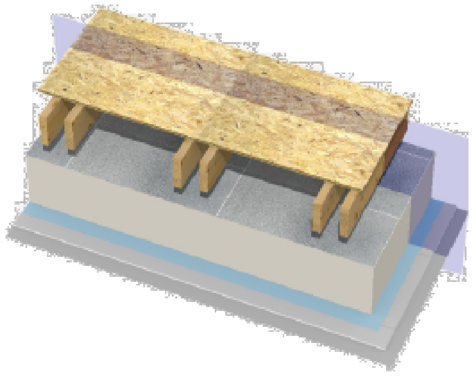
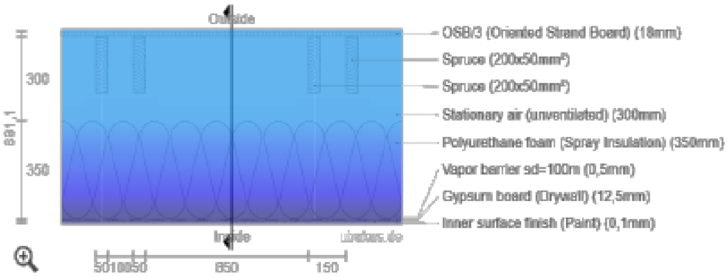
Thesis - Ceiling - SK, U=0,08 W/(m²K)

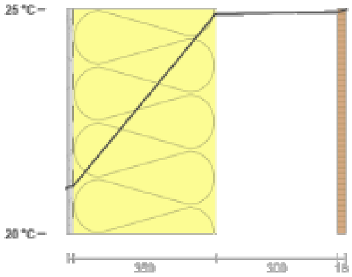
Diagrams



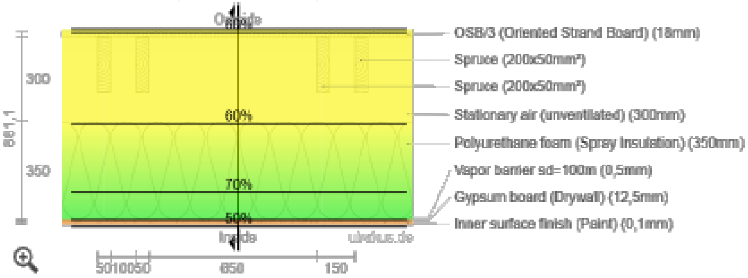


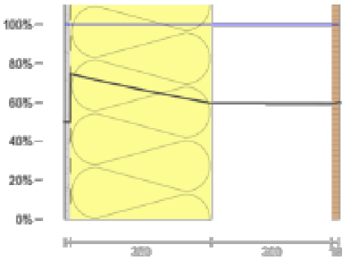
Temperature (summer)



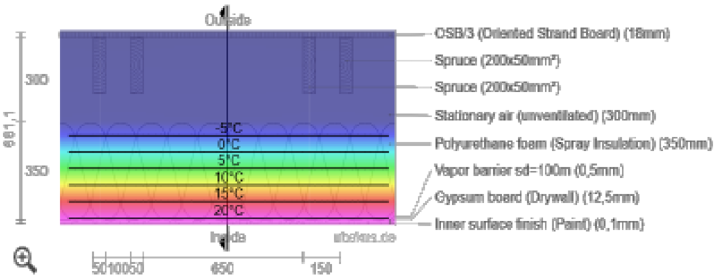


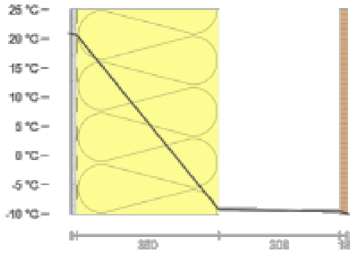
Humidity (summer)



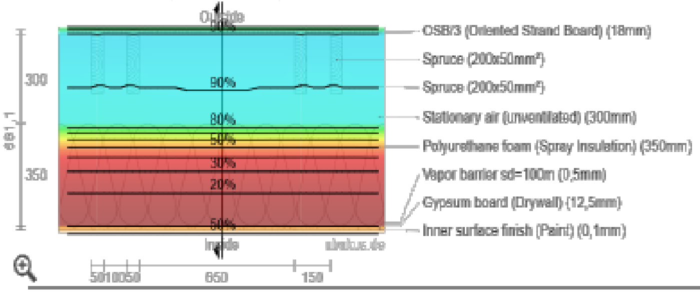


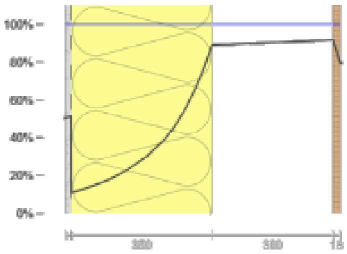
Temperature (winter)





Humidity (winter)





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Thesis - Wall - SK

Exterior wall
created on 18.9.2025

Thermal protection

U = 0,15 W/(m²K)

STN 73 0540-2: U<0.15W/(m²K)

excellent insufficient

Moisture proofing

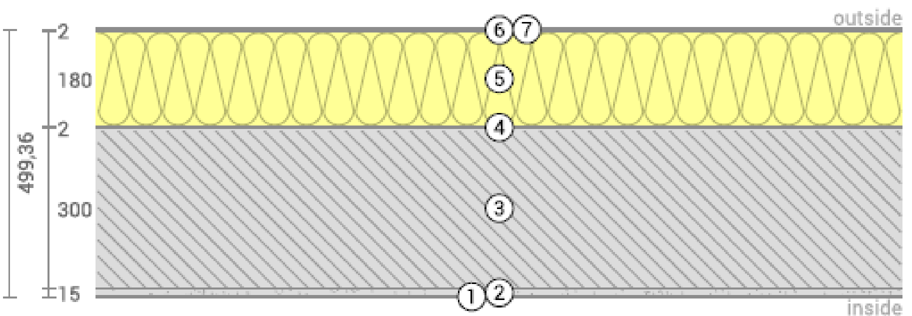
No condensate

excellent insufficient

Heat protection

Temperature amplitude damping: >100
phase shift: non relevant
Thermal capacity inside: 204 kJ/m²K

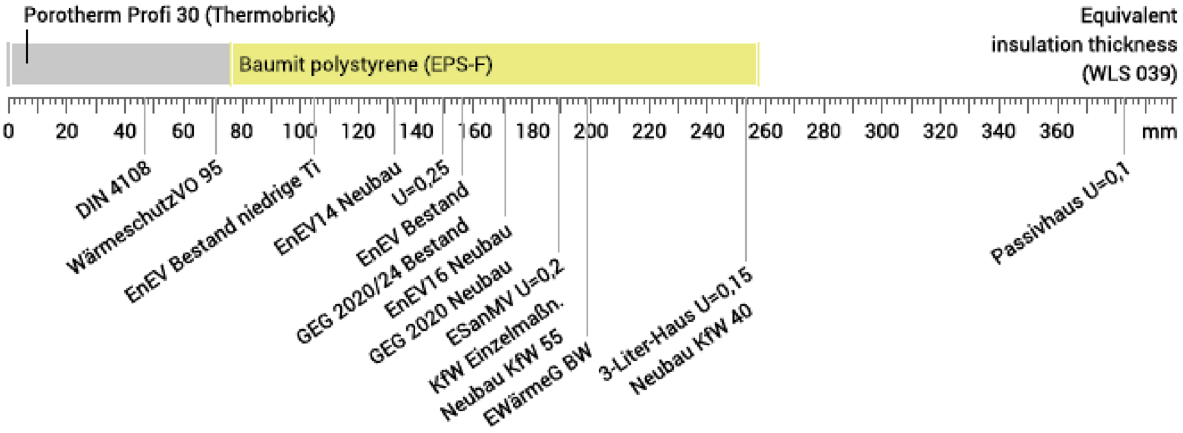
excellent insufficient



① Inner surface finish (0,1 mm)
② Lime cement plaster (15 mm)
③ Porotherm Profi 30 (300 mm)
④ Porotherm Profi mortar (2 mm)
⑤ Baumit polystyrene (180 mm)
⑥ Finishing plaster (2 mm)
⑦ Outer surface finish (0,26 mm)

Impact of each layer and comparison to reference values

For the following figure, the thermal resistances of the individual layers were converted in millimeters insulation. The scale refers to an insulation of thermal conductivity 0,039 W/mK.



Inside air : 21,0°C / 50%
Outside air: -2,0°C / 80%
Surface temperature.: 20,6°C / -1,9°C

sd-value: 14,1 m

Thickness: 49,9 cm
Weight: 247 kg/m²
Heat capacity: 244 kJ/m²K

☑ GEG 2020/24 Bestand ☑ BEG Einzelmaßn. ☑ GEG 2023/24 Neubau ☑ DIN 4108

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*Comparison of the U-value with den Höchstwerten aus GEG Anlage 7 (GEG 2020-2024 Bestand); den techn. Mindestanforderungen für BEG Einzelmaßnahmen; 70% des U-Werts der Referenzausführung aus GEG 2023/2024 Anlage 1 (GEG Neubau); den R-Werten aus DIN 4108-2 Tabelle 3

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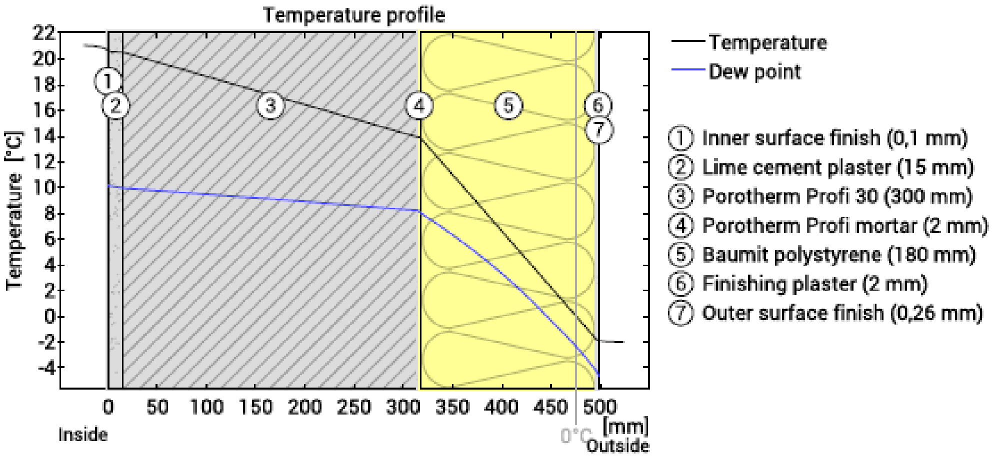
Thesis - Wall - SK, U=0,15 W/(m²K)

Temperature profile



Temperature and dew-point temperature in the component. The dew-point indicates the temperature, at which water vapour condensates. As long as the temperature of the component is everywhere above the dew-point temperature, no condensation occurs. If the curves have contact, condensation occurs at the corresponding position.

Layers (from inside to outside)

#		Material	λ	R	Temperatur [°C]		Weight
			[W/mK]	[m²K/W]	min	max	[kg/m²]
		Thermal contact resistance*		0,130	20,6	21,0	
1	0,01 cm	Inner surface finish (Paint)	1,000	0,000	20,6	20,6	0,1
2	1,5 cm	Lime cement plaster	0,700	0,021	20,5	20,6	27,0
3	30 cm	Porotherm Profi 30 (Thermobrick)	0,155	1,935	13,9	20,5	210,0
4	0,2 cm	Porotherm Profi mortar	0,800	0,003	13,9	13,9	3,0
5	18 cm	Baumit polystyrene (EPS-F)	0,039	4,615	-1,9	13,9	2,9
6	0,2 cm	Finishing plaster (Stolit® K)	0,700	0,003	-1,9	-1,9	3,6
7	0,026 cm	Outer surface finish (Paint)	0,700	0,000	-1,9	-1,9	0,4
		Thermal contact resistance*		0,040	-2,0	-1,9	
	49,936 cm	Whole component		6,748			247,0

*Assuming free circulating air at the inside surface.

Surface temperature inside (min / average / max):	20,6°C	20,6°C	20,6°C
Surface temperature outside (min / average / max):	-1,9°C	-1,9°C	-1,9°C

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Thesis - Wall - SK, U=0,15 W/(m²K)

Moisture proofing

For the calculation of the amount of condensation water, the component was exposed to the following constant climate for 90 days: inside: 21°C und 50% Humidity; outside: -2°C und 80% Humidity (Climate according to user input).

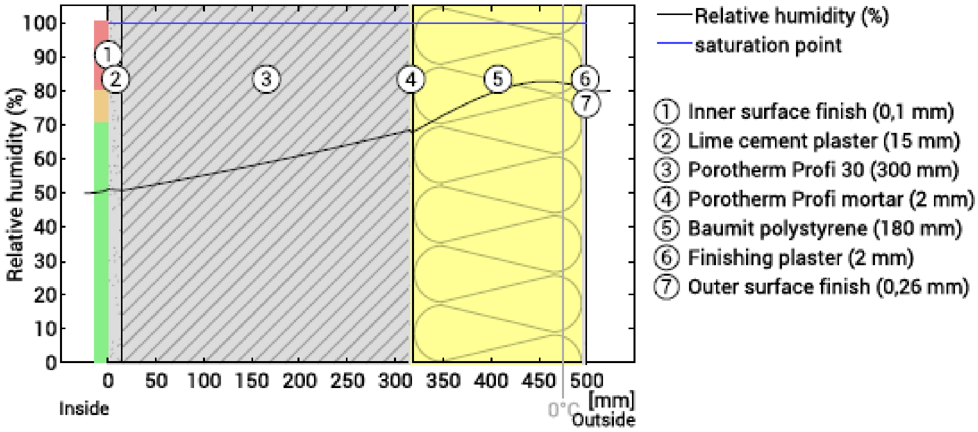
Interior heat transfer resistance Rsi (user input deviating from DIN 4108-3):0.13 m²K/W

This component is free of condensate under the given climate conditions.

#		Material	sd-value	Condensate		Weight
			[m]	[kg/m²]	[Gew.-%]	[kg/m²]
1	0,01 cm	Inner surface finish (Paint)	0,10	-		0,1
2	1,5 cm	Lime cement plaster	0,25	-		27,0
3	30 cm	Porotherm Profi 30 (Thermobrick)	2,30	-		210,0
4	0,2 cm	Porotherm Profi mortar	0,20	-		3,0
5	18 cm	Baumit polystyrene (EPS-F)	11,00	-		2,9
6	0,2 cm	Finishing plaster (Stolit® K)	0,20	-		3,6
7	0,026 cm	Outer surface finish (Paint)	0,01	-		0,4
	49,936 cm	Whole component	14,06	0		247,0

Humidity

The temperature of the inside surface is 20,6 °C leading to a relative humidity on the surface of 51%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.



Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

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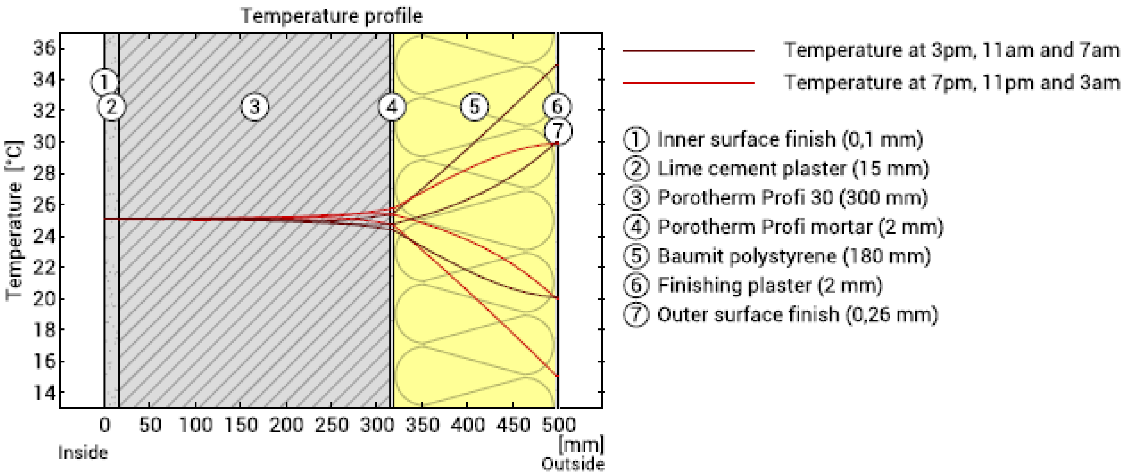
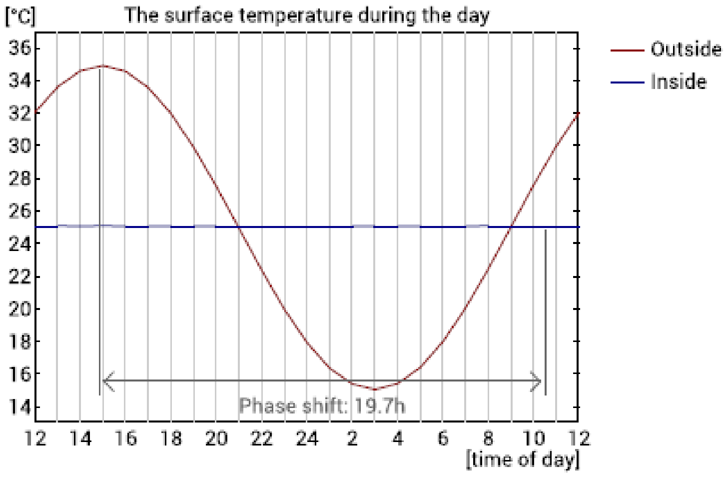
Thesis - Wall - SK, U=0,15 W/(m²K)

Heat protection

The following results are properties of the tested component alone and do not make any statement about the heat protection of the entire room:





Top: Temperature profile within the component at different times. From top to bottom, brown lines: at 3 pm, 11 am and 7 am and red lines at 7 pm , 11 pm and 3 am.
Bottom: Temperature on the outer (red) and inner (blue) surface in the course of a day. The arrows indicate the location of the temperature maximum values . The maximum of the inner surface temperature should preferably occur during the second half of the night.

Phase shift*	non relevant	Heat storage capacity (whole component):	244 kJ/m²K
Amplitude attenuation **	>100	Thermal capacity of inner layers:	204 kJ/m²K
TAV ***	0,002		

* The phase shift is the time in hours after which the temperature peak of the afternoon reaches the component interior.
** The amplitude attenuation describes the attenuation of the temperature wave when passing through the component. A value of 10 means that the temperature on the outside varies 10x stronger than on the inside, e.g. outside 15-35 °C, inside 24-26 °C.
*** The temperature amplitude ratio TAV is the reciprocal of the attenuation: TAV = 1 / amplitude attenuation

Note: The heat protection of a room is influenced by several factors, but essentially by the direct solar radiation through windows and the total amount of heat storage capacity (including floor, interior walls and furniture). A single component usually has only a very small influence on the heat protection of the room.

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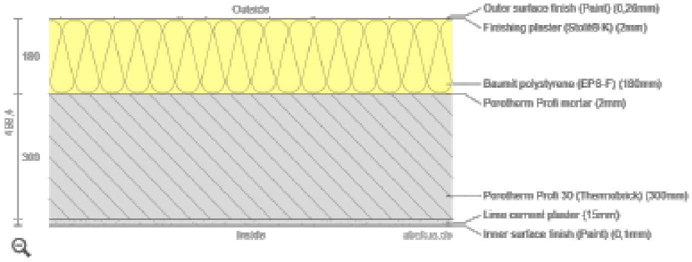
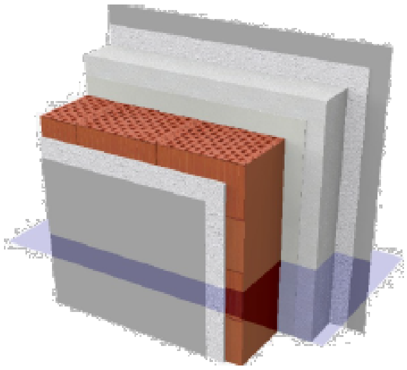
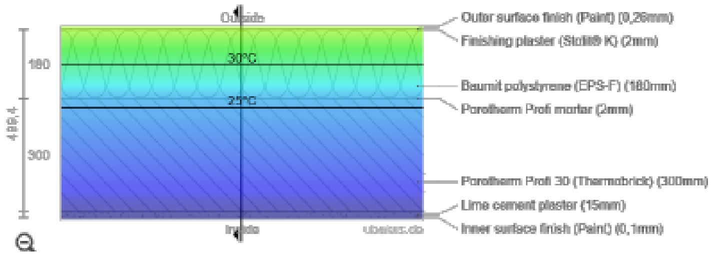
Thesis - Ceiling - SK, U=0,08 W/(m²K)

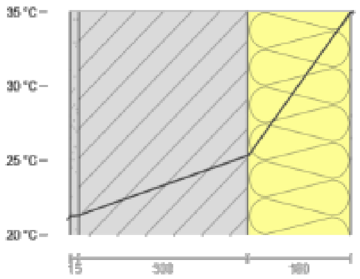
Diagrams



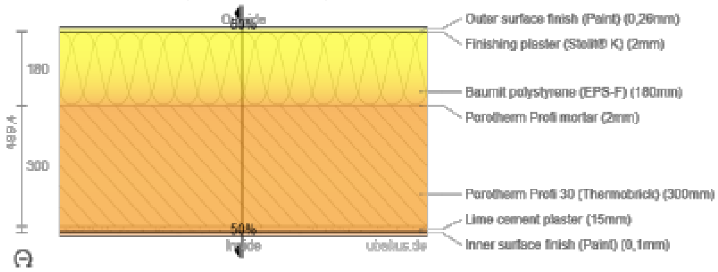


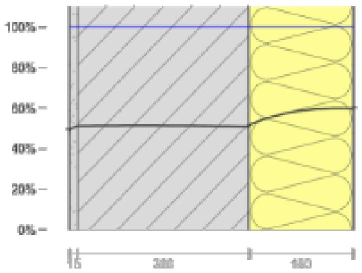
Temperature (summer)



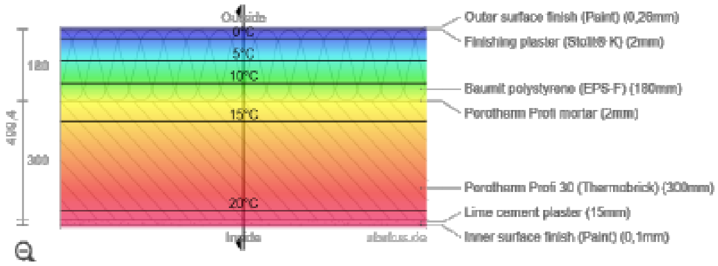


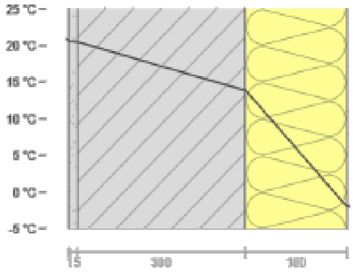
Humidity (summer)



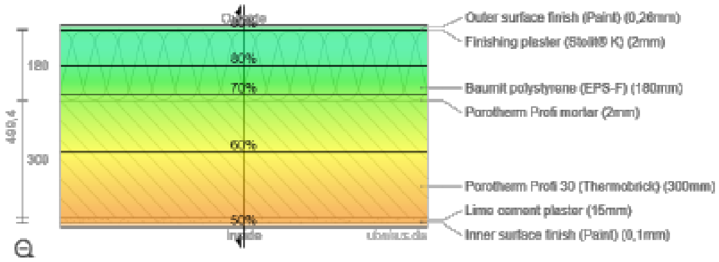


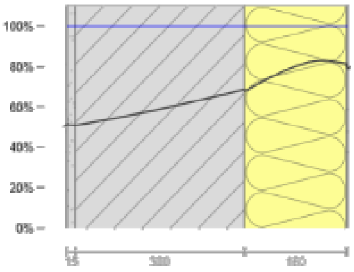
Temperature (winter)





Humidity (winter)





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Thesis - Wall - FIN

Exterior wall
created on 18.9.2025

Thermal protection

U = 0,12 W/(m²K)

SDK 1010/2017: U<0.12W/(m²K)

excellent insufficient

Moisture proofing

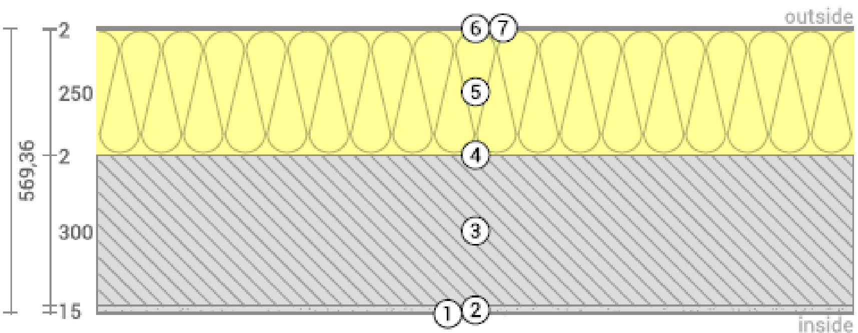
No condensate

excellent insufficient

Heat protection

Temperature amplitude damping: >100
phase shift: non relevant
Thermal capacity inside: 212 kJ/m²K

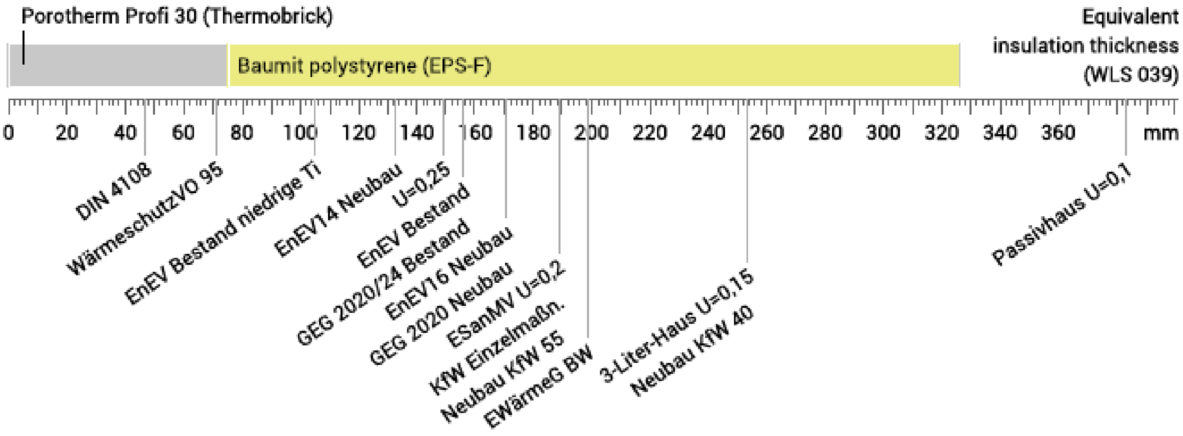
excellent insufficient



① Inner surface finish (0,1 mm)
② Lime cement plaster (15 mm)
③ Porotherm Profi 30 (300 mm)
④ Porotherm Profi mortar (2 mm)
⑤ Baumit polystyrene (250 mm)
⑥ Finishing plaster (2 mm)
⑦ Outer surface finish (0,26 mm)

Impact of each layer and comparison to reference values

For the following figure, the thermal resistances of the individual layers were converted in millimeters insulation. The scale refers to an insulation of thermal conductivity 0,039 W/mK.



Inside air :	21,0°C / 50%		Thickness:	56,9 cm
Outside air:	-10,0°C / 80%	sd-value: 14,1 m	Weight:	248 kg/m²
Surface temperature.:	20,5°C / -9,9°C		Heat capacity:	246 kJ/m²K

☑ GEG 2020/24 Bestand ☑ BEG Einzelmaßn. ☑ GEG 2023/24 Neubau ☑ DIN 4108

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*Comparison of the U-value with den Höchstwerten aus GEG Anlage 7 (GEG 2020-2024 Bestand); den techn. Mindestanforderungen für BEG Einzelmaßnahmen; 70% des U-Werts der Referenzausführung aus GEG 2023/2024 Anlage 1 (GEG Neubau); den R-Werten aus DIN 4108-2 Tabelle 3

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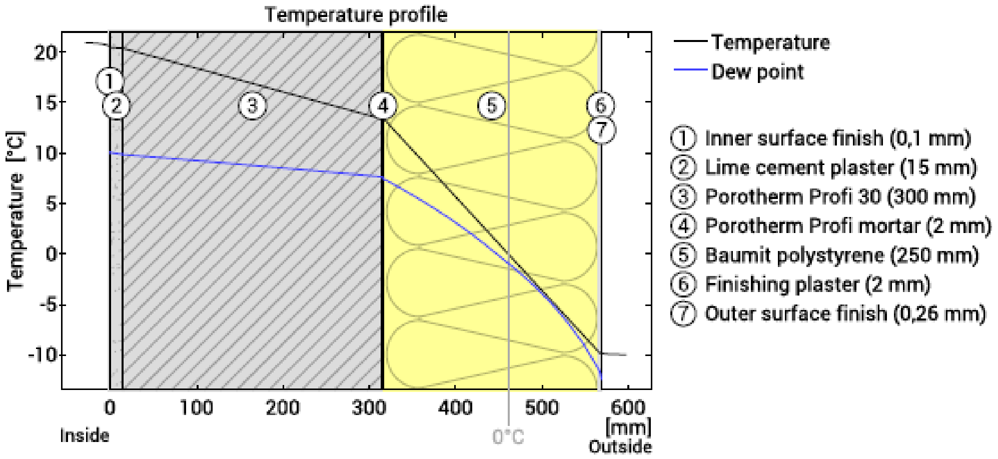
Thesis - Wall - FIN, U=0,12 W/(m²K)

Temperature profile



Temperature and dew-point temperature in the component. The dew-point indicates the temperature, at which water vapour condensates. As long as the temperature of the component is everywhere above the dew-point temperature, no condensation occurs. If the curves have contact, condensation occurs at the corresponding position.

Layers (from inside to outside)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C]		Weight [kg/m²]
					min	max	
		Thermal contact resistance*		0,130	20,5	21,0	
1	0,01 cm	Inner surface finish (Paint)	1,000	0,000	20,5	20,5	0,1
2	1,5 cm	Lime cement plaster	0,700	0,021	20,5	20,5	27,0
3	30 cm	Porotherm Profi 30 (Thermobrick)	0,155	1,935	13,4	20,5	210,0
4	0,2 cm	Porotherm Profi mortar	0,800	0,003	13,4	13,4	3,0
5	25 cm	Baumit polystyrene (EPS-F)	0,039	6,410	-9,8	13,4	4,0
6	0,2 cm	Finishing plaster (Stolit® K)	0,700	0,003	-9,9	-9,8	3,6
7	0,026 cm	Outer surface finish (Paint)	0,700	0,000	-9,9	-9,9	0,4
		Thermal contact resistance*		0,040	-10,0	-9,9	
	56,936 cm	Whole component		8,543			248,1

*Assuming free circulating air at the inside surface.

Surface temperature inside (min / average / max):	20,5°C	20,5°C	20,5°C
Surface temperature outside (min / average / max):	-9,9°C	-9,9°C	-9,9°C

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Thesis - Wall - FIN, U=0,12 W/(m²K)

Moisture proofing

For the calculation of the amount of condensation water, the component was exposed to the following constant climate for 90 days: inside: 21°C und 50% Humidity; outside: -10°C und 80% Humidity (Climate according to user input).

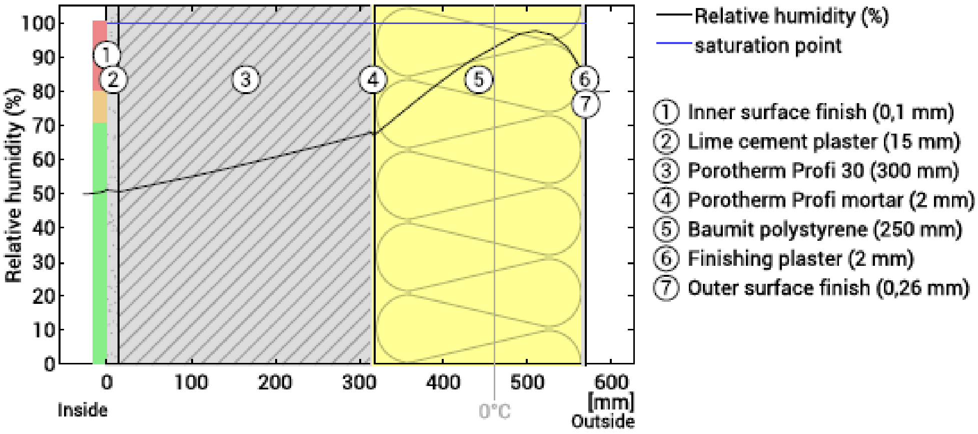
Interior heat transfer resistance Rsi (user input deviating from DIN 4108-3):0.13 m²K/W

This component is free of condensate under the given climate conditions.

#		Material	sd-value [m]	Condensate [kg/m²]	[Gew.-%]	Weight [kg/m²]
1	0,01 cm	Inner surface finish (Paint)	0,10	-		0,1
2	1,5 cm	Lime cement plaster	0,25	-		27,0
3	30 cm	Porotherm Profi 30 (Thermobrick)	2,30	-		210,0
4	0,2 cm	Porotherm Profi mortar	0,20	-		3,0
5	25 cm	Baumit polystyrene (EPS-F)	11,00	-		4,0
6	0,2 cm	Finishing plaster (Stolit® K)	0,20	-		3,6
7	0,026 cm	Outer surface finish (Paint)	0,01	-		0,4
	56,936 cm	Whole component	14,06	0		248,1

Humidity

The temperature of the inside surface is 20,5 °C leading to a relative humidity on the surface of 52%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.



Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

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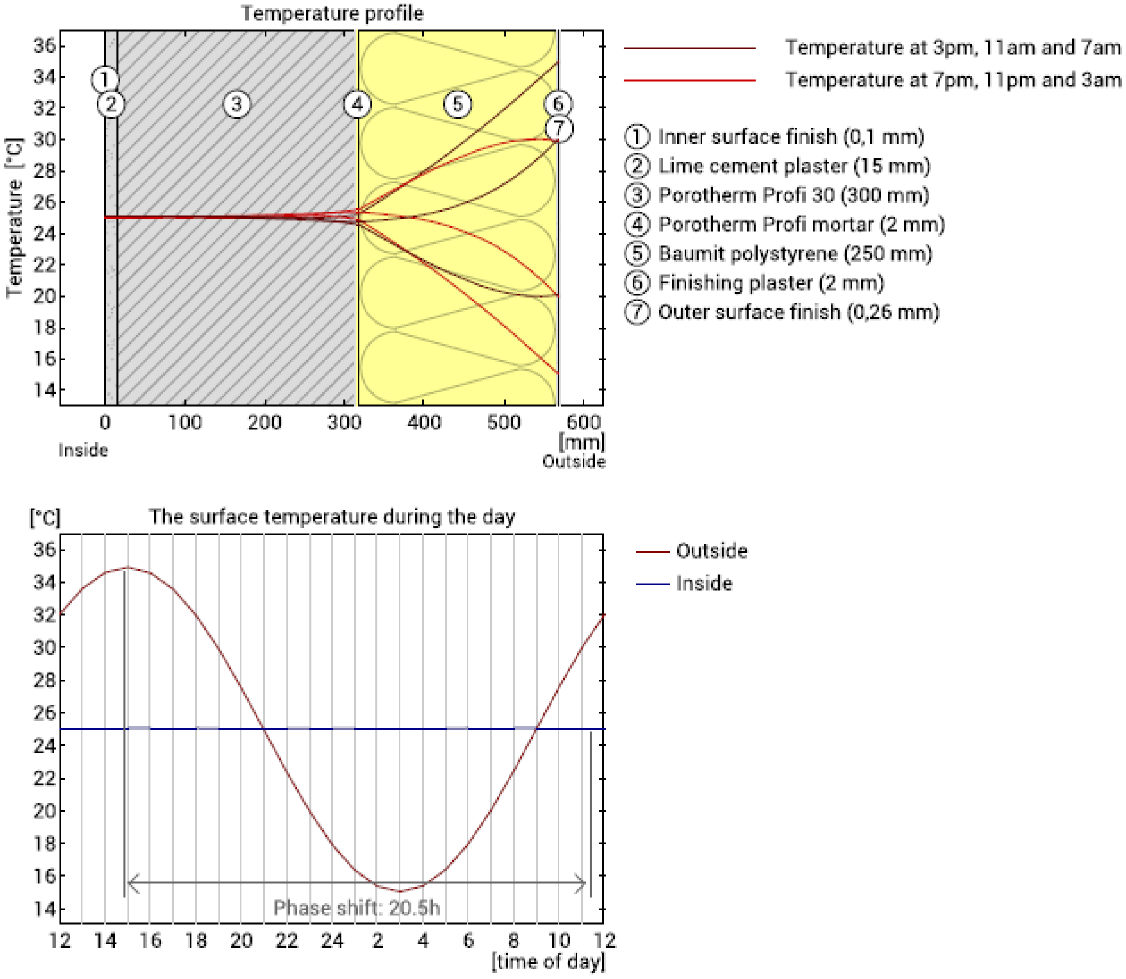
Heat protection

The following results are properties of the tested component alone and do not make any statement about the heat protection of the entire room:



Top: Temperature profile within the component at different times. From top to bottom, brown lines: at 3 pm, 11 am and 7 am and red lines at 7 pm , 11 pm and 3 am.
Bottom: Temperature on the outer (red) and inner (blue) surface in the course of a day. The arrows indicate the location of the temperature maximum values . The maximum of the inner surface temperature should preferably occur during the second half of the night.

Phase shift*	non relevant	Heat storage capacity (whole component):	246 kJ/m²K
Amplitude attenuation **	>100	Thermal capacity of inner layers:	212 kJ/m²K
TAV ***	0,001		

* The phase shift is the time in hours after which the temperature peak of the afternoon reaches the component interior.
** The amplitude attenuation describes the attenuation of the temperature wave when passing through the component. A value of 10 means that the temperature on the outside varies 10x stronger than on the inside, e.g. outside 15-35 °C, inside 24-26 °C.
*** The temperature amplitude ratio TAV is the reciprocal of the attenuation: TAV = 1 / amplitude attenuation

Note: The heat protection of a room is influenced by several factors, but essentially by the direct solar radiation through windows and the total amount of heat storage capacity (including floor, interior walls and furniture). A single component usually has only a very small influence on the heat protection of the room.

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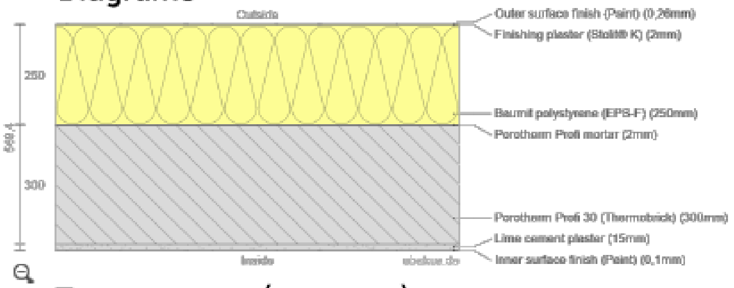
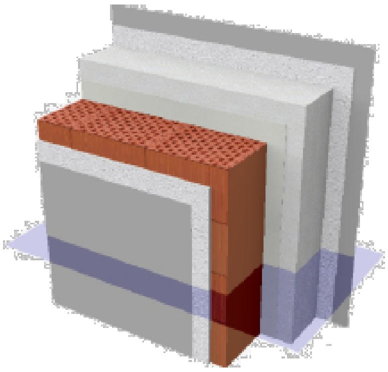
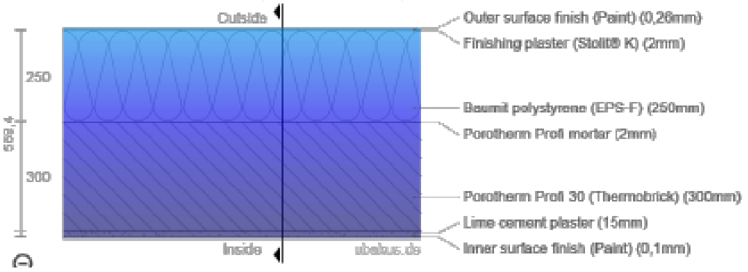
Thesis - Ceiling - SK, U=0,08 W/(m²K)

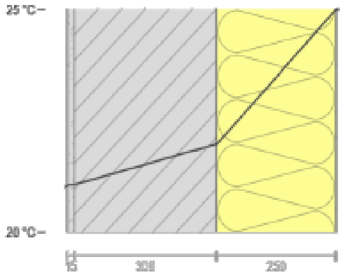
Diagrams



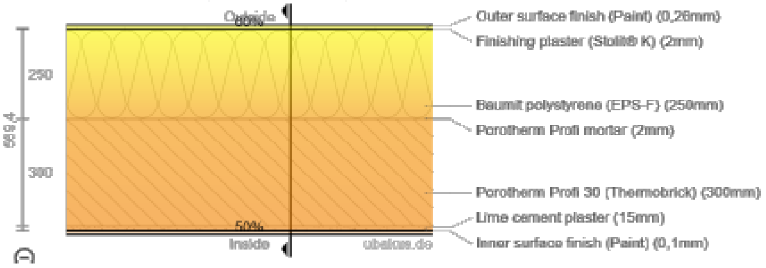


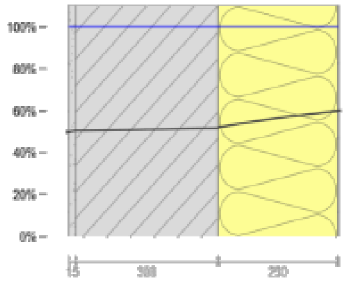
Temperature (summer)



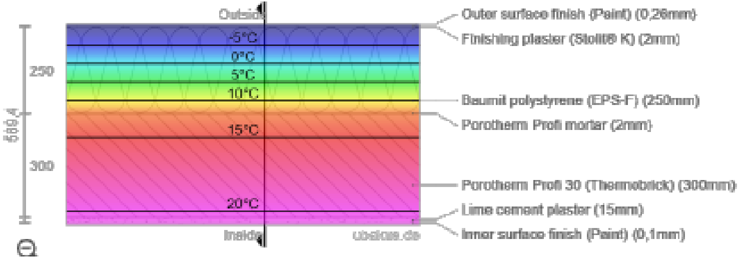


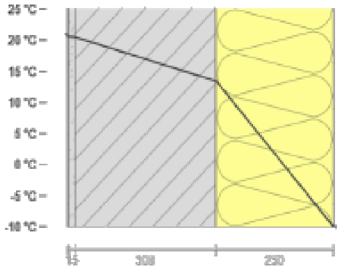
Humidity (summer)



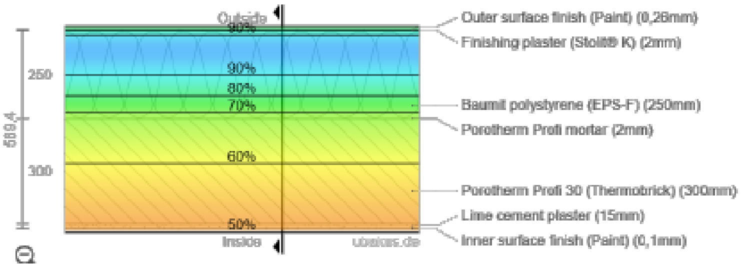


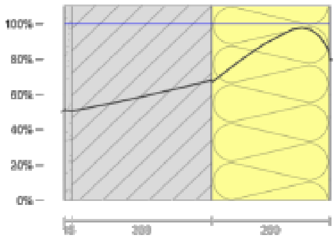
Temperature (winter)





Humidity (winter)





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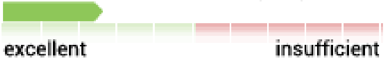
Thesis - Floor - SK

Floor
created on 18.9.2025

Thermal protection

U = 0,24 W/(m²K)

STN 73 0540-2: U<0.25 W/(m²K)

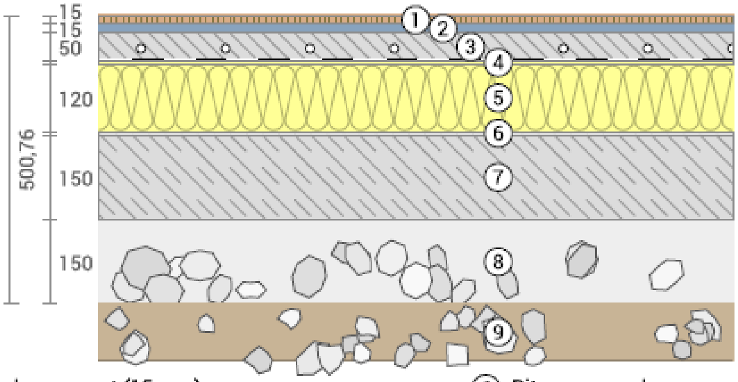


Moisture proofing

No condensate

Heat protection

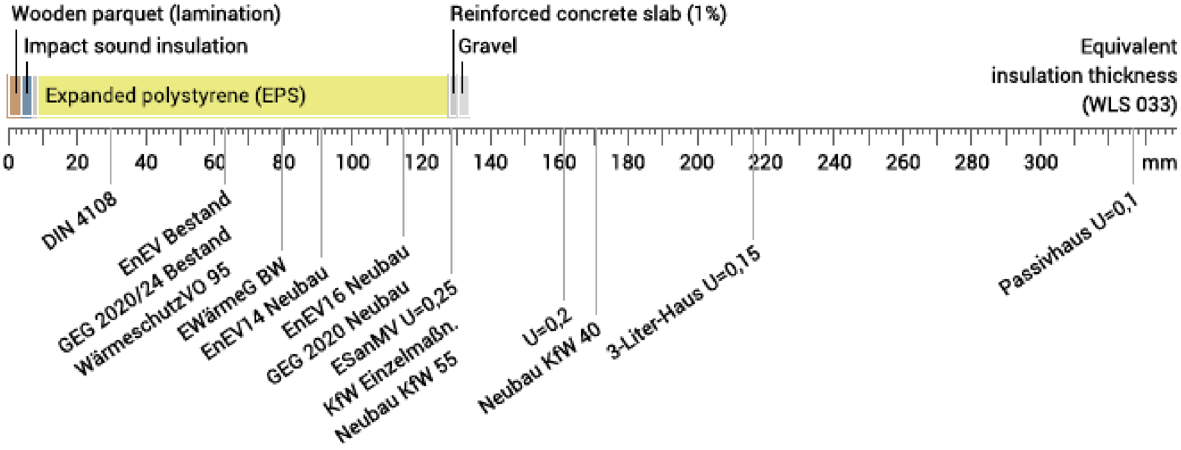
Component is adjacent to earth:
TAV and phase non relevant
Thermal capacity inside: 232 kJ/m²K



① Wooden parquet (15 mm)
② Impact sound insulation (15 mm)
③ Cement screed with underfloor heating (50 mm)
④ Polyethylene foil
⑤ Expanded polystyrene (120 mm)
⑥ Bitumen membrane
⑦ Reinforced concrete slab (150 mm)
⑧ Gravel (150 mm)
⑨ Soil

Impact of each layer and comparison to reference values

For the following figure, the thermal resistances of the individual layers were converted in millimeters insulation. The scale refers to an insulation of thermal conductivity 0,033 W/mK.



Inside air : 21,0°C / 50%
Ground: 0,0°C / 100%
Surface temperature.: 24,8°C / 0,4°C

sd-value: 124,9 m

Thickness: 50,1 cm
Weight: 797 kg/m²
Heat capacity: 766 kJ/m²K

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*Comparison of the U-value with den Höchstwerten aus GEG Anlage 7 (GEG 2020-2024 Bestand); den techn. Mindestanforderungen für BEG Einzelmaßnahmen; 70% des U-Werts der Referenzausführung aus GEG 2023/2024 Anlage 1 (GEG Neubau); den R-Werten aus DIN 4108-2 Tabelle 3

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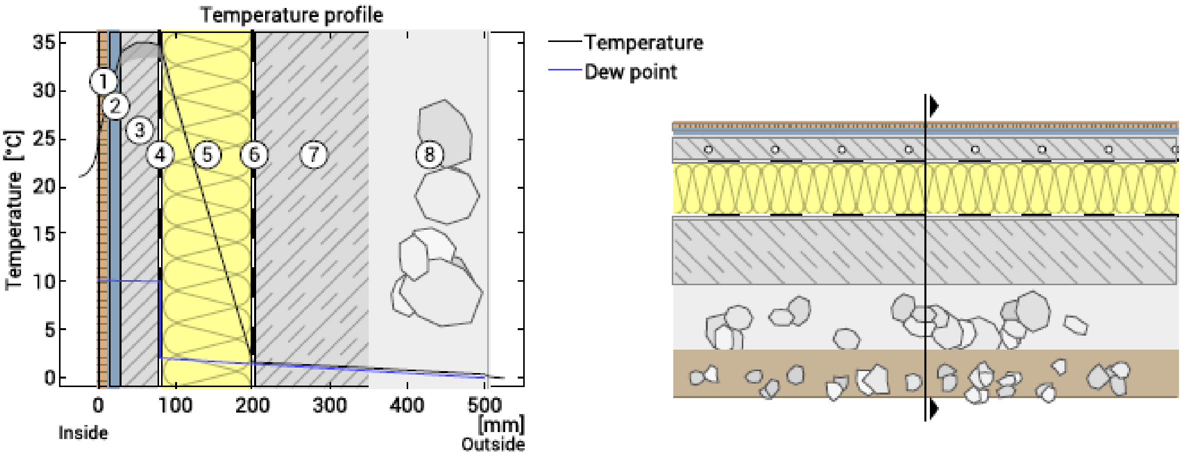
Thesis - Floor - SK, U=0,24 W/(m²K)

Temperature profile



① Wooden parquet (15 mm)
② Impact sound insulation (15 mm)
③ Cement screed with underfloor hea...
④ Polyethylene foil
⑤ Expanded polystyrene (120 mm)
⑥ Bitumen membrane
⑦ Reinforced concrete slab (150 mm)
⑧ Gravel (150 mm)

Left: Temperature and dew-point temperature at the place marked in the right figure. The dew-point indicates the temperature, at which water vapour condensates. As long as the temperature of the component is everywhere above the dew point, no condensation occurs. If the curves have contact, condensation occurs at the corresponding position.
Right: The component, drawn to scale.

Layers (from inside to outside)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	max	Weight [kg/m²]
		Thermal contact resistance*		0,100	21,0	25,1	
1	1,5 cm	Wooden parquet (lamination)	0,130	0,115	24,8	29,8	9,3
2	1,5 cm	Impact sound insulation	0,150	0,100	29,2	34,0	9,0
3	5 cm	Cement screed with underfloor heating	1,400	0,036	32,9	35,0	100,0
4	0,026 cm	Polyethylene foil	0,400	0,001	33,4	34,7	0,2
5	12 cm	Expanded polystyrene (EPS)	0,033	3,636	1,6	34,7	3,0
6	0,05 cm	Bitumen membrane (Breather)	0,500	0,001	1,6	1,6	0,4
7	15 cm	Reinforced concrete slab (1%)	2,300	0,065	1,0	1,6	345,0
8	15 cm	Gravel	2,000	0,075	0,4	1,0	330,0
		Thermal contact resistance*		0,000	0,0	0,4	
9		Soil			0,0	0,0	85,1
	50,076 cm	Whole component		4,130			796,9

*Assuming free circulating air at the inside surface.

Surface temperature inside (min / average / max):	24,8°C	24,9°C	25,1°C
Surface temperature outside (min / average / max):	0,4°C	0,4°C	0,4°C

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Moisture proofing

For the calculation of the amount of condensation water, the component was exposed to the following constant climate for 90 days: inside: 21°C und 50% Humidity; outside: 0°C und 100% Humidity (Climate according to user input).

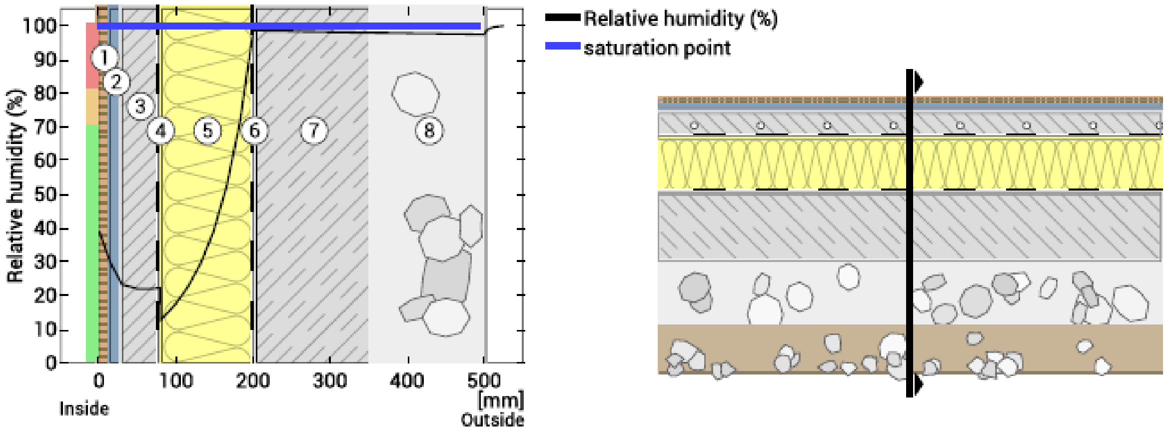
Interior heat transfer resistance Rsi (user input deviating from DIN 4108-3):0.1 m²K/W

This component is free of condensate under the given climate conditions.

#		Material	sd-value	Condensate		Weight
			[m]	[kg/m²]	[Gew.-%]	[kg/m²]
1	1,5 cm	Wooden parquet (lamination)	0,82	-	-	9,3
2	1,5 cm	Impact sound insulation	0,50	-		9,0
3	5 cm	Cement screed with underfloor heating	0,52	-		100,0
4	0,026 cm	Polyethylene foil	100,00	-		0,2
5	12 cm	Expanded polystyrene (EPS)	7,20	-		3,0
6	0,05 cm	Bitumen membrane (Breather)	0,10	-		0,4
7	15 cm	Reinforced concrete slab (1%)	7,50	-		345,0
8	15 cm	Gravel	7,50	-		330,0
	50,076 cm	Whole component	124,92	0		796,9

Humidity

The temperature of the inside surface is 21,0 °C leading to a relative humidity on the surface of 40%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.



① Wooden parquet (15 mm)
② Impact sound insulation (15 mm)
③ Cement screed with underfloor hea...
④ Polyethylene foil
⑤ Expanded polystyrene (120 mm)
⑥ Bitumen membrane
⑦ Reinforced concrete slab (150 mm)
⑧ Gravel (150 mm)

Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

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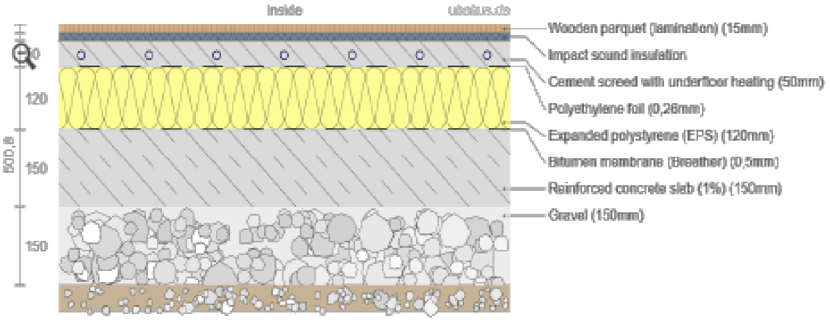
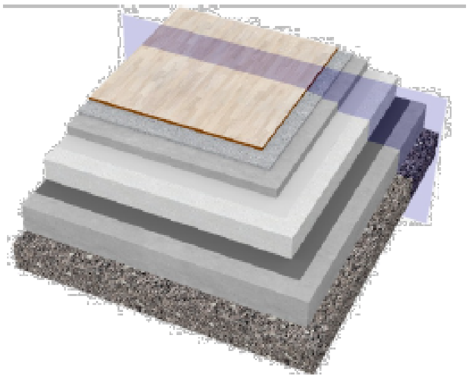
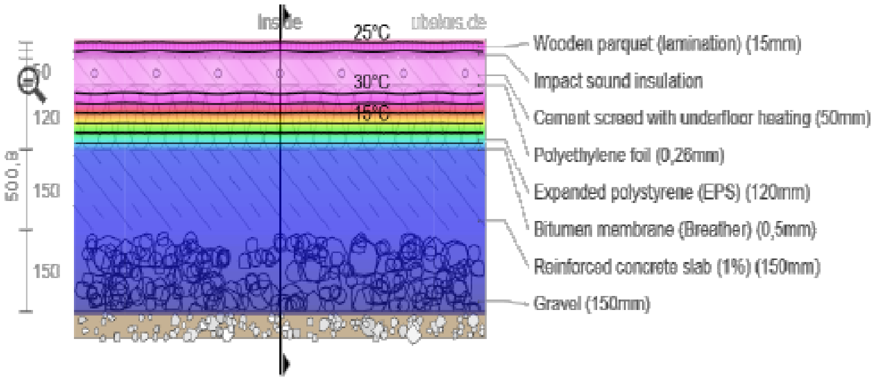
Thesis - Ceiling - SK, U=0,08 W/(m²K)

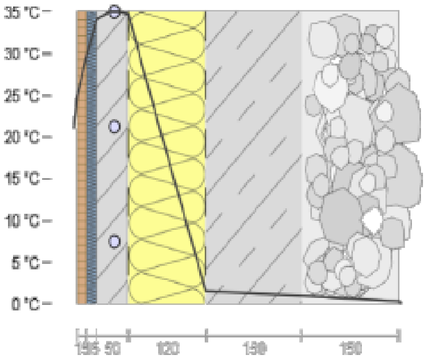
Diagrams



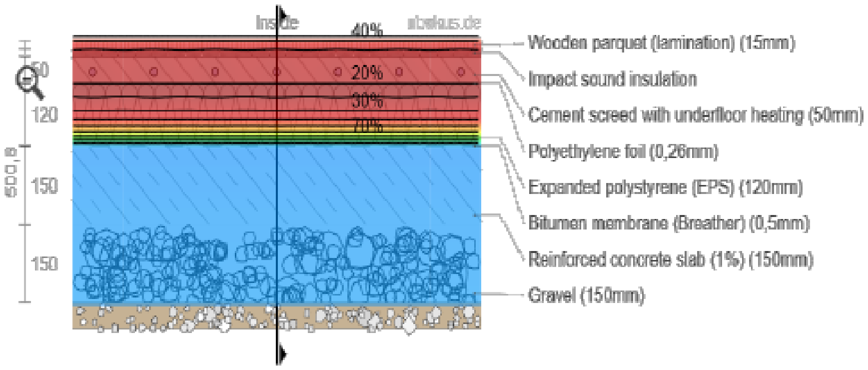


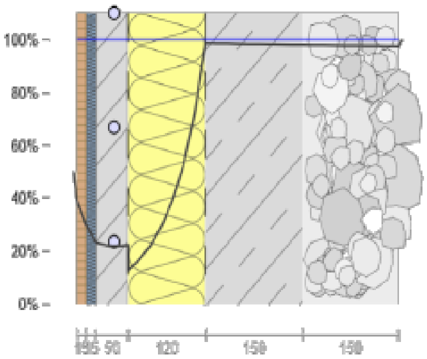
Temperature





Humidity





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Thesis - Floor - FIN

Floor
created on 18.9.2025

Thermal protection

U = 0,15 W/(m²K)

SDK 1010/2017: U<0.16W/(m²K)

excellent insufficient

Moisture proofing

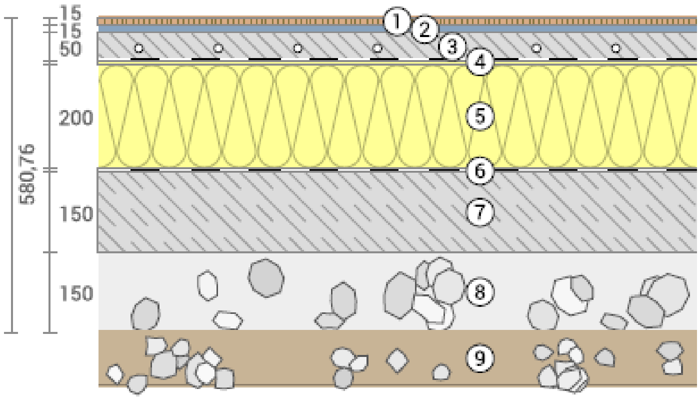
Dries 6 days
Condensate: 3,6 g/m²

excellent insufficient

Heat protection

Component is adjacent to earth:
TAV and phase non relevant
Thermal capacity inside: 223 kJ/m²K

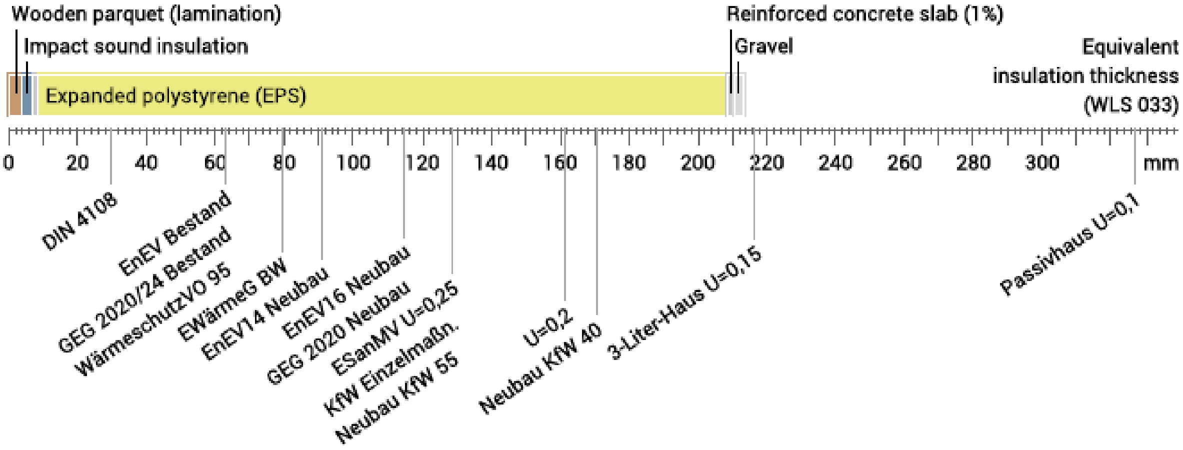
excellent insufficient



1. Wooden parquet (15 mm)
2. Impact sound insulation (15 mm)
3. Cement screed with underfloor heating (50 mm)
4. Polyethylene foil
5. Expanded polystyrene (200 mm)
6. Bitumen membrane
7. Reinforced concrete slab (150 mm)
8. Gravel (150 mm)
9. Soil

Impact of each layer and comparison to reference values

For the following figure, the thermal resistances of the individual layers were converted in millimeters insulation. The scale refers to an insulation of thermal conductivity 0,033 W/mK.



Inside air : 21,0°C / 50%
Ground: 0,0°C / 100%
Surface temperature.: 24,8°C / 0,2°C

sd-value: 124,9 m

Thickness: 58,1 cm
Weight: 799 kg/m²
Heat capacity: 769 kJ/m²K

☑ GEG 2020/24 Bestand ☑ BEG Einzelmaßn. ☑ GEG 2023/24 Neubau ☑ DIN 4108

---

*Comparison of the U-value with den Höchstwerten aus GEG Anlage 7 (GEG 2020-2024 Bestand); den techn. Mindestanforderungen für BEG Einzelmaßnahmen; 70% des U-Werts der Referenzausführung aus GEG 2023/2024 Anlage 1 (GEG Neubau); den R-Werten aus DIN 4108-2 Tabelle 3

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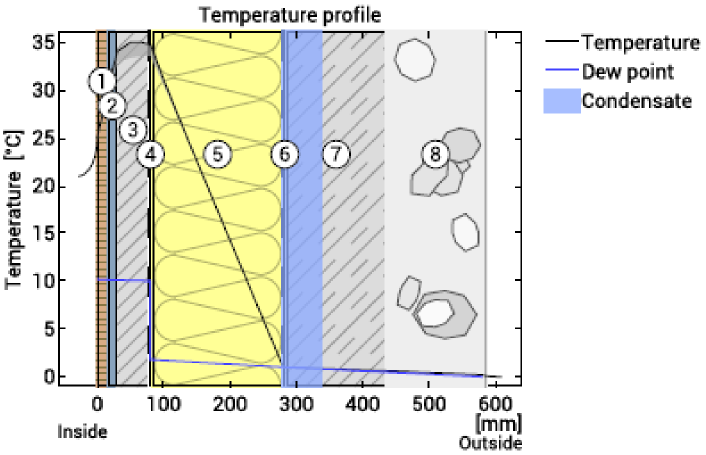
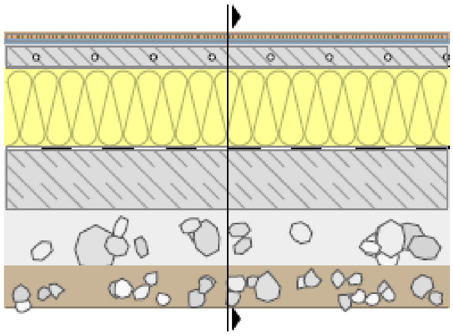
Thesis - Floor - FIN, U=0,15 W/(m²K)

Temperature profile





① Wooden parquet (15 mm)
② Impact sound insulation (15 mm)
③ Cement screed with underfloor hea...
④ Polyethylene foil
⑤ Expanded polystyrene (200 mm)
⑥ Bitumen membrane
⑦ Reinforced concrete slab (150 mm)
⑧ Gravel (150 mm)

Left: Temperature and dew-point temperature at the place marked in the right figure. The dew-point indicates the temperature, at which water vapour condensates. As long as the temperature of the component is everywhere above the dew point, no condensation occurs. If the curves have contact, condensation occurs at the corresponding position.
Right: The component, drawn to scale.

Layers (from inside to outside)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	max	Weight [kg/m²]
		Thermal contact resistance*		0,100	21,0	25,1	
1	1,5 cm	Wooden parquet (lamination)	0,130	0,115	24,8	29,8	9,3
2	1,5 cm	Impact sound insulation	0,150	0,100	29,2	34,1	9,0
3	5 cm	Cement screed with underfloor heating	1,400	0,036	33,0	35,0	100,0
4	0,026 cm	Polyethylene foil	0,400	0,001	33,6	34,8	0,2
5	20 cm	Expanded polystyrene (EPS)	0,033	6,061	1,0	34,8	5,0
6	0,05 cm	Bitumen membrane (Breather)	0,500	0,001	1,0	1,0	0,4
7	15 cm	Reinforced concrete slab (1%)	2,300	0,065	0,6	1,0	345,0
8	15 cm	Gravel	2,000	0,075	0,2	0,6	330,0
		Thermal contact resistance*		0,000	0,0	0,2	
9		Soil			0,0	0,0	98,7
	58,076 cm	Whole component		6,555			798,9

*Assuming free circulating air at the inside surface.

Surface temperature inside (min / average / max):	24,8°C	24,9°C	25,1°C
Surface temperature outside (min / average / max):	0,2°C	0,2°C	0,2°C

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Moisture proofing

For the calculation of the amount of condensation water, the component was exposed to the following constant climate for 90 days: inside: 21°C und 50% Humidity; outside: 0°C und 100% Humidity (Climate according to user input).

Interior heat transfer resistance Rsi (user input deviating from DIN 4108-3):0.1 m²K/W

Under these conditions, a total of 0,0036 kg of condensation water per square meter is accumulated.This quantity dries in summer in 6 days (Drying season according to DIN 4108-3:2018-10).

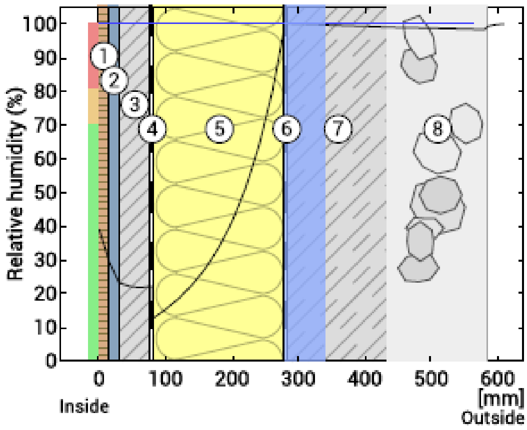
#		Material	sd-value	Condensate		Weight
			[m]	[kg/m²]	[Gew.-%]	[kg/m²]
1	1,5 cm	Wooden parquet (lamination)	0,82	-	-	9,3
2	1,5 cm	Impact sound insulation	0,50	-		9,0
3	5 cm	Cement screed with underfloor heating	0,52	-		100,0
4	0,026 cm	Polyethylene foil	100,00	-		0,2
5	20 cm	Expanded polystyrene (EPS)	7,20	-		5,0
6	0,05 cm	Bitumen membrane (Breather)	0,10	-		0,4
7	15 cm	Reinforced concrete slab (1%)	7,50	-		345,0
8	15 cm	Gravel	7,50	-		330,0
	58,076 cm	Whole component	124,92	0,0036		798,9

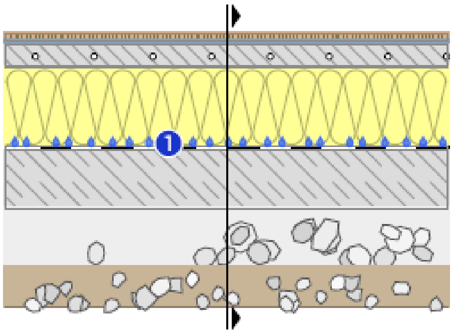
Condensation areas

① Condensate: 0,004 kg/m² Affected layers: Bitumen membrane (Breather), Expanded polystyrene (EPS)

Humidity

The temperature of the inside surface is 21,0 °C leading to a relative humidity on the surface of 40%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.





① Wooden parquet (15 mm)
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④ Polyethylene foil
⑤ Expanded polystyrene (200 mm)
⑥ Bitumen membrane
⑦ Reinforced concrete slab (150 mm)
⑧ Gravel (150 mm)

Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

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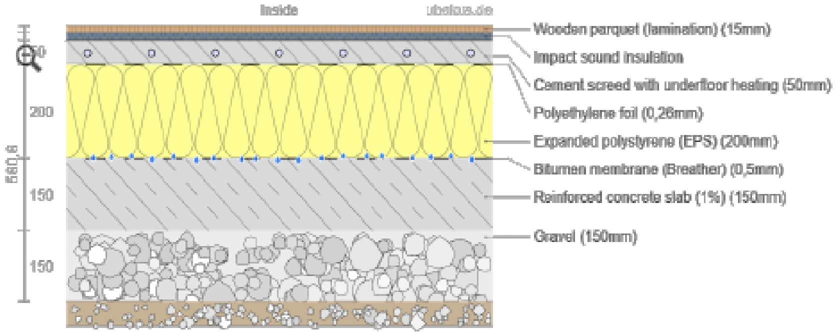
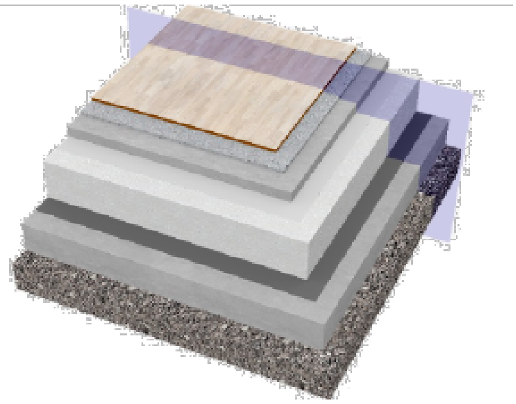
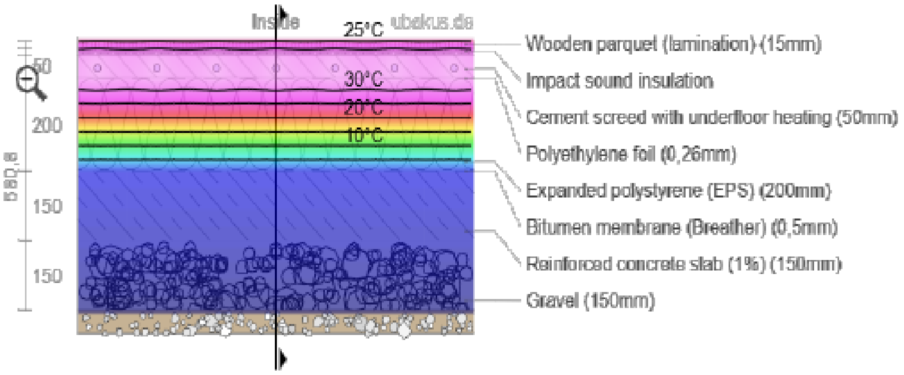
Thesis - Ceiling - SK, U=0,08 W/(m^{2}K)

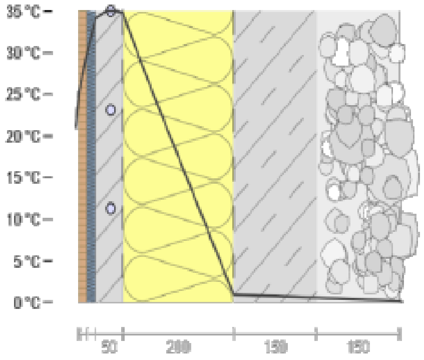
Diagrams



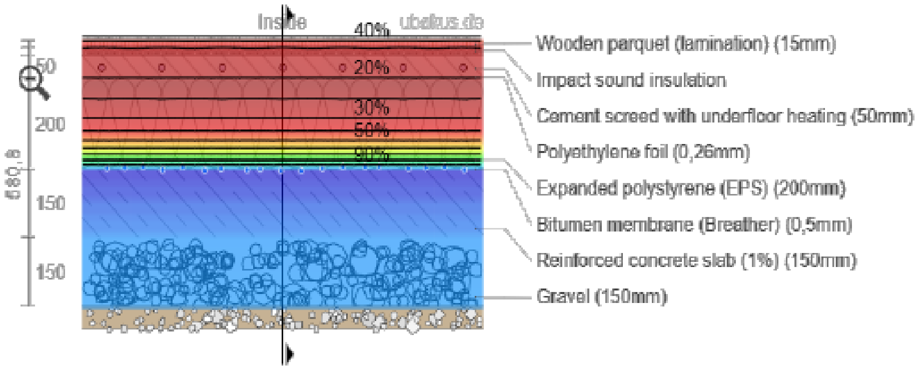


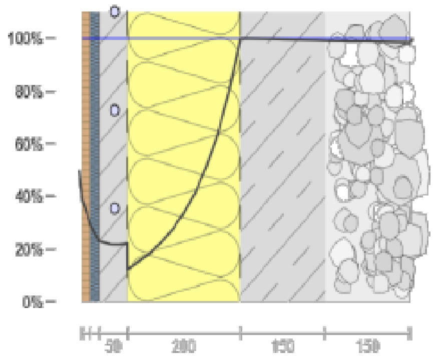
Temperature





Humidity





EQUA SIMULATION TECHNOLOGY GROUP		**Delivered Energy Report**	
Project		**Building**	
		Model floor area	140.0 m^2
Customer		Model volume	371.1 m^3
Created by	Daniel Mikolai	Model ground area	140.0 m^2
Location	BRATISLAVA-LETISKO_118160 (ASHRAE 2021)	Model envelope area	276.1 m^2
Climate file	SVK_BRATISLAVA-LETISKO_118160(IW2)	Window/Envelope	8.7 %
Case	Slovakia	Average U-value	0,2036 W/(m^2 K)
Simulated	04/11/2025 21:21:58	Envelope area per Volume	0.7442 m^2/m^3

Building Comfort Reference

Percentage of hours when operative temperature is above 27°C in worst zone	0 %
Percentage of hours when operative temperature is above 27°C in average zone	0 %
Percentage of total occupant hours with thermal dissatisfaction	9 %

Overall Energy Performance (ISO 52000-1, Chapter 9.6)

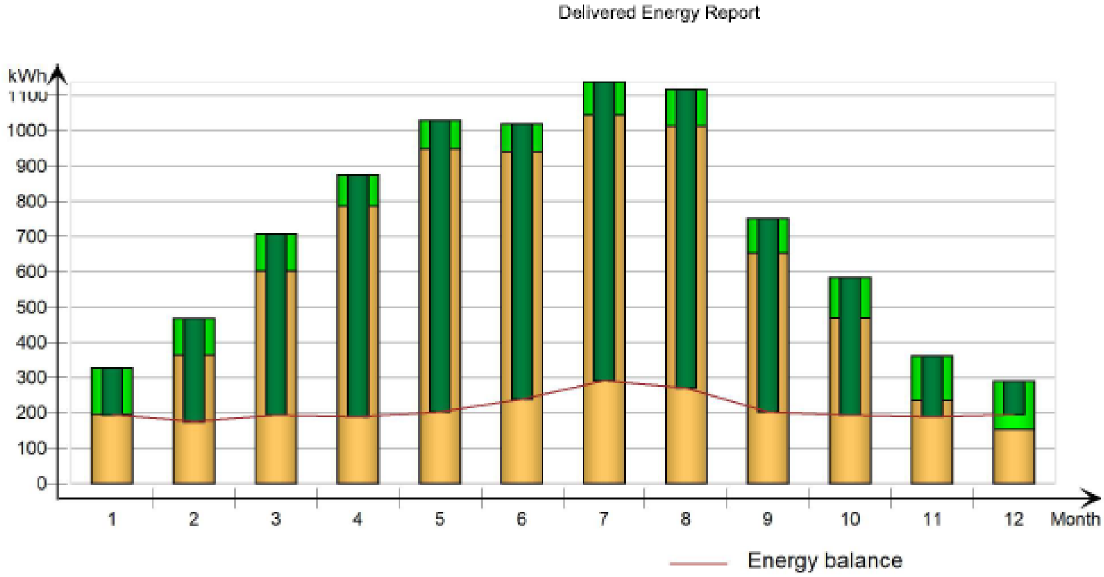
	Total		**Total primary energy**		**Non-renewable primary energy**		**CO2 Emission**	
	kWh	**kWh/m^2**	**kWh**	**kWh/m^2**	**kWh**	**kWh/m^2**	**kg**	**kg/m^2**
Produced by PV	7406,4	52,9	0,0	0,0	0,0	0,0	0,0	0,0
Purchased by facility (el)	1257,0	9,0	2765,3	19,8	2891,0	20,7	377,1	2,7
Exported by facility (el)	-6134,5	-43,8	-13496,0	-96,4	-14109,4	-100,8	-1840,4	-13,2
Total Electricity	2528,8	18,1	-10730,7	-76,7	-11218,4	-80,1	-1463,3	-10,5
Purchased by facility (dh)	10006,4	71,5	7004,5	50,0	13008,3	92,9	1601,0	11,4
Total Heat	10006,4	71,5	7004,5	50,0	13008,3	92,9	1601,0	11,4
Overall energy performance			-3726,2 (2)	-26,6	1789,9 (3)	12,8	137,7	1,0

* [(2) - (3)]/(2)

** Sum(prod*)/(2)

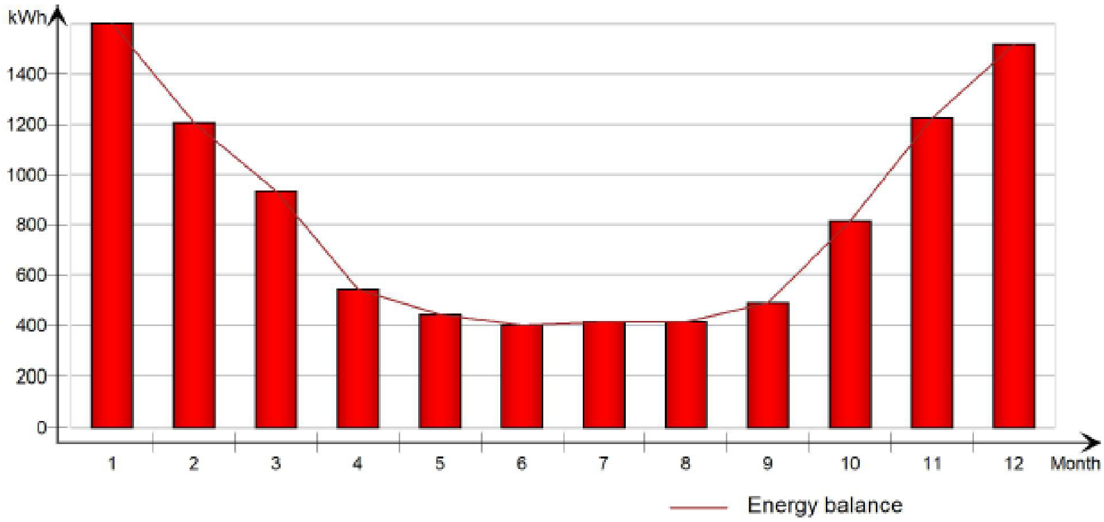
Monthly Energy Electricity

		Total		**Peak demand**	
		kWh	**kWh /m^2**	**kW**	**Time**
🟩	Exported by facility (el)	-6134,5	-43,8	-6,397	20 Aug 12:31
🟩	Purchased by facility (el)	1257,0	9,0	0,5546	15 Aug 20:30
🟫	Produced by PV	7406,0	52,9	6,976	20 Aug 12:31
	Total Electricity	2528,8	18,1		
	Overall energy performance	2528,8	18,1		



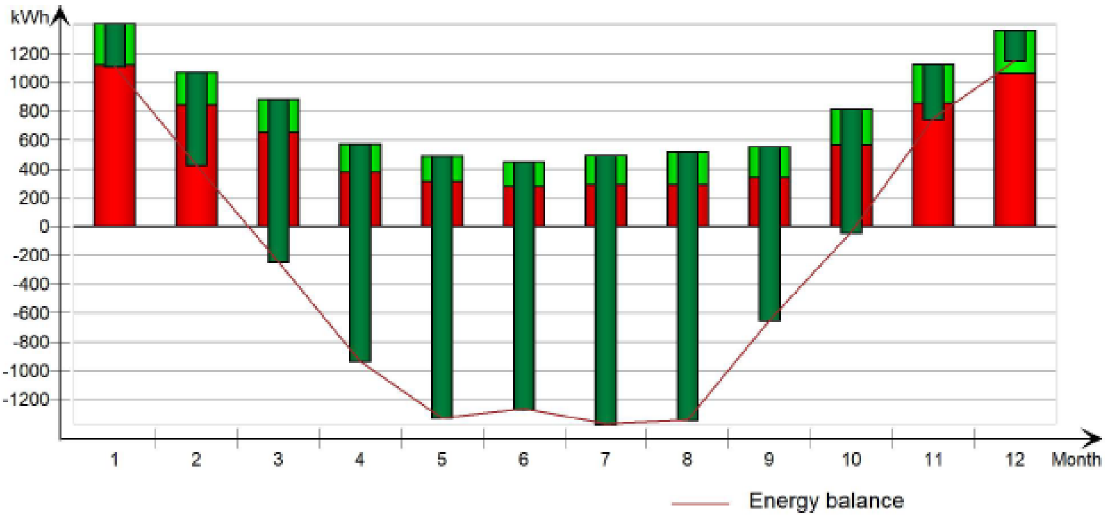
Monthly Energy Heat

		Total		Peak demand	
		kWh	kWh /m^2	kW	Time
🟥	Purchased by facility (dh)	10006,4	71,5	17,83	08 Jan 19:01
	Total Heat	10006,4	71,5		
	Overall energy performance	10006,4	71,5		



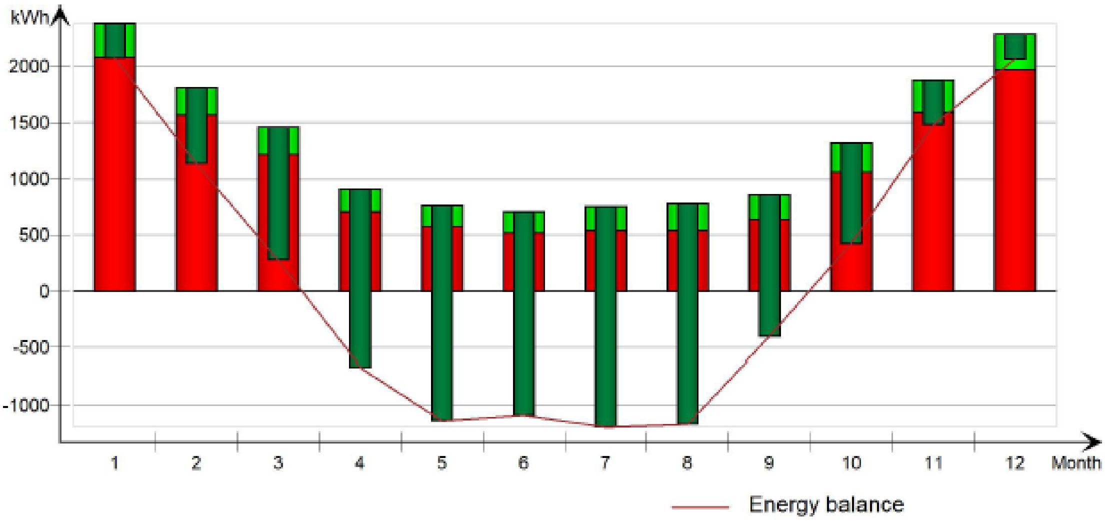
Monthly Total primary energy

		Total	
		kWh	kWh /m^2
🟩	Exported by facility (el)	-13496,0	-96,4
🟩	Purchased by facility (el)	2765,3	19,8
	Total Electricity	-10730,7	-76,7
🟥	Purchased by facility (dh)	7004,5	50,0
	Total Heat	7004,5	50,0
	Overall energy performance	-3726,2	-26,6



Monthly Non-renewable primary energy

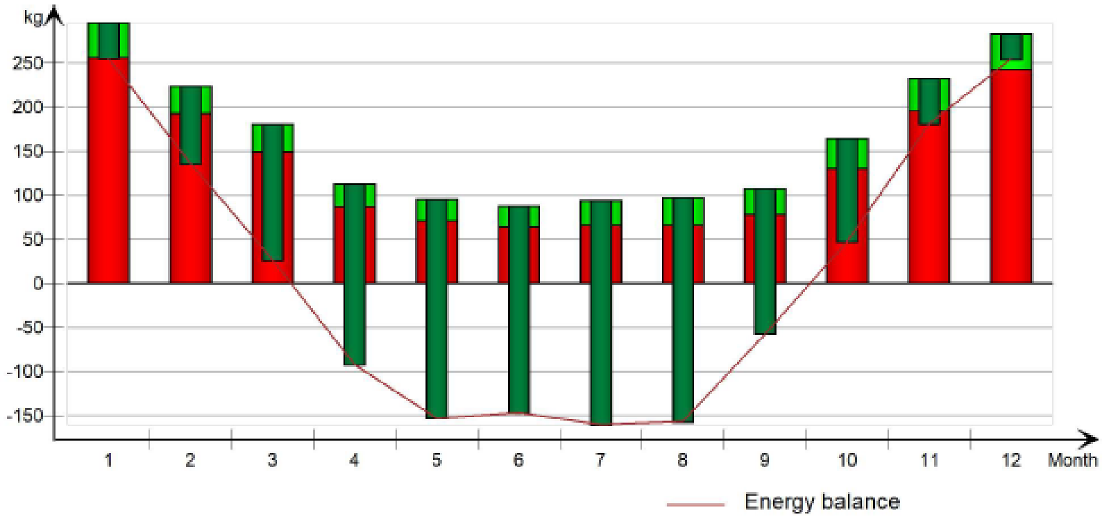
		Total	
		kWh	kWh /m^2
🟩	Exported by facility (el)	-14109,4	-100,8
🟩	Purchased by facility (el)	2891,0	20,7
	Total Electricity	-11218,4	-80,1
🟥	Purchased by facility (dh)	13008,3	92,9
	Total Heat	13008,3	92,9
	Overall energy performance	1789,9	12,8



Monthly CO2 Emission

Delivered Energy Report

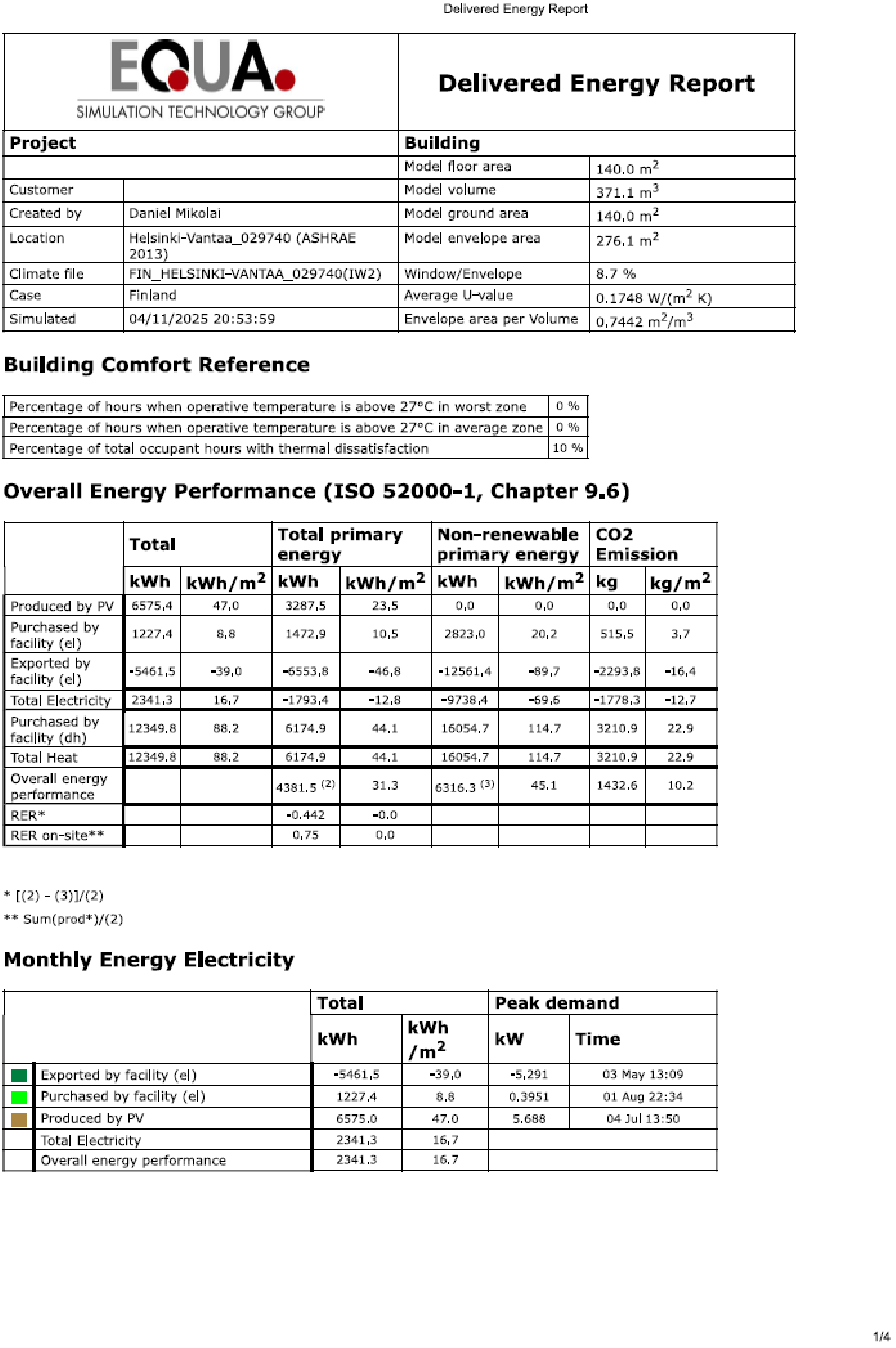
		Total	
		kg	kg /m^2
🟩	Exported by facility (el)	-1840,4	-13,2
🟩	Purchased by facility (el)	377,1	2,7
	Total Electricity	-1463.3	-10.5
🟥	Purchased by facility (dh)	1601,0	11,4
	Total Heat	1601.0	11.4
	Overall energy performance	137.7	1.0



IDA Indoor Climate and Energy

Version: 5.1

License: IDA40:ICE51X:25NOV/I0H9G (trial license)



EQUA SIMULATION TECHNOLOGY GROUP		**Delivered Energy Report**	
Project		**Building**	
		Model floor area	140,0 m^2
Customer		Model volume	371,1 m^3
Created by	Daniel Mikolai	Model ground area	140,0 m^2
Location	Helsinki-Vantaa_029740 (ASHRAE 2013)	Model envelope area	276,1 m^2
Climate file	FIN_HELSINKI-VANTAA_029740(IW2)	Window/Envelope	8.7 %
Case	Finland	Average U-value	0.1748 W/(m^2 K)
Simulated	04/11/2025 20:53:59	Envelope area per Volume	0,7442 m^2/m^3

Building Comfort Reference

Percentage of hours when operative temperature is above 27°C in worst zone	0 %
Percentage of hours when operative temperature is above 27°C in average zone	0 %
Percentage of total occupant hours with thermal dissatisfaction	10 %

Overall Energy Performance (ISO 52000-1, Chapter 9.6)

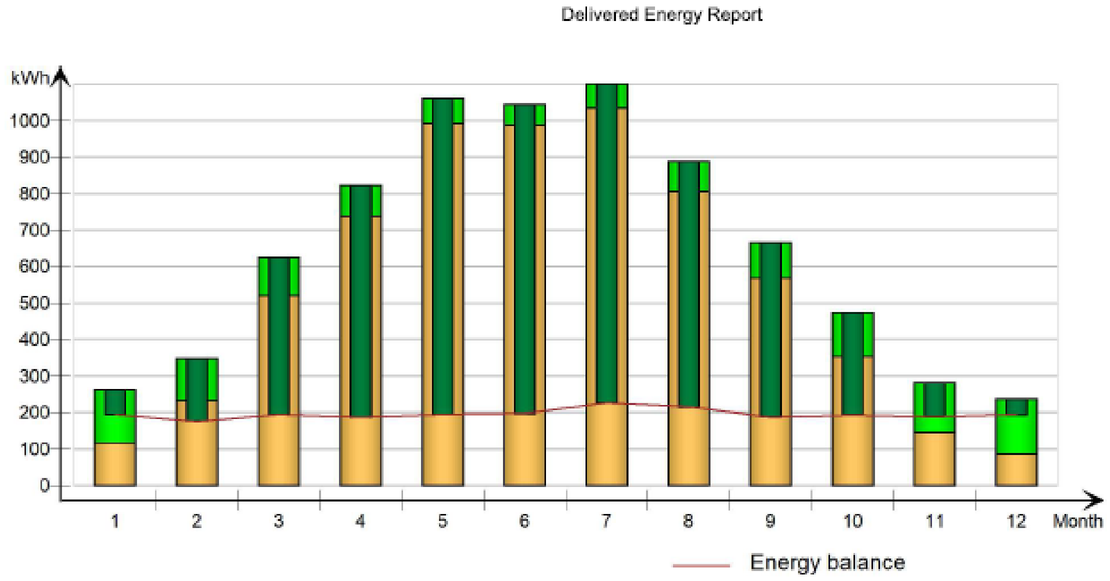
	Total		**Total primary energy**		**Non-renewable primary energy**		**CO2 Emission**	
	kWh	**kWh/m^2**	**kWh**	**kWh/m^2**	**kWh**	**kWh/m^2**	**kg**	**kg/m^2**
Produced by PV	6575,4	47,0	3287,5	23,5	0,0	0,0	0,0	0,0
Purchased by facility (el)	1227,4	8,8	1472,9	10,5	2823,0	20,2	515,5	3,7
Exported by facility (el)	-5461,5	-39,0	-6553,8	-46,8	-12561,4	-89,7	-2293,8	-16,4
Total Electricity	2341,3	16,7	-1793,4	-12,8	-9738,4	-69,6	-1778,3	-12,7
Purchased by facility (dh)	12349,8	88,2	6174,9	44,1	16054,7	114,7	3210,9	22,9
Total Heat	12349,8	88,2	6174,9	44,1	16054,7	114,7	3210,9	22,9
Overall energy performance			4381.5 (2)	31.3	6316.3 (3)	45.1	1432.6	10.2
RER*			-0.442	-0.0				
RER on-site**			0,75	0,0				

* [(2) - (3)]/(2)

** Sum(prod*)/(2)

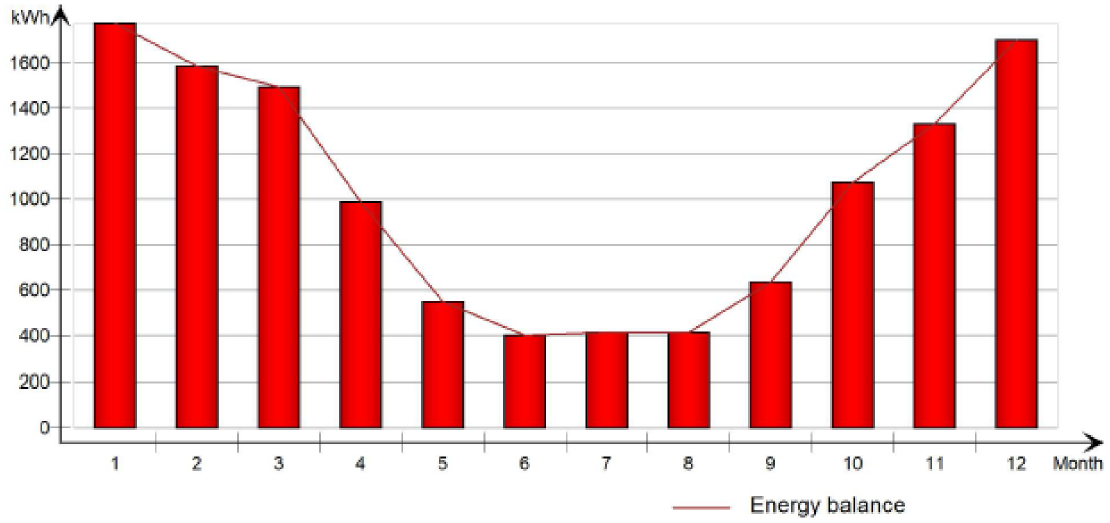
Monthly Energy Electricity

		Total		**Peak demand**	
		kWh	**kWh /m^2**	**kW**	**Time**
🟩	Exported by facility (el)	-5461,5	-39,0	-5,291	03 May 13:09
🟩	Purchased by facility (el)	1227,4	8,8	0,3951	01 Aug 22:34
🟫	Produced by PV	6575.0	47.0	5.688	04 Jul 13:50
	Total Electricity	2341,3	16,7		
	Overall energy performance	2341.3	16.7		



Monthly Energy Heat

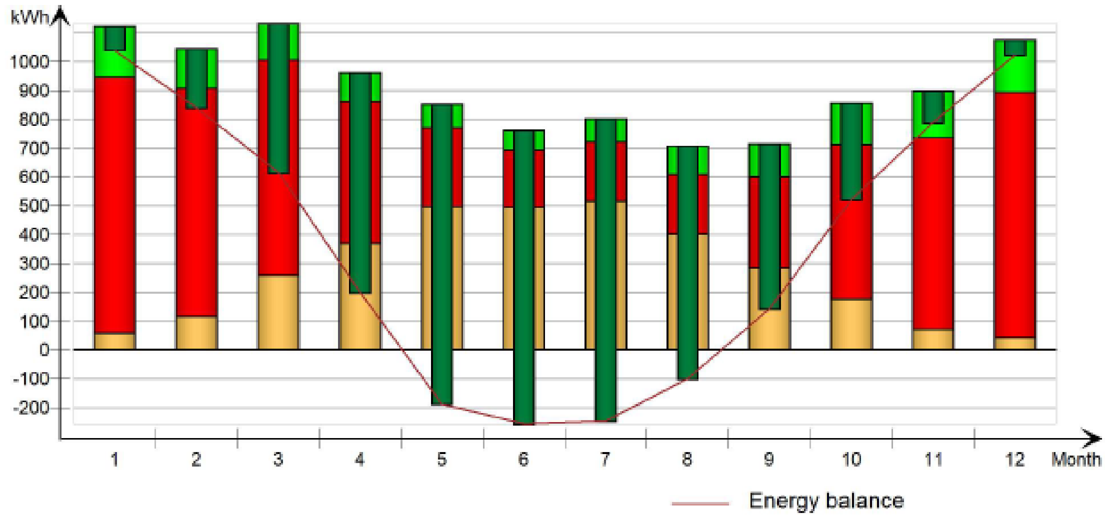
		Total		Peak demand	
		kWh	kWh /m^2	kW	Time
🟥	Purchased by facility (dh)	12349,8	88,2	20,29	17 Feb 19:46
	Total Heat	12349,8	88,2		
	Overall energy performance	12349,8	88,2		



Monthly Total primary energy

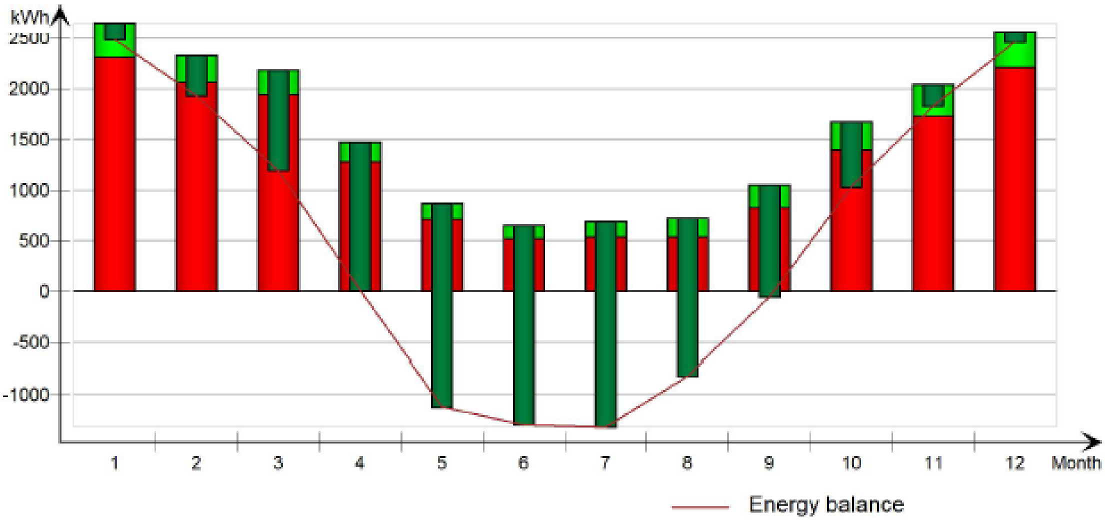
		Total	
		kWh	kWh /m^2
🟩	Exported by facility (el)	-6553,8	-46,8
🟩	Purchased by facility (el)	1472,9	10,5
🟫	Produced by PV	3287,0	23,5
	Total Electricity	-1793,4	-12,8
🟥	Purchased by facility (dh)	6174,9	44,1
	Total Heat	6174,9	44,1
	Overall energy performance	4381,5	31,3

Delivered Energy Report



Monthly Non-renewable primary energy

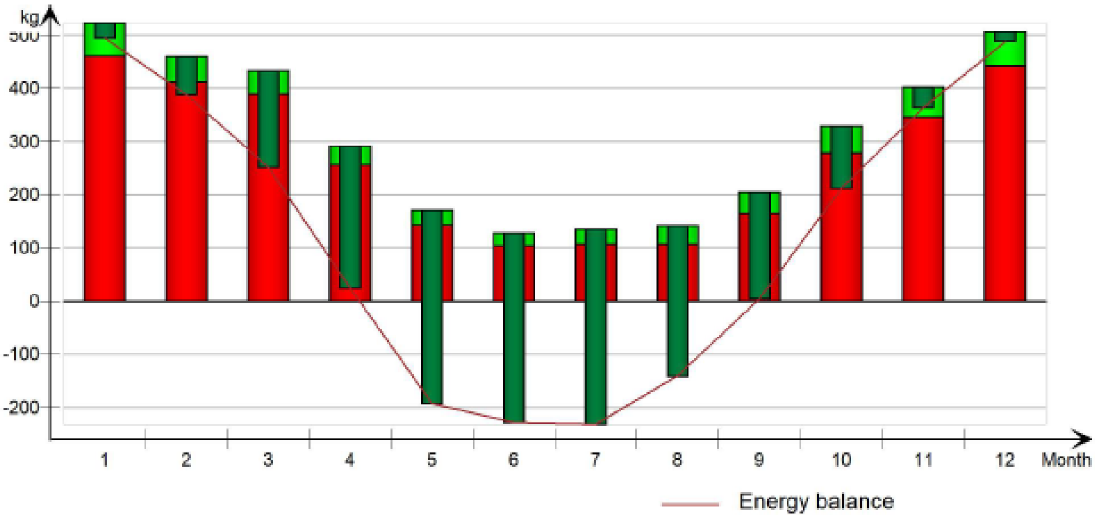
		Total	
		kWh	kWh $/m^2$
🟩	Exported by facility (el)	-12561,4	-89,7
🟩	Purchased by facility (el)	2823,0	20,2
	Total Electricity	-9738,4	-69,6
🟥	Purchased by facility (dh)	16054,7	114,7
	Total Heat	16054,7	114,7
	Overall energy performance	6316,3	45,1



Monthly CO2 Emission

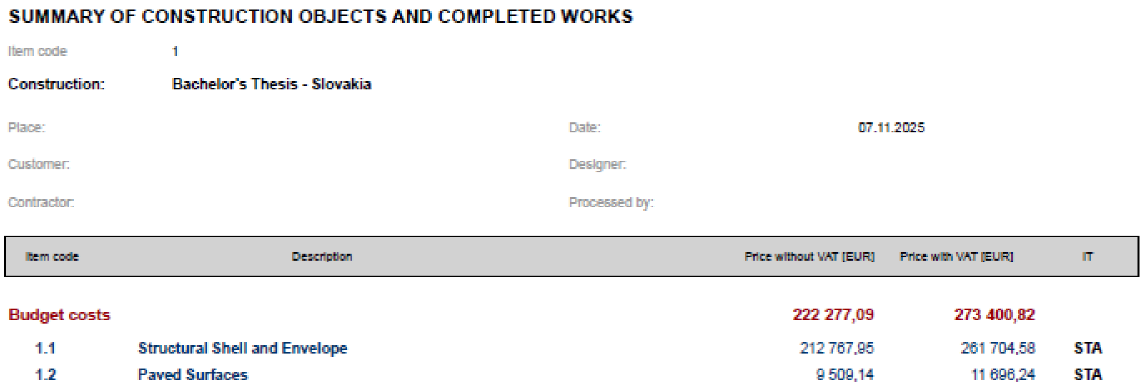
Delivered Energy Report

		Total	
		kg	**kg $/m^2$**
🟩	Exported by facility (el)	-2293,8	-16,4
🟩	Purchased by facility (el)	515,5	3,7
	Total Electricity	-1778.3	-12.7
🟥	Purchased by facility (dh)	3210,9	22,9
	Total Heat	3210.9	22.9
	Overall energy performance	1432.6	10.2



IDA Indoor Climate and Energy
Version: 5.1
License: IDA40:ICE51X:25NOV/I0H9G (trial license)

Appendix 8. Price estimation



SUMMARY OF CONSTRUCTION OBJECTS AND COMPLETED WORKS

Item code 1

Construction: Bachelor's Thesis - Slovakia

Place:

Date: 07.11.2025

Customer:

Designer:

Contractor:

Processed by:

Item code	Description	Price without VAT [EUR]	Price with VAT [EUR]	IT
Budget costs		**222 277,09**	**273 400,82**	
1.1	Structural Shell and Envelope	212 767,95	261 704,58	**STA**
1.2	Paved Surfaces	9 509,14	11 696,24	**STA**

BUDGET

Construction:

Bachelor's Thesis - Slovakia

Building:

1.1 - Structural Shell and Envelope

Place: Date: 07.11.2025

Customer: Designer:

Contractor: Processed by:

IN	IT	Item code	Description	MU	Amount	U. price [EUR]	Total price [EUR]
Budget costs							**212 767,95**
	D	1.1.1	Assemblies and Supplies PCW				90 735,84
	D	1.1.1.1	Earthworks				3 917,85
1	K	122101101.S	Unshored excavation and trenching in soils of classes 1–2, up to 100 m^3	m3	48,894	23,90	1 168,57
2	K	132101101.S	Trench excavation up to 600 mm wide in soils of classes 1–4, up to 100 m^3	m3	61,530	23,90	1 470,57
3	K	122302509.S	Surcharge for sticky soil	m3	110,424	2,17	239,62
4	K	162201101.S	Horizontal transport of excavated material from soils/rocks of classes 1–4, up to 20 m	m3	110,424	1,85	204,28
5	K	167101102.S	Loading of uncompacted excavated material from soils/rocks of classes 1–4, from 100 m^3 to 1000 m^3	m3	110,424	2,49	274,96
6	K	162501122.S	Horizontal transport of excavated material over a paved road from soils/rocks of classes 1–4, from 100 m^3 to 1000 m^3, up to a distance of 3000 m	m3	110,424	3,89	429,55
7	K	162501123.S	Horizontal transport of excavated material over a paved road from soils/rocks of classes 1–4, from 100 m^3 to 1000 m^3, surcharge for each additional or commenced 1000 m	m3	110,424	0,41	45,27
8	K	171201202.S	Disposal/placement of excavated material to dumps/landfills, from 100 m^3 to 1000 m^3	m3	110,424	0,77	85,03
	D	1.1.1.2	Foundation works				31 289,38
9	K	271533041.S	Compacted drainage fill around pipes adjacent to foundations made of coarse crushed aggregate, fraction 16–32 mm	m3	8,168	83,76	684,15
10	K	271573001.S	Compacted fill under foundation structures made of gravel-sand mixture, fraction 0–32 mm	m3	53,811	63,66	3 425,61
11	K	274361831.S	Fabrication and installation of reinforcement for strip foundations using reinforcing steel	t	2,971	888,01	2 638,28
12	*M*	*589510002500.S*	*Reinforcement EN 10080 for concrete made of steel 10 505 (B500B), diameter 6–14 mm*	*t*	*2,971*	*1 098,39*	*3 263,32*
13	K	274321421.S	Casting/concreting of strip foundations, plain concrete (without reinforcement)	m3	28,842	14,74	425,13
14	*M*	*589310004900.S*	*Concrete EN 206-1 - C20/25 - XC2 - CL 0.4 - Dmax 16 - S3 made from blast-furnace Portland cement*	*m3*	*29,707*	*116,96*	*3 474,53*
15	K	279351107.S	Installation of formwork for foundation walls, double-sided, traditional method	m2	39,780	18,74	745,48
16	K	274271146.S	Constructing of foundation wall using concrete formwork blocks with C 20/25 concrete infill, 300 mm thick	m3	10,913	151,49	1 653,21
17	*M*	*595120000400.S*	*Concrete plinth block (CMU), 300 mm wide (DT30)*	*m2*	*37,104*	*19,43*	*720,93*
18	K	274271126.S	Constructing of foundation wall using concrete formwork blocks with C 20/25 concrete infill, 200 mm thick	m3	1,105	146,14	161,48
19	*M*	*595120000200.S*	*Concrete plinth block (CMU), 200 mm wide (DT20)*	*m2*	*5,636*	*14,38*	*81,05*
20	K	279361831.S	Fabrication and installation of reinforcement for load-bearing foundation walls using reinforcing steel	t	0,464	908,59	421,59
21	*M*	*589510002500.S*	*Reinforcement EN 10080 for concrete made of steel 10 505 (B500B), diameter 6–14 mm*	*t*	*0,464*	*1 098,39*	*509,65*
22	K	274321421.S	Casting/concreting of foundation walls, plain concrete (without reinforcement)	m3	4,500	14,74	66,33
23	*M*	*589310004900.S*	*Concrete EN 206-1 - C20/25 - XC2 - CL 0.4 - Dmax 16 - S3 made from blast-furnace Portland cement*	*m3*	*4,635*	*116,96*	*542,11*
24	K	273361931.S	Fabrication of reinforcement for foundation slabs using welded meshes and KARI meshes	t	3,091	348,53	1 077,31
25	*M*	*313110006300.S*	*KARI mesh, grade BSt 500M KY 14 according to DIN 488, mesh size 6x2.4 m, opening 150x150 mm, wire Ø 8/8 mm*	*m2*	*1 203,504*	*5,85*	*7 040,50*
26	K	273321721.S	Casting/concreting of foundation slabs, plain concrete (without reinforcement)	m3	30,011	16,30	489,18
27	*M*	*589310004900.S*	*Concrete EN 206-1 - C20/25 - XC2 - CL 0.4 - Dmax 16 - S3 made from blast-furnace Portland cement*	*m3*	*30,911*	*116,96*	*3 615,35*
28	K	279351108.S	Removal of formwork for foundation walls, double-sided, traditional method	m2	39,780	6,39	254,19
	D	1.1.1.3	Vertical and complete structures				18 938,88
29	K	311236560	Constructing of masonry of load-bearing walls made of fired clay bricks POROTHERM 30 Profi P12, ground tongue-and-groove type, laid with POROTHERM Profi thin-joint mortar (300x250x249 mm)	m3	45,072	67,29	3 032,89
30	*M*	*596130004850*	*POROTHERM 30 Profi brick, P12, dimensions wxlxh 300x250x249 mm, laid with thin-joint mortar Porotherm Profi*	*ks*	*2 381,604*	*3,38*	*8 049,82*
31	*M*	*596130004860*	*POROTHERM 30 Profi 1/2 brick, P12, dimensions wxlxh 300x125x249 mm, laid with thin-joint mortar Porotherm Profi*	*ks*	*137,920*	*2,50*	*344,80*
32	*M*	*596130004865*	*POROTHERM 30 Profi R brick, P12, dimensions wxlxh 300x175x249 mm, laid with thin-joint mortar Porotherm Profi*	*ks*	*157,500*	*2,88*	*453,60*
33	K	311236561	Constructing of masonry of load-bearing walls made of fired clay bricks POROTHERM 25 Profi P12, ground tongue-and-groove type, laid with POROTHERM Profi thin-joint mortar (250x375x249 mm)	m3	7,563	72,26	546,50
34	*M*	*596130005600*	*POROTHERM 25 Profi brick, P12, dimensions wxlxh 250x375x249 mm, laid with thin-joint mortar Porotherm Profi*	*ks*	*330,201*	*4,17*	*1 376,94*

IN	IT	Item code	Description	MU	Amount	U. price [EUR]	Total price [EUR]
35	K	342273350	Constructing of masonry of partition walls made of smooth PORFIX blocks, 150 mm thick, strength class P2-500, laid with mortar for thin joints and PORFIX adhesive (150x250x500 mm)	m2	115,040	15,01	1 726,75
36	M	595310004300	PORFIX partition block P2-500 HL, dimensions wxlxh 150x500x250 mm	ks	938,726	3,63	3 407,58
	D	1.1.1.4	Horizontal structures				6 788,31
37	K	317121101.S	Installation of a prefabricated load-bearing lintel for an opening width from 600 to 1050 mm	ks	9,000	7,69	69,21
38	M	596450006500	HELUZ 23,8 load-bearing ceramic lintel, dimensions lxwxh 1000x70x238 mm	ks	9,000	17,05	153,45
39	K	317121102.S	Installation of a prefabricated load-bearing lintel for an opening width from 1050 to 1800 mm	ks	15,000	9,61	144,15
40	M	596450006600	HELUZ 23,8 load-bearing ceramic lintel, dimensions lxwxh 1250x70x238 mm	ks	3,000	22,75	68,25
41	M	596450006700	HELUZ 23,8 load-bearing ceramic lintel, dimensions lxwxh 1500x70x238 mm	ks	9,000	27,32	245,88
42	M	596450006800	HELUZ 23,8 load-bearing ceramic lintel, dimensions lxwxh 1750x70x238 mm	ks	3,000	35,24	105,72
43	K	317121103.S	Installation of a prefabricated load-bearing lintel for an opening width over 1800 mm up to 3750 mm	ks	12,000	14,52	174,24
44	M	596450007000	HELUZ 23,8 load-bearing ceramic lintel, dimensions lxwxh 2250x70x238 mm	ks	9,000	52,36	471,24
45	M	596450007100	HELUZ 23,8 load-bearing ceramic lintel, dimensions lxwxh 2500x70x238 mm	ks	3,000	66,44	199,32
46	K	317121101.S	Installation of a prefabricated non-load-bearing lintel	ks	7,000	10,85	75,95
47	M	596450010750.S	PORFIX non-load-bearing ceramic lintel, dimensions lxwxh 1000x150x250 mm	ks	2,000	20,90	41,80
48	M	596450010755.S	PORFIX non-load-bearing ceramic lintel, dimensions lxwxh 1250x150x250 mm	ks	5,000	25,40	127,00
49	K	317351107.S	Installation of formwork for lintel, including supporting structure up to 4 m in height	m2	11,105	32,75	363,69
50	K	417351115.S	Installation of formwork for the sides of tie beams and ring beams, including struts	m2	43,530	21,12	919,35
51	K	317361831.S	Fabrication and installation of reinforcement for concrete lintels and cornices using steel	t	0,139	650,60	90,43
52	M	589510002500.S	Reinforcement EN 10080 for concrete made of steel 10 505 (B500B), diameter 6–14 mm	t	0,139	1 098,39	152,68
53	K	317321521.S	Casting of plain concrete lintels (without reinforcement)	m3	1,350	33,31	44,97
54	M	589310005900.S	Concrete EN 206-1 - C25/30 - XC1 - CL 0.4 - Dmax 16 - S4 made from blast-furnace Portland cement	m3	1,391	122,41	170,27
55	K	417361831.S	Fabrication and installation of reinforcement for tie beams and ring beams using reinforcing steel	t	0,775	893,25	692,27
56	M	589510002500.S	Reinforcement EN 10080 for concrete made of steel 10 505 (B500B), diameter 6–14 mm	t	0,775	1 098,39	851,25
57	K	417321826.S	Casting of tie beams and ring beams in plain concrete (without reinforcement)	m3	7,750	37,31	289,15
58	M	589310005600.S	Concrete EN 206-1 - C25/30 - XC1 - CL 0.4 - Dmax 16 - S4 made from blast-furnace Portland cement	m3	7,983	122,31	976,40
59	K	417351116.S	Removal of formwork for the sides of tie beams and ring beams, including struts	m2	43,530	5,55	241,59
60	K	317351108.S	Removal of formwork for lintel, including supporting structure up to 4 m in height	m2	11,105	10,81	120,05
	D	1.1.1.5	Surface finishes, flooring, and installation				21 685,03
61	K	632455604	BAUMIT Estrich cement screed, class EN 13813 CT-C20-F5, thickness 50 mm	m2	171,600	30,82	5 288,71
62	K	632455606	BAUMIT Estrich cement screed, class EN 13813 CT-C20-F5, thickness 60 mm	m2	28,380	35,80	1 016,00
63	K	632001011.S	Installation of a polyethylene separation sheet in floor layers	m2	148,830	0,22	32,74
64	M	283290003600	FE separation foil, width x length 1.3x100 m, for screed separation, polyethylene, BAUMIT	m2	171,155	1,31	224,21
65	K	632001021.S	Installation of edge expansion strip made of polyethylene	m	80,000	0,34	27,20
66	M	283320004600	PE edge expansion strip RSS100/5 mm, without film, for separating screeds from wall structures, BAUMIT	m	80,800	0,52	42,02
67	K	610991111.S	Protection/covering of internal window openings, objects, and structures	m2	34,850	2,42	84,34
68	K	784481010.S	Wall skim coat on fine-grained substrate, up to 3.80 m in height	m2	407,314	2,54	1 034,58
69	K	612460262.S	Internal lime–gypsum plaster on walls, thickness 15 mm	m2	407,314	20,21	8 231,82
70	K	612481121.S	covering internal walls with fiberglass mesh, embedded without adhesive	m2	407,314	3,04	1 238,23
71	K	612467127	Preparation of internal wall substrate with CEMIX deep-penetrating primer, designation 2614	m2	407,314	2,41	981,63
72	K	622467317	Preparation of external wall substrate with CEMIX deep-penetrating primer, designation 2614	m2	150,240	3,31	497,29
73	K	622461032.S	External walls plaster, pasty silicate type, trowel-applied, thickness 1.5 mm	m2	150,240	17,64	2 650,23
74	K	784481110.S	Ceiling skim coat on fine-grained substrate, up to 3.80 m in height	m2	139,430	2,41	336,03
	D	1.1.1.6	Other structures and works – demolition				1 452,23
75	K	941955002.S	Light temporary working scaffolding with platform height over 1.20 m up to 1.90 m	m2	21,750	5,92	128,76
76	K	941955004.S	Light temporary working scaffolding with platform height over 2.50 m up to 3.50 m	m2	14,250	10,10	143,93
77	K	952902110.S	Cleaning of buildings by sweeping in rooms, corridors, staircases, and attics	m2	139,430	0,26	36,25
78	K	953945107	BAUMIT base profile SL 10 (aluminum)	m	61,200	9,99	611,39
79	K	953995183	BAUMIT window and door expansion profile Basic (plastic)	m	83,500	6,37	531,90
	D	1.1.1.7	Material handling for primary construction works				6 664,16
80	K	998011031.S	Handling of materials for buildings (801, 803, 812), vertical block structures, up to 6 m in height	t	413,153	16,13	6 664,16

IN	IT	Item code	Description	MU	Amount	U. price [EUR]	Total price [EUR]
	D	1.1.2	Assemblies and Supplies SCW				122 032,11
	D	1.1.2.1	Protection against water and moisture				3 629,84
81	K	711131101.S	Installation of horizontal damp-proofing (AIP) by dry method	m2	166,820	5,21	869,13
82	*M*	*628310001200.S*	*Bitumen membrane (breather), thickness 0.5 mm*	*m2*	*191,843*	*6,90*	*1 323,72*
83	K	711131103.S	Installation of horizontal damp-proofing, separation foil applied dry	m2	166,820	0,26	43,37
84	*M*	*283220003000.S*	*Vapor barrier – PE foil, thickness 0.26 mm*	*m2*	*191,843*	*1,63*	*312,70*
85	K	711210200.S	Application of a double-layer waterproofing screed on balconies and terraces on horizontal surfaces	m2	33,160	5,21	172,76
86	*M*	*247710007700.S*	*Sealing strip, 120 mm wide, for sealing corner and joint gaps during the application of waterproofing systems*	*m*	*13,264*	*1,70*	*22,55*
87	*M*	*245650000400.S*	*Cement–based waterproofing screed, single-component, flexible*	*kg*	*92,848*	*5,57*	*517,16*
88	K	711131103.S	Installation of horizontal damp-proofing, separation foil applied dry	m2	148,830	0,26	38,70
89	*M*	*283220003000.S*	*Vapor barrier – PE foil, thickness 0.5 mm*	*m2*	*171,155*	*1,63*	*278,98*
90	K	998711101.S	Handling of materials for waterproofing in structures up to 6 m in height	t	1,172	43,32	50,77
	D	1.1.2.2	Thermal insulation				21 105,49
91	K	713132215.S	Installation of XPS thermal insulation on underground walls and foundations by mechanical fastening and adhesive bonding	m2	53,166	7,75	412,04
92	*M*	*283750002100*	*XPS board STYRODUR 3000 CS, 100 mm thick, for building foundations, ISOVER*	*m2*	*54,229*	*22,55*	*1 222,86*
93	K	713122111.S	Installation of floor thermal insulation with polystyrene, laid loosely in a single layer	m2	148,830	1,44	214,32
94	*M*	*283720008100*	*EPS board 100S, 120 mm thick, for thermal insulation of floors, ISOVER*	*m2*	*151,807*	*13,45*	*2 041,80*
95	K	713170050.S	Installation of XPS thermal insulation on balconies and terraces, laid loosely	m2	33,160	1,46	48,41
96	*M*	*283750001000*	*XPS board STYRODUR 3000 C, 100 mm thick, for insulation of balconies and terraces, ISOVER*	*m2*	*33,823*	*22,55*	*762,71*
97	K	713132132.S	Installation of wall thermal insulation with polystyrene, bonded over the entire surface	m2	150,240	11,56	1 736,77
98	*M*	*283720002200*	*Facade insulation board BAUMIT EPS-F, 1000x500 mm*	*m3*	*27,043*	*165,36*	*4 471,83*
99	K	713144070.S	Installation of thermal insulation on lintels with XPS	m2	4,920	2,06	10,14
100	*M*	*283750000900.S*	*XPS board, 90 mm thick, for insulation of lintels*	*m2*	*5,018*	*18,49*	*92,78*
101	K	713144090.S	Installation of XPS thermal insulation on ring beams by mechanical fastening	m2	20,050	7,02	140,75
102	*M*	*283750001600.S*	*XPS board STYRODUR 3000 C, 30 mm thick, for ring beams*	*m2*	*20,451*	*8,50*	*173,83*
103	K	713116500.S	Ceiling thermal insulation with light spray-applied PUR foam, λ = 0.025 W/m·K, density 10 kg/m³	m3	44,649	216,46	9 664,72
104	K	998713101.S	Handling of materials for thermal insulation in structures up to 6 m in height	t	2,527	44,53	112,53
	D	1.1.2.3	Soundproofing and vibration protection measures				1 439,11
105	K	714181001.S	Installation of impact sound insulation for parquet floors, laid loosely	m2	111,060	3,13	347,62
106	*M*	*617210000100.S*	*Cork insulating anti-vibration board, 1000x500x15 mm, underlayment for laminate, wood, vinyl, ceramic, and stone floors*	*m2*	*113,281*	*9,35*	*1 059,18*
107	K	998714101.S	Handling of materials for acoustic insulation and anti-vibration measures in structures up to 6 m in height (depth)	t	0,595	54,31	32,31
	D	1.1.2.4	Roof insulation and membrane coverings				1 783,15
108	K	765901082.S	Installation of vapor–permeable roofing membrane, pitched at 22° to 35°, on rafters, with airtightness class 6 to 4	m2	179,790	3,66	658,03
109	*M*	*283230005900.S*	*Protective vapor–permeable waterproofing membrane under roofing, with a surface weight of 270 g/m²*	*m2*	*206,759*	*5,43*	*1 122,70*
110	K	998712101.S	Handling of materials for roofing membrane insulation in structures up to 6 m in height	t	0,064	37,74	2,42
	D	1.1.2.5	Carpentry structures				12 570,54
111	K	766662305.S	Installation of plastic entrance doors with waterproofing tapes (exterior and interior)	m	13,300	21,36	284,09
112	*M*	*611730000020.S*	*Single-leaf plastic entrance door with sidelight, triple-glazed insulation*	*m*	*13,300*	*197,26*	*2 623,56*
113	*M*	*283290008700.S*	*Vapor-impermeable sealing foil, polymer-fleece, 70 mm wide, 30 m long, for sealing the connection joint between the frame and masonry from the interior*	*m*	*13,965*	*1,81*	*25,28*
114	*M*	*283290008100.S*	*Vapor-permeable sealing foil, polymer-fleece, 70 mm wide, 30 m long, for sealing the connection joint between the frame and masonry from the exterior*	*m*	*13,965*	*1,81*	*25,28*
115	*M*	*611610006300.S*	*Installation materials for doors and windows*	*eur*	*115,000*	*1,00*	*115,00*
116	K	766651101.S	Installation of a sliding door pocket, single pocket for one leaf, passage width 0.6–1.2 m	ks	1,000	107,09	107,09
117	*M*	*553310013100.S*	*Construction pocket for sliding doors, single pocket for one leaf, clear passage 900 mm*	*ks*	*1,000*	*455,50*	*455,50*
118	*M*	*553420000300.S*	*Sliding door system – guide rail (raw profile)*	*m*	*1,000*	*7,59*	*7,59*
119	*M*	*553420000200.S*	*Sliding door system – set of carriages*	*súb.*	*1,000*	*27,23*	*27,23*
120	*M*	*549150001400.S*	*Door handle for sliding doors, thickness 8–12 mm, diameter 25 mm, length 200 mm*	*ks*	*2,000*	*5,80*	*11,60*
121	K	766664125.S	Installation of single-leaf wooden sliding doors, recessed sliding	ks	1,000	34,96	34,96
122	*M*	*611610002200.S*	*Single-leaf interior doors, width 600–900 mm, particleboard core, foil surface, solid*	*ks*	*1,000*	*144,88*	*144,88*
123	*M*	*611610006300.S*	*Installation materials for doors and windows*	*eur*	*80,000*	*1,00*	*80,00*
124	K	766702111.S	Installation of casings for single-leaf doors	ks	6,000	79,57	477,42
125	*M*	*611810002200.S*	*Interior casing frame, width 600–900 mm, height 1970 mm, particleboard core, foil surface, for wall thickness 60–170 mm, for single-leaf doors*	*ks*	*6,000*	*131,13*	*786,78*
126	K	766662112.S	Installation of a single-leaf half-lap hinged door leaf into an existing frame, including hardware	ks	6,000	28,45	170,70
127	*M*	*611610002200.S*	*Single-leaf interior door, width 600–900 mm, particleboard core, foil finish, solid*	*ks*	*3,000*	*144,88*	*434,64*

IN	IT	Item code	Description	MU	Amount	U. price [EUR]	Total price [EUR]
128	*M*	*611610002300.S*	*Single-leaf interior door, width 600–900 mm, particleboard core, foil finish, 1/3 glazed*	*ks*	*3,000*	*178,88*	*536,64*
129	*M*	*549150000600.S*	*Door handle with rosette x2, stainless steel, brushed finish*	*ks*	*6,000*	*24,11*	*144,66*
130	*M*	*611610006300.S*	*Installation materials for doors and windows*	*eur*	*6,000*	*1,00*	*6,00*
131	K	766641071.S	Installation of plastic teracce doors with waterproofing tapes (exterior and interior)	m	5,060	19,94	100,90
132	*M*	*611420091010.S*	*Single-leaf plastic door, inward-opening, with insulating triple glazing*	*m*	*5,060*	*139,06*	*703,64*
133	*M*	*283290008700.S*	*Vapor-impermeable sealing foil, polymer-fleece, 70 mm wide, 30 m long, for sealing the connection joint between the frame and masonry from the interior*	*m*	*5,865*	*1,81*	*10,62*
134	*M*	*283290008100.S*	*Vapor-permeable sealing foil, polymer-fleece, 70 mm wide, 30 m long, for sealing the connection joint between the frame and masonry from the exterior*	*m*	*5,865*	*1,81*	*10,62*
135	*M*	*611610006300.S*	*Installation materials for doors and windows*	*eur*	*115,000*	*1,00*	*115,00*
136	K	766621400.S	Installation of plastic windows with waterproofing tapes (exterior and interior)	m	52,290	18,04	943,31
137	*M*	*611410091020.S*	*Single-leaf plastic window, inward-opening, with insulating triple glazing*	*m*	*25,590*	*46,47*	*1 189,17*
138	*M*	*611410091030.S*	*Double-leaf plastic window, inward-opening + inward-opening, with insulating triple glazing*	*m*	*26,700*	*63,80*	*1 703,46*
139	*M*	*283290008700.S*	*Vapor-impermeable sealing foil, polymer-fleece, 70 mm wide, 30 m long, for sealing the connection joint between the frame and masonry from the interior*	*m*	*54,905*	*1,81*	*99,38*
140	*M*	*283290008100.S*	*Vapor-permeable sealing foil, polymer-fleece, 70 mm wide, 30 m long, for sealing the connection joint between the frame and masonry from the exterior*	*m*	*54,905*	*1,81*	*99,38*
141	*M*	*611610006300.S*	*Installation materials for doors and windows*	*eur*	*115,000*	*1,00*	*115,00*
142	K	766691610.S	Installation of exterior cover strip to conceal joints between window and teracce doors, with sealing	m	57,350	3,92	224,81
143	*M*	*611990004800.S*	*45x15 mm strips for window finishing*	*m*	*57,350*	*6,83*	*391,70*
144	K	766691510.S	Installation of sealing for windows and teracce doors at the junction of the sash and frame using polyurethane tape	m	57,350	1,33	76,28
145	*M*	*247710000400.S*	*Self-adhesive sealing tape made of foam polyethylene for windows and doors, width 9 mm, thickness 2 mm, length 20 m*	*ks*	*3,000*	*2,11*	*6,33*
146	K	766694141.S	Installation of plastic window sill, width up to 300 mm, length up to 1000 mm	ks	3,000	9,24	27,72
147	*M*	*611560000100.S*	*Plastic window sill, width 150 mm, hollow core*	*m*	*2,100*	*9,36*	*19,66*
148	K	766694142.S	Installation of plastic window sill, width up to 300 mm, length 1000–1600 mm	ks	3,000	12,21	36,63
149	*M*	*611560000100.S*	*Plastic window sill, width 150 mm, hollow core*	*m*	*3,900*	*9,36*	*36,50*
150	K	766694143.S	Installation of plastic window sill, width up to 300 mm, length 1600–2600 mm	ks	3,000	16,36	49,08
151	*M*	*611560000100.S*	*Plastic window sill, width 150 mm, hollow core*	*m*	*5,250*	*9,36*	*49,14*
152	K	998766101.S	Handling of materials for carpentry structures in buildings up to 6 m high	t	1,450	43,66	63,31
	D	1.1.2.6	Sheet metal structures				2 302,29
153	K	764359341.S	Installation of accessories for gutters made of galvanized PZ sheet, hook for semi-circular eaves gutters, diameter 200–400 mm	ks	85,000	4,79	407,15
154	*M*	*553440036900.S*	*Galvanized semi-circular hook with embossing, diameter 200 mm, extended by 50 mm*	*ks*	*85,000*	*1,64*	*139,40*
155	K	764359301.S	Installation of gutter made of galvanized PZ sheet, semi-circular eaves, diameter 200–400 mm	m	36,610	17,82	652,39
156	*M*	*553440033900.S*	*Galvanized semi-circular eaves gutter, diameter 200 mm*	*m*	*38,441*	*3,69*	*141,85*
157	K	764359331.S	Installation of accessories for gutters made of galvanized PZ sheet, corner for semi-circular eaves gutters, diameter 200–400 mm	ks	1,000	4,38	4,38
158	*M*	*553440036400.S*	*Pressed semi-circular corner, galvanized, internal/external, diameter 200 mm*	*ks*	*1,000*	*7,94*	*7,94*
159	K	764359311.S	Installation of accessories for gutters made of galvanized PZ sheet, end cap for semi-circular eaves gutters, diameter 200–400 mm	ks	6,000	3,38	20,28
160	*M*	*553440034700.S*	*Pressed semi-circular end cap, galvanized, size 200 mm*	*ks*	*6,000*	*0,49*	*2,94*
161	K	764359371.S	Installation of accessories for gutters made of galvanized PZ sheet, downpipe outlet for semi-circular eaves gutters, diameter 80–120 mm	ks	6,000	3,59	21,54
162	*M*	*553440035500.S*	*Pressed galvanized gutter outlet, diameter 80 mm*	*ks*	*6,000*	*1,11*	*6,66*
163	K	764454233.S	Installation of circular collector made of galvanized PZ sheet, for downpipes with diameter 80–120 mm	ks	6,000	6,44	38,64
164	*M*	*553440043200.S*	*Galvanized water collector, diameter 80 mm*	*ks*	*6,000*	*7,36*	*44,16*
165	K	764454241.S	Installation of hammered clamp made of galvanized PZ sheet, for circular downpipes with diameter 80–120 mm	ks	12,000	2,93	35,16
166	*M*	*553440041400.S*	*Pressed galvanized clamp, spike 200 mm, diameter 80 mm*	*ks*	*12,000*	*1,92*	*23,04*
167	K	764454234.S	Installation of circular elbows made of galvanized PZ sheet, for downpipes with diameter 60–150 mm	ks	12,000	8,62	103,44
168	*M*	*553440039000.S*	*Pressed galvanized elbow 72°, diameter 80 mm*	*ks*	*12,000*	*3,13*	*37,56*
169	K	764752165.S	Installation of colored galvanized downpipe connector, diameter up to 100 mm	ks	12,000	4,21	50,52
170	*M*	*553440005600.S*	*Pressed galvanized downpipe – connector, diameter 80 mm*	*m*	*12,000*	*8,22*	*98,64*
171	K	764752121.S	Installation of the bottom section of colored galvanized downpipe with flange, diameter up to 100 mm	ks	6,000	9,97	59,82
172	*M*	*553440002100.S*	*Pressed galvanized downpipe – bottom section with flange, diameter 80 mm*	*ks*	*6,000*	*13,02*	*78,12*
173	K	764758245.S	Gutter outlet made of PVC-HI	ks	6,000	10,28	61,68
174	K	764762141.S	Installation of filter insert against leaf blockage in the gutter outlet	ks	6,000	1,89	11,34
175	*M*	*553440008900.S*	*Stainless steel filter insert, diameter 80 mm*	*ks*	*6,000*	*21,53*	*129,18*
176	K	764410211.S	Installation of window sill flashing made of galvanized PZ sheet, including corners, width 100 mm	m	12,100	8,68	105,03
177	*M*	*138210000200.S*	*Smooth galvanized sheet metal, thickness 0.60 mm*	*m2*	*1,367*	*7,71*	*10,54*
178	K	998764101.S	Handling of materials for sheet-metal structures in buildings up to 6 m high	t	0,116	93,84	10,89
	D	1.1.2.7	Timber structures				17 941,69

IN	IT	Item code	Description	MU	Amount	U. price [EUR]	Total price [EUR]
179	K	762333110.S	Installation of tied roof truss structures of irregular ground plan made of timber with cross-sectional area up to 120 cm^2	m	413,060	8,31	3 432,53
180	*M*	*605120002900.S*	*Sawn softwood beams, rough-edged, grade I*	*m3*	*5,452*	*365,85*	*1 994,61*
181	K	762333120.S	Installation of tied roof truss structures of irregular ground plan made of timber with cross-sectional area 120–224 cm^2	m	270,055	11,76	3 175,85
182	*M*	*605120002900.S*	*Sawn softwood beams, rough-edged, grade I*	*m3*	*6,654*	*365,85*	*2 434,37*
183	K	762333130.S	Installation of tied roof truss structures of irregular ground plan made of timber with cross-sectional area 224–288 cm^2	m	56,815	16,11	915,29
184	*M*	*605120002900.S*	*Sawn softwood beams, rough-edged, grade I*	*m3*	*1,800*	*365,85*	*658,53*
185	K	762333140.S	Installation of tied roof truss structures of irregular ground plan made of timber with cross-sectional area 288–450 cm^2	m	56,815	17,54	996,54
186	*M*	*605120002900.S*	*Sawn softwood beams, rough-edged, grade I*	*m3*	*2,812*	*365,85*	*1 028,77*
187	K	762341252.S	Installation of counter battens for roof slopes from 22° to 35°	m	245,000	2,21	541,45
188	*M*	*605120000200.S*	*Sawn softwood beams, rough-edged, grade II*	*m3*	*0,980*	*295,85*	*289,93*
189	K	762341202.S	Installation of battens for complex roofs with slope up to 60°	m	520,000	1,30	676,00
190	*M*	*605120000200.S*	*Sawn softwood beams, rough-edged, grade II*	*m3*	*1,144*	*295,85*	*338,45*
191	K	762395000.S	Fasteners for tied roof truss structures, formwork and battens, superstructure, slope wedges – clamps, boards, nails, steel straps, screws	m3	20,000	36,91	738,20
192	K	998762102.S	Handling of materials for carpentry structures in buildings up to 12 m high	t	11,017	65,46	721,17
	D	1.1.2.8	Metal structures				5 611,15
193	K	767661016.S	Installation of pre-window roller shutter, width 80–120 cm, length up to 260 cm	ks	5,000	39,54	197,70
194	*M*	*611520000300.S*	*Aluminum pre-window roller shutter, width x height 600x800 mm, with exposed box*	*ks*	*3,000*	*154,18*	*462,54*
195	*M*	*611520001500.S*	*Aluminum pre-window roller shutter, width x height 600x2000 mm, with exposed box*	*ks*	*2,000*	*287,45*	*574,90*
196	K	767661021.S	Installation of pre-window roller shutter, width 120–200 cm, length up to 260 cm	ks	5,000	41,88	209,40
197	*M*	*611520017700.S*	*Aluminum pre-window roller shutter, width x height 1500x800 mm, with exposed box*	*ks*	*1,000*	*279,45*	*279,45*
198	*M*	*611520021800.S*	*Aluminum pre-window roller shutter, width x height 1800x2000 mm, with exposed box*	*ks*	*3,000*	*637,36*	*1 912,08*
199	*M*	*611520025000.S*	*Aluminum pre-window roller shutter, width x height 2000x2300 mm, with exposed box*	*ks*	*1,000*	*791,73*	*791,73*
200	K	767661026.S	Installation of pre-window roller shutter, width 200–350 cm, length up to 260 cm	ks	1,000	41,90	41,90
201	*M*	*611520034500.S*	*Aluminum pre-window roller shutter, width x height 3500x2300 mm, with exposed box*	*ks*	*1,000*	*1 132,60*	*1 132,60*
202	K	998767101.S	Handling of materials for metal building structures in buildings up to 6 m high	t	0,137	64,63	8,85
	D	1.1.2.9	Supplementary structures				1 884,80
203	K	767660005.S	Installation of insect screen on window, fixed with clips to the sealing	m2	58,600	6,73	394,38
204	*M*	*553420000005.S*	*Fixed insect screen for window with inner frame flange, reversible from interior, color white*	*m2*	*58,600*	*17,02*	*997,37*
205	K	767660035.S	Installation of sliding insect screen doors, mounted on the frame of the opening infill	m2	6,800	22,35	151,98
206	*M*	*553420000065.S*	*Sliding insect screen door, mounted on frame, color white*	*m2*	*6,800*	*50,13*	*340,88*
207	K	998767101.S	Handling of materials for auxiliary building structures in buildings up to 6 m high	t	0,017	11,30	0,19
	D	1.1.2.10	Hard coverings				25 044,41
208	K	765310193.S	Installation of ceramic roofing on complex roofs with a slope of up to 35°	m2	179,790	19,20	3 451,97
209	*M*	*596610027100.S*	*Smooth ceramic roofing tiles, consumption 20–25 units per square meter*	*ks*	*3 473,543*	*3,95*	*13 720,49*
210	*M*	*596610002400.S*	*Smooth ceramic roofing tiles, half size*	*ks*	*215,748*	*3,65*	*787,48*
211	*M*	*596610023200.S*	*Smooth ceramic roofing tiles, right/left edge tiles*	*ks*	*77,816*	*21,56*	*1 677,71*
212	K	765314491.S	Installation of gable edges using edge tiles	m	27,400	7,23	198,10
213	*M*	*596610032380.S*	*Smooth ceramic roofing edge tile, semicircular*	*ks*	*25,000*	*21,09*	*527,25*
214	*M*	*596610023700.S*	*Smooth ceramic semicircular edge tile, terminating/end piece*	*ks*	*1,000*	*60,59*	*60,59*
215	*M*	*596610009000.S*	*Smooth ceramic branching edge tile*	*ks*	*0,400*	*58,53*	*23,41*
216	K	765310433.S	Installation of ceramic roof valley with a ventilation strip, for slopes up to 35°	m	10,000	27,26	272,60
217	*M*	*596610032380.S*	*Smooth ceramic valley tile with a semicircular profile.*	*ks*	*63,038*	*22,09*	*1 392,51*
218	*M*	*596610023700.S*	*Smooth ceramic semicircular valley tile, end/terminating piece.*	*ks*	*2,522*	*60,59*	*152,81*
219	K	765310430.S	Installation of a ceramic ridge with a ventilation strip, for slopes up to 35°	m	25,215	27,75	699,72
220	*M*	*596610024500.S*	*Smooth ceramic ventilated ridge roofing tile, ventilation cross-section 30 cm^2*	*ks*	*14,383*	*88,05*	*1 266,42*
221	K	765331825	BRAMAC universal antenna mounting bracket	ks	2,000	82,06	164,12
222	K	765315455.S	Installation of a lightning rod bracket for ceramic roofing	ks	30,000	1,85	55,50
223	*M*	*553450030900.S*	*Lightning rod holder for tile, suitable for ceramic roofing*	*ks*	*30,000*	*4,61*	*138,30*
224	K	998765101.S	Handling of hard roofing materials in structures with a maximum height of 6 meters	t	9,268	49,14	455,43
	D	1.1.2.11	Timber coverings				10 439,04
225	K	762810026.S	Ceiling sheathing of OSB boards screwed onto beams with tongue-and-groove joints, board thickness 18 mm	m2	148,830	24,63	3 665,68
226	K	763782213.S	Installation of a ceiling structure using solid-web beams, cross-sectional area 150–500 cm^2	m	59,350	9,08	538,90
227	*M*	*605710003603.S*	*Glulam (KVH) structural timber beams, non-visible quality*	*m3*	*1,840*	*662,08*	*1 218,23*
228	K	763138221	Suspended gypsum board ceiling (Rigips RF, 12.5 mm) on a double-level CD steel substructure.	m2	139,430	33,74	4 704,37
229	K	998763301.S	Handling of timber covering construction materials in structures with a maximum height of 7 meters	t	4,295	72,61	311,86
	D	1.1.2.12	Strip and parquet flooring				3 774,09

IN	IT	Item code	Description	MU	Amount	U. price [EUR]	Total price [EUR]
230	K	775550110.S	Installation of laminate and wooden parquet flooring, click-lock system, laid floating	m2	111,060	6,22	690,79
231	*M*	*611980003080.S*	*Laminate flooring, thickness 15 mm*	*m2*	*113,281*	*18,23*	*2 065,11*
232	K	775413130.S	Installation of floor skirting boards or perimeter moldings by adhesive bonding	m	95,230	4,27	406,63
233	*M*	*611990000100.S*	*Wooden floor skirting board, hxw 30x10 mm*	*m*	*96,182*	*5,74*	*552,08*
234	K	998775101.S	Handling of parquet and inlay flooring materials in structures with a maximum height of 6 meters	t	1,142	52,08	59,48
	D	1.1.2.13	Tiled floors				2 040,71
235	K	771991101.S	Sweeping the substrate prior to tile installation	m2	28,380	0,76	21,57
236	K	771541025.S	Installation of floorings with gres tiles laid in mortar with thickness 10 mm, size 600x600 mm	m2	28,380	29,26	830,40
237	*M*	*597740002100.S*	*Ceramic tiles, lxwxh 598x598x10 mm, gres*	*m2*	*30,083*	*35,24*	*1 060,12*
238	K	771991251.S	Joint filling for floor tiles with silicone sealant	m2	28,380	2,36	66,98
239	K	998771101.S	Handling of floor tile materials in structures with a maximum height of 6 meters	t	1,963	31,40	61,64
	D	1.1.2.14	Poured terrazzo floors				1 119,11
240	K	773521360.S	Colored terrazzo flooring – simple type, thickness 30 mm	m2	33,160	32,00	1 061,12
241	K	998773101.S	Handling of terrazzo flooring materials in structures with a maximum height of 6 meters	t	1,919	30,22	57,99
	D	1.1.2.15	Coatings				3 301,98
242	K	783782406.S	Coatings for carpentry structures, 3-in-1 deep impregnation with biocide, single application	m2	571,276	5,78	3 301,98
	D	1.1.2.16	Wall cladding				7 253,61
243	K	781445406.S	Installation of interior wall tiles laid in dispersion adhesive, size 100x100 mm	m2	92,871	42,11	3 910,80
244	*M*	*597640000100.S*	*Single-color smooth glazed ceramic tiles, lxwxh 100x100x14 mm*	*m2*	*96,586*	*24,58*	*2 374,08*
245	K	781445411.S	Installation of interior wall tiles laid in dispersion adhesive, size 200x200 mm	m2	9,650	34,34	331,38
246	*M*	*597640000400.S*	*Single-color smooth glazed ceramic tiles, lxwxh 200x200x14 mm*	*m2*	*10,036*	*31,58*	*316,94*
247	K	781991131.S	Joint filling for wall tiles with silicone sealant, joint width up to 5 mm	m2	101,521	2,36	239,59
248	K	998781101.S	Handling of ceramic wall tile materials in structures with a maximum height of 6 meters	t	2,574	31,40	80,82
	D	1.1.2.17	Paint finishes				791,10
249	K	784410500.S	Sanding and dusting of fine-textured surfaces up to 3.80 m in height	m2	304,793	0,18	54,86
250	K	784410600.S	Repair of cracks and surface irregularities on fine-textured surfaces up to 3.80 m in height	m2	304,793	0,29	88,39
251	K	784418011.S	Covering openings, floors, and equipment with plastic sheeting in rooms or staircases	m2	70,090	1,38	96,72
252	K	784418012.S	Covering floors and equipment with paper in rooms or on staircases	m2	139,430	1,57	218,91
253	K	784491200.S	Single-coat rolling on fine-textured substrate up to 5.00 m in height	m2	304,793	1,09	332,22

BUDGET

Construction:
Bachelor's Thesis - Slovakia
Building:
1.2 - Paved Surfaces

Place: Date: 07.11.2025

Customer: Designer:
Contractor: Processed by:

IN	IT	Item code	Description	MU	Amount	U. price [EUR]	Total price [EUR]
Budget costs							**9 509,14**
	D	1.2.1	Assemblies and Supplies PCW				9 251,23
	D	1.2.1.1	Earthworks				413,40
254	K	121101112.S	Removal of topsoil with relocation to heaps, including placement at a distance up to 100 m, for volumes up to 1000 m^3	m3	16,470	1,10	18,12
255	K	181301102.S	Spreading of topsoil on a level surface, area up to 500 m^2, thickness up to 150 mm	m2	109,800	3,34	366,73
256	K	215901101.S	Compaction of subgrade from natural soils of classes 1 to 4 under embankments, from cohesive soils up to 92% Proctor density and from non-cohesive soils	m2	109,800	0,26	28,55
	D	1.2.1.2	Foundation works				1 158,83
257	K	271533001.S	Fill under foundation structures, compacted, made of coarse crushed aggregate, fraction 32–63 mm	m3	5,490	83,76	459,84
258	K	271573001.S	Fill under foundation structures, compacted, made of gravel–sand mixture, fraction 0–32 mm	m3	10,980	63,66	698,99
	D	1.2.1.3	Circulation areas				5 512,27
259	K	596911243.S	Installation of 100 mm thick concrete interlocking pavement for pedestrian pathways up to 300 m^2, including a 50 mm thick bedding layer of crushed stone	m2	109,800	24,05	2 640,69
260	*M*	*592460011700*	*PREMAC KLASIKO concrete paving block, dimensions 200x200x100 mm, grey*	*m2*	*111,996*	*25,64*	*2 871,58*
	D	1.2.1.4	Surface finishes, flooring, and installation				7,68
261	K	631571015.S	Sand infill between joints	m3	0,100	76,78	7,68
	D	1.2.1.5	Other structures and works – demolition				923,59
262	K	917111111.S	Installation of horizontal stone curbstone in a bed of compacted crushed stone, without lateral support	m	73,200	9,72	711,50
263	*M*	*592170001800*	*PREMAC park curbstone, length x width x height 1000x50x200 mm, grey*	*ks*	*76,566*	*2,77*	*212,09*
	D	1.2.1.6	Material handling for primary construction works				1 235,46
264	K	998011031.S	Handling of materials for buildings (801, 803, 812), vertical block structures, up to 6 m in height	t	76,594	16,13	1 235,46
	D	1.2.2	Assemblies and Supplies SCW				257,91
	D	1.2.2.1	Protection against water and moisture				257,91
265	K	711132102.S	Installation of geotextile or fabric on a vertical surface	m2	109,800	0,78	85,64
266	*M*	*693110001200*	*Polypropylene geotextile Tatratex GTX N PP 300, width 1.75–3.5 m, length 90 m, thickness 2.7 mm, non-woven, MIVA*	*m2*	*131,760*	*1,29*	*169,97*
267	K	998711101.S	Handling of materials for waterproofing in buildings up to 6 m in height	t	0,053	43,32	2,30

SUMMARY OF CONSTRUCTION OBJECTS AND COMPLETED WORKS

Item code 1

Construction: **Bachelor's Thesis - Finland**

Place:		Date:	07.11.2025
Customer:		Designer:	
Contractor:		Processed by:	

Item code	Description	Price without VAT [EUR]	Price with VAT [EUR]	IT
Budget costs		**384 776,48**	**482 894,48**	
1.1	Structural Shell and Envelope	363 305,24	455 948,08	STA
1.2	Paved Surfaces	21 471,24	26 946,41	STA

BUDGET

Construction:
Bachelor's Thesis - Finland
Building:
1.1 - Structural Shell and Envelope

Place:
Date: 07.11.2025

Customer:
Contractor:
Designer:
Processed by:

IN	IT	Item code	Description	MU	Amount	U. price [EUR]	Total price [EUR]
Budget costs							**363 305,24**
	D	1.1.1	Assemblies and Supplies PCW				174 939,41
	D	1.1.1.1	Earthworks				9 797,93
1	K	122101101.S	Unshored excavation and trenching in soils of classes 1–2, up to 100 m^3	m3	48,894	59,75	2 921,42
2	K	132101101.S	Trench excavation up to 600 mm wide in soils of classes 1–4, up to 100 m^3	m3	61,530	59,75	3 676,42
3	K	122302509.S	Surcharge for sticky soil	m3	110,424	5,43	599,60
4	K	162201101.S	Horizontal transport of excavated material from soils/rocks of classes 1–4, up to 20 m	m3	110,424	4,63	511,26
5	K	167101102.S	Loading of uncompacted excavated material from soils/rocks of classes 1–4, from 100 m^3 to 1000 m^3	m3	110,424	6,23	687,94
6	K	162501122.S	Horizontal transport of excavated material over a paved road from soils/rocks of classes 1–4, from 100 m^3 to 1000 m^3, up to a distance of 3000 m	m3	110,424	9,73	1 074,43
7	K	162501123.S	Horizontal transport of excavated material over a paved road from soils/rocks of classes 1–4, from 100 m^3 to 1000 m^3, surcharge for each additional or commenced 1000 m	m3	110,424	1,03	113,74
8	K	171201202.S	Disposal/placement of excavated material to dumps/landfills, from 100 m^3 to 1000 m^3	m3	110,424	1,93	213,12
	D	1.1.1.2	Foundation works				63 640,37
9	K	271533041.S	Compacted drainage fill around pipes adjacent to foundations made of coarse crushed aggregate, fraction 16–32 mm	m3	8,168	209,40	1 710,38
10	K	271573001.S	Compacted fill under foundation structures made of gravel-sand mixture, fraction 0–32 mm	m3	53,811	159,15	8 564,02
11	K	274361831.S	Fabrication and installation of reinforcement for strip foundations using reinforcing steel	t	2,971	2 220,03	6 595,71
12	*M*	*589510002500.S*	*Reinforcement EN 10080 for concrete made of steel 10 505 (B500B), diameter 6–14 mm*	*t*	*2,971*	*3 300,00*	*9 804,30*
13	K	274321421.S	Casting/concreting of strip foundations, plain concrete (without reinforcement)	m3	28,842	36,85	1 062,83
14	*M*	*589310004900.S*	*Concrete EN 206-1 - C20/25 - XC2 - CL 0.4 - Dmax 16 - S3 made from blast-furnace Portland cement*	*m3*	*29,707*	*210,53*	*6 254,21*
15	K	279351107.S	Installation of formwork for foundation walls, double-sided, traditional method	m2	39,780	46,85	1 863,69
16	K	274271146.S	Constructing of foundation wall using concrete formwork blocks with C 20/25 concrete infill, 300 mm thick	m3	10,913	378,73	4 133,08
17	*M*	*595120000400.S*	*Concrete plinth block (CMU), 300 mm wide (DT30)*	*m2*	*37,104*	*33,26*	*1 234,08*
18	K	274271126.S	Constructing of foundation wall using concrete formwork blocks with C 20/25 concrete infill, 200 mm thick	m3	1,105	365,35	403,71
19	*M*	*595120000200.S*	*Concrete plinth block (CMU), 200 mm wide (DT20)*	*m2*	*5,636*	*33,26*	*187,45*
20	K	279361831.S	Fabrication and installation of reinforcement for load-bearing foundation walls using reinforcing steel	t	0,464	2 271,48	1 053,97
21	*M*	*589510002500.S*	*Reinforcement EN 10080 for concrete made of steel 10 505 (B500B), diameter 6–14 mm*	*t*	*0,464*	*3 300,00*	*1 531,20*
22	K	274321421.S	Casting/concreting of foundation walls, plain concrete (without reinforcement)	m3	4,500	36,85	165,83
23	*M*	*589310004900.S*	*Concrete EN 206-1 - C20/25 - XC2 - CL 0.4 - Dmax 16 - S3 made from blast-furnace Portland cement*	*m3*	*4,635*	*210,53*	*975,81*
24	K	273361931.S	Fabrication of reinforcement for foundation slabs using welded meshes and KARI meshes	t	3,091	871,33	2 693,28
25	*M*	*313110006300.S*	*KARI mesh, grade BSt 500M KY 14 according to DIN 488, mesh size 6x2.4 m, opening 150x150 mm, wire Ø 8/8 mm*	*m2*	*1 203,504*	*5,85*	*7 040,50*
26	K	273321721.S	Casting/concreting of foundation slabs, plain concrete (without reinforcement)	m3	30,011	40,75	1 222,95
27	*M*	*589310004900.S*	*Concrete EN 206-1 - C20/25 - XC2 - CL 0.4 - Dmax 16 - S3 made from blast-furnace Portland cement*	*m3*	*30,911*	*210,53*	*6 507,69*
28	K	279351108.S	Removal of formwork for foundation walls, double-sided, traditional method	m2	39,780	15,98	635,68
	D	1.1.1.3	Vertical and complete structures				35 084,85
29	K	311236560	Constructing of masonry of load-bearing walls made of fired clay bricks POROTHERM 30 Profi P12, ground tongue-and-groove type, laid with POROTHERM Profi thin-joint mortar (300x250x249 mm)	m3	45,072	168,23	7 582,46
30	*M*	*596130004850*	*POROTHERM 30 Profi brick, P12, dimensions wxlxh 300x250x249 mm, laid with thin-joint mortar Porotherm Profi*	*ks*	*2 381,604*	*5,41*	*12 884,48*
31	*M*	*596130004860*	*POROTHERM 30 Profi 1/2 brick, P12, dimensions wxlxh 300x125x249 mm, laid with thin-joint mortar Porotherm Profi*	*ks*	*137,920*	*4,00*	*551,68*
32	*M*	*596130004865*	*POROTHERM 30 Profi R brick, P12, dimensions wxlxh 300x175x249 mm, laid with thin-joint mortar Porotherm Profi*	*ks*	*157,500*	*4,61*	*726,08*
33	K	311236561	Constructing of masonry of load-bearing walls made of fired clay bricks POROTHERM 25 Profi P12, ground tongue-and-groove type, laid with POROTHERM Profi thin-joint mortar (250x375x249 mm)	m3	7,563	180,65	1 366,26
34	*M*	*596130005600*	*POROTHERM 25 Profi brick, P12, dimensions wxlxh 250x375x249 mm, laid with thin-joint mortar Porotherm Profi*	*ks*	*330,201*	*6,67*	*2 202,44*

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35	K	342273350	Constructing of masonry of partition walls made of smooth PORFIX blocks, 150 mm thick, strength class P2-500, laid with mortar for thin joints and PORFIX adhesive (150x250x500 mm)	m2	115,040	37,53	4 317,45
36	*M*	*595310004300*	*PORFIX partition block P2-500 HL, dimensions wxlxh 150x500x250 mm*	*ks*	*938,726*	*5,81*	*5 454,00*
	D	1.1.1.4	Horizontal structures				15 371,76
37	K	317121101.S	Installation of a prefabricated load-bearing lintel for an opening width from 600 to 1050 mm	ks	9,000	19,23	173,07
38	*M*	*596460006500*	*HELUZ 23,8 load-bearing ceramic lintel, dimensions lxwxh 1000x70x238 mm*	*ks*	*9,000*	*27,28*	*245,52*
39	K	317121102.S	Installation of a prefabricated load-bearing lintel for an opening width from 1050 to 1800 mm	ks	15,000	24,03	360,45
40	*M*	*596460006600*	*HELUZ 23,8 load-bearing ceramic lintel, dimensions lxwxh 1250x70x238 mm*	*ks*	*3,000*	*36,40*	*109,20*
41	*M*	*596460006700*	*HELUZ 23,8 load-bearing ceramic lintel, dimensions lxwxh 1500x70x238 mm*	*ks*	*9,000*	*43,71*	*393,39*
42	*M*	*596460006800*	*HELUZ 23,8 load-bearing ceramic lintel, dimensions lxwxh 1750x70x238 mm*	*ks*	*3,000*	*56,38*	*169,14*
43	K	317121103.S	Installation of a prefabricated load-bearing lintel for an opening width over 1800 mm up to 3750 mm	ks	12,000	36,30	435,60
44	*M*	*596460007000*	*HELUZ 23,8 load-bearing ceramic lintel, dimensions lxwxh 2250x70x238 mm*	*ks*	*9,000*	*83,78*	*754,02*
45	*M*	*596460007100*	*HELUZ 23,8 load-bearing ceramic lintel, dimensions lxwxh 2500x70x238 mm*	*ks*	*3,000*	*95,67*	*287,01*
46	K	317121101.S	Installation of a prefabricated non-load-bearing lintel	ks	7,000	27,13	189,91
47	*M*	*596460010750.S*	*PORFIX non-load-bearing ceramic lintel, dimensions lxwxh 1000x150x250 mm*	*ks*	*2,000*	*33,44*	*66,88*
48	*M*	*596460010755.S*	*PORFIX non-load-bearing ceramic lintel, dimensions lxwxh 1250x150x250 mm*	*ks*	*5,000*	*40,64*	*203,20*
49	K	317351107.S	Installation of formwork for lintel, including supporting structure up to 4 m in height	m2	11,105	81,88	909,28
50	K	417351115.S	Installation of formwork for the sides of tie beams and ring beams, including struts	m2	43,530	52,80	2 298,38
51	K	317361831.S	Fabrication and installation of reinforcement for concrete lintels and cornices using steel	t	0,139	1 626,50	226,08
52	*M*	*589510002500.S*	*Reinforcement EN 10080 for concrete made of steel 10 505 (B500B), diameter 6–14 mm*	*t*	*0,139*	*3 300,00*	*458,70*
53	K	317321521.S	Casting of plain concrete lintels (without reinforcement)	m3	1,350	83,28	112,43
54	*M*	*589310005900.S*	*Concrete EN 206-1 - C25/30 - XC1 - CL 0.4 - Dmax 16 - S4 made from blast-furnace Portland cement*	*m3*	*1,391*	*220,34*	*306,49*
55	K	417361831.S	Fabrication and installation of reinforcement for tie beams and ring beams using reinforcing steel	t	0,775	2 233,13	1 730,68
56	*M*	*589510002500.S*	*Reinforcement EN 10080 for concrete made of steel 10 505 (B500B), diameter 6–14 mm*	*t*	*0,775*	*3 300,00*	*2 557,50*
57	K	417321626.S	Casting of tie beams and ring beams in plain concrete (without reinforcement)	m3	7,750	93,28	722,92
58	*M*	*589310005600.S*	*Concrete EN 206-1 - C25/30 - XC1 - CL 0.4 - Dmax 16 - S4 made from blast-furnace Portland cement*	*m3*	*7,983*	*220,16*	*1 757,54*
59	K	417351116.S	Removal of formwork for the sides of tie beams and ring beams, including struts	m2	43,530	13,88	604,20
60	K	317351108.S	Removal of formwork for lintel, including supporting structure up to 4 m in height	m2	11,105	27,03	300,17
	D	1.1.1.5	Surface finishes, flooring, and installation				31 894,05
61	K	632455604	BAUMIT Estrich cement screed, class EN 13813 CT-C20-F5, thickness 50 mm	m2	171,600	43,15	7 404,54
62	K	632455606	BAUMIT Estrich cement screed, class EN 13813 CT-C20-F5, thickness 60 mm	m2	28,380	50,12	1 422,41
63	K	632001011.S	Installation of a polyethylene separation sheet in floor layers	m2	148,830	0,55	81,86
64	*M*	*283290003600*	*FE separation foil, width x length 1.3x100 m, for screed separation, polyethylene, BAUMIT*	*m2*	*171,155*	*1,07*	*183,14*
65	K	632001021.S	Installation of edge expansion strip made of polyethylene	m	80,000	0,85	68,00
66	*M*	*283320004800*	*PE edge expansion strip RSS100/5 mm, without film, for separating screeds from wall structures, BAUMIT*	*m*	*80,800*	*0,78*	*63,02*
67	K	610991111.S	Protection/covering of internal window openings, objects, and structures	m2	34,850	6,05	210,84
68	K	784481010.S	Wall skim coat on fine-grained substrate, up to 3.80 m in height	m2	407,314	3,81	1 551,87
69	K	612460262.S	Internal lime–gypsum plaster on walls, thickness 15 mm	m2	407,314	30,32	12 349,76
70	K	612481121.S	covering internal walls with fiberglass mesh, embedded without adhesive	m2	407,314	4,56	1 857,35
71	K	612467127	Preparation of internal wall substrate with CEMIX deep-penetrating primer, designation 2614	m2	407,314	3,62	1 474,48
72	K	622467317	Preparation of external wall substrate with CEMIX deep-penetrating primer, designation 2614	m2	150,240	4,97	746,69
73	K	622461032.S	External walls plaster, pasty silicate type, trowel-applied, thickness 1.5 mm	m2	150,240	26,46	3 975,35
74	K	784481110.S	Ceiling skim coat on fine-grained substrate, up to 3.80 m in height	m2	139,430	3,62	504,74
	D	1.1.1.6	Other structures and works – demolition				2 487,99
75	K	941955002.S	Light temporary working scaffolding with platform height over 1.20 m up to 1.90 m	m2	21,750	14,80	321,90
76	K	941955004.S	Light temporary working scaffolding with platform height over 2.50 m up to 3.50 m	m2	14,250	25,25	359,81
77	K	952902110.S	Cleaning of buildings by sweeping in rooms, corridors, staircases, and attics	m2	139,430	0,65	90,63
78	K	953945107	BAUMIT base profile SL 10 (aluminum)	m	61,200	14,99	917,39
79	K	953995183	BAUMIT window and door expansion profile Basic (plastic)	m	83,500	9,56	798,26
	D	1.1.1.7	Material handling for primary construction works				16 662,46
80	K	998011031.S	Handling of materials for buildings (801, 803, 812), vertical block structures, up to 6 m in height	t	413,153	40,33	16 662,46

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	D	1.1.2	Assemblies and Supplies SCW				188 365,83
	D	1.1.2.1	Protection against water and moisture				6 084,57
81	K	711131101.S	Installation of horizontal damp-proofing (AIP) by dry method	m2	166,820	13,03	2 173,66
82	*M*	*628310001200.S*	*Bitumen membrane (breather), thickness 0.5 mm*	*m2*	*191,843*	*10,07*	*1 931,86*
83	K	711131103.S	Installation of horizontal damp-proofing, separation foil applied dry	m2	166,820	0,65	108,43
84	*M*	*283220003000.S*	*Vapor barrier – PE foil, thickness 0.26 mm*	*m2*	*191,843*	*1,34*	*257,07*
85	K	711210200.S	Application of a double-layer waterproofing screed on balconies and terraces on horizontal surfaces	m2	33,160	13,03	432,07
86	*M*	*247710007700.S*	*Sealing strip, 120 mm wide, for sealing corner and joint gaps during the application of waterproofing systems*	*m*	*13,264*	*2,07*	*27,46*
87	*M*	*245650000400.S*	*Cement–based waterproofing screed, single-component, flexible*	*kg*	*92,848*	*7,55*	*701,00*
88	K	711131103.S	Installation of horizontal damp-proofing, separation foil applied dry	m2	148,830	0,65	96,74
89	*M*	*283220003000.S*	*Vapor barrier – PE foil, thickness 0.5 mm*	*m2*	*171,155*	*1,34*	*229,35*
90	K	998711101.S	Handling of materials for waterproofing in structures up to 6 m in height	t	1,172	108,30	126,93
	D	1.1.2.2	Thermal insulation				30 359,65
91	K	713132215.S	Installation of XPS thermal insulation on underground walls and foundations by mechanical fastening and adhesive bonding	m2	53,166	19,38	1 030,36
92	*M*	*283750002100*	*XPS board STYRODUR 3000 CS, 100 mm thick, for building foundations, ISOVER*	*m2*	*54,229*	*29,20*	*1 583,49*
93	K	713122111.S	Installation of floor thermal insulation with polystyrene, laid loosely in a single layer	m2	148,830	3,60	535,79
94	*M*	*283720008100*	*EPS board 100S, 120 mm thick, for thermal insulation of floors, ISOVER*	*m2*	*151,807*	*13,45*	*2 041,80*
95	K	713170050.S	Installation of XPS thermal insulation on balconies and terraces, laid loosely	m2	33,160	3,65	121,03
96	*M*	*283750001000*	*XPS board STYRODUR 3000 C, 100 mm thick, for insulation of balconies and terraces, ISOVER*	*m2*	*33,823*	*29,20*	*987,63*
97	K	713132132.S	Installation of wall thermal insulation with polystyrene, bonded over the entire surface	m2	150,240	28,90	4 341,94
98	*M*	*283720002200*	*Facade insulation board BAUMIT EPS-F, 1000x500 mm*	*m3*	*27,043*	*248,04*	*6 707,75*
99	K	713144070.S	Installation of thermal insulation on lintels with XPS	m2	4,920	5,15	25,34
100	*M*	*283750000900.S*	*XPS board, 90 mm thick, for insulation of lintels*	*m2*	*5,018*	*19,20*	*96,35*
101	K	713144090.S	Installation of XPS thermal insulation on ring beams by mechanical fastening	m2	20,050	17,55	351,88
102	*M*	*283750001600.S*	*XPS board STYRODUR 3000 C, 30 mm thick, for ring beams*	*m2*	*20,451*	*8,50*	*173,83*
103	K	713116500.S	Ceiling thermal insulation with light spray-applied PUR foam, λ = 0.025 W/ m·K, density 10 kg/m^3	m3	44,649	270,58	12 081,13
104	K	998713101.S	Handling of materials for thermal insulation in structures up to 6 m in height	t	2,527	111,33	281,33
	D	1.1.2.3	Soundproofing and vibration protection measures				2 139,84
105	K	714181001.S	Installation of impact sound insulation for parquet floors, laid loosely	m2	111,060	7,83	869,60
106	*M*	*617210000100.S*	*Cork insulating anti-vibration board, 1000x500x15 mm, underlayment for laminate, wood, vinyl, ceramic, and stone floors*	*m2*	*113,281*	*10,50*	*1 189,45*
107	K	998714101.S	Handling of materials for acoustic insulation and anti-vibration measures in structures up to 6 m in height (depth)	t	0,595	135,78	80,79
	D	1.1.2.4	Roof insulation and membrane coverings				3 447,86
108	K	765901082.S	Installation of vapor–permeable roofing membrane, pitched at 22° to 35°, on rafters, with airtightness class 6 to 4	m2	179,790	9,15	1 645,08
109	*M*	*283230005900.S*	*Protective vapor–permeable waterproofing membrane under roofing, with a surface weight of 270 g/m^2*	*m2*	*206,759*	*8,69*	*1 796,74*
110	K	998712101.S	Handling of materials for roofing membrane insulation in structures up to 6 m in height	t	0,064	94,35	6,04
	D	1.1.2.5	Carpentry structures				21 653,23
111	K	766662305.S	Installation of plastic entrance doors with waterproofing tapes (exterior and interior)	m	13,300	53,40	710,22
112	*M*	*611730000020.S*	*Single-leaf plastic entrance door with sidelight, triple-glazed insulation*	*m*	*13,300*	*295,89*	*3 935,34*
113	*M*	*283290008700.S*	*Vapor-impermeable sealing foil, polymer-fleece, 70 mm wide, 30 m long, for sealing the connection joint between the frame and masonry from the interior*	*m*	*13,965*	*2,23*	*31,14*
114	*M*	*283290008100.S*	*Vapor-permeable sealing foil, polymer-fleece, 70 mm wide, 30 m long, for sealing the connection joint between the frame and masonry from the exterior*	*m*	*13,965*	*2,23*	*31,14*
115	*M*	*611610006300.S*	*Installation materials for doors and windows*	*eur*	*115,000*	*1,20*	*138,00*
116	K	766651101.S	Installation of a sliding door pocket, single pocket for one leaf, passage width 0.6–1.2 m	ks	1,000	267,73	267,73
117	*M*	*553310013100.S*	*Construction pocket for sliding doors, single pocket for one leaf, clear passage 900 mm*	*ks*	*1,000*	*269,90*	*269,90*
118	*M*	*553420000300.S*	*Sliding door system – guide rail (raw profile)*	*m*	*1,000*	*9,11*	*9,11*
119	*M*	*553420000200.S*	*Sliding door system – set of carriages*	*súb.*	*1,000*	*32,68*	*32,68*
120	*M*	*549150001400.S*	*Door handle for sliding doors, thickness 8–12 mm, diameter 25 mm, length 200 mm*	*ks*	*2,000*	*6,96*	*13,92*
121	K	766664125.S	Installation of single-leaf wooden sliding doors, recessed sliding	ks	1,000	87,40	87,40
122	*M*	*611610002200.S*	*Single-leaf interior doors, width 600–900 mm, particleboard core, foil surface, solid*	*ks*	*1,000*	*149,00*	*149,00*
123	*M*	*611610006300.S*	*Installation materials for doors and windows*	*eur*	*80,000*	*1,20*	*96,00*
124	K	766702111.S	Installation of casings for single-leaf doors	ks	6,000	198,93	1 193,58
125	*M*	*611810002200.S*	*Interior casing frame, width 600–900 mm, height 1970 mm, particleboard core, foil surface, for wall thickness 60–170 mm, for single-leaf doors*	*ks*	*6,000*	*157,36*	*944,16*
126	K	766662112.S	Installation of a single-leaf half-lap hinged door leaf into an existing frame, including hardware	ks	6,000	71,13	426,78
127	*M*	*611610002200.S*	*Single-leaf interior door, width 600–900 mm, particleboard core, foil finish, solid*	*ks*	*3,000*	*259,87*	*779,61*

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128	*M*	*611610002300.S*	*Single-leaf interior door, width 600–900 mm, particleboard core, foil finish, 1/3 glazed*	*ks*	*3,000*	*353,28*	*1 059,84*
129	*M*	*549150000600.S*	*Door handle with rosette x2, stainless steel, brushed finish*	*ks*	*6,000*	*28,93*	*173,58*
130	*M*	*611610006300.S*	*Installation materials for doors and windows*	*eur*	*6,000*	*1,20*	*7,20*
131	K	766641071.S	Installation of plastic teracce doors with waterproofing tapes (exterior and interior)	m	5,060	49,85	252,24
132	*M*	*611420091010.S*	*Single-leaf plastic door, inward-opening, with insulating triple glazing*	*m*	*5,060*	*166,87*	*844,36*
133	*M*	*283290008700.S*	*Vapor-impermeable sealing foil, polymer-fleece, 70 mm wide, 30 m long, for sealing the connection joint between the frame and masonry from the interior*	*m*	*5,865*	*2,23*	*13,08*
134	*M*	*283290008100.S*	*Vapor-permeable sealing foil, polymer-fleece, 70 mm wide, 30 m long, for sealing the connection joint between the frame and masonry from the exterior*	*m*	*5,865*	*2,23*	*13,08*
135	*M*	*611610006300.S*	*Installation materials for doors and windows*	*eur*	*115,000*	*1,20*	*138,00*
136	K	766621400.S	Installation of plastic windows with waterproofing tapes (exterior and interior)	m	52,290	45,10	2 358,28
137	*M*	*611410091020.S*	*Single-leaf plastic window, inward-opening, with insulating triple glazing*	*m*	*25,590*	*88,29*	*2 259,34*
138	*M*	*611410091030.S*	*Double-leaf plastic window, inward-opening + inward-opening, with insulating triple glazing*	*m*	*26,700*	*121,22*	*3 236,57*
139	*M*	*283290008700.S*	*Vapor-impermeable sealing foil, polymer-fleece, 70 mm wide, 30 m long, for sealing the connection joint between the frame and masonry from the interior*	*m*	*54,905*	*2,23*	*122,44*
140	*M*	*283290008100.S*	*Vapor-permeable sealing foil, polymer-fleece, 70 mm wide, 30 m long, for sealing the connection joint between the frame and masonry from the exterior*	*m*	*54,905*	*2,23*	*122,44*
141	*M*	*611610006300.S*	*Installation materials for doors and windows*	*eur*	*115,000*	*1,20*	*138,00*
142	K	766691610.S	Installation of exterior cover strip to conceal joints between window and teracce doors, with sealing	m	57,350	9,80	562,03
143	*M*	*611990004800.S*	*45x15 mm strips for window finishing*	*m*	*57,350*	*8,20*	*470,27*
144	K	766691510.S	Installation of sealing for windows and teracce doors at the junction of the sash and frame using polyurethane tape	m	57,350	3,33	190,98
145	*M*	*247710000400.S*	*Self-adhesive sealing tape made of foam polyethylene for windows and doors, width 9 mm, thickness 2 mm, length 20 m*	*ks*	*3,000*	*2,53*	*7,59*
146	K	766694141.S	Installation of plastic window sill, width up to 300 mm, length up to 1000 mm	ks	3,000	23,10	69,30
147	*M*	*611560000100.S*	*Plastic window sill, width 150 mm, hollow core*	*m*	*2,100*	*11,23*	*23,58*
148	K	766694142.S	Installation of plastic window sill, width up to 300 mm, length 1000–1600 mm	ks	3,000	30,53	91,59
149	*M*	*611560000100.S*	*Plastic window sill, width 150 mm, hollow core*	*m*	*3,900*	*11,23*	*43,80*
150	K	766694143.S	Installation of plastic window sill, width up to 300 mm, length 1600–2600 mm	ks	3,000	40,90	122,70
151	*M*	*611560000100.S*	*Plastic window sill, width 150 mm, hollow core*	*m*	*5,250*	*11,23*	*58,96*
152	K	998766101.S	Handling of materials for carpentry structures in buildings up to 6 m high	t	1,450	109,15	158,27
	D	1.1.2.6	Sheet metal structures				4 960,30
153	K	764359341.S	Installation of accessories for gutters made of galvanized PZ sheet, hook for semi-circular eaves gutters, diameter 200–400 mm	ks	85,000	11,98	1 018,30
154	*M*	*553440036900.S*	*Galvanized semi-circular hook with embossing, diameter 200 mm, extended by 50 mm*	*ks*	*85,000*	*3,69*	*313,65*
155	K	764359301.S	Installation of gutter made of galvanized PZ sheet, semi-circular eaves, diameter 200–400 mm	m	36,610	44,55	1 630,98
156	*M*	*553440033900.S*	*Galvanized semi-circular eaves gutter, diameter 200 mm*	*m*	*38,441*	*5,87*	*225,65*
157	K	764359331.S	Installation of accessories for gutters made of galvanized PZ sheet, corner for semi-circular eaves gutters, diameter 200–400 mm	ks	1,000	10,95	10,95
158	*M*	*553440036400.S*	*Pressed semi-circular corner, galvanized, internal/external, diameter 200 mm*	*ks*	*1,000*	*12,18*	*12,18*
159	K	764359311.S	Installation of accessories for gutters made of galvanized PZ sheet, end cap for semi-circular eaves gutters, diameter 200–400 mm	ks	6,000	8,45	50,70
160	*M*	*553440034700.S*	*Pressed semi-circular end cap, galvanized, size 200 mm*	*ks*	*6,000*	*4,43*	*26,58*
161	K	764359371.S	Installation of accessories for gutters made of galvanized PZ sheet, downpipe outlet for semi-circular eaves gutters, diameter 80–120 mm	ks	6,000	8,98	53,88
162	*M*	*553440035500.S*	*Pressed galvanized gutter outlet, diameter 80 mm*	*ks*	*6,000*	*6,71*	*40,26*
163	K	764454233.S	Installation of circular collector made of galvanized PZ sheet, for downpipes with diameter 80–120 mm	ks	6,000	16,10	96,60
164	*M*	*553440043200.S*	*Galvanized water collector, diameter 80 mm*	*ks*	*6,000*	*7,36*	*44,16*
165	K	764454241.S	Installation of hammered clamp made of galvanized PZ sheet, for circular downpipes with diameter 80–120 mm	ks	12,000	7,33	87,96
166	*M*	*553440041400.S*	*Pressed galvanized clamp, spike 200 mm, diameter 80 mm*	*ks*	*12,000*	*1,49*	*17,88*
167	K	764454234.S	Installation of circular elbows made of galvanized PZ sheet, for downpipes with diameter 60–150 mm	ks	12,000	21,55	258,60
168	*M*	*553440039000.S*	*Pressed galvanized elbow 72°, diameter 80 mm*	*ks*	*12,000*	*5,22*	*62,64*
169	K	764752165.S	Installation of colored galvanized downpipe connector, diameter up to 100 mm	ks	12,000	10,53	126,36
170	*M*	*553440005600.S*	*Pressed galvanized downpipe – connector, diameter 80 mm*	*m*	*12,000*	*8,70*	*104,40*
171	K	764752121.S	Installation of the bottom section of colored galvanized downpipe with flange, diameter up to 100 mm	ks	6,000	24,93	149,58
172	*M*	*553440002100.S*	*Pressed galvanized downpipe – bottom section with flange, diameter 80 mm*	*ks*	*6,000*	*9,87*	*59,22*
173	K	764758245.S	Gutter outlet made of PVC-HI	ks	6,000	22,28	133,68
174	K	764762141.S	Installation of filter insert against leaf blockage in the gutter outlet	ks	6,000	4,73	28,38
175	*M*	*553440008900.S*	*Stainless steel filter insert, diameter 80 mm*	*ks*	*6,000*	*17,95*	*107,70*
176	K	764410211.S	Installation of window sill flashing made of galvanized PZ sheet, including corners, width 100 mm	m	12,100	21,70	262,57
177	*M*	*138210000200.S*	*Smooth galvanized sheet metal, thickness 0.60 mm*	*m2*	*1,367*	*7,48*	*10,23*
178	K	998764101.S	Handling of materials for sheet-metal structures in buildings up to 6 m high	t	0,116	234,60	27,21
	D	1.1.2.7	Timber structures				35 334,42

IN	IT	Item code	Description	MU	Amount	U. price [EUR]	Total price [EUR]
179	K	762333110.S	Installation of tied roof truss structures of irregular ground plan made of timber with cross-sectional area up to 120 cm^2	m	413,060	20,78	8 583,39
180	*M*	*605120002900.S*	*Sawn softwood beams, rough-edged, grade I*	*m3*	*5,452*	*457,31*	*2 493,25*
181	K	762333120.S	Installation of tied roof truss structures of irregular ground plan made of timber with cross-sectional area 120–224 cm^2	m	270,055	29,40	7 939,62
182	*M*	*605120002900.S*	*Sawn softwood beams, rough-edged, grade I*	*m3*	*6,654*	*457,31*	*3 042,94*
183	K	762333130.S	Installation of tied roof truss structures of irregular ground plan made of timber with cross-sectional area 224–288 cm^2	m	56,815	40,28	2 288,51
184	*M*	*605120002900.S*	*Sawn softwood beams, rough-edged, grade I*	*m3*	*1,800*	*457,31*	*823,16*
185	K	762333140.S	Installation of tied roof truss structures of irregular ground plan made of timber with cross-sectional area 288–450 cm^2	m	56,815	43,85	2 491,34
186	*M*	*605120002900.S*	*Sawn softwood beams, rough-edged, grade I*	*m3*	*2,812*	*457,31*	*1 285,96*
187	K	762341252.S	Installation of counter battens for roof slopes from 22° to 35°	m	245,000	5,53	1 354,85
188	*M*	*605120000200.S*	*Sawn softwood beams, rough-edged, grade II*	*m3*	*0,980*	*369,81*	*362,41*
189	K	762341202.S	Installation of battens for complex roofs with slope up to 60°	m	520,000	3,25	1 690,00
190	*M*	*605120000200.S*	*Sawn softwood beams, rough-edged, grade II*	*m3*	*1,144*	*369,81*	*423,06*
191	K	762395000.S	Fasteners for tied roof truss structures, formwork and battens, superstructure, slope wedges – clamps, boards, nails, steel straps, screws	m3	20,000	37,65	753,00
192	K	998762102.S	Handling of materials for carpentry structures in buildings up to 12 m high	t	11,017	163,65	1 802,93
	D	1.1.2.8	Metal structures				8 874,61
193	K	767661016.S	Installation of pre-window roller shutter, width 80–120 cm, length up to 260 cm	ks	5,000	98,85	494,25
194	*M*	*611520000300.S*	*Aluminum pre-window roller shutter, width x height 600x800 mm, with exposed box*	*ks*	*3,000*	*231,27*	*693,81*
195	*M*	*611520001500.S*	*Aluminum pre-window roller shutter, width x height 600x2000 mm, with exposed box*	*ks*	*2,000*	*431,18*	*862,36*
196	K	767661021.S	Installation of pre-window roller shutter, width 120–200 cm, length up to 260 cm	ks	5,000	104,70	523,50
197	*M*	*611520017700.S*	*Aluminum pre-window roller shutter, width x height 1500x800 mm, with exposed box*	*ks*	*1,000*	*419,18*	*419,18*
198	*M*	*611520021800.S*	*Aluminum pre-window roller shutter, width x height 1800x2000 mm, with exposed box*	*ks*	*3,000*	*956,04*	*2 868,12*
199	*M*	*611520025000.S*	*Aluminum pre-window roller shutter, width x height 2000x2300 mm, with exposed box*	*ks*	*1,000*	*1 187,60*	*1 187,60*
200	K	767661026.S	Installation of pre-window roller shutter, width 200–350 cm, length up to 260 cm	ks	1,000	104,75	104,75
201	*M*	*611520034500.S*	*Aluminum pre-window roller shutter, width x height 3500x2300 mm, with exposed box*	*ks*	*1,000*	*1 698,90*	*1 698,90*
202	K	998767101.S	Handling of materials for metal building structures in buildings up to 6 m high	t	0,137	161,58	22,14
	D	1.1.2.9	Supplementary structures				2 664,87
203	K	767660005.S	Installation of insect screen on window, fixed with clips to the sealing	m2	58,600	16,83	986,24
204	*M*	*553420000005.S*	*Fixed insect screen for window with inner frame flange, reversible from interior, color white*	*m2*	*58,600*	*16,51*	*967,49*
205	K	767660035.S	Installation of sliding insect screen doors, mounted on the frame of the opening infill	m2	6,800	55,88	379,98
206	*M*	*553420000065.S*	*Sliding insect screen door, mounted on frame, color white*	*m2*	*6,800*	*48,63*	*330,68*
207	K	998767101.S	Handling of materials for auxiliary building structures in buildings up to 6 m high	t	0,017	28,25	0,48
	D	1.1.2.10	Hard coverings				25 654,14
208	K	765310193.S	Installation of ceramic roofing on complex roofs with a slope of up to 35°	m2	179,790	48,00	8 629,92
209	*M*	*596610027100.S*	*Smooth ceramic roofing tiles, consumption 20–25 units per square meter*	*ks*	*3 473,543*	*2,45*	*8 510,18*
210	*M*	*596610002400.S*	*Smooth ceramic roofing tiles, half size*	*ks*	*215,748*	*3,00*	*647,24*
211	*M*	*596610023200.S*	*Smooth ceramic roofing tiles, right/left edge tiles*	*ks*	*77,816*	*8,00*	*622,53*
212	K	765314491.S	Installation of gable edges using edge tiles	m	27,400	18,08	495,39
213	*M*	*596610032380.S*	*Smooth ceramic roofing edge tile, semicircular*	*ks*	*25,000*	*25,60*	*640,00*
214	*M*	*596610023700.S*	*Smooth ceramic semicircular edge tile, terminating/end piece*	*ks*	*1,000*	*66,50*	*66,50*
215	*M*	*596610009000.S*	*Smooth ceramic branching edge tile*	*ks*	*0,400*	*59,60*	*23,84*
216	K	765310433.S	Installation of ceramic roof valley with a ventilation strip, for slopes up to 35°	m	10,000	68,15	681,50
217	*M*	*596610032380.S*	*Smooth ceramic valley tile with a semicircular profile.*	*ks*	*63,038*	*22,09*	*1 392,51*
218	*M*	*596610023700.S*	*Smooth ceramic semicircular valley tile, end/terminating piece.*	*ks*	*2,522*	*60,59*	*152,81*
219	K	765310430.S	Installation of a ceramic ridge with a ventilation strip, for slopes up to 35°	m	25,215	69,38	1 749,42
220	*M*	*596610024500.S*	*Smooth ceramic ventilated ridge roofing tile, ventilation cross-section 30 cm^2*	*ks*	*14,383*	*32,15*	*462,41*
221	K	765331825	BRAMAC universal antenna mounting bracket	ks	2,000	82,06	164,12
222	K	765315455.S	Installation of a lightning rod bracket for ceramic roofing	ks	30,000	4,63	138,90
223	*M*	*553450030900.S*	*Lightning rod holder for tile, suitable for ceramic roofing*	*ks*	*30,000*	*4,61*	*138,30*
224	K	998765101.S	Handling of hard roofing materials in structures with a maximum height of 6 meters	t	9,268	122,85	1 138,57
	D	1.1.2.11	Timber coverings				15 027,30
225	K	762810026.S	Ceiling sheathing of OSB boards screwed onto beams with tongue-and-groove joints, board thickness 18 mm	m2	148,830	42,09	6 264,25
226	K	763782213.S	Installation of a ceiling structure using solid-web beams, cross-sectional area 150–500 cm^2	m	59,350	22,70	1 347,25
227	*M*	*605710003603.S*	*Glulam (KVH) structural timber beams, non-visible quality*	*m3*	*1,840*	*794,50*	*1 461,88*
228	K	763138221	Suspended gypsum board ceiling (Rigips RF, 12.5 mm) on a double-level CD steel substructure.	m2	139,430	37,11	5 174,25
229	K	998763301.S	Handling of timber covering construction materials in structures with a maximum height of 7 meters	t	4,295	181,53	779,67
	D	1.1.2.12	Strip and parquet flooring				6 258,29

IN	IT	Item code	Description	MU	Amount	U. price [EUR]	Total price [EUR]
230	K	775550110.S	Installation of laminate and wooden parquet flooring, click-lock system, laid floating	m2	111,060	15,55	1 726,98
231	*M*	*611980003080.S*	*Laminate flooring, thickness 15 mm*	*m2*	*113,281*	*24,59*	*2 785,58*
232	K	775413130.S	Installation of floor skirting boards or perimeter moldings by adhesive bonding	m	95,230	10,68	1 017,06
233	*M*	*611990000100.S*	*Wooden floor skirting board, hxw 30x10 mm*	*m*	*96,182*	*6,03*	*579,98*
234	K	998775101.S	Handling of parquet and inlay flooring materials in structures with a maximum height of 6 meters	t	1,142	130,20	148,69
	D	1.1.2.13	Tiled floors				4 164,29
235	K	771991101.S	Sweeping the substrate prior to tile installation	m2	28,380	1,90	53,92
236	K	771541025.S	Installation of floorings with gres tiles laid in mortar with thickness 10 mm, size 600x600 mm	m2	28,380	73,15	2 076,00
237	*M*	*597740002100.S*	*Ceramic tiles, lxwxh 598x598x10 mm, gres*	*m2*	*30,083*	*60,05*	*1 806,48*
238	K	771991251.S	Joint filling for floor tiles with silicone sealant	m2	28,380	2,60	73,79
239	K	998771101.S	Handling of floor tile materials in structures with a maximum height of 6 meters	t	1,963	78,50	154,10
	D	1.1.2.14	Poured terrazzo floors				1 312,21
240	K	773521360.S	Colored terrazzo flooring – simple type, thickness 30 mm	m2	33,160	35,20	1 167,23
241	K	998773101.S	Handling of terrazzo flooring materials in structures with a maximum height of 6 meters	t	1,919	75,55	144,98
	D	1.1.2.15	Coatings				3 964,66
242	K	783782406.S	Coatings for carpentry structures, 3-in-1 deep impregnation with biocide, single application	m2	571,276	6,94	3 964,66
	D	1.1.2.16	Wall cladding				14 883,35
243	K	781445406.S	Installation of interior wall tiles laid in dispersion adhesive, size 100x100 mm	m2	92,871	105,28	9 777,46
244	*M*	*597640000100.S*	*Single-color smooth glazed ceramic tiles, lxwxh 100x100x14 mm*	*m2*	*96,586*	*29,80*	*2 878,26*
245	K	781445411.S	Installation of interior wall tiles laid in dispersion adhesive, size 200x200 mm	m2	9,650	85,85	828,45
246	*M*	*597640000400.S*	*Single-color smooth glazed ceramic tiles, lxwxh 200x200x14 mm*	*m2*	*10,036*	*59,60*	*598,15*
247	K	781991131.S	Joint filling for wall tiles with silicone sealant, joint width up to 5 mm	m2	101,521	5,90	598,97
248	K	998781101.S	Handling of ceramic wall tile materials in structures with a maximum height of 6 meters	t	2,574	78,50	202,06
	D	1.1.2.17	Paint finishes				1 582,24
249	K	784410500.S	Sanding and dusting of fine-textured surfaces up to 3.80 m in height	m2	304,793	0,45	137,16
250	K	784410600.S	Repair of cracks and surface irregularities on fine-textured surfaces up to 3.80 m in height	m2	304,793	0,73	222,50
251	K	784418011.S	Covering openings, floors, and equipment with plastic sheeting in rooms or staircases	m2	70,090	3,45	241,81
252	K	784418012.S	Covering floors and equipment with paper in rooms or on staircases	m2	139,430	3,93	547,96
253	K	784491200.S	Single-coat rolling on fine-textured substrate up to 5.00 m in height	m2	304,793	1,42	432,81

BUDGET

Construction:
Bachelor's Thesis - Finland
Building:
1.2 - Paved Surfaces

Place:

Date: 07.11.2025

Customer:

Contractor:

Designer:

Processed by:

IN	IT	Item code	Description	MU	Amount	U. price [EUR]	Total price [EUR]
Budget costs							**21 471,24**
	D	1.2.1	Assemblies and Supplies PCW				20 962,84
	D	1.2.1.1	Earthworks				1 033,49
254	K	121101112.S	Removal of topsoil with relocation to heaps, including placement at a distance up to 100 m, for volumes up to 1000 m³	m3	16,470	2,75	45,29
255	K	181301102.S	Spreading of topsoil on a level surface, area up to 500 m², thickness up to 150 mm	m2	109,800	8,35	916,83
256	K	215901101.S	Compaction of subgrade from natural soils of classes 1 to 4 under embankments, from cohesive soils up to 92% Proctor density and from non-cohesive soils	m2	109,800	0,65	71,37
	D	1.2.1.2	Foundation works				2 897,08
257	K	271533001.S	Fill under foundation structures, compacted, made of coarse crushed aggregate, fraction 32–63 mm	m3	5,490	209,40	1 149,61
258	K	271573001.S	Fill under foundation structures, compacted, made of gravel–sand mixture, fraction 0–32 mm	m3	10,980	159,15	1 747,47
	D	1.2.1.3	Circulation areas				11 770,89
259	K	596911243.S	Installation of 100 mm thick concrete interlocking pavement for pedestrian pathways up to 300 m², including a 50 mm thick bedding layer of crushed stone	m2	109,800	60,13	6 602,27
260	*M*	*592450011700*	*PREMAC KLASIKO concrete paving block, dimensions 200x200x100 mm, grey*	*m2*	*111,996*	*46,15*	*5 168,62*
	D	1.2.1.4	Surface finishes, flooring, and installation				11,52
261	K	631571015.S	Sand infill between joints	m3	0,100	115,17	11,52
	D	1.2.1.5	Other structures and works – demolition				2 160,82
262	K	917111111.S	Installation of horizontal stone curbstone in a bed of compacted crushed stone, without lateral support	m	73,200	24,30	1 778,76
263	*M*	*592170001800*	*PREMAC park curbstone, length x width x height 1000x50x200 mm, grey*	*ks*	*76,566*	*4,99*	*382,06*
	D	1.2.1.6	Material handling for primary construction works				3 089,04
264	K	998011031.S	Handling of materials for buildings (801, 803, 812), vertical block structures, up to 6 m in height	t	76,594	40,33	3 089,04
	D	1.2.2	Assemblies and Supplies SCW				508,40
	D	1.2.2.1	Protection against water and moisture				508,40
265	K	711132102.S	Installation of geotextile or fabric on a vertical surface	m2	109,800	1,95	214,11
266	*M*	*693110001200*	*Polypropylene geotextile Tatratex GTX N PP 300, width 1.75–3.5 m, length 90 m, thickness 2.7 mm, non-woven, MIVA*	*m2*	*131,760*	*2,19*	*288,55*
267	K	998711101.S	Handling of materials for waterproofing in buildings up to 6 m in height	t	0,053	108,30	5,74