Swiss Structural Timber Construction - Fundamentals of Fire Safety Regulations

A Research on Public Wooden Buildings in Switzerland in Course of the European Public Wood Project

HÄMEEN AMMATTIKORKEAKOULU
HÄME UNIVERSITY OF APPLIED SCIENCES

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Yannick Schüdde

ABSTRACT

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Supervisor(s) Jari Komsi

ABSTRACT

This Bachelor's thesis was part of the European Public Wood Project. This project aims to achieve a trans-disciplinary and trans-national course for higher education institutions (HEI) on public wood buildings. The purpose of the thesis was to briefly introduce wood as a building material, conduct research on the Swiss fire safety standards, and facilitate the implementation of a trans-national course by comparing the obtained data to other European standards.

The main subject of the research was the Swiss fire safety regulation VKF 2015. The VKF 2015 was thoroughly analyzed and compared to the Finish Decree on Fire Safety in the thesis. Furthermore, the national annexes of the Eurocode 5 Part 1-2 from Switzerland and Finland were compared.

The results of the thesis show that the Swiss fire regulations formulate the requirements for the fire resistance of the building elements independent of the material. Timber structures can, therefore, be constructed in all building, and utilization categories as long as the fire safety requirements are met. These requirements and their practical implementation in building elements are given in this thesis. The comparison of the national regulations and the national annexes presented fundamental similarities as well as differences due to national conditions. Those differences complicate the implementation of a course that is similar in every country. It was proposed to approach this problem by creating a course based on the structure of the Eurocodes, including a section where certain parameters are left open for national choice. The course could, therefore, be implemented by the individual HEIs according to the national conditions

Keywords properties, fire safety regulations, European comparison, implementation

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1 INTRODUCTION

Society expresses a clear urge for environmentally friendly building materials and a concern about the impact of traditional materials such as steel and concrete on the environment. Therefore, the European construction sector has high demands for skilled junior staff in the wood building field. Those demands cannot yet be met by Higher Education Institutions (HEI). Most degrees in design, construction, and material of complex buildings are still focused on concrete and steel studies. The education in wooden construction is mostly limited to one- or two-story buildings. The European Public Wood Project was launched to meet those demands.

The Public Wood project aims to achieve a trans-disciplinary and trans-national course for HEIs on sustainable public wooden buildings, including design, construction, and management. This thesis composes a part of the Pub-Wood Project.

For the creation of a transnational course on public wooden buildings, it is necessary to conduct research on the standards in design, construction, and management of wooden buildings of several partner countries.

This thesis focuses on the research for Switzerland, more specifically on the standards in fire regulations. It starts by briefly outlining the importance and the history of wood as a building material. Furthermore, since Switzerland is not part of the European Union, the connection between the Eurocodes and the national codes and standards in wooden buildings will be analyzed. The main part comprises the analysis of the national fire regulations, with a summary of the most significant terms for wooden buildings. This is followed by a listing of the most striking differences in fire regulations between the Swiss Codes, the Finish National Building Code and the Eurocodes to simplify the development of a trans-national wood building course. The closing aspect will show examples of the implementation of the fire regulations in actual building elements and the structural achievement of the fire resistance.

2 WOOD AS A BUILDING MATERIAL

Before the examination of timber constructions in Switzerland, the following chapters will summarize the most important aspects and the history of wood as a building material to generate a general comprehension for the subject at hand.

2.1 Timber and Other Materials

Timber, as a structural material, is one of the oldest known materials in construction. However, over the last century, it has been almost neglected, limited only to small one- or two-story buildings. It was replaced by other materials such as steel and concrete. Only recently it has once again experienced a rise in popularity. To be able to understand and grasp the role of timber in the construction industry one must first consider its strength properties and differences compared to other materials before analyzing its development over the centuries.

On condition of well-managed forestry, timber is the most sustainable building material. Since it is a natural resource it comes in various species, sizes, and shapes, making it an extremely versatile material. It has a multiplicity of advantages compared to steel and concrete. Its high strength to weight ratio makes it superior to steel. This means that a member made of timber that can sustain the same stress as a steel member will be considerately lighter than the steel member. Due to its various growth characteristics, like the grain pattern, timber has great insulation properties and can sustain compression as well as tension forces. Concrete, on the other hand, can only withstand compression forces. Timber elements are easily connected by screws, bolts, nails or adhesives. Therefore, another advantage of wood is that it can easily be reshaped, altered and repaired. The natural limitations of wood due to strength, susceptibility to weather conditions, and size are nowadays overcome by composite, engineered wood products. These products will be briefly analyzed in the course of this thesis report.

However, the greatest benefit of timber buildings is its environmental friendliness. The emission of carbon dioxide (CO2) is one of the most urgent problems concerning our environment. The rise of the CO2 concentration in the atmosphere is one of the main reasons for the greenhouse effect, resulting in global warming and climate change. Since the year 1900, the global emissions of CO2 increased from 2 billion tonnes to over 36 billion tonnes in 114 years. Between 2014 and 2017 the development seemed to stagnate, but preliminary data reported a 2.7% increase in 2018. (Ritchie & Roser, 2019)
For 2017, an average of 1.83 tonnes of CO2 was emitted for every tonne of steel produced. In total, the steel industry generates around 7% to 9%

of direct emissions from the global use of fossil fuels. (World Steel Association, n.d.)
Cement is the most used construction material. Due to chemical and thermal combustion processes during the production, it is a large source of CO_2 emissions. With the production of 4 billion tonnes of cement, it is responsible for roughly 8% of the global CO_2 emissions. (Lehne & Preston, 2018)
Timber, on the other hand, has little to no CO_2 emissions during the production process – with an exception for the CO_2 emissions of the machinery, transport and sawing mills. On the contrary, trees actually absorb CO_2 from the air. The carbon (C) is used for building organic substances, while oxygen (O_2) is released into the air. However, after the tree dies and starts to decompose the contained carbon is once again released into the atmosphere. Therefore, by cutting down the tree and manufacturing timber elements, the bound carbon stays contained. As a result, the CO_2 level of the atmosphere is actually reduced by working with structural timber. In Switzerland a net amount of 45 million tons of carbon are contained in wooden buildings or building parts. The emissions from the production process are already subtracted. This amount roughly equals the yearly CO_2 emissions of the whole country and could be increased significantly by increasing the percentage of timber construction in the country. (Holzbau Schweiz, n.d.)

2.2 **Properties**

After showing that timber is an equivalent, if not superior, alternative to steel or concrete, the different species, engineered timbers, and strength properties will be examined.

There are two types of natural timber, softwoods, and hardwoods. Softwoods such as spruce, larch, pine, and douglas fir, are commonly evergreen trees with a straw-like cell structure in plan. The characteristically quick growth rate of these woods is the reason for a low density and comparatively low strength. However, the quick growth also allows rapid felling, causing a steady supply and relatively cheap prices. Hardwoods such as oak, beech, ash, alder, maple, poplar, and willow, are commonly broad-leaved trees that mostly lose their leaves during winter. These woods have a more complex cell structure, resulting in a slower growth rate than softwoods with a higher density and strength. Consequently, the supply of hardwoods is much slighter and the prices relatively higher.

The characteristic strength and stiffness properties and density values for the different strength classes of soft- and hardwoods can be observed in Table 1.

Table 1. Strength and stiffness properties and density values for structural timber strength classes (in accordance with Table 1, of BS EN 338: 2003) (Porteous & Kermani, 2007, p.15)

Strength class		Characteristic strength properties (N/mm²)						Stiffness properties (kN/mm²)				Density (kg/m³)	
		Bending ($f_{m,k}$)	Tension 0 ($f_{t,0,k}$)	Tension 90 ($f_{t,90,k}$)	Compression 0 ($f_{c,0,k}$)	Compression 90 ($f_{c,90,k}$)	Shear ($f_{v,k}$)	Mean modulus of elasticity 0 ($E_{0,mean}$)	5% modulus of elasticity 0 ($E_{0.05}$)	Mean modulus of elasticity 90 ($E_{90,mean}$)	Mean shear modulus (G_{mean})	Density (ρ_k)	Mean density (ρ_{mean})
Softwood and poplar species	C14	14	8	0.4	16	2.0	1.7	7.0	4.7	0.23	0.44	290	350
	C16	16	10	0.5	17	2.2	1.8	8.0	5.4	0.27	0.50	310	370
	C18	18	11	0.5	18	2.2	2.0	9.0	6.0	0.30	0.56	320	380
	C20	20	12	0.5	19	2.3	2.2	9.5	6.4	0.32	0.59	330	390
	C22	22	13	0.5	20	2.4	2.4	10.0	6.7	0.33	0.63	340	410
	C24	24	14	0.5	21	2.5	2.5	11.0	7.4	0.37	0.69	350	420
	C27	27	16	0.6	22	2.6	2.8	11.5	7.7	0.38	0.72	370	450
	C30	30	18	0.6	23	2.7	3.0	12.0	8.0	0.40	0.75	380	460
	C35	35	21	0.6	25	2.8	3.4	13.0	8.7	0.43	0.81	400	480
	C40	40	24	0.6	26	2.9	3.8	14.0	9.4	0.47	0.88	420	500
	C45	45	27	0.6	27	3.1	3.8	15.0	10.0	0.50	0.94	440	520
	C50	50	30	0.6	29	3.2	3.8	16.0	10.7	0.53	1.00	460	550
Hardwood species	D30	30	18	0.6	23	8.0	3.0	10.0	8.0	0.64	0.60	530	640
	D35	35	21	0.6	25	8.4	3.4	10.0	8.7	0.69	0.65	560	670
	D40	40	24	0.6	26	8.8	3.8	11.0	9.4	0.75	0.70	590	700
	D50	50	30	0.6	29	9.7	4.6	14.0	11.8	0.93	0.88	650	780
	D60	60	36	0.6	32	10.5	5.3	17.0	14.3	1.13	1.06	700	840
	D70	70	42	0.6	34	13.5	6.0	20.0	16.8	1.33	1.25	900	1080

Subscripts used are: 0, direction parallel to grain; 90, direction perpendicular to grain; m, bending; t, tension; c, compression; v, shear; k, characteristic.

2.2.1 Engineered Woods

With the purpose of enhancing the properties of sawn timber, overcoming its natural limitations, and meeting national and international standards, engineered wood products were developed.

Although there are several different kinds of engineered woods, the basic functionality is the same. The properties of the timber are improved by bonding multiple wooden layers together, using durable, moisture-resistant, structural adhesives. Some examples for these kinds of wood products are plywood, glued-laminated timber (glulam), cross-laminated timber (CLT) and laminated veneer lumber (LVL). The functionality of each of those examples will be briefly explained in the following paragraphs.

Plywood is produced by bonding wood veneers together to produce a flat sheet. A plywood panel is composed of at least three wood veneers. The grains of alternating sheets are perpendicular to each other. The perpendicular arrangement causes plywood to remain considerably stable under changes in temperature and moisture. Furthermore, it causes the ability to withstand high panel shear forces. (Wood Solutions, n.d.)

Glued laminated timber is composed of small timber laminates with a thickness 19-50mm and a length of 1.5-5m. The grain of the laminates is aligned along the longitudinal axis. At the ends, the laminates are finger-joined together. The different layers are bonded together by covering the faces of the laminates with adhesives and then pressurizing the stack at a perpendicular angle until the adhesives are dried out. After drying, the glulam can then be cut and shaped in any form. Thus, allowing to manufacture members of extraordinary lengths and thickness. (Wood Solutions, n.d.a)

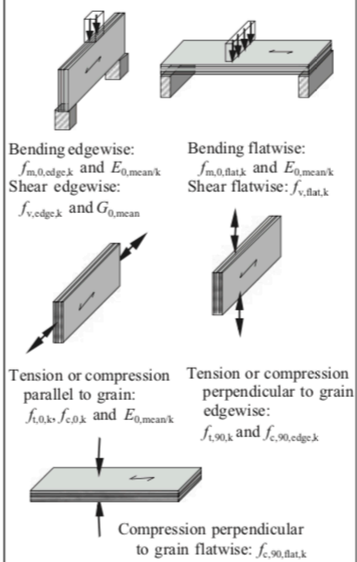
Cross laminated timber is manufactured in a similar way to glulam, except that CLT is layered with the grain patterns perpendicular to each other. Cross-laminating the layers of wood veneer improves the structure of wood by distributing the along-the-grain strength of wood in both directions. The exterior layers grains run lengthways to provide optimum strength. (Wood Solutions, n.d.b)

Laminated veneer lumber has properties comparable to concrete and steel. It is produced by bonding peeled or sliced thin wood veneers together under heat and pressure. The orientation of the grain of each layer is directed in the same way. This procedure makes LVL stronger, straighter and more uniform than sawn timber. The natural defects due to knots are eliminated. It can be manufactured to any lengths (within the means of transportation) and is mostly used for structural purposes. (Wood Solutions, n.d.c)

To exemplify the differences in properties between laminated lumber and sawn timber, the properties of a Kerto-LVL, given in Table 2 can be compared to Table 1 (provided above). Furthermore, there are tables given that provide the material strength of both steel (Table 3) and concrete (Table 4).

Table 2. Kerto-LVL: strength and stiffness properties and density values (Porteous & Kermani, 2006, p.32)

	Symbol	Units	Kerto-S®	Kerto-Q®
Characteristic values				
Bending				
Edgewise	$f_{m,0,edge,k}$	N/mm^2	44.0	32.0
Size effect parameter*	s	N/mm^2	0.12	0.12
Flatwise	$f_{m,0,flat,k}$		50.0	36.0
Tension				
Parallel to grain	$f_{t,0,k}$	N/mm^2	35.0	26.0
Perpendicular to grain	$f_{t,90,k}$	N/mm^2	0.8	6.0
Compression				
Parallel to grain	$f_{c,0,k}$	N/mm^2	35.0	26.0
Perpendicular to grain edgewise	$f_{c,90,edge,k}$	N/mm^2	6.0	9.0
Perpendicular to grain flatwise	$f_{c,90,flat,k}$	N/mm^2	1.8	1.8
Shear				
Edgewise	$f_{v,0,edge,k}$	N/mm^2	4.1	4.5
Flatwise	$f_{v,0,flat,k}$	N/mm^2	2.3	1.3
Modulus of elasticity				
Parallel to grain	$E_{0,k}$	N/mm^2	11600	8800
Shear modulus				
Edgewise	$G_{0,k}$	N/mm^2	400	400
Density	ρ_k	kg/m^3	480	480
Mean values				
Modulus of elasticity				
Parallel to grain	$E_{0,mean}$	N/mm^2	13800	10500
Shear modulus				
Edgewise	$G_{0,mean}$	N/mm^2	600	600
Density	ρ_{mean}	kg/m^3	510	510



*s is the size effect exponent referred to in Clause 3.4 of EC5 [12].

Table 3. Characteristic strength properties in N/mm^2 of rolled steel (Albert, 2014, p.8.4)

Material-norm	Steel grade	Manufacturing thickness t in mm			
		t ≤ 40mm		40mm < t ≥ 80mm	
		f_y	f_u	f_y	f_u
DIN EN 10 025 - 2	S235	235	360	215	360
	S275	275	430	255	410
	S355	355	490	335	490
DIN EN 10 025 - 3	S420 N/NL	420	520	390	520
	S460 N/NL	460	540	430	540

Table 4. Characteristic compressive strength properties in N/mm^2 for concrete (Albert, 2014, p.5.9)

Compressive strength class	$f_{ck,cyl}$ in N/mm^2	$f_{ck,cub}$ in N/mm^2
C8/10	8	10
C12/15	12	15
C16/20	16	20
C20/25	20	25
C25/30	25	30
C30/37	30	37
C35/45	35	45
C40/50	40	50
C45/55	45	55
C50/60	50	60
C55/67	55	67
C60/75	60	75
C70/85	70	85
C80/95	80	95
C90/105	90	105
C100/115	100	115

The tables show that the compressive properties of laminated veneer lumber can be compared to those of the concrete class C35/45. The compressive as well as the tensile properties of steel, on the other hand, are much higher than those of the timber. However, due to the low density of the wood with 510 kg/m^3, it is possible to construct building members of much larger proportions than steel members with a density of 7850 kg/m^3.

2.3 Behavior during Fire

Contrary to popular beliefs, the risk of fire formation is completely independent of the building materials used in a building. The reason for this is the fact that fires are caused by external influences and not by the building material itself. The main causes of fires are, among other things, defective equipment, short circuits, chimney fires, and human errors. Moreover, wood is not overly flammable but is classified as normally flammable in the Eurocode. However, what is of great importance in the case of fire is fire behavior and fire resistance. Wood shows favorable properties in both aspects.

Wood has the special feature of charring on the surface. The charring already starts at temperatures of 200 °C. This creates a special protective layer that hinders the further burning of the wood. In addition, due to the low burning rate (about 20mm per 30min), the strength and load-bearing capacity of the components are maintained relatively long. The decisive

reason for this lies in the low heat conduction of the wood. The components are heated very slowly and remain dimensionally stable. The wooden components themselves are protected by the formation of charcoal and thus preserve the statics of a burning building longer than construction elements out of steel and concrete. Furthermore, the smoke emissions of burning wood are relatively low and non-toxic compared to other materials.
The calculable burning of wood leads to very good predictability. This predictability and the creation of high-quality fire protection concepts ensure the development of wood into a building material without special regulations

2.4 History of Wood Building in Central Europe

It has previously been established that wood is equal to other building materials such as steel and concrete. In some aspects, it even appears to be the superior material. As a CO2-storing building material, it has a much smaller carbon footprint than the other two. It is the most load bearing heat insulating material and can sustain compressive as well as tensile forces. Considering these arguments, it poses the question of why structural timber still plays such a minor role in urban construction today. The answer can be found by considering the history of wood as a construction material.

Since the beginning of use in the Neolithic age, wood has been acknowledged for its construction-innovative and culture-building potential. The first evidence of timber construction was found in the form of so-called stilt houses or lakeside dwellings. The earliest appearances of those domiciles in Switzerland are estimated to have been around 4300 BC. The first large structural wooden building in Switzerland was discovered to be from the Bronze Age (1525 BC). A bridge in the lake of Zurich appears to have been able to carry large weights of cattle and carriages of freight. (Hürlimann, n.d.)
Since then, the rise of wood can be easily recognized throughout history. It was decisive in the development of vehicles, machinery, naval architecture, urban construction, and even aircraft construction. The peak of timber construction occurred during the 16th and 17th century. Urban construction was dominated by frame houses. Many of our knowledge and experiences in timber construction originated from that time. Wood remained the dominating building material until the 19th century when it experienced a stagnation due to the trend of industrialization.

The Industrial Revolution caused a transfer from wood, as the main construction material, to steel in the 19^{th} century and to concrete in the 20^{th} century. The construction processes in wood-working at the time were developed over centuries with longsome adaptions to reality. The industrialization demanded the building materials to have the ability to quickly adapt to changes in use and requirement. It was thought to be impossible for wood to meet these demands. Furthermore, wooden goods were seen as unfit for mass production, an important factor of the Industrial Revolution. As a result, newly developed materials, such as steel and concrete, became the major components of construction. They were the result of scientific research and development to satisfy the requirements of the quickly changing building standards. Wood was thought to be obsolete. It was only used for traditional building without many specializations or for decorative purposes. After 1945 wooden materials were mostly limited to roof frameworks and interior fittings.

It was only after the oil crisis in the 1970s, and the beginning of the debates about environment protection that wood was to become one of the major building materials once again. The consciousness of the level of resource consumption of the former technological development was growing. The resulting consequences on the environment and the limited natural resources became apparent. Due to its properties as a sustainable resource, wood represented an environmentally friendly alternative. Despite the break in popularity, the knowledge in timber construction was still available and has been complemented by new innovations since the mid-eighties. Due to the technological development of timber structures, the popularity of wood as a building material kept on rising. The foundations of this development were improved sawn wood, innovative adhesives, and bonding techniques. The product of these innovations were the engineered wood products described in the previous chapter. Figure 1 shows the use of different construction materials over the last centuries.

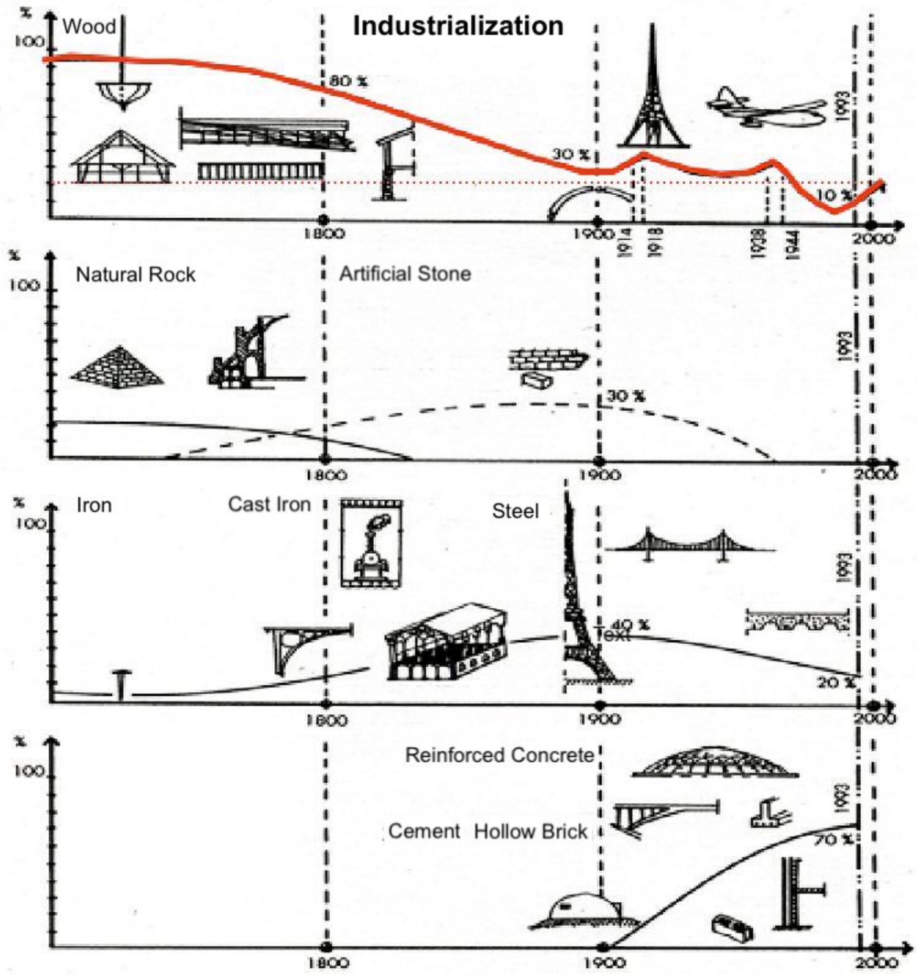


Figure 1. Comparison of the market share of wood, rock, steel, and concrete in high building since 1700 (Cheret & Seidel, 2013)

Considering the history of wood, the answer to the previously posed question as to why structural timber still plays a minor role in urban construction seems obvious. Even though it is one of the oldest building materials, it still is a rather unfamiliar and new material in the construction methods used today. Only recent developments enabled it to meet the demands given by the rapid growth of urban life.

3 STRUCTURAL TIMBER IN SWITZERLAND

Advances and developments of structural timber demanded the adaption of national and international codes and standards to meet the safety regulations of the construction industry. On a European scale, these safety regulations are met by the use of the Eurocodes. Eurocode 5 (EN 1995) applies to the design of timber structures. Additionally, in Switzerland national codes and standards have been developed. The following paragraphs will list the most important Swiss organizations around structural timber and explain the connection between the Eurocodes and the Swiss Codes.
These institutions are:

- Bundesamt für Umwelt BAFU (Federal Office for the Environment FOEN)
- Lignum Holzwirtschaft Schweiz (Timber Industry Switzerland)
- Vereinigung Kantonaler Feuerversicherungen VKF (Association of Canton Fire Insurances)
- SIA Schweizer Ingenieur- und Architektenverein (Swiss Society of Engineers and Architects)

3.1 FOEN

“The mission of the Federal Office for the Environment (FOEN) is to ensure the sustainable use of natural resources including soil, water, air, quietness, and forests. It is responsible for the protection against natural hazards, safeguarding the environment and human health against excessive impacts, and conserving biodiversity and landscape quality. It is also responsible for international environmental policy.” (Swiss Confederation, 2018)

In 2009, the FOEN launched an agenda called the Aktionsplan Holz (in English Course of Action Wood). The agenda implements the resource politics of the state and deals with the resource wood and its exploitation. The Aktionsplan Holz is funded with around 4 million CHF yearly (≈ 4 million USD).

The Agenda wishes for Swiss wood to be harvested, supplied and processed sustainably. It is managed by the FOEN with the advisory support of a committee consisting of representatives from the Swiss forest and wood economy, cantons, other federal offices, nature conversation organizations, and real estate sector. For the years 2017 -2020 the plan set its priorities on three topics: optimized cascade utilization, climate-friendly construction and renovation, and communication, knowledge transfer and cooperation. Topic 1 deals with the most reasonable use of wood, advantages and disadvantages of multiple uses, and ecological and economical assessment of cascade utilization. Topic 2 deals with the technical basics, quality assurance, competitiveness, new construction, reconstruction, concentration, maintenance, durability and energy efficiency. Topic 3 deals with the sensitization of the population for Swiss wood, sensitization of constructors for wood building, knowledge transfer between associates, and cooperation between sectors, research, economy and state sectors. Projects that contribute to these topics can be financially supported. (Swiss Confederation, 2017)

3.2 **Lignum**

Lignum is the umbrella organization of the Swiss forest and wood economy. Founded in 1931 it is the official contact in the wood industry. It unites all important unions and organizations, including forest economy, sawmills, trade, production, and carpentry.

The core activities of the organization are as follows:
Broaden the knowledge base of wood application, improve the technical basic conditions, improve the degree of familiarity of wood, distinguish wood as part of the sustainable development, and unite the wood sector in terms of political issues. To achieve these goals, Lignum has two dozen regional consortiums on a cantonal level, guaranteeing influence on a political level and quick reactions to competitive bidding of construction opportunities. (Lignum, n.d.)

3.3 **VKF**

The Association of Canton Fire Insurances created fire protection regulations, consisting of standards and guidelines. These regulations were put into force and declared binding by the Inter-Cantonal Institution of Technical Barriers to Trade [abbr. IOTH (from ger. *Interkantonalen Organ Technische Handelshemmnisse*). The exact structure, content, and application of those regulations will be discussed later on.

3.4 **SIA**

“The Swiss Society of Engineers and Architects (SIA) is Switzerland’s leading professional association for construction, technology, and environment specialists. With over 16,000 members from the fields of engineering and architecture, the SIA is a highly professional and interdisciplinary network whose central aim is to promote sustainable and high-quality design of the built environment in Switzerland.”
(Swiss Society of Engineers and Architects, n.d.a)

The SIA is most known for its compact standards. Roughly 200 committees constantly develop, maintain, and publish standards, regulations guidelines, recommendations, and documentations. They are creating an important basis for the Swiss construction sector.

3.4.1 Standards

Three different kinds of standards can be found in the standard collection of SIA. Technological standards contain the rules of constructions and the state-of-the-art construction processes. Created by experts, they stand to some degree on legal grounds. However, every technical standard contains a paragraph called exception article [from German *Ausnahmeartikel*], making it possible to deviate from the said standard if the proposed solution has been proven to be of equivalence. Contractual standards are terms and conditions between the parties involved that are supposed to simplify the cooperation during a project. The contractual standards have to be agreed upon in the legal contract to become binding. Terminological standards contain definitions, specific values, classifications, calculations, and explanations to improve the cooperation between the building parties. (Swiss Society of Engineers and Architects, n.d.b)

The fundamentally most important standards for construction are the structural standards:

- Norm SIA 260 – Basis of structural design
- Norm SIA 261 – Actions on structures
- Norm SIA 262 – Design of concrete structures
- Norm SIA 263 – Design of steel structures
- Norm SIA 264 – Design of composite steel and concrete structures
- Norm SIA 265 – Design of timber structures
- Norm SIA 266 – Design or masonry structures
- Norm SIA 267 – Geotechnical Design

The structural standards have been developed in accordance with the Eurocodes, further information will be given below. For the research conducted in this thesis the standard SIA 265 – Design of timber structures is of the most significance. In addition to the SIA 265 that contains both technological and terminological standards, the SIA 118/265 must also be considered. SIA 118/265 is a supplement to the SIA 118, which contains general conditions for construction works and represents a contractual standard.

3.4.2 SIA / Eurocodes

Since the early nineties, European standards started being developed under the supervision of the European Union (EU) and the European Free Trade Association (EFTA). These standards mostly regulate tradable goods that are being used for the construction of structures. All the product properties having an impact on a building are described in the standards mentioned above. They have to be implemented on a national level.

In the course of the European standardization, the Swiss Association of standards (SNV) has obligated itself to adopt all European standards. When adopting these standards, they have to be supplemented with a national preface. Furthermore, it must be ensured that the purely national standards, which deal mainly with entire systems and not with individual products, comply with the European standards. Since structural design could also be considered a tradable good, it had to be standardized throughout Europe. Thus, the structural standards “Eurocodes” have been developed. Compared to the product standards, the adoption of the Eurocodes had a significant effect on the SIA standards. As a result, the Swisscodes Project was launched in 1999. Aiming to develop simple, and structural standards for Switzerland that are compatible with the Eurocodes, in 2003 the SIA 260ff. (as listed above) were created.

Eurocodes could also be used in Switzerland. However, only on the condition that the nationally determined parameters (NDP) had been defined between the planner and the client. Although it was intended by the Eurocodes, the SIA decided not to define these parameters throughout Switzerland for the time being due to the following reason:

“Die Schweiz verzichtet bis auf Weiteres auf die Festlegung nationaler Parameter, da die nationalen Tragwerksnormen SIA 260 bis SIA 267 einer adäquaten Umsetzung der Eurocodes für Schweizer Verhältnisse entsprechen.“ [For the time being, Switzerland is refraining from defining national parameters, as the national structural standards SIA 260 to SIA 267 correspond to an adequate implementation of the Eurocodes for Swiss conditions] (SN EN 1995-1-1:2004 D, 2005, p.2)

It was only in November 2011 that the project *Development of the National Parameters for the Eurocodes* was initiated. In order to be able to cope with the different national, climatic, and safety-relevant conditions, the system of the NDP was introduced. The NDP are published in the National Annex to the corresponding Eurocodes. Although the SIA was still confident in the Swiss structural standards, the introduction of the NDP in 2013 was meant to contribute to a harmonization at an European level. This was expected to increase the use of European structural standards in Switzerland. However, a withdrawal of the Swiss structural standards was not intended. They are continuously supplemented, corrected, updated, and thus adapted to the growing requirements of the Eurocodes. All changes made are added to the standard texts in the form of corrections.

In summary, the application of national structural standards, as well as the application of the Eurocodes with corresponding NDP, is now legally permitted in Switzerland.

4 PUBLIC WOODEN BUILDINGS

The European Wood Project is about public buildings. Therefore, before conducting any further research, the attributes of a public building had first to be examined.

4.1 Interpretation

In Switzerland, there is no defined classification of what a public building is and what is not. However, the Oxford Dictionary defines it as follows:
"A building used by the public for any purpose, such as assembly, education entertainment, or worship." (Oxford University Press, n.d.) In a broader sense, one could classify all buildings that serve the public or handle public concerns and affairs as public buildings. Based on this classification, the following buildings can be considered examples of public buildings:

- Federal Offices
- Police Stations, Post Offices, Fire Stations
- Clinics, Retirement Homes, Nursing Homes
- Theatres, Museums, Concert Halls
- Libraries, Archives
- Schools, Universities
- Sport Centres
- Churches
- Exhibition halls

4.2 Significance for the Standards

Having analyzed the classification of buildings as public buildings, the effect on construction processes must now be considered. This effect can be explained quite briefly since there is none. Neither the Eurocodes nor the Swiss National Standards define whether a building is a public building or not. What is of great significance, is the category of use. The category of use provides which loads will be imposed on the structure, what safety factors have to be applied, and what parameters have to be used. As a result, two buildings, that are both considered public buildings can have different regulations and construction processes depending on their category of use. This discovery must be considered in the course of this research. An example of the different conditions for a structure, imposed by the purpose of use can be seen in the following research on the fire regulations in Switzerland.

5 FIRE SAFETY REGULATIONS VKF 2015

The fire safety regulations are indirectly referred to in the Swiss Codes as well as in the Swiss National Annex of the Eurocode. As stated before, they have a legal character and were put into force on 01.01.2015. The regulations are revised every ten years and contain the current state-of-the-art and European standards. The VKF 2015 regulates the use of flammable materials in structures, fire compartments, exterior wall cladding, roofing, and interior applications. The following paragraphs list and summarize the decisive specifications given in the VKF fire safety regulations, concerning wooden structures, wooden elements and multilayer elements with wooden parts.

5.1 Structure of the VKF 2015

The VKF 2015 consists of the fire protection standard, 19 fire protection guidelines, directories, explanations, working aids, and leaflets. The guidelines are divided into the following areas:

- 10-15 Terms and Definitions
- 11-15 Quality Assurance in Fire Protection
- 12-15 Fire Prevention and Organizational Fire Protection
- 13-15 Building Materials and Components
- 14-15 Use of Building Materials
- 15-15 Fire Protection Distances, Bearing Structures, Fire Sections
- 16-15 Escape and Rescue Routes
- 17-15 Marking of Escape Routes, Safety Lighting, Safety Power Supply
- 18-15 Extinguishing Installations
- 19-15 Sprinkler Systems
- 20-15 Fire Alarm Systems
- 21-15 Fume and Heat Extraction Systems
- 22-15 Lightning Protection Systems
- 23-15 Transport System
- 24-15 Heating Systems
- 25-15 Air Conditioning Systems
- 26-15 Dangerous Substances
- 27-15 Detection Procedures in Fire Protection
- 28-15 Approval Procedure

5.2 Quality Assurance in Fire Protection

The VKF 2015 defines the minimum measures for quality assurance. These measures must be regularly reviewed and adjusted if necessary. Depending on use, building geometry (height, extent), construction method, and special fire risks, all new buildings, as well as structural or usage-related changes to all buildings and facilities, are divided into four quality assurance levels (abbr. = QSS [from German *Qualitätssicherungsstufen*]). Tables 5 and 6 show the relevant classifications in the QSS for timber construction.

Table 5. Determination of the QSS for buildings and facilities with certain uses (VKF-BSR 11-15/2015, p.7)

Building Height Category Use	**Buildings of small height**	**Buildings of medium height**	**High-rise buidlings**
Living Office School Praking (above ground, 1. or 2. level below ground) Agriculture Industry and commerce with $q < 1000$ MJ/m^2	**1**	**1**	**2**
Accomodation facility [b] and [c] Rooms with large occupancy rate (>300) Sales business Parking (3. level below ground or lower) Industry and commerce with q > 1000 MJ/m2 High-bay storages	**2**	**2**	**3**
Accomodation facility [a] Structures of unknown use	**2**	**3**	**3**

[a] in particular hospitals, retirement, and nursing homes, in which permanently or temporarily 20 or more persons are housed, who are dependent on outside help;
[b] in particular hotels, boarding houses, and holiday homes, in which permanently or temporarily 20 or more persons are housed, who are not dependent on outside help;
[c] in particular remote, not fully accessible accommodation areas, in which permanently or temporarily 20 or more persons are housed, who are exclusively mountain experienced.

Table 6. Determination of the QSS for buildings and facilities with sections with special fire risks (VKF-BSR 11-15/2015, p.8)

Special Fire Risks Dimensions, construction, fire load	**Buildings of small height**	**Buildings of medium height**	**High-rise buidlings**
Outter Wall: Facade and/or insulation in facade with flamable materials	**1**	**2**	**[1]**
Bearing structure or fire compartement building elements with flamable building materials or enclosure	**1**	**2**	**3**

[1] No application according to the fire protection guideline "Use of Building Materials"

The different QSS impose corresponding demands on the persons and processes involved. The demands of the QSS, relevant for timber, construction are briefly explained in the following paragraphs. A definition of the mentioned fire protection concepts will be given in the next chapter.

Quality Assurance Level 1 (QSS1)

Buildings of QSS1 are small and simple, have few parts, and show no increased risk of fire due to use and construction. Simple fire protection plans are sufficient for QSS1. For certain buildings, these must be submitted only at the request of the fire protection authority. Fire safety is ensured by the standard concept of the fire protection regulations.

Quality Assurance Level 2 (QSS2)
Buildings of QSS2 are small to medium-large, have multiple and different parts, and can show an increased risk of fire due to use and construction. Fire protection plans have to be prepared for QSS2. Should there be a deviation from the standard concept of the fire protection regulations, an individual fire protection concept must be created. Fire safety is ensured by said concepts.

Quality Assurance Level 3 (QSS3)
Buildings of QSS3 are medium-large to large, have many different parts, and show an increased risk of fire due to use and construction. Fire protection plans and, if necessary, individual fire protection concepts have to be prepared for QSS3. The fire safety is ensured by the standard concept of the fire protection regulations or a fire protection concept, if necessary, by application of verification methods.

5.3 **Fire Protection Concepts**

Fire protection concepts serve the purpose of achieving the fire protection goals. These are to guarantee the safety of persons and animals, prevent the formation of fires and explosions, limit the spreading of fires, remain the structural properties of a building for a certain amount of time and ensure the possibility of firefighting. The fire protection regulations distinguish three different concepts:

- Standard concepts
- Deviation from standard concepts
- Verification method

The most commonly used procedure is the standard concept. Here, the protection goals are achieved by using prescribed measures. The standard concept is subdivided into two concepts. The structural concept achieves the protection goals with structural fire protection measures and, if necessary, technical fire protection measures. The extinguishing system concept achieves the protection goals by means of extinguishing systems, which are considered in addition to structural measures.

In case of deviations from the standard concepts, the protection goals can be achieved with alternative fire protection measures. However, the fire protection authority must approve the equivalence of the said alternative measures. Furthermore, deviations from the standard concepts occur if they are insufficient or disproportionate for the existent risk of fire.

To fulfill the protection goals in a holistic approach it is permitted to apply verification methods for the assessment of fire hazard, and fire risk, or for the verification of conceptual approaches. Verification methods are mostly used for special projects with high complexity. The fire protection authority examines the for the fire protection relevant concepts and verifications for completeness, traceability, and plausibility. (VKF-BSN 1-15/2015, p.6/7)

5.4 **Building Categories**

As already stated, the geometry of a building is decisive for the fire protection measures. The main criterion is the height of the building since it is most relevant for the fire brigade in a fire extinguishing and rescue operation. In the VKF 2015 are three building categories:

- Buildings of low height (up to 11m)
- buildings of medium height (up to 30m)
- Skyscrapers (more than 30m)

In addition to this classification based on the building height, there are two more subcategories that allow reduced requirements. The first subcategory includes buildings of small dimensions. To be ranked among this subcategory, a building must comply with the following requirements:

- low height
- max. 2 floors over terrain
- max. 1 floor under terrain
- sum of all floor areas max. 600m2
- no sleeping persons except in form of an apartment
- no use as a nursery
- rooms with large occupancy only on the ground floor

The second subcategory includes ancillary buildings. A building is defined as a secondary building if it is a one-story building, which is not intended for the permanent residence of persons, has no open fires, has no dangerous substances stored in large quantities, and has a base area not exceeding 150m^2.
(VKF-BSN 1-15/2015, p.8/9)

5.5 **Building Materials**

The building materials are classified by standardized tests or other VKF-approved procedures on the basis of fire and smoke behavior, dripping while burning and corrosivity. Due to their fire behavior, they are classified into one of the following categories [abbr. = RF (from French *reaction au feu*)]:

- RF1 (no fire contribution)
- RF2 (low fire contribution)
- RF3 (permitted fire contribution)
- RF4 (improper fire contribution

Building materials whose smoke development and/or dripping while burning and/or corrosiveness in the event of a fire can lead to unacceptable fire effects are referred to as critical building materials [abbr. = cr (from French *comportement critique*)].

Building materials can be classified according to the VKF as well as the EN. If they have therefore to be assigned to different fire behavior groups, the application under both groups is possible without restriction. Only the classification by the VKF is considered in the course of this work.
(VKF-BSR 13-15/2015, p.5)

The VKF provides a list of generally approved building products. The construction products listed on the list can be used without proof of verification or VKF approval, as their suitability has already been proven by experience and the state of the art. Table 7 shows the generally approved building materials which are most commonly used in timber construction. The values given in the tables contain a certain cushion, which creates a fire protection robustness. The building materials have already been assigned to a fire behavior group.

Table 7. Generally approved building materials (VKF-BSA, 2015, p.5/7/8)

Product label / Product standard	**Technical conditions**	**Fire behavior category**
Hardwoods	Maple, beech, alder, ash, cherry, walnut etc.	**RF 3**
	Oak, robinia (false acacia), afromosia, afzelia (Doussie) bilinga, iroko, laman, makore, dark red meranti, sapele, sipo, teak, wenge	**RF 2**
Softwoods	Spruce, fir, larch, pine, douglas fir, arve, red cedar etc.	**RF 3**
Plasterboard / SN EN 520 Paper / SN EN ISO 536	Density ≥ 800 kg/m^3 Plate thickness ≥ 6.5 mm Paper weight ≤ 220 g/m^2 (≤ 5% organic additive)	**RF 1**
Wood fibreboard	MDF	**RF 3**
	Hard, medium hard, and porous fibreboards Density ≥ 230 kg/m^3	**RF 3**
Solid wood panel	Single layer and multi layer solid wood panels, cross laminated timber boards	**RF 3**
OSB	Slabs of long, slender, alligned chips	**RF 3**
Chipboard	Chipboard	**RF 3**
Plywood	Plywood boards	**RF 3**
Cement-Bonded Chipboard	Density ≥ 1200 kg/m3 Thickness ≥ 10mm Cement content ≥ 75% by mass	**RF 1**
Parquet and wooden floors	Parquet sealed or oiled from maple, beech, oak, ash	**RF 2**
	Wooden floors with building materials (wood species) RF2	**RF 2**
	Wooden floors with building materials (wood species) RF3	**RF 3**

5.6 Building Elements

When classifying building elements, the classification of the Eurocode applies. Components are classified according to the criteria of load bearing capacity (R), integrity (E), and insulation (I). In addition, the classification can be extended by the following criteria:

- W – if the transmitted radiation is assessed
- M – if special mechanical effects are taken into account
- C – for mobile fire barriers, with self-closing feature
- S – for components with special limitation of smoke permeability

The classification is marked as follows:

R	E	I	W		t	t	-	M	C	S

tt = Duration of fire resistance

The duration of fire resistance is the minimum time in minutes during which a component must meet the requirements imposed on it. The durations of fire resistance for building components are 30, 60, 90, 120, 180 or 240 minutes, depending on the use of the building part and the building height. Depending on the safety requirements, some components must be made of materials that comply with the fire behavior group RF1 (RF1 = no fire contribution). If a component must consist of building materials of RF1, the marking "-RF1" is added to the classification shown above. Multilayer fire-resistant components with wooden parts can comply with RF1 if the component is encapsulated with RF1 building materials. Here, the minimum fire resistance K of encapsulation is 30 minutes less than the fire resistance of the entire component but not less than K 30-RF1. The cavities between flammable parts must be tightly filled with building materials of RF1. Figure 2 shows various design possibilities for components of RF1, including a multi-layered design with flammable materials. (VKF-BSR 13-15/2015, p.13-14)

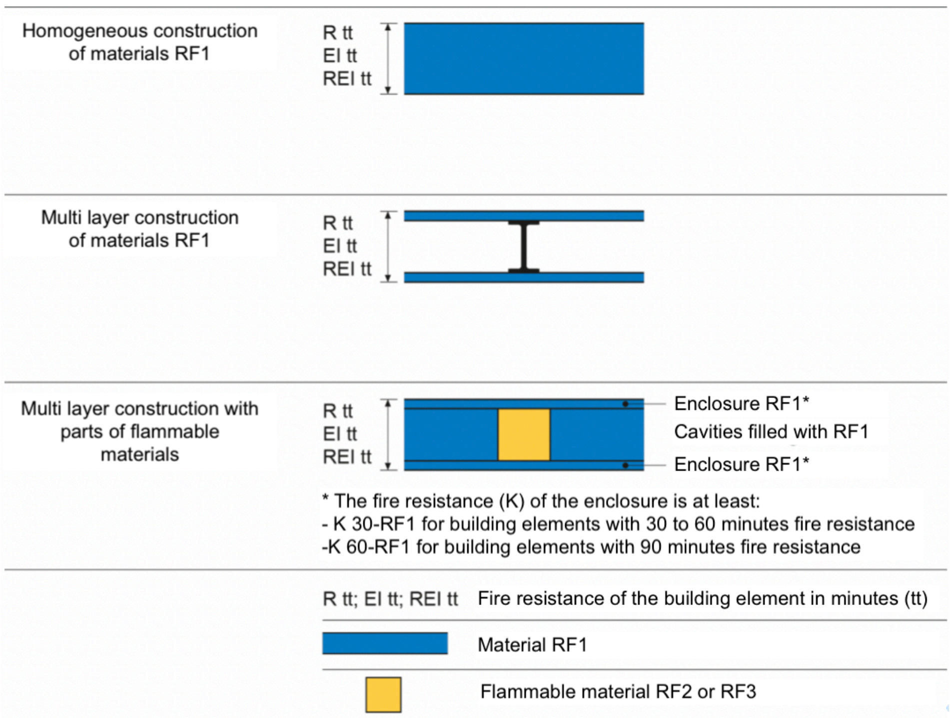


Figure 2. Fire-resistant components that comply with RF1 constructions (VKF-BSR 13-15/2015, p.22)

The use of RF1 components with wood content is restricted to the fire resistance classes REI 30-RF1, REI 60-RF1, and REI 90-RF1.

5.7 Fire Protection Distance

Fire protection distances are to be determined in such a way that there is no danger to buildings and installations due to mutual fire transmission. The fire protection distances indicate the distance between the facades. In the case of overhangs of components of more than one meter, the fire protection distance increases by the measure exceeding one meter.

The VKF 2015 defines the following fire protection distances between buildings and facilities:

- 5 m, if the outermost layers of both outer wall constructions consist of RF1 building materials;
- 7.5 m, if the outermost layer of one of the two outer wall constructions consists of combustible building materials;
- 10 m, if the outermost layers of both outer wall constructions consist of combustible building materials.

Between single-family houses, buildings of low and buildings of medium height the fire protection distances may be reduced, if the outer walls have a fire resistance of at least 30 minutes (excluding windows and doors).This reduction results in the following distances:

- 4 m, if the outermost layers of both outer wall constructions consist of RF1 building materials;
- 5 m, if the outermost layer of one of the two outer wall constructions consists of combustible building materials;
- 6 m, if the outermost layers of both outer wall constructions consist of combustible building materials.

Auxiliary structures do not need to be separated from each other by fire protection distances if the total area does not exceed $150m^2$. Furthermore, office, commercial, industrial, and agricultural buildings are mutually exempted from a fire protection distance, as far as they are single-story buildings with comparable use, fire hazard and a total area of not more than $3600m^2$.

If the fire protection distances are below the limits, the requirements regarding flammability and fire resistance for the external walls are increased.
(VKF-BSR 15-15/2015, p.5-6)

5.8 Requirements of structures and Fire Compartments

The fire resistance of structures and fire compartments shall be chosen as to ensure personal safety and fire-fighting possibilities. In addition, the spread of fire to other fire compartments during the defined time must be prevented. For determining the fire resistance, the use, the location, the building geometry, and the fire load of buildings and facilities are relevant. The use of extinguishing systems also plays a major role. Depending on the design, location, extent, building geometry and use of buildings, fire compartments are formed. The following list describes situations in which the construction of fire compartments is particularly important:

- Connected and extended buildings and facilities
- Stories above and below terrain
- Vertical and horizontal escape routes
- Vertical connections such as ventilation and installation shafts
- Rooms with building equipment
- Rooms of different use, especially with different fire hazards
- Areas with technical fire protection equipment
- Areas serving evacuation

The essential requirements for the fire resistance of buildings from the three building categories are briefly explained below. In addition, the possibility of application of wooden materials will be mentioned. In Appendices 1-3 there are tables with the exact fire resistance requirements for structure, fire compartment, and escape routes. The values given in the tables are according to the standard concepts of fire protection. Deviations from the standard solutions are possible (see chapter 6.3).

Buildings of small height (≤ 11m)

The specified fire resistance duration of structures, fire compartments and escape routes of low-rise buildings is between 30 and 60 minutes. In many uses, a concept with an extinguishing system provides a reduction of 30 minutes compared to the purely structural concept. Nevertheless, some exceptions are made, especially for vertical escape routes. (exact values can be found in Appendix 1). Load-bearing and fire-section-forming components made completely or partially out of wood can be used in all categories. However, in the structural fire protection concept accommodations and vertical escape routes must be carried out with RF1 components. With the concept of extinguishing system, this is no longer necessary.

Buildings of medium height (≤ 30m)

The specified fire resistance duration of structures, fire compartments and escape routes of medium-rise buildings is between 30 and 90 minutes. In many uses, a concept with an extinguishing system provides a reduction of 30 minutes compared to the purely structural concept. Nevertheless, some exceptions are made, especially for vertical escape routes. (exact values can be found in Appendix 2). Load-bearing and fire-section-forming components made completely or partially out of wood can be used in all categories. However, in the structural fire protection concept accommodations and vertical escape routes must be carried out with RF1 components. With the concept of extinguishing system, this is no longer necessary.

High Rise Buildings (≤100m)

The specified fire resistance duration of structures, fire compartments and escape routes of high-rise buildings is between 30 and 120 minutes. In many uses, a concept with an extinguishing system provides a reduction of 30 minutes compared to the purely structural concept. Nevertheless, some exceptions are made, especially for vertical escape routes. (exact values can be found in Appendix 3). Load-bearing and fire-section-forming components with wooden parts can be used in high-rise buildings. For fire compartment forming components with fire resistance requirements up to and including 90 minutes, RF1 components with wood content can be used. If a sprinkler system is installed, wood can be used for linear, load-bearing components.
(VKF-BSR 15-15/2015, p.7/11-13) (VKF-BSR 14-15/2015, p.11)

5.9 **Fire Protection Walls**

In addition to the above-mentioned fire compartments, the construction of a firewall might be necessary under certain circumstances. According to VKF 2015, this is the case for:

- Agricultural buildings with a volume of more than 3000m^3; Residential and business parts must be separated by a firewall with fire resistance REI 90
- Connected and extended buildings with insufficient fire section formation within the buildings (e.g. row houses in old towns or industrial plants); Separation of the buildings through a firewall with fire resistance REI 180
    - For single-story buildings and buildings with low height, fire resistance REI 90 is sufficient
- Utilizations with very high fire loads; Areas are separated by firewalls with fire resistance REI 180
    - For single-story buildings of any fire load, fire resistance REI 90 is sufficient
- Firewalls prescribed by cantonal fire legislation (in particular on a parcel boundary):
    - REI 180 for buildings of medium height and skyscrapers
    - REI 90 for buildings of low height
    - REI 60 for single-family homes and ancillary buildings

Firewalls must be constructed vertically throughout the extent of the higher facade up to the topmost roof layer. They shall be constructed in such a way as to take into account roof overhangs and nooks. Firewalls can be built both single-shelled and double-shelled. Single-shell structures with fire resistance REI 180 are made of building materials RF1. For double-shell firewalls, each of the two shells must have a certain fire resistance. Firewalls with REI 180 must have two REI 90 shells, firewalls with REI 90 must have two REI 60 shells, and firewalls with REI 60 must have two REI

30 shells. Therefore, firewalls can be constructed of timber. The area between the shells is filled with building materials RF1.
(VKF-BSE 100-15/2015, p.4)

5.10 **Emergency and Escape Routes**

Escape and rescue routes must be planned in such a way that they can be used quickly and safely at any time. If a vertical escape route is not separated from a horizontal escape route by a fire cut, the requirements of a vertical escape route apply to the horizontal escape route (Appendix 1-3). The number of vertical escape routes depends on floor area, escape route length and occupancy. Buildings without adequate, ground-level escape routes leading to the outside need at least one vertical escape route for a floor area not greater than 900 m^2, and at least two for a floor area greater than 900 m2. Rooms with a person occupancy of more than 100 persons without adequate, ground-level escape routes leading to the outside must have access to at least two vertical escape routes.Horizontal escape routes that lead only to one vertical escape route or one exit may be a maximum of 35m long. If two vertical escape routes or exits are connected, the horizontal escape route must not exceed 50m in length.
(VKF-BSR 16-15/2015 p.5-6)

5.11 **Application of Timber Elements**

To summarize, the possible uses of wooden components and components with wooden parts are listed below. It is once again pointed out that multi-layer components, which contain flammable building materials, are as a whole assigned to RF1, as long as they are encapsulated on all sides by K 30-RF1.

5.11.1 Building Shell - Exterior Wall Constructions

For buildings of medium height, external wall cladding, and insulation made of flammable materials may be used as long as the accessibility for the fire brigade is guaranteed. The exterior wall must be constructed in a way that a fire on the outside of the wall will not spread to more than two stories above before the extinguishing starts. In the case of thermal insulation and composite systems, this can be achieved by means of separation through fire locks or by VKF approved constructions. In the case of ventilated facades made of combustible building materials, the fire transmission is prevented by means of constructions approved by the VKF. Double facades may only consist of building materials of the RF1, with the exception of linear, flammable window profiles. However, using combustible building materials is possible under certain measures (e.g. sprinkler system). A construction is VKF-approved, if the above-mentioned protection goal, “The exterior wall must be constructed in a way that a fire on the outside of the wall will not spread to more than two stories above before the extinguishing starts," is achieved. The basic constructive specifications are to be taken from a VKF approval, a VKF-approved state-of-the-art paper or the construction specifications in the fire protection guidelines. Exterior walls and exterior wall cladding systems of skyscrapers shall consist of building materials RF1. Exceptions are selective fixings and back anchoring of thermal insulation which must at least consist of building materials of RF3 (cr).

5.11.2 Building Shell – Roof Constructions

Roof constructions in buildings of medium height can under some conditions be completely constructed with timber. Burning through the roof must be prevented by either an outer layer of RF1 material or by the installation of an EI 30 fire protection board. As an alternative to a fire protection board, it is possible to use a roof with a fire resistance of EI 30 of its own. In the area of firewalls, the roof structure is to be interrupted in such a way that a fire transmission is prevented. If the outermost layer is made of flammable material, accessibility to the roof surface by the fire department must be ensured. For high-rise buildings, only the design with an outer layer of RF1 building materials and RF2 (cr) classified systems according to SN EN 13501-5 are possible.

5.11.3 Building Structure

The application possibilities of wooden components and their requirements in the building structure can be found in Table 8. The requirements for horizontal and vertical escape routes are listed separately. The load of vertical escape routes, which serve to escape from several floors, is significantly higher than the load of horizontal escape routes, which serve to escape from a single floor. Furthermore, the differences between a purely structural fire protection concept and a fire protection concept with extinguishing systems are presented.

With the exception of escape routes, buildings of low and medium height can, under some conditions, be constructed entirely of timber. In high rise buildings staircases, walls, ceilings (more than 5m above accessible area) and columns without fire resistance requirements, as well as their insulation, interlayers, and cladding may be constructed of flammable materials. An exception is again made for escape routes. (VKF-BSR 14-15/2015, p.4-11)

Table 8. Requirements for the fire behavior of escape routes and interior rooms (VKF-BSR 14-15/2015, p.11)

			Buildings of small and medium height								High rise buildings							
			Walls, ceilings and columns with fire resistance requirements	Walls, ceilings and columns without fire resistance requirements	Insulation and intermediate layers	Wall and ceiling panelling, suspended ceilings, raised floor	Classified Systems	Ceiling covering	Flooring	Stairs and platform constructions	Walls, ceilings and columns with fire resistance requirements	Walls, ceilings and columns without fire resistance requirements	Insulation and intermediate layers	Wall and ceiling panelling, suspended ceilings, raised floor	Classified Systems	Ceiling covering	Flooring	Stairs and platform constructions
Escape Route	Vertical escape routes	Structural	RF1 [7]	RF3 [1]	RF1 [1] [5]	RF1 [2]	RF1 [2]	RF1	RF2 [3]	RF1 [3]	RF1	RF1	RF1	RF1 [2]	RF1 [2]	RF1	RF1	RF1
		Sprinkler System	RF3 [1]	RF3 [1]	RF3 [1]	RF1 [2]	RF1 [2]	RF1	RF3	RF1 [3]	RF1	RF1	RF1	RF1 [2]	RF1 [2]	RF1	RF1	RF1
	Horizontal escape routes	Structural	RF3 [1] [6]	RF3 [1]	RF3 [1]	RF1 [2]	RF1 [2]	RF1 [4]	RF3	no application	RF1	RF1	RF1	RF1 [2]	RF1 [2]	RF1 [4]	RF2	no application
		Sprinkler System	RF3	RF3	RF3	RF2	RF2	RF2 [4]	RF3	no application	RF1	RF1	RF1	RF1 [2]	RF1 [2]	RF1 [4]	RF2	no application
Other interior rooms	Accomodation facilities [a]	Structural	RF1 [7]	RF3	RF1 [5]	RF3	RF1 [5]	RF1 [4]	RF3 cr	RF3	RF1	RF3	RF1 [5]	RF3	RF1 [5]	RF1 [4]	RF3 cr	RF2
		Sprinkler System	RF3	RF3	RF3	RF3	RF3	RF2 [4]	RF3 cr	RF3	RF2	RF3	RF2 [5]	RF3	RF2 [5]	RF2 [4]	RF3 cr	RF3
	Rooms with large occupancy rate	Structural	RF3	RF3	RF3	RF3	RF3	RF1 [4]	RF3 cr	RF3	RF1	RF3	RF1 [5]	RF3	RF1 [5]	RF1 [4]	RF3 cr	RF2
		Sprinkler System	RF3	RF3	RF3	RF3	RF3	RF2 [4]	RF3 cr	RF3	RF2	RF3	RF2 [5]	RF3	RF2 [5]	RF2 [4]	RF3 cr	RF3
	Other use	Structural	RF3	RF3	RF3	RF3	RF3	RF3	RF3 cr	RF3	RF1	RF3	RF1 [5]	RF3	RF1 [5]	RF2 [4]	RF3 cr	RF2
		Sprinkler System	RF3	RF3	RF3	RF3	RF3	RF3	RF3 cr	RF3	RF2 [7]	RF3	RF2 [5]	RF3	RF3	RF3	RF3 cr	RF3

(blue) = RF1 (orange) = RF2 (yellow) = RF3 (white) = no application

[1] Components containing flammable materials must be covered on the visible side of the room by a fire protection panel with a fire resistance of 30 minutes consisting of building materials of RF1. This requirement does not apply to individual linear load-bearing timber components.

[2] The area percentage of combustible materials (lights, pin boards, clothing, railing infills, etc.) in vertical escape routes per floor is max. 10% of the staircase floor area and in horizontal escape routes max. 10% of the floor area of the considered horizontal escape route. Sections may not exceed max. 2 m^2 and must have a safety distance of at least 2 m between them. Area proportions of doors, windows, handrails, etc. as well as individual linear load-bearing timber components are not taken into account in this calculation.

[3] In low-rise buildings, instead of building materials of RF1, materials of RF2 may be used and for building materials of RF2 those of RF3.

[4] Insofar as the ceiling coverings are more than 5 m above accessible areas, RF1 materials may be replaced by those of RF2, and RF2 materials by those of RF3. Single-layered membrane structures are not considered ceiling coverings.

[5] For walls and ceilings without fire resistance requirements, construction products of RF3 are permitted.

[6] In accommodation facilities [a] fire-resistant interior walls, ceilings, and supports must consist of RF1 materials must be used.

[7] Building materials of RF3 are permitted for individual linear load-bearing components. These may be installed visibly.

6 SWISS STANDARDS BY COMPARISON

To facilitate the incorporation of the previously examined standards into a transdisciplinary timber construction course, the following paragraphs compare the wood application options of the Swiss Standards with those of a second European partner of the "Public Wood Project". Since this research was conducted at a Finnish HEI, Finland was chosen as the analog country. On the Swiss side, the comparison refers to the VKF 2015, the SIA-Norm 265 and the National Annex of the Eurocode, and on the Finnish side to the Decree on Fire Safety from the National Building Code and the National Annex of the Eurocode. The VKF 2015 and the Finnish National Building Code are compared separately from the National Annexes of the Eurocodes and the SIA-Norm 265.

6.1 VKF 2015 – Finnish National Building Code

The VKF 2015 and the 848/2017 Decree of the Ministry of the Environment on fire safety have a lot in common. For example, both regulations allow the use of standard concepts based on the given values as well as alternative verification methods to meet the fire protection conditions. The most striking difference between the two national regulations is their classification of building categories. While the system of fire classification of the Swiss regulation is based purely on the building height, the Finnish classification is somewhat more complicated. In Finland, buildings are divided into four fire protection classes: P0, P1, P2, and P3. In the following comparison, however, class P0 is disregarded because it does not apply to the standard concepts. The classification depends on the use of the building, occupants, size, and number of floors. The demand for fire safety decreases with each stage. The first fire protection class places the highest demands on fire safety and applies to buildings from eight stories upwards. The second fire protection class refers to residential buildings, as well as smaller commercial and public buildings, ranging in size from two to eight stories. The third fire protection class is the least demanding. It refers to one- to two-story residential buildings. There are very few fire protection requirements for the products of this class. Table 9 below summarizes the most important characteristics of each class.

Table 9. Fire safety classes of buildings in Finland (848/2017 Decree of the Ministry of Environment on Fire safety of Buildings/2018, p.5/6)

	max.Number of stories	max. Height	max. Gross floor area
P1	free	free	free
P2			
General	2	9m	free
Residential building	4	14m	12000m^2
Residential building with extinguishing system	8	28m	12000m^2
P3			
one-story general	1	9m	2400m^2-4800m^2*
one-story general	2	9m	1600m^2-2400m^2*
Production or storage	1	14m	free
Agriculture	1	18m	free

In the following, the Finnish fire protection classes are put on equal terms with the Swiss height categories for a simplified comparison. The next section clarifies the different fire protection requirements and possible timber applications provided in the standards in terms of the building structure (including fire compartment forming components), exterior wall cladding, interior wall cladding, and roof.
Note: The following comparisons are only an approximate listing of the most important features. Deviations from the values given in the tables are possible under certain circumstances; for details please refer to the Finnish Decree on Fire Safety and the Swiss VKF 2015 (Appendices 1-7).

6.1.1 Structure

As stated before, the Swiss classifications are compared with the Finnish ones. Low-height buildings are compared with class P3, medium-height buildings with P2 and skyscrapers with P1. However, the comparison turned out to be rather difficult. The reason for this was that the Finnish Decree on the Fire Safety is a slightly more "inaccurate" than the VKF 2015. The Finnish regulations specify both the fire protection class of the components and their product requirements according to the use of the building, while the Swiss regulations only determine the fire protection class of the elements based on the use of the building; the product requirements are determined according to the kind of the element (wall, stairs, ceiling, insulation, etc.).However, with some adjustments, it was possible to show the fire protection and product requirements of the individual classes in Table 10. The possibilities of wood application were indicated by color:

- Yellow: elements with normal flammable properties (B2 or possibly B1 according to European and Finnish material classes and RF3 or Rf2 according to Swiss material classes)

- Orange: elements with normal flammable properties that may be used under certain circumstances; these circumstances include, among others: increased fire resistance of insulating materials, type of component (e.g. lower requirements for linear load-bearing timber components), distance between ceilings and accessible areas
- Blue: non-combustible elements (A2 according to European and Finnish material classes and RF1 according to Swiss material classes)

In both countries, it is possible to construct components of levels A2 and RF1 with wooden parts, as long as the flammable components are adequately encapsulated with non-flammable fire protection plates.

The comparison in Table 10 makes it clear that the product requirements of both countries for small and medium-sized buildings are relatively similar. In high-rise buildings, Finnish product requirements seem to be slightly higher than those in Switzerland. However, this could also be a fallacy which is based on the diversity of the classification approach of the building elements in different countries. The requirements for the fire protection class of Swiss buildings are in general slightly lower than the Finnish requirements. Vertical escape routes were excluded from the listing. According to both regulations, they must be carried out with materials of A2 or RF1 for most uses.

Table 10. Comparison of the fire requirements of building elements and the possible wood application in structural building elements between Switzerland and Finland (848/2017 Decree of the Ministry of Environment on Fire safety of Buildings/2018, p.8) (VKF-BSR 14-15/2015, p.11)

vertical escape-routes are neglected

		P3	Building of small height	P2	Building of medium height	P1			High-rise Building
	concept	-	n.r. for 1 story buildings	-	-	more than 1200 MJ/m²	600-1200 MJ/m²	less than 600 MJ/m²	-
one- or two-story building, general	structural	n.r.	R 30	R 30	/	R 120	R 90	R 60	/
	sprinkler system	n.r.	n.r.	n.i.	/	R 60	R 60	n.i.	/
institutions, accomodation facilities	structural	n.r.	R 60	R 30	/	R 120	R 90	R 60	/
	sprinkler system	n.r.	R 30	n.i.	/	R 60	R 60	n.i.	/
uppermost floor in a building	structural	n.r.	n.r.	R 30	/	R 60	R 60	R 60	/
	sprinkler system	n.r.	n.r.	n.i.	/	n.i.	n.i.	n.i.	/
production and storage building (for swiss classification q > 1000 MJ/m²)	structural	n.r.	R 30	R 30	/	R 60	R 60	R 60	/
	sprinkler system	n.r.	n.r.	R 15	/	R 30	R 30	R 30	/
fire-separating building elements (not necessarily load bearing)	structural	EI 30	REI 60 (C) EI 60 (W)	EI 30	/	EI 120	EI 90	EI 60	/
	sprinkler system	n.i.	REI 30 (C) EI 30 (W)	n.i.	/	EI 60	EI 60	n.i.	/
Building of over two stories max. 28m, general	structural	/	/	/	R60	R 180	R 120	R 60	/
	sprinkler system	/	/	R 60	R30	R 90	R 60	n.i.	/
institutions, accomodation facilities	structural	/	/	/	R 60	R 180	R 120	R 60	/
	sprinkler system	/	/	R 60	R 30	R 90	R60	n.i.	/
uppermost floor in a building	structural	/	/	/	n.r.	R 60	R 60	R 60	/
	sprinkler system	/	/	R 60	n.r.	n.i.	n.i.	n.i.	/
production and storage building (for swiss classification q > 1000 MJ/m²)	structural	/	/	/	R 90	R 180	R 120	R 60	/
	sprinkler system	/	/	R 60	R 60	R 90	R 80	n.i.	/
fire-separating building elements	structural	/	/	EI 60	REI 90 -REI 60 (C) EI 60-EI 30 (W)	EI 120	EI 90	EI 60	/
	sprinkler system	/	/	n.i.	REI 60 - REI 30 (C) EI 30 (W)	EI 60	EI 60	n.i.	/
Building of over 2 stories with a greater height than 28m but not exceeding 56m, general	structural	/	/	/	/	R 240	R 180	R 120	R 90
	sprinkler system	/	/	/	/	R 180	R 120	R 90	R 60
institutions, accomodation facilities	structural	/	/	/	/	R 240	R 180	R 120	R 90
	sprinkler system	/	/	/	/	R 180	R 120	R 90	R 60
uppermost floor in a building	structural	/	/	/	/	R 240	R 180	R 120	R 60
	sprinkler system	/	/	/	/	R 180	R 120	R 90	R 30
production and storage building (for swiss classification q > 1000 MJ/m²)	structural	/	/	/	/	R 240	R 180	R 120	R 120
	sprinkler system	/	/	/	/	R 180	R 120	R 90	R 90
fire-separating building elements (not necessarily load bearing)	structural	/	/	/	/	EI 120	EI 90	EI 60	REI 120 - REI 90 (C) EI 90 - EI 60 (W)
	sprinkler system	/	/	/	/	EI 60	EI 60	n.i.	REI 90 - REI 60 (C) EI 60 - EI 30 (W)
Building of over 2 stories with a height exceeding 56 m, general	structural	/	/	/	/	/	/	/	R 90
	sprinkler system	/	/	/	/	R 180	R 120	R 120	R 60
institutions, accomodation facilities	structural	/	/	/	/	/	/	/	R 90
	sprinkler system	/	/	/	/	R 180	R 120	R 120	R 60
uppermost floor in a building	structural	/	/	/	/	/	/	/	R 60
	sprinkler system	/	/	/	/	R 180	R 120	R 120	R 30
production and storage building (for swiss classification q > 1000 MJ/m²)	structural	/	/	/	/	/	/	/	R 120
	sprinkler system	/	/	/	/	R 180	R 120	R 120	R 90
fire-separating building elements (not necessarily load bearing)	structural	/	/	/	/	/	/	/	REI 120 - REI 90 (C) EI 90 - EI 60 (W)
	sprinkler system	/	/	/	/	EI 90	EI 60	EI 60	REI 90 - REI 60 (C) EI 60 - EI 30 (W)

[yellow] = application of wood is possible [orange] = application of wood is possible under certain circumstances [blue] = non flammable elements (RF1, A2)

n.r. = no requirement / = no application n.i. = no information

6.1.2 Exterior Wall Cladding

While the product requirements for load-bearing and bracing components were more specific in the Swiss regulations than in the Finnish ones, it is the opposite for the requirements for exterior wall claddings. Nevertheless, the two regulations are generally very similar. Once more classifications were conducted according to building height (Switzerland) and fire protection class P1-3 (Finland). The Swiss regulations restrict the use of wood-based materials in buildings of small and medium height only in accommodation establishments (concerns thermal insulation layer,

interlayer, and multi-layer structures which are tested as complete systems and classified as building materials). For exterior wall claddings of high-rise buildings, only building materials of class RF1 are permitted. The Finish Decree on Fire Safety generally only permits B1 or A2 building materials to be used for the claddings of the inner ventilation gap in the building categories P1 and P2. Similar to the Swiss standards, according to the Finnish regulations buildings above 28 meters high must be clad with flame retardant or non-combustible components; for buildings with a height greater than 56 meters, a cladding is to be designed exclusively with A2 building materials. For buildings of the fire protection class P1 and P2, with a height above 14 meters but no greater than 28 meters, building materials of class B1 are set as a standard for the exterior wall cladding. However, this standard can be reduced to B2 building materials for some uses or by use of an extinguishing system. Buildings of class P3 or buildings that are no greater than 14m high must have an outer wall cladding of B2 building materials (for exact values see Appendix 6).
(848/2017 Decree of the Ministry of Environment on Fire safety of Buildings/2018, p.18)

6.1.3 Interior Lining

Again, concerning the product requirements for the interior lining of buildings, the Finnish regulations are stricter and more detailed than the Swiss regulations. Except for escape routes, which are for the most part covered with RF1 materials, Swiss regulations allow the lining of walls, ceilings, and floors to be designed with wood, regardless of the type of building or the utilization (Table 8). Likewise, according to the Finnish regulations most linings in all classes may be carried out with building materials B2. In particular, interior linings of apartments, accommodation buildings (except P2), assembly and commercial buildings with small fire compartments, offices, industrial buildings with a low fire risk, saunas, and attics separated as a fire compartment may be designed with B2 building materials. When using fire extinguishing systems, larger assembly and commercial buildings may also be equipped with a B2 interior lining. For parts of the building with a higher fire risk, such as technical centers, boiler rooms, gas and fuel storage facilities and parts of the building which are relevant for evacuation, the requirements are correspondingly increased (for exact values see Appendix 7).
(848/2017 Decree of the Ministry of Environment on Fire safety of Buildings/2018, p.15)

6.1.4 Roof

The requirements of both regulations for the fire safety of roofing are relatively similar. As already stated, it is possible to construct the roof structure out of wood in Switzerland, as long as an outer layer of RF1 material (high-rise buildings) or an EI 30 fire-protection board prevent the

roof from burning through. The Finnish regulations also permit a design from wood. Roof structures of an attic or void that are not essential load-bearing structures of the building's structural body or structures that brace the structural body in a fire have no fire resistance requirements. The roofing itself must not be easily flammable and the spreading of fire inside the roof to any dangerous extent should be prevented. This is prevented by matching the roof to class B_{ROOF} (t2). B_{ROOF} (t2) means that the roof must withstand moderate fire exposures. It must withstand the fire for one hour before ignition; this must be tested under wind and fire simulation. This class can be achieved by pressure treating and impregnating shakes and shingles with fire retardant chemicals. In some cases, the inside of the roof is covered with a fire protection board.
(848/2017 Decree of the Ministry of Environment on Fire safety of Buildings/2018, p.19)

6.2 National Annex Eurocodes – SIA-Norm

The main focus of this thesis is on the standard of fire safety and the possible wood application in Switzerland. However, it is also interesting to get a brief insight into the calculation method used in the case of fire. Therefore, this chapter deals with the main differences or similarities between the methods of the Eurocode and the Swiss national standard.

Since the SIA standards were created as an implementation of the Eurocodes in Switzerland, they have similar structures in the calculation approaches. Differences between the Eurocode 5 Part 1-2 and the SIA Standard 265 are mainly in the detailing. Three pages in the SIA standard for the design calculations in the case of fire compare to 80 pages in Eurocode 5. The reason for this is that the SIA 265 only describes the fundamental design method for fire scenarios. EC 5, on the other hand, includes definitions, material properties, detailed calculations for individual components, and constructive designs. Additionally, design values in the SIA are given in a somewhat simplified form, whereas in the Eurocode some are obtained through multiple calculations. However, the shortage of detailing does not mean that these points are not neglected by the SIA. Instead, the SIA standards refer to the fire protection documentation of the LIGNUM. The fire protection documentation of the LIGNUM are state of the art papers that were created on the basis of the VKF 2015 and deal with the design and the requirements in case of fire. Nonetheless, despite the differences in detail and small differences in the design coefficients, the basic method of calculation of both standards is the same. This said method is the reduced cross-section method (The Eurocode presents the reduced-property method as an alternative, but it is used in neither Finland nor Switzerland).

For this method, the same verifications as for normal temperature have to be performed. However, an ideal residual cross-section and coefficients that correspond to the valid design situation have to be applied. The idea behind this method is the fact that as the fire duration progresses, the cross-section of wood shrinks. Due to the properties of wood, this shrinkage or charring can be calculated. In this case, the fire duration t [min] is multiplied with the charring rate β [mm / min] to obtain the charring depth d [mm]. With the help of the charring depth, the ideal remaining cross-section can be calculated. Formerly, the stress and stability analysis of the elements may be conducted with the new cross-section. The decisive factor in this calculation is the charring rate. This is given in Table 11 for different wooden materials according to both EC 5 and SIA 265.

Table 11. Burning Rate of different wooden materials according to the SIA-Norm 265 and the EN 1995-1-2

Buildingmaterial		β_n	
		SIA-Norm 265	EN 1995-1-2
softwood or beech	solid wood	0,8	0,8
	laminated timber	0,7	0,7
oak or robinia (SIA 265) hardwood (EC5)	solid wood	0,5	0,55
	laminated timber	0,5	0,7
solid wood framing		0,9	/
laminated veneer lumber		/	0,7

Table 11 shows that the charring rate in both standards is relatively equal. This means that even if specific calculations or safety factors lead to minor deviations, the basis of calculation of both standards is the same.

In addition to deviations from national standards, differences within the Eurocodes occur when used in different countries. The main text, however, remains the same; national changes are supplemented in the so-called annexes in the form of Nationally Determined Parameters (NDP) and non-contradictory complementary information (NCI) and can, therefore, be easily compared. NDPs are parameters that were left open in the Eurocodes for national decision. NCIs include guidelines on the use of the informative annexes and references to the use of the Eurocodes, to the extent that they complement but not contradict them. Table 12 provides a list of the changeable NDPs of the EC5 and their application in the countries Switzerland and Finland. In addition, possible NCIs are listed in Table 13.

Note: The purpose of the following tables is mainly to facilitate the development of a transnational course by pointing out the main differences of the national annexes. To evaluate the effect of these NDPs and NCIs on the design methods of wooden elements, they have to be examined in collaboration with the EN 1995-1-2 (This not part of this paper).

Table 12. Swiss and Finish Nationally Determined Parameters (SN EN 1995-1-2/NA:2014 de/2014) (Ministry of the Environment / 2016, p.21-23)

Clauses of EN 1995-1-2	Recommendation	National Annex		Reason for decision
2.1.3 (2) Maximum temperature rise for separating function in parametric fire exposure	The recommended values for maximum temperature rise during the decay phase are $\triangle\theta_1$=200 K and $\triangle\theta_2$=240 K	CH	Rec. Value applies	Values are based on requirements, that are applied in Sweden since 1975 without problems. Also limited relevance.
		FIN	no values are given for $\triangle\theta_1$ and $\triangle\theta_2$	The requirement for the separation function is only based on a standard fire and on temperature limits set by it. The fire safety requirement is also deemed to be satisfied if the building is designed and executed based on design fire scenarios which cover the situations likely to occur in the said building.
2.3 (1)P Partial factor for material properties	The recommended partial safety factor for material properties in fire is $\gamma_{M,fi}$ = 1,0 used for calculation of design values of strength and stiffness properties	CH	Rec. Value applies	Consistent with standard SIA 265:2012, clause 4.5.1.1
		FIN	Rec. Value applies	/
2.3 (2)P Partial factor for material properties	The recommended partial safety factor for material properties in fire is $\gamma_{M,fi}$ = 1,0 Used for calculation of design value of load-bearing capacity	CH	Rec. Value applies	Consistent with standard SIA 265:2012, clause 4.5.1.1
		FIN	Rec. Value applies	/
2.4.2 (3) Reduction factor for combination of actions	The recommended value is η_{fi} = 0,6 except for imposed loads according to category E given in EN 1991-2-1 where the recommended value is η_{fi} = 0,7	CH	For category A and B η_{fi} = 0,6	Consistent with standard SIA 265:2012, clause 4.5.1.1; for other categories η_{fi} is to be calculated acc. to equ. (2.9) of the SN EN 1995-1-2
		FIN	Table given in Annex 8 applies. No approximate value given	Consideration of partial factors from standard SFS-EN 1990 and the Ministry of Environment Decree 3/16 in determination of reduction factor
4.2.1 (1) Method for determining cross-sectional properties	The recommended procedure is the reduced cross-section method	CH	Rec. procedure applies	Consistent with standard SIA 265:2012, clause 4.5.2.2
		FIN	Rec. procedure applies	/
3.4.3.1 (1) Surfaces of beams and columns initially protected from fire exposure (not marked as NDP in EN 1995-1-2)	Other available fire protection coverings available include intumescent coatings and impregnation	CH	intumescent coatings and impregnation not allowed	no sufficient experience as fire protection covering
		FIN	/	/

Table 13. Swiss and Finish Non-Contradictory Complementary Information (SN EN 1995-1-2/NA:2014 de/2014) (Ministry of the Environment / 2016, p.21-23)

Clauses of EN 1995-1-2		National Annex
Foreword Additional information specific to EN 1995-1-2	CH	For the application of SN EN 1995-1-2, the Lignum documentation Fire Protection 2 "Building with wood - Quality assurance and fire protection", in addition to the quality assurance measures of the fire protection regulations, must be used in consultation with the responsible fire protection authority
	FIN	/
1.2 Normative References	CH	Technical guidelines and recommendations: - Lignum documentation Fire Protection 2 "Building with wood - Quality assurance and fire protection" - Lignum documentation Fire Protection 3 "Fire Resistance Dimensioning - Components and Connections"
	FIN	/
7.1.2 Detailing of Panel connections	CH	For the execution of plate connections, the rules for the design at normal temperatures apply in principle
	FIN	/
Annex A Parametric fire exposure	CH	Annex A may be used
	FIN	Annex A may be used
Annex B Advanced calculation methods	CH	Annex B may be used
	FIN	Annex B may be used
Annex C Load-bearing floor joists and wall studs in assemblies whose cavities are completely filled with insulation	CH	Annex C must not be used; The design method given in the Lignum documentation Fire Protection 3 "Fire Resistance Dimensioning - Components and Connections" is more comprehensive and may be used
	FIN	Annex C must not be used; Instead the document NCCI 1 for standard SFS-EN 1995-1-2: Load-bearing floor joists and wall studs in assemblies whose cavities are completely filled with insulation
Annex D Charring of members in wall and floor assemblies with void cavities	CH	Annex D must not be used; The design method given in the Lignum documentation Fire Protection 3 "Fire Resistance Dimensioning - Components and Connections" is more comprehensive and may be used
	FIN	Annex D must not be used; Instead the document NCCI 2 for standard SFS-EN 1995-1-2 "Charring of members in wall and floor assemblies with void cavities" may be used
Annex E Analysis of the separating function of wall and floor assemblies	CH	Annex E must not be used; The design method given in the Lignum documentation Fire Protection 3 "Fire Resistance Dimensioning - Components and Connections" is based on numerous experiments and numerical research, it is more reliable and may be used
	FIN	Annex E may only be used for the analysis of wall structures
Annex F Guidance for users of this Eurocode Part	CH	/
	FIN	Reduced cross-section method is chosen as design procedure for mechanical resistance in the flow chart F.1 of Informative Annex F

The comparison of the NDPs and NCIs of Switzerland and Finland shows many similarities. Many of the values and annexes recommended in the Eurocode have been incorporated in both national annexes. The deviation from the recommendations in both versions mainly concerns the same points. It is particularly striking that the reasons given for the deviations are also generally. For example, in both versions of the national annex, comments are made on the moderate relevance of the maximum temperature rise values given in EN 1995-1-2, point 2.1.3 (2). Furthermore, both appendices reject the application of Annexes C and D because of their incompleteness and instead point to alternative calculation methods.

Differences between parameters in the national annexes can only be found in small numbers (e.g. EN 1995-1-2, paragraph 2.42). In addition, differences occur in points that have been treated only in one of the two annexes (e.g. EN 1995-1-2, section 7.1.2).

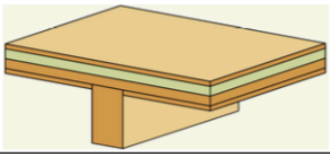
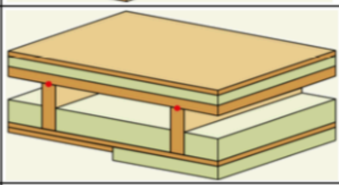
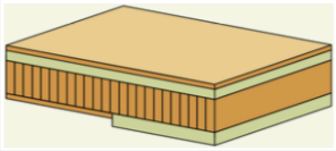
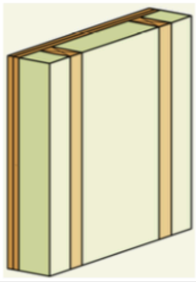
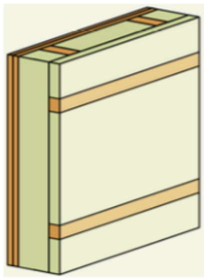
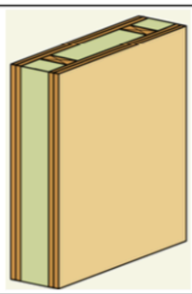
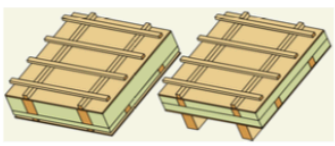
Besides the similarities in the National Annexes, another important realization became clear in the tables. For a large number of NDPs and NCIs in the Swiss annex, reference is made to the LIGNUM fire protection documentation. As previously stated, these state-of-the-art papers have already been referenced to in the SIA Standard 265. This statement again underlines the fundamental accordance between the text of the SIA-Norm 265 and the text of the EN 1995-1-2. Since the LIGNUM fire protection documentation was created on the basis of the VKF fire protection regulations, its application in the national and international standards once again illustrates the role of the VKF 2015 as the authoritative regulation for Swiss fire protection in timber construction.

7 REALISATION OF THE VKF REGULATIONS IN BUILDING ELEMENTS

The final chapter of this research provides examples of the application of the Swiss fire regulations to some of the main building materials. The given collection of building elements comprises ceilings, walls, and roofs. For each of those elements, an example will be given for the fire resistance class REI 30, 60, and 90; walls and ceilings will also be shown as a RF1 building element. The structural fire protection requirements and their implementation in the following building elements are based on the Swiss fire regulations VKF 2015 and the Lignum documentation Fire Protection 4.1 “Wooden Building Elements – Ceilings, Walls, and Cladding with Fire Resistance”. Alternative construction methods to the ones given below can be found in the publication of the design manual “Fire Protection in Timber Construction” by the Swiss rockwool manufacturer and distributor Flumroc. A link to their website will be provided in the references.

Before starting the listing of the different building elements some general remarks have to be made. For the presentation of the implementation options for the fire classes, only three to four examples will be shown in the following chapter. However, that does not imply that there are no other options besides those presented in the listing. These three to four element compositions are simply examples chosen from a far greater range of possible wooden building elements. Furthermore, a different kind of ceiling and wall construction was chosen for each fire resistance class. This, again, does not imply that one of the chosen elements cannot comply with all three fire classes. For a better understanding, the chosen elements, their possible fire classes, and the chosen fire classes (marked in orange) for this listing are presented in Table 14.

Table 14. Chosen building element with the according fire classes

Building Element		Fire Resistance Class		
		REI 30	REI 60	REI 90
Ceiling				
Beam ceiling		X	X	
Ribbed slab			X	X
Laminated timber ceiling		X	X	X
Walls				
One-sided planked construction with fire protection effective insulation (one layer)		X		
One-sided planked construction with fire protection effective insulation (two layers)		X	X	
Two-sided planked construction with fire protection effective insulation (one layer)		X	X	X
Roof				
Roof		X (EI)		

The data given in the following listings are the minimal dimensions required to achieve the according fire resistance classes. Therefore, the tables must not replace any verifications concerning structural safety for normal temperatures, sound insulation, heat insulation, moisture protection, etc. Furthermore, the listings only provide examples for the elements themselves. When using adhesives for the production of the timber elements, their bearing capacity during the required fire duration and the expected temperature has to be guaranteed. The connection between the building elements must comply with the same fire resistance as the elements themselves.

7.1 **Ceiling**

The following examples show the composition of ceilings in four different fire classes. As stated before, this composition is constructed to meet the fire safety requirements. Changes due to sound, heat and moisture insulation might have to be made.

7.1.1 REI 30 – Beam Ceiling

A ceiling of the fire class REI 30 can be achieved by a beam ceiling. A beam ceiling comprises the layers shown in Figure 3. However, not all of those layers are necessary to create the fire safety class REI 30. The example shows one out of many options as of how this ceiling could be constructed. The maximum distance between the beams must be no greater than 700mm. The maximum live load qk for which this ceiling is designed is 3.0 kN/m2. Different materials as the ones provided in the example may be used; the thickness of the layers might vary accordingly.

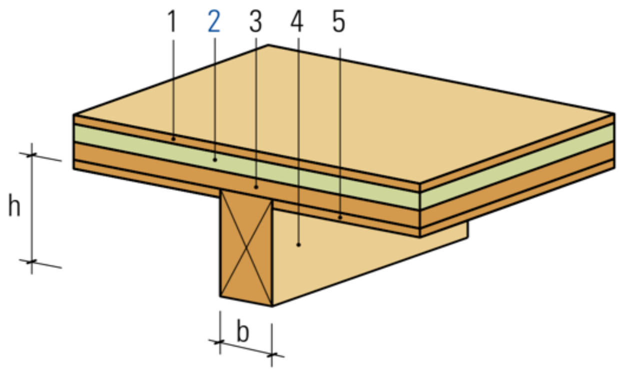


Figure 3. Composition of a beam ceiling (Flumroc/ 2018, p.24)

1. Plating 12mm (chipboard)
2. Impact sound insulation (not necessary)
3. Bearing layer 40mm (solid wood plate)
4. Beam work 120x200mm (solid wood)
5. Lower cladding (not necessary)

7.1.2 REI 60 – Ribbed Slab

A ceiling of the fire class REI 60 can be achieved by a ribbed slab. A ribbed slab comprises the layers shown in Figure 4. However, not all of those layers are necessary to create the fire safety class REI 60. The example shows one out of many options as of how this ceiling could be constructed. The maximum distance between the ribs must be no greater than 700mm. The maximum live load qk for which this ceiling is designed is 3.0 kN/m2. Different materials as the ones provided in the example may be used; the thickness of the layers might vary accordingly.

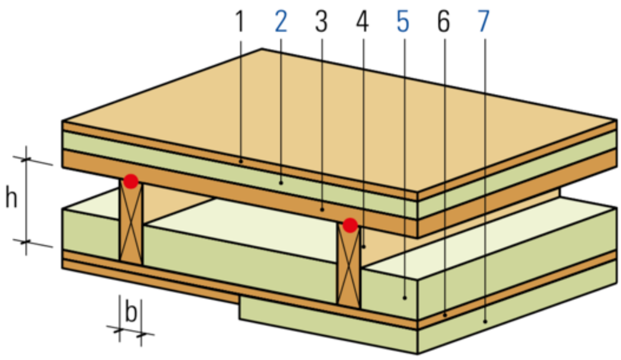


Figure 4. Composition of a ribbed slab (Flumroc/ 2018, p.29)

1. Plating 20mm (solid wood plate)
2. Impact sound insulation (not necessary)
3. Bearing layer 48mm (solid wood plate)
4. Rib 60x140mm (solid wood)
5. Cavity insulation140mm (mineral wool)
6. lower cladding 19mm (chipboard)
7. Ceiling covering/insulation 19mm (chipboard)

7.1.3 REI 90 – Laminated Timber Ceiling

A ceiling of the fire class REI 90 can be achieved by a laminated timber ceiling. A ribbed slab comprises the layers shown in Figure 5. However, not all of those layers are necessary to create the fire safety class REI 90. Different materials as the ones provided in the example may be used in layer four (insulation with a thickness of 50-80mm instead of fire protection board).

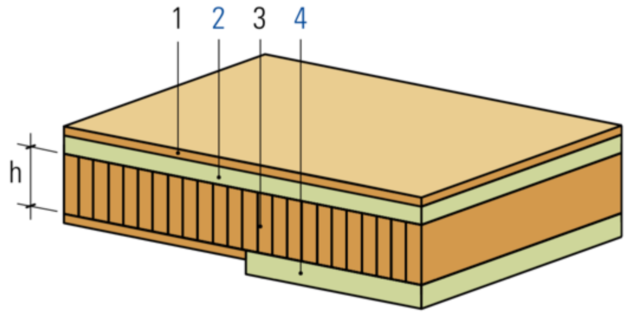


Figure 5. Composition of a Laminated timber ceiling (Flumroc/ 2018, p.34)

1. Plating (fire protection board BSP 30)
2. Impact sound insulation (not necessary)
3. Supporting structure 160mm (laminated timber)
4. Lower cladding/insulation (fire protection board BSP 30)

7.1.4 REI 60-RF1 – Beam Ceiling

A ceiling of the fire class REI 60-RF1 can be achieved by a beam ceiling. A beam ceiling comprises the layers shown in Figure 6. However, not all of those layers are necessary to create the fire safety class REI 60-RF1. The example shows one out of many options as of how this ceiling could be constructed. The maximum distance between the beams must be no greater than 700mm. The maximum live load qk for which this ceiling is designed is 3.0 kN/m2. All cavities must be filled with RF1 building material. Different materials as the ones provided in the example may be used; the thickness of the layers might vary accordingly.

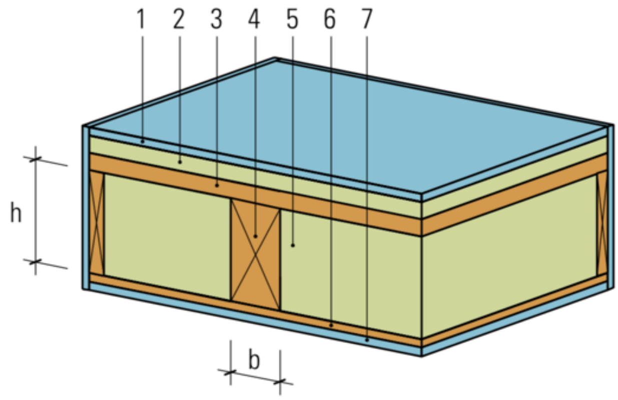


Figure 6. Composition of a beam ceiling RF1 (Flumroc/ 2018, p.68)

1. Fire protection plating (K30-RF1)
2. Impact sound insulation (not necessary)
3. Bearing Layer 38mm (solid wood plate)
4. Beam work 120x200mm (solid wood)
5. Cavity insulation 200mm (mineral wool)

6. Lower cladding 25mm (solid wood)
7. Fire protection covering (K30-RF1)

7.2 **Walls**

The following examples show the composition of ceilings in four different fire classes. As stated before, this composition is constructed to meet the fire safety requirements. Changes due to sound, heat and moisture insulation might have to be made.

7.2.1 REI 30 – One-sided Planked Construction (one layer insulation)

A wall of the fire class REI 30 can be achieved by a one-sided planked construction with a single layer of insulation. A one-sided planked construction comprises the layers shown in Figure 7. The maximum distance between the vertical stands must be no greater than 700mm. The maximum live load qd,fi for which this wall is designed is 20 kN/m, while the maximum height is three meters. Different materials as the ones provided in the example may be used; the thickness of the layers might vary accordingly.

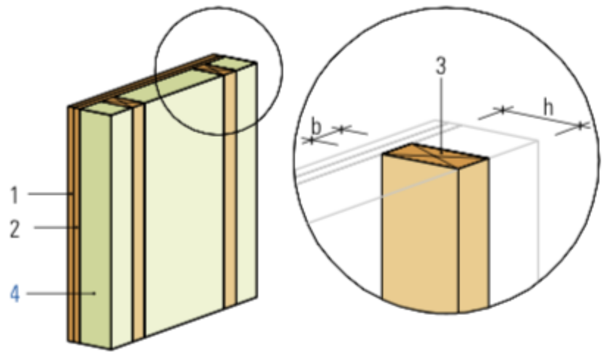


Figure 7. Composition of a one-sided planked construction (Flumroc/ 2018, p.38)

1. Paneling 1 20mm (solid wood plate)
2. Paneling 2 15mm (solid wood plate)
3. Timber Frame 60x160mm (solid wood)
4. Insulation 120mm (mineral wool)

7.2.2 REI 60 – One-sided Planked Construction (two layers insulation)

A wall of the fire class REI 60 can be achieved by a one-sided planked construction with two layers of insulation. A one-sided planked construction comprises the layers shown in Figure 8. The maximum distance between the vertical stands must be no greater than 700mm. The maximum live load qd,fi for which this wall is designed is 50 kN/m, while the maximum height is three meters. Different materials as the ones provided in the example may be used; the thickness of the layers might vary accordingly.

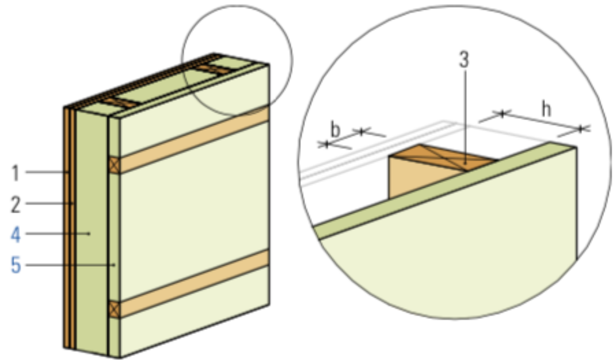


Figure 8. Composition of a one-sided planked construction (Flumroc/ 2018, p.42)

1. Paneling 1 35mm (solid wood plating)
2. Paneling 2 35mm (solid wood plating)
3. Timber frame 75x165mm (solid wood)
4. Insulation 1 100mm (mineral wool)
5. Insulation 2 80mm (Flumroc-DPL 1)

7.2.3 REI 90 – Two-sided Planked Construction (one layer insulation)

A wall of the fire class REI 90 can be achieved by a two-sided planked construction with one layer of insulation. A two-sided planked construction comprises the layers shown in Figure 9. The maximum distance between the vertical stands must be no greater than 700mm. The maximum live load qd,fi for which this wall is designed is 50 kN/m, while the maximum height is three meters. Different materials as the ones provided in the example may be used; the thickness of the layers might vary accordingly.

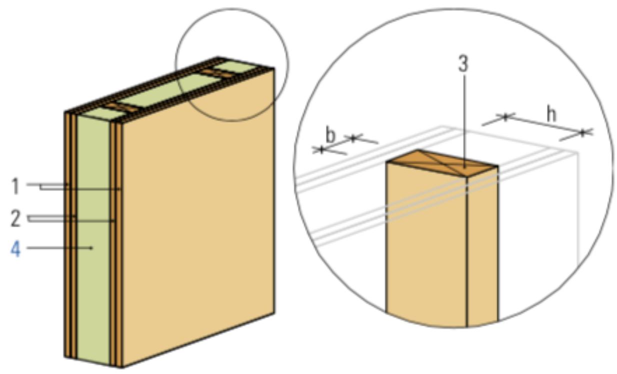


Figure 9. Composition of a two-sided planked construction (Flumroc/ 2018, p.47)

1. Paneling 1 27mm (solid wood plating)

2. Paneling 2 27mm (solid wood plating)
3. Timber frame 60x180mm (solid wood)
4. Cavity insulation 180mm (mineral wool)

7.2.4 REI 60-RF1 – Two-sided Planked Construction (one layer insulation)

A wall of the fire class REI 60-RF1 can be achieved by a two-sided planked construction with one layer of insulation. A two-sided planked construction comprises the layers shown in Figure 10. The maximum distance between the vertical stands must be no greater than 700mm. The maximum live load qd,fi for which this wall is designed is 50 kN/m, while the maximum height is three meters. Different materials as the ones provided in the example may be used; the thickness of the layers might vary accordingly. The cavities have to be filled with insulation material of class RF1.

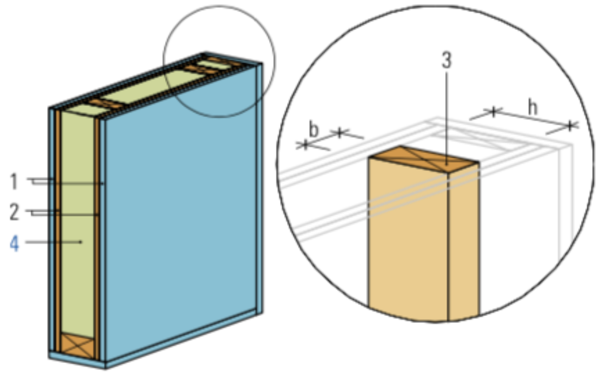


Figure 10. Composition of a two-sided planked construction RF1 (Flumroc/ 2018, p.75)

1. Fire protection plating (K 30-RF1)
2. Paneling 18mm (solid wood)
3. Timber framing 105x140mm (solid wood)
4. Cavity insulation 140mm (mineral wool)

7.3 **Roof**

The following example shows the composition of a roof in the fire class EI 30. As stated before, this composition is constructed to meet the fire safety requirements. Changes due to sound, heat and moisture insulation might have to be made

7.3.1 EI 30 – Roof

A roof of the fire class EI 30 comprises the layers shown in Figure 3. However, not all of those layers are necessary to create the fire safety class EI 30. The example shows one out of many options as of how this roof could be constructed. Different materials as the ones provided in the example may be used; the thickness of the layers might vary accordingly.

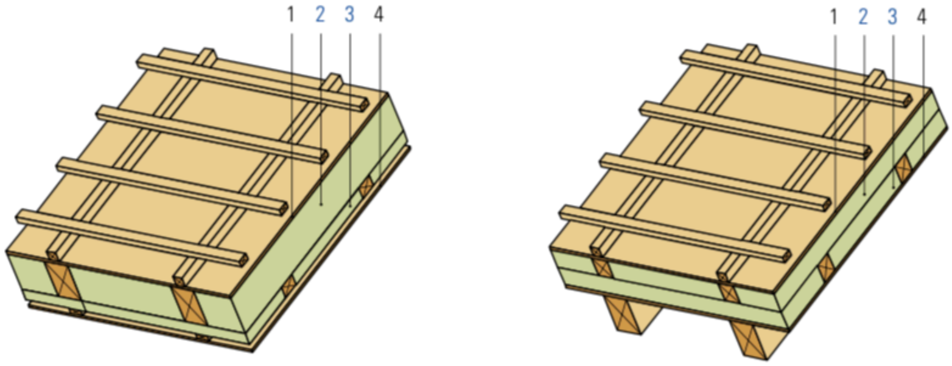


Figure 11. Composition of a roof structure (Flumroc/ 2018, p.59)

1. Roof deck 15mm (solid wood)
2. Insulation 1 60mm (Flumroc-DPL PARA)
3. Insulation 2 60mm (Flumroc-DPL PARA)
4. Interior Lining (not necessary)

8 CONCLUSION

“The European Public Wood project aims to achieve a trans-disciplinary and trans-national course for HEIs on sustainable public wooden buildings, including design, construction, and management.”

The idea of having one uniform course on wooden buildings in Europe seems splendid. The actual implementation of such a course, however, seems rather unrealistic.

The conducted research showed that even though Switzerland and Finland could be considered equally advanced countries in terms of construction, there are still some differences in regulations, calculation parameters, and wood application possibilities. It is easy to imagine that the differences to relatively less advanced countries are even greater. Does this mean that the implementation of a trans-national course is impossible? The answer is no. A development of a course on a European level is possible if national differences as those discovered in the research are considered.

One possible approach could be the creation of a course based on the model of the Eurocodes. To be able to achieve such a course, the research on all partner countries would have to be compared. Based on this comparison, a uniform base course would have to be created considering all the calculations and regulations that are similar in the partner countries. Differences between the countries would be left open for national choice; this would be similar to the NDPs and NCLs of the Eurocode. Recommendations could be made on differing points. However, the ultimate implementation would be done by HEIs themselves according to the national conditions.

The most important aspect for Switzerland that was discovered in the previous research and should be considered in the transnational course, is that the regulations formulate the requirements for the fire resistance for fire compartments and structures regardless of the building material. Wood can, therefore, be used for all relevant building elements in buildings of small and medium height as long as the fire resistance is fulfilled. Limitations can be found in high-rise buildings, staircases or accommodation facilities. Nevertheless, the research has shown that the application of wood in those sections is possible with the use of some precautions.

9 REFERENCES

848/2017 Decree of the Ministry of Environment on Fire safety of Buildings. (2018). National Building Code of Finland. Helsinki: Ministry of the Environment

Albert A. (2014). Bautabellen für Ingenieure mit Berechnungshinweisen und Beispielen. Köln: Bundesanzeiger Verlag

Cheret P. & Seidel A. (2013). *Kapitel 1: Der neue Holzbau*. Retrieved 31 March 2019 from: https://informationsdienst-holz.de/urbaner-holzbau/kapitel-1-der-neue-holzbau/

Flumroc. (2018). *Panungshandbuch: Brandschutz im Holzbau*. Retrieved 20 April 2019 from: https://www.flumroc.ch/adl/anwendungen/brandschutz/d-downloads/brandschutz-im-holzbau/d-c/Download/d-a/download/

Holzbau Schweiz. (n.d.). *Ökologie*. Retrieved 29 March 2019 from: https://www.holzbau-schweiz.ch/de/bauen-mit-holz/baustoff-holz/oekologie/

Hürlimann K. (n.d.). *Holzwirtschaft*. Retrieved 31 March 2019 from: http://mobile.hls-dhs-dss.ch/m.php?article=D14025.php

Lehne J. & Preston F. (2018). *Making Concrete Change: Innovation in Low-carbon Cement and Concrete*. Retrieved 29 March 2019 from: https://reader.chathamhouse.org/making-concrete-change-innovation-low-carbon-cement-and-concrete#

Lignum. (n.d.). *Portät*. Retrieved 01 April 2019 from: https://www.lignum.ch/organisation/portraet/

Ministry of the Environment. (2016). *Strength and stability of structures*. Retrieved 17 April 2019 from: https://www.ym.fi/download/noname/%7B1E3E4CEB-D73B-4EB7-9842-41D47651DE53%7D/134890

Oxford University Press. (n.d.). Definition of *public building in English*. Retrieved 08.04.2019 from: https://en.oxforddictionaries.com/definition/public_building

Porteus J. & Kermani A. (2006). *Structural Timber Design to Eurocode 5.* Oxford: Backwell Publishing

Ritchie H. & Roser M. (2019). *CO_2 and other Greenhouse Gas Emissions*. Retrieved 29 March 2019 from:
https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

SN EN 1995-1-1:2004 D. (2005). Eurocode 5 Teil 1-1: Bemessung und Konstruktion von Holzbauten – Teil 1-1: Allgemeine Regeln und Regeln für den Hochbau. Zürich: Schweizerischer Ingenieur und Architektenverein.

SN EN 1995-1-2/NA:2014 de. (2014). Eurocode 5 Teil 1-2: Bemessung und Konstruktion von Holzbauten – Teil 1-2: Allgemeine Regeln – Tragwerksbemessung für den Brandfall – Nationaler Anhang NA zu SN EN 1995-1-2:2004

Swiss Confederation. (2017). *Schwerpunkte Aktionsplan Holz*. Retrieved 01 April 2019 from:
https://www.bafu.admin.ch/bafu/de/home/themen/wald/fachinformationen/strategien-und-massnahmen-des-bundes/aktionsplan-holz/schwerpunkte-aktionsplan-holz.html

Swiss Confederation. (2018). *The FOEN in brief*. Retrieved 01 April 2019 from:
https://www.bafu.admin.ch/bafu/en/home/office/the-foen-in-brief.html

Swiss Society of Engineers and Architects. (n.d.a). *Der SIA*. Retrieved 02 April 2019 from:
http://www.sia.ch/en/the-sia/

Swiss Society of Engineers and Architects. (n.d.b). *Der SIA*. Retrieved 03 April 2019 from:
http://www.sia.ch/de/dienstleistungen/sianorm/normenwerk/normenarten/

VKF-BSA. (2015). Brandschutzarbeitshilfe. Allgemein Anerkannte Bauprodukte. Bern: Verein Kantonaler Feuerversicherungen VKF

VKF-BSN 1-15 (2015). Brandschutznorm. Bern: Verein Kantonaler Feuerversicherungen VKF

VKF-BSR 11-15 (2015). Brandschutzrichtlinie – Qualitätssicherung im Brandschutz. Bern: Verein Kantonaler Feuerversicherungen VKF

VKF-BSR 13-15 (2015). Brandschutzrichtlinie – Baustoffe und Bauteile. Bern: Verein Kantonaler Feuerversicherungen VKF

VKF-BSR 14-15 (2015). Brandschutzrichtlinie – Verwendung von Baustoffen. Bern: Verein Kantonaler Feuerversicherungen VKF

VKF-BSR 15-15 (2015). Brandschutzrichtlinie – Brandschutzabstände Tragwerke Brandabschnitte. Bern: Verein Kantonaler Feuerversicherungen VKF

VKF-BSR 16-15 (2015). Brandschutzrichtlinie – Flucht- und Rettungswege. Bern: Verein Kantonaler Feuerversicherungen VKF

VKF-BSE 100-15 (2015). Brandschutzerläuterung – Brandmauern. Bern: Verein Kantonaler Feuerversicherungen VKF

Wood Solutions. (n.d.). *Plywood*. Retrieved 29 March 2019 from: https://www.woodsolutions.com.au/wood-product-categories/plywood

Wood Solutions. (n.d.a.). *Glulam*. Retrieved 29 March 2019 from: https://www.woodsolutions.com.au/wood-product-categories/glulam

Wood Solutions. (n.d.b.). *Cross Laminated Timber (CLT)*. Retrieved 29 March 2019 from: https://www.woodsolutions.com.au/wood-product-categories/Cross-Laminated-Timber-CLT

Wood Solutions. (n.d.c.). *Laminated Veneer Lumber (LVL)*. Retrieved 29 March 2019 from: https://www.woodsolutions.com.au/wood-product-categories/laminated-veneer-lumber-lvl

World Steel Association. (n.d.). *Steel's Contribution to a low Carbon Future*. Retrieved 29 March 2019 from: https://www.worldsteel.org/en/dam/jcr:7ec64bc1-c51c-439b-84b8-94496686b8c6/Position_paper_climate_2019_vfinal.pdf

Appendix 1

REQUIREMENTS FOR SPECIFIC USE AND TYPES OF BUIDINGS – LOW RISE BUILDINGS (VKF-BSR 15-15/2015, p. 11)

Building height category		**Buildings of small height (≤11m)**			
Use	**Concept**	**Bearing stucure** [1]	**fire compartment building ceiling**	**fire compartment building walls and horizontal escape routes**	**vertical escape routes**
Living **Office** **School** **Sales areas** (fire compartement area ≤ 1200m² and person occupancy ≤ 300 persons) **Praking** [3] **Industry and commerce with q ≤ 1000 MJ/m²** **Agriculture**	**Structural**	R 30 [5]	REI 30 [5]	EI 30	REI 30
	Sprinkler system	k.A.	EI 30	EI 30	REI 30
Industry and commerce with q > 1000 MJ/m²	**Structural**	R 60 [5]	REI 60 [5]	EI 60 [2][5]	REI 60
	Sprinkler system	R 30 [5]	REI 30 [5]	EI 30	REI 60
Accomodation facility [a] e.g. Hospitals e.g. Retirement and nursing homes	**Structural**	R 60	REI 60	EI 60	REI 60
	Sprinkler system	R 30	REI 30	EI 30	REI 60
Accomodation facility [b] e.g. Hotels **Remote accomodation facility** [c][5] e.g. Mountain Cabin **Rooms with high person occupancy** **Sales Offices**	**Structural**	R 60	REI 60	EI 30	REI 60
	Sprinkler system [4]	R 30	REI 30	EI 30	REI 60

k. A.: There are no requirements for the fire resistance of structural components.

[1] For single-story buildings and on the top floor of multi-story buildings, there is no requirement to the fire resistance of load-bearing components.

[2] For single-story buildings and on the top floor of multi-story buildings, the fire resistance of fire compartment forming walls can be reduced to 30 minutes.

[3] If the enclosing walls have at least 25% non-closable openings, the following minimum requirements shall apply to components that conform to RF1 constructions:

- no requirements for the fire resistance of load-bearing components in areas not exceeding 35 m from a non-closable opening.

[4] For accommodation establishments, the installation of a fire alarm system can be dispensed with.

[5] For two-story buildings with a total floor area over terrain of a maximum of 2'400 m² applies:

- the fire resistance can be reduced by 30 minutes. In the case of floor slabs with fire resistance REI 30, the fire resistance can only be reduced to EI 30;
- for accommodations [c] the fire resistance can generally be reduced by 30 minutes.

Appendix 2

REQUIREMENTS FOR SPECIFIC USE AND TYPES OF BUIDINGS – MEDIUM RISE BUILDINGS (VKF-BSR 15-15/2015, p.12)

Building height category		**Buildings of medium height (≤30m)** [7]			
Use	**Concept**	**Bearing stucure** [1]	**fire compartment building ceiling**	**fire compartment building walls and horizontal escape routes**	**vertical escape routes**
Living **Office** **School** **Sales areas** (fire compartement area ≤ 1200m² and person occupancy ≤ 300 persons) **Praking** [6] **Industry and commerce with q ≤ 1000 MJ/m²** **Agriculture**	**Structural**	R 60	REI 60	EI 30	REI 60
	Sprinkler system	R 30	REI 30	EI 30	REI 60
Industry and commerce with q > 1000 MJ/m²	**Structural**	R 90	REI 90	EI 60 [2]	REI 90
	Sprinkler system	R 60	REI 60	EI 30	REI 60
Accomodation facility [a] e.g. Hospitals e.g. Retirement and nursing homes	**Structural**	R 60	REI 60	EI 60	REI 60
	Sprinkler system	R 30	REI 30	EI 30	REI 60
Accomodation facility [b] e.g. Hotels **Remote accomodation facility** [c] e.g. Mountain Cabin **Rooms with high person occupancy** **Sales Offices**	**Structural**	R 60	REI 60	EI 30	REI 60
	Sprinkler system	R 30	REI 30	EI 30	REI 60

[1] For single-story buildings and on the top floor of multi-story buildings, there is no requirement for the fire resistance of structural components.
[2] For single-story buildings and on the top floor of multi-story buildings, the fire resistance of fire compartment forming walls can be reduced to 30 minutes.
[6] If the enclosing walls have at least 25% non-closable openings, the following minimum requirements shall apply to components that conform to RF1 constructions:

- structure R 30;
- fire compartment forming components EI 30 (except fire section staircase);
- no requirements for the fire resistance of load-bearing components in areas not exceeding 35 m from a non-closable opening.

[7] In the case of two-story buildings with a total height of more than 11 m and a ground floor level of a maximum of 8 m, the requirements for buildings of low height apply to the load-bearing and fire section-forming components

Appendix 3

REQUIREMENTS FOR SPECIFIC USE AND TYPES OF BUIDINGS – HIGH RISE BUILDINGS (VKF-BSR 15-15/2015, p. 13)

Building height category		**High rise buildings (≤100m)**			
Use	**Concept**	**Bearing stucure** [8][9]	**fire compartment building ceiling**	**fire compartment building walls and horizontal escape routes**	**vertical escape routes**
Living **Office** **School** **Sales areas** (fire compartement area ≤ 1200m^2 and person occupancy ≤ 300 persons) **Praking** **Industry and commerce with q ≤ 1000 MJ/m^2**	**Structural**	R 90	REI 90	EI 60	REI 90
	Sprinkler system	R 60	REI 60	EI 30	REI 90
Industry and commerce with q > 1000 MJ/m^2	**Structural**	R 120	REI 120	EI 90	REI 120
	Sprinkler system	R 90	REI 90	EI 60	REI 90
Accomodation facility [a] e.g. Hospitals e.g. Retirement and nursing homes	**Structural**	R 90	REI 90	EI 60	REI 90
	Sprinkler system	R 60	REI 60	EI 30	REI 90
Accomodation facility [b] e.g. Hotels **Rooms with high person occupancy** **Sales Offices**	**Structural**	R 90	REI 90	EI 60	REI 90
	Sprinkler system	R 60	REI 60	EI 30	REI 90

[8] The fire resistance of load-bearing components on the top floor can be reduced by 30 minutes.
[9] In the case of single-story buildings (e.g. high-bay warehouses, halls), there is no requirement for the fire resistance of load-bearing components.

Appendix 4

CLASS REQUIREMENTS FOR LOAD-BEARING STRUCTURES IN P1 AND P2 FIRE CLASS BUILDINGS (848/2017 Decree of the Ministry of Environment on Fire safety of Buildings/2018, p.8)

Building	**Building's fire class and fire load categories MJ/m²**			
	P1			**P2**
	more than 1,200	**600-1,200**	**less than 600**	**-**
one- or two-storey building, general	R 120 (R60 *)	R 90 (R60 *)	R 60	R 30
- institutions, accommodation premises	R 120, A2 (R60 *, A2)	R 90, A2 (R60 *, A2)	R 60, A2	R 30
- uppermost basement storey	R 120, A2 (R90 *, A2)	R 90, A2 (R60 *, A2)	R 60, A2	R 60, A2
- uppermost floor in a building where there is no attic and the structure is an essential part of the structural body [1]	R 60	R 60	R 60	R 30
- single-storey production and storage building	R 60 (R30 *) (R15, A2 *)	R 60 (R30 *) (R15, A2 *)	R 60 (R30 *) (R15, A2 *)	R 30 (R15 *) (R15, A2)
- uppermost floor in a building where there is no attic and the structure is not an essential part of the structural body [1]	R 15	R 15	R 15	R 15
Building of over two storeys with a height not exceeding 28 m, general	R 180, A2 (R90 *, A2)	R 120, A2 (R60 *, A2)	R 60, A2	R 60 * # [3,4]
- uppermost basement storey	R 180, A2 (R90 *, A2)	R 120, A2 (R60 *, A2)	R 60, A2	R 60 * A2
- residential building, dwelling, uppermost storey	R 60 +	R 60 +	R 60 +	R 60 * # [3]
- residential building, dwelling, two uppermost storeys [2]	R60 * #	R60 * #	R60 * #	R 60 * # [3]
- a residential building of more than two storeys, with a height not exceeding 14 m and where all the storeys of each housing unit belong to one and the same apartment	R 45, A2 (R30, A2 *)	R 45, A2 (R30, A2 *)	R 45, A2 (R30, A2 *)	R 45 # (R30 * #)
Building of over two storeys with a height greater than 28 m but not exceeding 56 m	R 240, A2 (R180 *, A2)	R 180, A2 (R120 *, A2)	R 120, A2 (R90 *, A2)	not possible
Building of over two storeys with a height exceeding 56 m	R180 *, A2	R120*, A2	R 120 *, A2	not possible
Basement storeys below uppermost basement storey	R 240, A2 (R180 *, A2)	R 180, A2 (R120 *, A2)	R 120, A2	R 120, A2 (R90 *, A2)

The fire resistance time requirement for balconies is half that of the load-bearing structures of the storey.

Load-bearing structures must be made of building materials of at least class D-s2, d2, unless otherwise stated in the table. The class requirement for the flight of stairs and staircase landing of an exit is R 30. The class requirement for the flight of stairs and staircase landing of the exit of a basement storey below the uppermost basement storey is R 60. If class requirement A2-s1, d0 is prescribed for load-bearing structures, this also applies to flights of stairs and staircase landings. Flights of stairs and staircase landings of the exit of a building of over two storeys and P1 fire class must be made of at least A2-s1, d0-class building materials.

No fire resistance requirements are prescribed for roof structures of an attic or void that are not essential load-bearing structures of the building's structural body or structures that brace the structural body in a fire.

1) Essential parts of the structural body' are the main trusses, the secondary trusses that brace the structural body and the stiffeners for the uppermost floor, and other such individual structures that act to preserve the stability of the uppermost floor, plus the connections between them.

2) When the three uppermost storeys, excluding the exit, are provided with an automatic fire-extinguishing system that is suitable for its purpose.

3) NB the requirements laid down in section 24, subsection 3.

4) If the fire load category according to use is 600–1,200 MJ/m², the class requirement will be R 90 * # [3]

*	The building is provided with an automatic fire-extinguishing system that is suitable for its purpose.
#	Thermal insulation products and other fillings must be at least A2-s1, d0-class.
+	The essential insulating part of thermal insulation products and other fillings must be at least D-s2, d2-class.
A2	Load-bearing structures must be made at least A2-s1, d0-class.

Appendix 5

CLASS REQUIREMENTS FOR FIRE-SEPARATING BUILDING ELEMENTS (848/2017 Decree of the Ministry of Environment on Fire safety of Buildings/2018, p.12)

	Building's fire class and number of storeys, and fire load category MJ/m²					
	P1			**P2 over two storeys**	**P2 one or two storeys**	**P3**
	more than 1,200	**600-1,200**	**less than 600**	**-**	**-**	**-**
Storeys, general	EI 120 [1] (EI 60 *) [1]	EI 90 [1] (EI 60 *) [1]	EI 60 [1]	EI 60 [2]	EI 30	EI 30
- building over 56 metres high	EI 90, A2 *	EI 60, A2 *	EI 60, A2 *	not possible	not possible	not possible
- uppermost floor, if a fire compartmentation requirement	EI 60	EI 60	EI 60	EI 60 [2]	EI 30	EI 30
- production and storage premises, fire hazard class 1, compartmentation by area	EI-M 90, A1 (EI-M 60, A1 *)	EI-M 90, A1 (EI-M 60, A1 *)	EI-M 90, A1 (EI-M 60, A1 *)	not possible	EI-M 90, A1 (EI-M 60, A1 *)	EI-M 90, A1 (EI-M 60, A1 *)
- production and storage premises, fire hazard class 2, compartmentation by area	EI-M 120, A1 (EI-M 60, A1 *)	EI-M 120, A1 (EI-M 60, A1 *)	EI-M 120, A1 (EI-M 60, A1 *)	not possible	EI-M 120, A1 (EI-M 60, A1 *)	EI-M 60, A1 *
- garages, compartmentation by area	EI 60, A2	EI 60, A2	EI 60, A2	not possible	EI 60	EI 30
Compartmenting walls of the attic, compartmentation by area	EI 30	EI 30	EI 30	EI 30	EI 30	EI 30
Basement storeys	EI 120, A2 (EI 90, A2 *)	EI 90, A2 (EI 60, A2 *)	EI 60, A2	EI 60, A2	EI 60, A2	EI 30, A2 [3]

[1] Fire-separating building elements of exits of a building of over two storeys and P1 fire class must be made of at least A2-s1, d0-class building materials.
[2] NB the requirements laid down in section 24, subsection 3.
[3] In a basement belonging to a single dwelling, the class requirement is EI 30.
A1 Building materials A1 class
A2 Building materials at least A2-s1, d0-class
* When the building or premises is provided with an automatic fire-extinguishing system that is suitable for its purpose.

Appendix 6

CLASS REQUIREMENTS FOR SURFACES OF EXTERNAL WALLS AND VENTILATION GAPS (848/2017 Decree of the Ministry of Environment on Fire safety of Buildings/2018, p.18)

Use and fire class	**External surface of external wall**	**External surface of ventilation gap**	**Internal surface of ventilation gap**	**Conditions for use of classes**
Building over 56 metres high	A2-s1, d0	A2-s1, d0	A2-s1, d0	
Building of P1 fire class and no more than 56 m in height, general	B-s1, d0	B-s1, d0	B-s1, d0	1)
Residential and office building no more than 28 m in height, general	B-s2, d0	B-s2, d0	B-s1, d0	6)
- residential building, when additional thermal insulation whose insulating part does not meet the B-s1, d0 requirement and whose thickness does not exceed 100 mm has been used in repair and alteration work	B-s2, d0	B-s2, d0	B-s1, d0	7)
- external surface part of external wall, if the structures surrounding that part protect the wall surface from the spread of fire	D-s2, d2	D-s2, d2	B-s1, d0	6)
- residential building, uppermost storey	D-s2, d2	D-s2, d2	A2-s1, d0	6) 4)
Residential and office building with a height exceeding 14 m but no more than 28 m	D-s2, d2 *	D-s2, d2 *	B-s1, d0 *	1) 2) 3) 4) 5)
Residential and office building of no more than 14 m in height	D-s2, d2	D-s2, d2	B-s1, d0	1) 2) 3) 4)
Production and storage building or assembly and business building of one or two storeys and no more than 28 m in height	D-s2, d2	D-s2, d2	B-s1, d0	3) 4) 5) 6) 8)
P2 fire class building				
Building of over two storeys and no more than 28 m in height, general	B-s2, d0 *	B-s2, d0 *	K_2 10, A2-s1, d0 *	
- residential, accommodation and office building, and assembly and business building	D-s2, d2 *	D-s2, d2 *	K_2 10, A2-s1, d0 *	2) 3) 4) 5)
Residential building of more than two storeys and no more than 14 m in height, whose basement and storeys of each housing unit belong to one and the same apartment	D-s2, d2	D-s2, d2	B-s1, d0	2) 3) 4)
Building of no more than two storeys, general	D-s2, d2	D-s2, d2	D-s2, d2	
- institutions	B-s2, d0 (D-s2, d2 *) 3)	B-s2, d0 (D-s2, d2 *) 3)	B-s1, d0	
P3 fire class building	D-s2, d2	D-s2, d2	no requirement	

Balconies shall comply with the requirements set for the outer surface of an exterior wall. However, the requirement for the surfaces (excluding floors) of a balcony designed for use as a fire escape of a building not exceeding 28 metres in height is B-s2, d0. By way of derogation from the above, the beams and columns of a balcony of a P2 fire class building of more than two storeys may be class D-s2, d2, if the balcony is provided with an automatic fire-extinguishing system that is suitable for its purpose. The requirements shall not apply to minor surfaces such as hand railings.

In the case of an open-access balcony, compliance shall be made with the requirements set for an exit. However, the walls and columns of the open-access balcony of a P2 fire class building of not more than two storeys may be class D-s2, d2. The beams and columns of an open-access balcony of a P2 fire class building of more than two storeys may be class D-s2, d2, if the access balcony is provided with an automatic fire-extinguishing system that is suitable for its purpose. The requirements shall not apply to minor surfaces such as hand railings.

The mounting accessories for the facade cladding may, to a small extent, be of class D-s2, d2 in a building with a height not exceeding 28 m.

1) If the insulating part of a thermal insulation product does not meet the B-s1, d0 requirements, the surface structures of the external surface must protect the thermal insulation product from fire in such a way that the protection corresponds to an EI 30 building element, or the inner surface of the ventilation gap must be fitted with K_2 30, A2-s1, d0 protective covering.

2) Apart from the first storey and the surfaces above and below the fire escapes, whose participation in a fire may jeopardise use of the fire escapes.

3) The spread of fire in a ventilation gap must be restricted at each storey, and the spread of fire in a horizontal direction to the ventilation gap in the external wall of a fire-compartmented staircase must be prevented.

4) The spread of fire from the facade into an attic and the uppermost floor must be restricted so that this corresponds to an EI 30-building element.

5) The collapse of extensive parts of the facade structure in the event of a fire must be restricted.

6) If the insulating part of a thermal insulation product does not meet the B-s1, d0 requirements, the surface structures of the external surface must protect the thermal insulation product from fire in such a way that the protection corresponds to an EI 15 building element, or the inner surface of the ventilation gap must be fitted with a $K_2$10, A2-s1, d0 protective covering.

7 The partitioning of thermal insulation products on each storey referred to in section 25 shall not be required if the requirements in comment 6) are met.

8) An external wall and its windows and other openings must meet the EI 30 requirement.

* The building is provided with an automatic fire-extinguishing system that is suitable for this purpose.

Appendix 7

CLASS REQUIREMENTS FOR INTERNAL SURFACES (848/2017 Decree of the Ministry of Environment on Fire safety of Buildings/2018, p.15)

Use	**Surface**	**Fire class of building**		
		P1	**P2**	**P3**
Dwellings	walls and roofs	D-s2, d2 [1]	D-s2, d2 [4]	D-s2, d2 [1]
Accommodation premises	walls and roofs	D-s2, d2	B-s1, d0 [4,2] (C-s2, d1 * [4,2])	D-s2, d2
Institutions	walls and roofs floors	B-s1, d0 D_{FL}-s1	B-s1, d0 [4] D_{FL}-s1	D-s2, d2 -
Assembly and business premises				
- fire compartment maximum 300 m²: restaurants, shops, schools, sports halls, theatres, churches, day-care centres and day-care institutions	walls and roofs	D-s2, d2	D-s2, d2 [4]	D-s2, d2
- fire compartment exceeding 300 m²: restaurants, schools, sports halls, theatres, churches, day-care centres and day-care institutions	walls and roofs	C-s2, d1 (D-s2, d2 *)	C-s2, d1 [4] (D-s2, d2 * [4])	D-s2, d2
- fire compartment exceeding 300 m²: shops, exhibition halls and libraries	walls and roofs floors	B-s1, d0 (C-s2, d1 *) D_{FL}-s1	B-s1, d0 [4] (C-s2, d1 * [4]) D_{FL}-s1	B-s1, d0 (C-s2, d1 *) -
Office premises	walls and roofs	D-s2, d2 [1]	B-s1, d0 [4,2] (D-s2, d2 * [4])	D-s2, d2 [1]
Production and storage premises				
- fire hazard class 1	walls roofs floors	D-s2, d2 D-s2, d2 D_{FL}-s1	D-s2, d2 [4] B-s1, d0 D_{FL}-s1	D-s2, d2 D-s2, d2 -
- fire hazard class 2	walls and roofs floors	B-s1, d0 $A2_{FL}$-s1	B-s1, d0 $A2_{FL}$-s1	B-s1, d0 $A2_{FL}$-s1
Car repair shops and service stations, garages	walls and roofs floors	B-s1, d0 $A2_{FL}$-s1	B-s1, d0 $A2_{FL}$-s1	B-s1, d0 [5] $A2_{FL}$-s1
Attics and uppermost floor voids				
- attics and voids in the uppermost floor that have been fire-compartmented from the premises below	inner surfaces of the attic or void	D-s2, d2 [1]	D-s2, d2 [1]	-
- An attic of a residential building, intended for storage of moveable property or for drying laundry	floors	D_{FL}-s1	D_{FL}-s1	D_{FL}-s1
- voids in the uppermost floor that have not been fire-compartmented from the premises below This requirement does not apply to a thermal insulation product's ventilation slots.	inner surfaces of void	B-s1, d0 [1]	B-s1, d0 [1]	-
Basements	walls and roofs floors	C-s2, d1 D_{FL}-s1	B-s1, d0 D_{FL}-s1	D-s2, d2 D_{FL}-s1
Technical servicing areas	walls and roofs floors	B-s1, d0 D_{FL}-s1	B-s1, d0 [4] D_{FL}-s1	B-s1, d0 D_{FL}-s1
Boiler rooms, feeder rooms and liquid fuel stores	walls and roofs floors	B-s1, d0 $A2_{FL}$-s1	B-s1, d0 [4] $A2_{FL}$-s1	B-s1, d0 $A2_{FL}$-s1
Solid fuel store	walls and roofs floors	B-s1, d0 $A2_{FL}$-s1	B-s1, d0 [4] $A2_{FL}$-s1	D-s2, d2 -
Exits and exit enclosures	walls and roofs floors	A2-s1, d0 [3] D_{FL}-s1	A2-s1, d0 [3] D_{FL}-s1	B-s1, d0 D_{FL}-s1
Internal corridors in accommodation and office premises	walls and roofs floors	B-s1, d0 D_{FL}-s1	B-s1, d0 [4] D_{FL}-s1	B-s1, d0 D_{FL}-s1
Saunas and bathroom areas	walls and roofs	D-s2, d2	D-s2, d2	D-s2, d2

The requirements in the table also apply to the surface of pipes and ventilation ducts or their insulating material, unless the number of these is insignificant. In the case of pipe-like insulating materials, the values of the table shall apply, with the subindex L added to the entry depicting fire participation for walls and roofs. The additional attributes regarding smoke production and flaming droplets remain unchanged.

1) Minor parts of the surfaces may be covered by building materials that do not meet the class.

2) Minor parts of wall surfaces may be covered by D-s2, d2-class building materials. This also applies to walls with protective covering.

3) The class requirement for minor building element surfaces is B-s1, d0.

4) When protective covering is required, the surface class requirement is determined according to the building material class requirement of the protective covering.

5) In a separate garage, not exceeding 1,000 square metres, and in a garage (forming part of a building) not exceeding 60 square metres, the class requirement (apart from basement level) is D-s2, d2.

* When the area is provided with an automatic fire-extinguishing system that is suitable for its purpose.

\- no requirement

Appendix 8

THE VARIATION OF THE REDUCTION FACTOR η_{fi} AS A FUNCTION OF THE LOAD RATIO OF THE NOMINAL VALUES OF DOMINANT VARIABLE ACTION AND PERMANENT ACTION $Q_{k,1}$ / G_k ACCORDING TO THE LOAD COMBINATION RULES PRESENTED IN THE MINISTRY OF ENVIRONMENT DECREE 3/16 CONCERNING THE APPLICATION OF STANDARD SFS-EN 1990 (Ministry of the Environment / 2016, p. 23)