Quality of timber construction

- Guidance for buildings and load bearing structures

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PREFACE

This work is part of a Finnish-Swedish project ‘Innovative design, a new strength paradigm for joints of, QA and reliability for long-span wood construction’. The project belongs to a Swedish-Finnish research programme "Wood Material Science Research and Engineering Programme 2003-2006". The objective of this project is to promote the use of large span timbers structures by developing connection methods and design methods for these connections, as well as ensuring quality in design, construction and in maintenance. The Finnish part of the project has been funded by TEKES, VTT, Metsäliitto Cooperative/Wood Products Industry, Versowood Oy, SPU Systems Oy, Late-Rakenteet Oy and Exel Oyj.

The part of the project dealing with the development of quality in timber structures has been divided so that the Swedish partners (Lund University and SP) have focused on the analysis of known failures, and the knowledge learned from these to quality assurance procedures. The Finnish partners have focused mainly on the drafting of the quality assurance guidelines for timber construction and making use of the results gathered by the Swedish partners. This document on quality of timber construction is a result of the Finnish work.

These timber construction guidelines were drafted in a working group with the following participants:

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I wish to thank all who have participated in the drafting and commenting of this document.

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1 INTRODUCTION

1.1 Scope

In this document, quality requirements are set for the design and construction of timber buildings, so that sufficient reliability, durability and overall usefulness of the building are ensured. This document is particularly meant for the design, construction, use and maintenance of high span or otherwise demanding timber structures and joints. However, the document may be used also for other structures as well.

1.2 Definition of building quality

Quality in construction is developed from a combination of: decision on reasonable objectives, good design, viable working methods, sufficient resources and adequate control of quality. Building quality may be divided into the *process quality* and *to end product q*uality.

The *process quality* is made up of the design and building processes as well as the communication and co-operation between these parties. The *quality of the end-product* on the other hand may be divided to visual, functionality, ecological and technical quality. The service-life perspective is an essential part of the end-product quality.

The building developer is the main responsible partner for ensuring the building quality. He should state the objectives for quality and verify that sufficient resources are allocated to achieve them. His prime objective should naturally be the quality of the end-product. With a good quality process, a good end-quality may also be achieved. When setting the objectives for quality, these are assessed in relation to the estimated building costs and use costs.

Indicators of a good quality process are:
- The objectives of the building project are well defined and clear
- The schedule is realistic
- The staging and decision making processes function
- The responsibilities and tasks of the building partners as well as the related scheduling is agreed
- The competences of the persons involved is adequate
- The building partners form a positive atmosphere and a desire to cooperate
- Sufficient resources are allocated to the design and building processes
- The security measures are taken care of
- The critical stages are identified and these are emphasized

Visual quality is composed of the appearance of the visible structures, the rooms and building volumes, the environment and the combinations of the above.

The *functionality quality* is determined on how the building performs its intended functions, eg. logistics and ergonomics or in other ways efficiently and comfortably.

The *technical quality* is made up of durability, strength, safety and healthiness. The *ecological quality* is first effected when the building materials are chosen in the initial stages of the project, however the major part is determined on the building use. The main issues are the energy efficiency of the building, long service life, good maintenance procedures and modifiability of the building.

Considering timber buildings, the following should receive special attention:
- Handling of information and communication between the building project partners
- Security during construction, specially on temporary bracing of load bearing structures
- Considerations on performance of connections and how these are effected by variable humidity conditions
- Swelling and shrinking of timber elements
- Cracks caused by shrinkage of moist wood
- Orthotropic strength of wood
- Fire safety

The scope of this report is on the quality assurance of the end-product quality, which is achieved by a functional cooperation among the project partners, sufficient coverage and quality of design and on the documentation to be produced in a building project.

This report describes the following means for quality assurance:
- The project description
- The moisture control plan
- The assembly plan
- The security measures
- Tolerances of work, materials and building components
- The maintenance manual

1.3 Partners in a building project and their tasks for ensuring quality

The responsibility and task descriptions given in the following are indicative. Depending on organizational differences in a project by project case these may be structured in another way. These responsibilities are usually drafted in contracts between the partners in the initial stage of the project.

- <u>Building developer</u> (or his representative) assures that the buildings is designed and built according to the regulations and permits. He or she has to have sufficient competence considering the project demands and sufficient project personnel at use. A specialized consultant may perform as a building developer.
  The quality ensuring tasks are:
  - the quality objectives of the building are clearly set and documented so that these can be obtained by the building partners
  - for the design and for the execution sufficient resources are reserved considering the quality objectives
  - the project is organized so that each design or performer has a responsible person with competence and information flow between partners is described and agreed
  - alterations during the construction phase are dealt with in a controlled and agreed manner
  - deliveries are carried out ensuring sufficient recourses from the deliverer
  - ensures that the main designers have sufficient competence
  - ensures that the project description, which performs as an information management tool

(described later), is up to date at all times and the responsible persons provide the information required for this document.
- organizes project meetings prior to critical stages, where tasks, responsibilities and timings are dealt
- ensures that the security plan, moisture control plan and assembly plan are properly drafted and that these are followed during the construction phase.

- Main designer, his main task is to assure the sufficient quality and extent of the building design, so that the requirements and the quality level set for the building are realized. The main designer is responsible that all aspects of the building that need designing are in fact designed and that the work produced by the different designers are compatible. He is the main contact toward the building officials during the design and construction phases of the project. The main designer may be the project architect or the main structural designer. The quality ensuring tasks are:
  - ensures that sufficient information is available to all designers and that these are compatible and up to date
  - ensures that all designers are aware of their responsibilities and design tasks
  - ensures the cooperation between designers from different domains,
  -ensures that the necessary design are done and that these are compatible with each other
  - he is the main coordinator in the drafting of the project description and ensures that the necessary information is collected and updated from the different parties.

- Architectural designer, is responsible for the architectural aspects ensuring the visual and functional quality of the building. He also drafts the geometry, the dimensions and modular network of the building. Cooperation with the structural engineer is required when considering the technical quality as materials and surface treatments.

- Structural designer, he is responsible for the co-ordination of the structural designs of the building, so that the whole construction is covered in the structural design.
  The quality ensuring tasks are:
  - responsible for the quality of the structural plan based on the architectural drawings
  - responsible for the structural security and drafts the initial risk assessment of the project (risk assessment and inspections)
  - acts as an advisor (and partly drafts) in the drafting of the project description, assembly plan and moisture control plan.

- The contractors, depending on the extent of the contracts, they may be involved in the drafting of the above plans and designs. Their main responsibility is however in the execution phase ensuring that the building designs and regulations are followed.
  The quality ensuring tasks are:
  - the main contractor takes care of the quality assurance on the buildings site in cooperation with the other contractors (if any),
  - the main contractor is involved in the drafting of the moisture control plan,
  - the assembling contractor drafts the assembly plan together with main structural designer

- Building element producers and element designers are responsible for the quality of the products they deliver and they should hand out information on the correct storage and usage of their products along with the deliveries. They should also examine the moisture control plan as well as the assembly plan and check that their products can comply with them.

- The building officials (including fire officials) controls that building laws and rules are fulfilled in the building project.

1.4 Identified risks

Here is a list of some typical cases, which have resulted in structural failures and which could have been avoided with quality assurance. Such cases demand special attention.

- Failures of inner ceilings, where in most cases the ceiling has been supported relying on the withdrawal strength of nails. Possibly additional hanging loads have been applied which have not been considered in the design.
- Large connection areas constructed in a way that does not allow for shrinkage of the wood, thus checking is developed in the connection area.
- Lack of stabilizing structures, either partly lacking or totally lacking. Especially in roofs of agricultural buildings and halls such failures have occurred. The structural performance has not been understood or the stabilization has not been designed to start with.
- Agricultural buildings are normally large and are structurally demanding buildings and normal do-it-yourself building is not recommended.
- The modular network has been differently understood by the project partners. It is important that element designer and producer as well as the assembly contractor have a similar understanding of the modular network.

In another publication of this Nordic project, Fruwald & al. 2007, structural failures have been further assessed involving a large number of cases and recommendations have been given. The present report is inspired by these findings.

2 PLANS AND DOCUMENTS FOR QUALITY ASSURANCE

The target levels of quality of a building project are drafted in documents together with the means on how these levels are achieved. Also in the usual design and building contract documents, quality is often referenced (for example in setting requirements, method descriptions and inspection plans).

This report describes the contents and implementation of some crucial tasks and documents with respect to quality assurance. These are:

1. Project description
2. Initial risk assessment
3. Structural design
4. Risk analysis and external supervision of the design
5. Moisture control plan
6. Assembly plan
7. Maintenance manual of the building

Figure 2.1 shows a schematic diagram on the timing of the drafting of these documents. Some of these documents for constantly updated as the project progresses from initial planning to design and execution. The main objective is that in every stage of the project, the documents have sufficient updated information that certain design or execution phases can progress. Such documents needing updating are the project description and the moisture control plan.

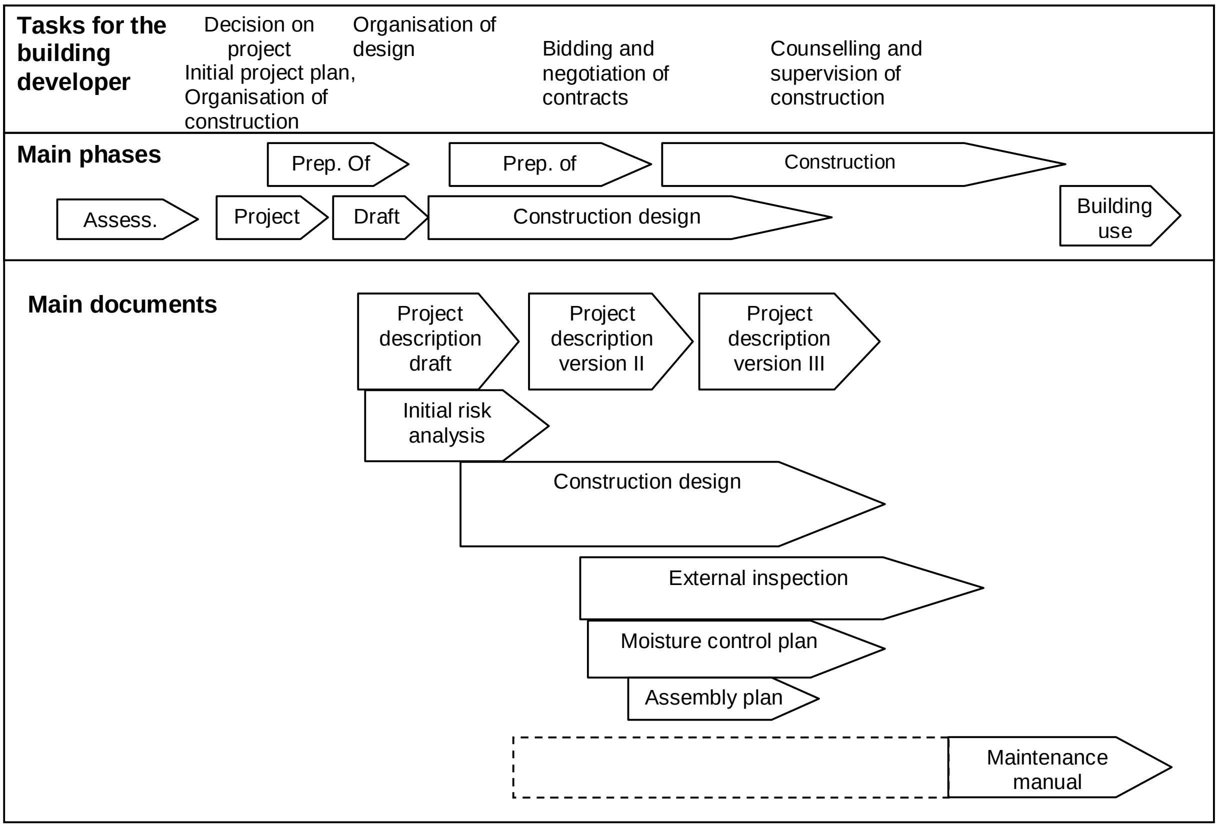

Figure 2.1 Plans and documents related to the quality assurance of a building project.

3 PROJECT DESCRIPTION

3.1 Introduction

3.1.1 The use and the purpose of the project description

The project description is a unique document of a building project specifying all the technical requirements and the initial information of the project. The project description gives quality requirements on the design and on the construction. It also gives the boundary conditions and contents to be drafted for the moisture control plan as well as for the assembly plan and the security plan. The project description is also a description of the work involved.

The purpose of the project description is to facilitate the communication between the building partners and to assure that the necessary decisions are done in time. Before the design or execution works are initiated, the essential initial information is drafted to the project description. The project description also explains how updates and changes to an earlier project description are carried out.

The basic requirement of this unique project description is that the descriptions given in this report are followed. If the project description is done in another manner or other rules are applied, this should be clearly stated.

The main coordinator on the drafting of the project description is normally the main designer of the building project.

3.1.2 The main contents of the project description

The project description includes the following main parts:

A- Basic information and tentative schedule of the project
B- Construction materials and products to be used
C- Quality requirements of the structural design
D- Quality requirements on the construction
E- Security guidance and requirements
F- The requirements set on the moisture control plan
G- Realization of the assembly plan

3.1.3 Updates to the project description

The project description is updated as the construction project advances and new decisions are done. There are however three basic updates in the project description (although there may be more updates). These updates are:

- I. Project description, initial version
- II. Project description, bidding version (2.update, before competitive bidding)
- III. Project description, construction version (3. update, before start of construction)

In table 3.1 the project description is explained in more detail and the decisions to be drafted in the different updates are given.

3.1.4 Presentation and approval

The project description is presented to all the partners of the building project at latest before the competitive bidding and before start of construction. The project description should be approved by all the partners.

Acceptable methods for making changes to an approved project description are given at this stage. These methods are noted to the project description.

3.1.5 Other documents that supplement the project description

During the construction phase, documents are drafted where the procedures are verified to be in accordance to the project description and any deviations are noted. This may include:
- Material specifications and test results, producer's attestation of conformity
- Record of measurements done on site,

The main structural designer may carry out on site inspections and an inspection report is drafted on the progress and comparison to the design.

3.2 The content of the project description

The content of the project description is in principle as given in table 3.1. However, the content may be different on depending on the nature of the project in question.

The content of the project description, where a recommendation of the partner responsible to deliver the content is given using the following abbreviations:

Building developer (or representative): BD,
Main designer: MD,
Architectural designer: AD,
Structural designer: SD

Table 3.1 The recommended content of the project description, together with the partner responsible (if more than one, the first partner is prime responsible) to deliver the information. The version stage by which the decision has to be drafted is also indicated.

Responsible	The building developer is responsible that the project description is done and that the responsible partners deliver there part of the information	
Who delivers:	The main designer, the architectural designer, the structural designer, the element designer or any other constant involved	
Who verifies:	The building developer, the main designer, the building officials and the contractors before initiation of building work	
Who follows:	All partners, especially the contractors and element producers.	
Content:		**Version I, II or III** (a recommendation at which latest stage a decision has to be done)
Cover page	• Name and address of building project location • The name of the main author of the project description • The name of the contact person of the partners: - the building developer - The building supervisor (if not the same as above) - The main designer - The main structural designer - The architect designer - Other designers • Update version and date (of last update) *List of updates:* - What updates are done compared to last version, and date	

A. Basic information	
	1. A description of the end-use of the building, **I BD** 2. The consequence class and other risk related classes, **I SD** 3. The designed in-service life period of the building and the service intervals, **I BD, SD** 4. Climatic conditions of the building (exterior and interior) , **I AD, SD** 5. The loads applied on the building and other special conditions (snow, wind etc.), **I SD** 6. The initial survey of building condition report, in cases where the project is a reparation or restoration assignment, **I SD** 7. The fire class of the building, and other fire requirements set for the building, **I MD, AD, SD** 8. Other special requirements set for the building, **I AD** 9. The initial schedule of the building project, which involves the timing of the following main tasks, **I BD, MD** (This schedule is initial and not binding, it is updated as needed): 9.1 Project plan 9.2 Preparation of the design work 9.3 Preparation of the building and call for bids 9.4 Timing of the decision on the method of building 9.5 Design work period 9.6 Construction of elements, assembly and the period of building 10. A Brief description of the organization of the building project, **II BD** 10.1 The chosen contract organization 10.2 The contract limits of design and of building. 11. Design procedure and the responsibilities of the designer, **II MD, BD** 11.1 The tasks of the main designer and the skills/experience required 11.2 The approval method of subcontracting design work 12. The exchange of information and contact methods used in the building project, **II MD, BD** 12.1 The exchange of information and cooperation among the designers 12.2 Data file method used and delivery methods for the documents 12.3 File formats used 12.4 The method how alterations on the building site are delivered for the designers approval. 13. The method to make changes to an approved project description, **I BD, MD**

B. Materials and construction products used	1. The construction materials used in the building project. It may be possible to deliver a list of essential materials to be used in a specific building project (wood materials, connectors etc.), in which case the price, the required technical specifications and the availability are considered. If necessary, the requirements on the façade or the roof materials may also be set by the building officials or the building owner and these are then listed here, **I SD, AD** 2. The surface treatments on main surfaces, **II AD, SD** 3. The method how the use of alternative materials is approved (in case there is a list of materials to be used), **II MD, BD**
C. Quality requirements on the structural design This is a verbal description on the technical information of the design and requirements	1. The loads, the duration classes and the service classes to be used in the design, **I SD** 2. Schedule of design work, **I MD, BD, SD** 2.1 Timing of the design work, in comparison to the building actions on site. 2.2 Inspections to be done on the design 2.3 The timing of an external evaluator of the design work (if necessary). 3. The standards and guides to be used in the design and construction (Eurocodes), **II SD** 4. A brief description on the requirements set on the structures by the fire class and how these are implemented on the building, **I SD** 5. A brief description on the structural design, **II SD** 5.1 Foundation conditions and foundation method 5.2 The load-bearing frame system of the building 5.3 The method of stabilizing the structure, during construction and final 5.4 The most critical structural connections 6. Requirements set by the structural designer, **II SD** on the moisture control plan and assembly plan (which are described later), as: 6.1 Tolerance requirements of the structures 6.2 Requirements set on the external wall structures (thermal, surface coatings etc.) 6.2 Requirements based on building site conditions and any other requirements.

D. Quality requirements on the construction work	1. The method how alterations from the design and quality disputes are dealt with, **I MD, BD** 2. Guidance on how alterations in structural design are dealt with, **I MD, BD** 3. The main tasks of the building developer in the project, **II BD** 4. A statement on how the partners are able to fulfill the requirements set on the project description, **II BD** 4.1 Competence requirements on the contractor and the management 4.2 Assurance of sufficient resources in line with the project size 4.3 Earlier experience and references 5. Construction methods to be followed:, **III SD** 5.1 General work guides 5.2 Guidance given from the structural designer 5.3 Guidance for the production of structural parts and elements – external inspections 5.4 Requirements on tolerances 5.5 Specific instructions to be followed in the assembly plan 6. Inspection and test plan on the construction work, **III MD, AD, SD** 6.1 Inspection of the main modular network positions on site, 6.2 Foundation, frame and final inspections (possibly other inspections) 6.3 Persons responsible for the different inspections

E. Security guidance and requirements	1. Initial risk assessment and need of external evaluation of the design, **I SD** The structural designer drafts the initial risk assessment before the design work (for buildings that are demanding) for the use of the building officials. Based on this a decision on the need for an external evaluation of the structural design is done. *(Reference (in Finnish) Menettelytavat vaativan rakennushankkeen rakenteellisen turvallisuuden varmistamiseksi, RIL luonnos 15.09.2005)* 2. A decision is done whether a full risk analysis needs to be done and at what stage this has to be ready, **II SD** The timing of the external evaluation of the design is also set. The co-operation work of the designer and the evaluator initiates from the beginning of the design work. *(Reference, in Finnish, Menettelytavat vaativan rakennushankkeen rakenteellisen turvallisuuden varmistamiseksi, RIL luonnos 15.09.2005)* 3. Other requirements set on the security of the building project, **III BD** 4. The inspections carried out by the structural designer on site and on the fabrication plant for prefab elements are assigned, **III BD, SD**

F. The requirements set on the moisture control plan	The moisture control plan is drafted as described in section 7.3. In the project description, the following are drafted: 1. The schedule of the realization of the moisture control plan, **I BD, MD, SD** 2. The person responsible for drafting the moisture control plan, **I BD** 3. The inspection of the moisture control plan, who carries it out and when, **I BD, MD** 4. The protection level used in the construction, **II SD** **(**Protection level PL0: no protection, ST1: mobile covering used, ST2: temporary roof , ST3: indoor conditions or a full tent protection with heating) 5. The target moisture content of the wood and wooden elements in the different phases of construction, **II SD**: 5.1 Fabrication phase of elements, 5.2 When delivered to construction site, 5.3 When stored at the construction site 5.4 At the assembly and building phase and the final (during use) 6. Methods of drying wood, if necessary, **II SD**
G. The requirements set on the assembly plan	The assembly plan is required in construction methods where prefabricated building parts are used. The assembly plan is done as described in section 7.4. In the project description, the following are drafted: 1. The schedule of the realization of the assembly plan, **II BD, MD, SD** 2. The person responsible for the drafting of the assembly plan (for instance Element producer or contractor carrying out the assembly), **III BD** 3. The inspection of the assembly plan, who carries it out and when, **III BD, SD**

4 QUALITY ASSURANCE OF THE STRUCTURAL DESIGN

4.1 Introduction

The assurance of quality is based on minimizing possibilities for errors, identifying the risks and their probabilities and on proper management procedures. The first step in a structural design is an initial risk analysis on the structure of the building, where the procedures to follow are identified. On very demanding structures a special procedure involving external supervision and evaluation of the structural design and dimensioning of structures are required.

In timber construction the assurance of quality is particularly challenging because of the following:
- properties are highly dependant on moisture, brittle fracture and low strength perpendicular to grain, high orthotropic,
- the high strength of wood in the grain direction enables small cross sections and these may lead to slender structures and stability problems,
- account has to be taken for the shrinkage of wood specially if structures are moist initially,
- fire safety.

The competence of the main structural designer and having sufficient recourses reserved for the building project is a responsibility of the building developer.

4.2 Main requirements of the structural design

A prerequisite for a high quality structural design is a precise and unambiguous description of the task. In the drafting phase of the construction project and before the contracts on the structural design work are made, the following information have to be known and noted in the contracts:

- The results of the initial risk assessment
- The use of the building (how demanding)
- The design service life
- The building fire class
- The standards to be used in the structural design. Eurocodes or the national building codes may be used. It is important to use the same standard set for the loads and the strengths for a particular building part.
- The inspection procedure for the design (possible use of an external evaluator)
- The organization of the partnership, at least of the main designer and main structural designer (if not the same person)
- The schedule of the construction project
- The principles for documentation, archiving and distribution of documents

The information above is contained in the project description document together with the description, drafted by the structural designer, of the structural system to be used, the assumptions taken and the loads applied. This document is updated and it evolves into a structural calculation description, where the software used and the input data on loads, service conditions etc. are stated.

The main structural planning and dimensioning is done after the essential input information is fixed in contracts.

The structural design has to cover all phases of the construction including the assembly. The methods of erection are described in the assembly plan. The structural designer and the assembling contractor should verify together that the erection is carried out feasible and the necessary connections are possible to assemble.

4.3 Documents to be drafted

The description of the extent of the structural design task is very important to be made clear so that it is equally understood by the designer and the client. The structural designer drafts and updates a list of the designs that are carried out and this serves also the purpose of an output list of the structural plans. This list should be inspected, either by a building official or by an external evaluator, that the structural design fully covers all the load bearing structures of the building.

The structural design should cover at least the following documents:

- Initial risk analysis
- Project description
- Output plan of building documents
- Description of structural calculations
- The structural design
    - Layout drawings
    - Cross section drawings
    - Detail drawings
    - Work descriptions

The structural planning has to cover all phases of construction and therefore separate distinct construction and assembly phase structural designs are done for these special loading and supporting situations.

The designer and the contractor responsible for the assembly and erection should discuss the plans in a common workshop, so that the structural details and designs are possible and that these perform as required with the building methods applied. The intention should be to notice possible needs for alterations and carry out such corrections on the structural designs before the initiation of construction.

4.4 The structural design and quality

A central point in the quality assurance of the structural design is that the design work, which is done normally by several designers, is compatible to each other and that these together provide an explicit design of the whole building leaving no uncovered parts.

The level and the extent of quality control are determined in the risk analysis. In a normal procedure, the inspection methods are agreed with the building officials, together with documentation needed for this inspection. In the beginning of the structural design, it is good practice to have a kick-off meeting with the building officials, where the initial risk assessment and the quality control procedures are decided. This is to be done not later than in the kick-off meeting of the construction work. It is advised that the structural plans are inspected by an external expert (building developer, building official, external evaluator). This inspection does not affect the responsibility of the designer on his work.

When an external evaluation is used for the design, it is important that the intercommunication is initiated at a very early stage between the evaluator and the designer and that the input values, structural analysis methods and assumption are approved.
(A detailed guide on the external evaluation of the structural design can be found from Association of civil engineers in Finland RIL)

The inspection has to be done before the respective construction work is initiated, so that alterations to the design plan can be easily done.

4.5 Following the structural design during construction work

The supervision responsibility that the structural design is followed during the construction is on the building developer. It is good practice to call the designers to carry out inspections periodically. The extent and the methods of building supervision are to be agreed upon between the building officials, building developer and the contractors on site. Also the presence of the designers in such meetings is recommended.

Ensuring a satisfactory result may require specific inspections, measurements and possibly also testing.

The use of testing may be considered based on the risks involved, but the expense of testing is in principle small compared to the expenses in building and expenses caused by errors or failures. Therefore testing may be recommended, when new structures or working methods are used.

4.6 Structural risk analysis

If a risk analysis is found necessary, as noted in the project description, this should be coordinated by the main structural designer. The risk analysis covers the design planning, the erection and the use of the building. (reference to ‘Menettelytavat… 2006’, in Finnish).

A risk analysis basically involves the following steps:
- Identification of the risks in design, construction and use
- Modeling the risks (assessing probabilities and consequences of failure)
- Assessing the risk and acceptance of the risk level

The following are to be considered in a risk analysis:

a. <u>Risks in the structural design:</u>
- Is there sufficient human resources available to complete the design task in time,
- Coverage of the structural design (completeness),
- Deviations in loading and conditions between design and reality,
- Stability of structures, both during erection and final
- Deformation and durability issues
- Uncertainties in calculation analysis,
- Possibilities for human errors
- Real strength of materials and connections and comparison to estimated strengths

b. <u>Risks during construction</u>
- Risks during assembly, where detailed working procedures and methods are to be described, in line with the security plan and the moisture control plan.
- Proper temporary bracing, stability assurance during all phases of construction and final building.
- Risk posed by weather, where the sensitivity to heavy rains or winds or other is analyzed and how these are considered in the construction.

c. <u>Risks during building use</u> (This should be also considered in the building maintenance manual)
- Moisture conditions which differ or where not considered in the design
- Deterioration, damage or loss of strength of structures
- Settings, shrinkages and other deformations
The building maintenance manual gives guidelines for inspections of the structures and how these deficiencies are dealt with, see chapter 11.

4.7 Information transfer and control of updates on the plans

A critical factor on the quality of the structural design is the transfer of information between the designers, the builders, the customers and the quality control body. To ensure the correct timing and content of the information transferred, an agreed method of transfer must be decided. A project based electronic database is recommended for automatic transfer and filing of the documents.

A mechanism on the transfer of documentation should be built so that the key partners are reached and records on the transfer occurrences are marked for the quality assurance documents. The transfer of information between designers is to be initially agreed so that an agreed file format is used for instance.

The information transfer between the designers is the responsibility of the main designer or the main structural designer. The information transfer between project partners is confirmed in the minutes of project meetings.

A guide paper should be drafted on how updates and changes to the plans is to be realized ensuring that information reaches all project partners. The update list should be marked in the documents in such a way that the update chain may be figured out afterwards. Changes in the design plans are updated in the documents and a revision marking is made together with the date and the update list. Changes made in the building site, which are agreed upon, are documented and brought to the designs and quality assurance documents, responsible being the on site building partner organization.

5 MATERIALS

5.1 Wood materials and product standards

The project description may include specific demands on materials to be used and references to respective grading or product standards, CE-marked products or type approvals. These may include for example:

- Wood materials – strength class or other classifications,
- Fasteners – steel materials used, glues etc.
- Preservatives or coatings to be used.

The materials have to be marked appropriately and the marking should be readable at all stages of the building process. Degrading of material properties during storage on site is not allowed.

Table 5.1 EN standards covering wood materials and related properties.

Strength graded timber	Strength grading	EN338 Structural timber – Strength classes EN 1912 - Structural timber - Strength classes - Assignment of visual grades and species EN 14081 – Strength graded structural timber with rectangular cross section – part 1, 2, 3, and 4
Finger jointed timber		EN 385 Finger jointed timber. Performance requirements and minimum production requirements.
Glue laminated timber		EN 1194 Glued laminated timber – Strength classes and determination of characteristic properties EN 386 Glued laminated timber – Performance requirements and minimum production requirements. EN 390 Glued laminated timber – Sizes – Permissible deviations EN 14080 Timber structures - glued laminated timber - requirements EN 387 Glued laminated timber. Large finger joints. Performance requirements and minimum production requirements.
Laminated		VTT:n certificate 184/03 (Kerto-S and Kerto-Q)

veneer lumber		YM 113/6221/2000 and VTT RTE2719/05 (Kerto-T) EN 14374 Timber structures - Structural laminated veneer lumber – Requirements EN 14279 Laminated Veneer Lumber (LVL). Definitions, classification and specifications.
Plywood		SFS-EN 313 Plywood. Classification and terminology SFS-EN 636 Plywood, specifications EN 636-1 (requirements for service class 1) EN636-2 (requirements for service class 2) EN 636-3 (requirements for service class 3) Plywood Manual, Finnish forest industries federation
Glues		EN 301 Adhesives, phenolic and aminoplastic, for load bearing timber structures. Classification and performance requirements.

Table 5.2 Standards and other guide documents related to fasteners and their properties

Nails	EN 14592 Timber structures - Dowel-type fasteners - Requirements. EN 10230-1 Steel wire nails - Part 1: Loose nails for general applications
Screws	EN 14592 Timber structures – Dowel-type fasteners - Requirements EN ISO 10666 Drilling screws with tapping screw threads - Mechanical and functional properties ISO 1891 Lag screws Specifications and properties given by the producer
Bolts, nuts and washers	EN 14592 Timber structures - Dowel-type fasteners - Requirements EN ISO 4014 Hexagon bolts - Product grades A and B EN ISO 4016 Hexagon bolts - Product grade C EN 24032 Hexagon nuts - Product grade A and B EN 24034 Hexagon nuts - Product grade C EN ISO 887 (washers), ISO 7094, DIN 436
Dowels	EN 14592 Timber structures - Dowel-type fasteners - Requirements Minimum strength class S235 Diameter between 6 – 30 mm, bevelled head Tolerance of drilled hole -0/+0,1 mm
Nailing plates	EN 14545 Timber structures – Connectors - Requirements
Three-dimensional nailing plates	Connector specific European ETA approval or a VTT statement
Shear plates	EN 14545 Timber structures – Connectors - Requirements EN 912 Timber fasteners – Specification for connectors for timber
Nailplates	EN 14545 Timber structures – Connectors - Requirements

	Connector specific VTT statement or a CE marked nailplate properties given by the producer (In service class 3 only stainless steel may be used)

5.2 Durability of wood

Requirements on durability wood, such as mould, rot, checking, radiation, corrosion or fire retardation, may be set for a building. This may include treatments carried out in the prefab plant or on the building site.

Wood and wood products should have sufficient natural durability for the different use classes defined in standard EN 350-2 or these should be treated as defined by standards EN 351-1 and EN 460. The biological use classes are defined in EN 335. Requirements and rules for treatments are given in standards EN 250-2, EN 331-1 and EN 599. It should be emphasized that treatments may effect the strength and stiffness properties of wood.

Wood with rot or mold may not be used. Blue stain is normally only a visual defect, with no effect on the strength or stiffness of wood. Wood which has excess of moisture should be allowed to dry before it is covered inside structures.

Wood may be treated with pressure or vacuum treatments, surface treatments or heat treatments. The durability of wood, treatment methods and the use of treated wood are explained in more detail in appendix A.

5.3 Corrosion of fasteners

Metal fasteners and other structural connectors should be corrosion resistant or these should be treated for corrosion.

Table 5.3 describes example of minimum treatments and choice of materials regarding corrosion in different service classes.

Table 5.3 Minimum requirements on fastener corrosion treatments (ref. standard ISO 2081)

Fastener	Service class[b)]		
	1	2	3
Nails and screws with d ≤ 4 mm	no requirement	Fe/Zn 12c[a)]	Fe/Zn 25c[a)]
Bolts, dowels, nails and screws with d > 4 mm	no requirement	no requirement	Fe/Zn 25c[a)]
Staples	Fe/Zn 12c[a)]	Fe/Zn 12c[a)]	Stainless steel
Nailplates and other steel plates of max thickness of 3 mm	Fe/Zn 12c[a)]	Fe/Zn 12c[a)]	Stainless steel

Steel plates of thickness 3 mm…5 mm	no requirement	Fe/Zn 12c[a)]	Fe/Zn 25c[a)]
Steel plates of thickness over 5 mm	no requirement	no requirement	Fe/Zn 25c[a)]
[a)] If hot galvanizing is used, Fe/Zn 12c is replaced with coating type Z275 (EN 10147) and Fe/Zn 25c is replaced with coating type Z350.			
[b)] For very aggressive conditions, a thicker galvanized coating should be considered or stainless steel should be used.			

For wood treated with substances, which cause corrosion (as for example copper salts or some organic substances), the fasteners and connectors should be of stainless steel if these are in conditions of service class 3 for prolonged periods. In most cases, treated wood has corrosive properties.

For permanent structures exposed to use classes 4 and 5 (as defined in EN 335), fasteners and connectors made from stainless steel should be used. For ground and unsalted water contact in use class 4, normally the base class stainless steel EN 1.4301 is sufficient. For salt water contact in use class 5 acid-proof stainless steel is required EN 1.4401.

Because of the stress corrosion hazard in the environment of swimming halls, the fasteners and connectors should not be made of basic stainless steels EN 1.4301, 1.4401 or 1.4432 . According to standard EN 1993-1-4, for the indoor conditions of swimming halls, suitable stainless steel grades are EN 1.4529, 1.4547, 1.4539 and 1.4565 when the chloride content of the water is equal to or less than 250 mg/l.

For the indoor conditions of agricultural buildings involving livestock, fasteners and connectors of timber structures should be treated for corrosion which is accelerated due to ammonia gases according to the requirements set for service class 3 in table 5.3, even if the indoor conditions would be as for service class 2.

For the conditions on the roof structures of decanting tanks, the fasteners and connectors should be treated as a minimum by galvanizing Z450 and if he the steel thickness is lower than 3 mm stainless steel should be used. However, if such a structure is designed for over 25 years service, only the use of stainless steel is recommended, such as class EN 1.4301.

In humid environments (use classes 3, 4 and 5) the same steel quality should be used for the metal plates and the fasteners, since the contact of different metals may induce galvanic corrosion.

6 INDUSTRIALLY FABRICATED ELEMENTS AND BUILDING COMPONENTS AND QUALITY CONTROL

6.1 Introduction

The following are basic requirements set for industrially fabricated building components:

A relevant quality control scheme is required on industrially fabricated building components where accepted quality control procedures are followed. These quality control procedures should be compatible with the handling conditions quality surveillance of these components on the building site.

Industrial space and equipment should be appropriate, sufficient storage of materials, possibilities for conditioning wood (if relevant) and storage of the produced building components.

The management should possess sufficient knowledge on the raw materials used, the requirements given for the building component and on the relevant industrial fabrication processes involved.

The personnel should have the appropriate training.

6.2 The control of the process

In an industrial fabrication of timber components, at least the following processes should be controlled:

- Drying of timber
- Strength or quality grading of timber or wood product
- The dimensions of the product and coatings
- Finger joints and lamella joints
- Composition of glues
- Temperatures and moisture conditions
- Internal and external quality control (glulam, laminated veneer lumber, plywood).

Besides the control of these processes, sufficient quality proper facilities and equipment is necessary together with trained and competent personnel. The designer may need to carry out industrial inspections in different phases of the work depending complexity of the structure.

6.3 Storage and transportation

The storage of the building component should be done so that the quality is not affected. The weather protection during transportation should be adequate. Abnormal stressing or overstressing during transportation is to be avoided. The supporting during transportation and storage is to be arranged so that permanent deformations and other failures are avoided.

The instructions for storage should be delivered along with the building components to the building site. These instructions should also mention on the lifting points and lifting methods.

6.4 Connection techniques

Concerning the quality of connections of industrially fabricated building components, the following points should be emphasized.

- The fabrication and assembly of connections should always have a quality control method.
- This method may be an industrial production based continuous third party quality control scheme or it may be a project based quality control scheme.
- The procedures in quality control have to be documented and the requirements set prior to such actions in the quality procedures document.

For the installation of connection on the building site, an initial meeting should be arranged where working methods and quality control procedures are briefed for the working personnel.

The general requirements on mechanical fasteners are; minimum thicknesses of the wood pieces and sufficient side and end distances of the connectors. In addition there are some connector specific requirements as:

- nails: Should be sharp pointed to avoid checking of wood,
- screws: Should avoid checking of wood, the screw may not break or yield during installation
- bolts: The hole tolerances should be given and the tightening method
- dowels: Thickness and hole tolerances should be given,
- nailplates: treated for corrosion, these are hydraulically pressed into the wood members, location and gap tolerances, additional requirements given in the nailplate structure standard (EN 14250).

The production and assembly tolerance for timber structures and their connections are given in section 7.5 .

For structural glued joints and glued in rods, the production requirements are set by the certification given by a notified body on the attestation of conformity on these specific joints (AC-class 1). The initial inspection on the gluing production and on the factory production control concern the approval of the used glues, gluing methods, quality control of gluing and on the conditions and preparations of the gluing work (as surfaces, moisture contents, gluing pressures and temperatures).

6.5 Specific guidelines

Specific guidelines for some components and connections are given in table 6.1 .

Table 6.1 The following industrially produced building components require specific guidelines as below.

Structures with glued-in rods, Glued and screw-glued elements	For each product and producer, the following specific documents and requirements should be given: The required three guide documents and the minimum content are the following: 1. Design guideline (if not included in Eurocode 5) o A description of the load bearing building component involving the geometry information and on materials it is produced from, o Dimensioning procedures, o An example of the dimensioning, 2. Production guidelines o The materials used: wood, glues, connectors etc., o The conditions for gluing, a description of the gluing process and method of spreading the glue, o Marking, o Tolerances on the dimensions, (section 7.6) o Quality control specimens, o Storage and packing procedures 3. Description of quality control o Product description, o Internal quality control procedures, o External quality control procedures.
Type accepted and ETA	As according to the approval documents
Nailplate structures	EN 14250 Timber structures - Product requirements for prefabricated structural members assembled with punched metal plate fasteners

Other industrially fabricated building components with mechanical fasteners: Dowel type joints Bolted joints Screwed joints Nailed joints Shear plate joints	For each product and producer, the following specific documents and requirements should be given (which are approved by a notified body): The required two documents and their minimum content is: 1. Design guideline , only if not included in Eurocode 5 2. Production guidelines o Materials used: Wood, fasteners etc., o Required wood moisture content during production phases, o A description of the work methods, o Marking, o Storage and packing procedures, o Tolerances on the dimensions, o Quality control scheme

7 QUALITY ASSURANCE OF THE BUILDING PROCESS

7.1 General requirements

The personnel on the building site should be fully introduced to the project during which expected difficulties or demanding procedures are to be discussed. The basic documents involved are the project description, the structural drawings, the moisture control plan and other relevant documents. A good communication practice is required between the different partners involved in a building project.

The storage of wood materials on site concerns at least the following: The different materials or grades do not mix, do not gain moisture or dry too much. The corners of elements and cantilevered parts have to be protected on site. The building materials designed for service class 1 and 2 have to be protected from rain, ground and snow. Further instructions on the storage of elements are to be delivered by the element producer.

During the assembly, the assembly plan and the structural drawings are followed together with possible additional instructions from the producer. The following is emphasized:

- Lifting methods of building components,
- Description on stabilization during assembly, specially with columns, walls, trusses, arches and high beams,
- The support levels of statically undetermined structures and assembly tolerances,
- Structural gluing on site only with a specific approval,
- The connected elements should not form cracks on the connections.

The loading conditions during erection may not exceed the characteristic loads and loads that could result in permanent deflections. Sheeting materials may deform due to moisture alterations and these are to be conditioned to the service class conditions before assembly.

7.2 Supervision on building site

<u>Assurance of quality</u>
Before approval of the building permit, the building officials may require a quality assurance document which describes how quality is maintained during the erection. The information needed here is included in the project description document (not so in every country).

<u>Quality control of the building materials</u>
The suitability of the building materials is demonstrated through type acceptance, ETA approvals, materials tests or by experience. The possible damages caused by transportation on building materials should be checked. The materials should be checked in any case before these are used.

<u>Supervision of the building work</u>
The responsible manager on the building site should have expertise with timber structures. He supervises on site, so that the structural drawings and plans are followed and that the materials and workmanship are of sufficient quality.

Control of the structures
The quality of the load bearing timber structures is evaluated by the main structural designer on site (see chapter 4). If necessary, tests are performed or external (third party) expert statements are called upon.

Structures of insufficient quality
If the building materials or components do not fulfil the requirements or the structural designs, an evaluation has to be done on what basis the structure can be used and possibly on how the loads on the structure are decreased if this is found necessary.

7.3 Moisture control plan

The target moisture contents of timber structure in different phases of production and construction as well as the required inspections of moisture content are described in the moisture control plan. The moisture control plan covers the whole process from industrial production to the construction on site and the final building. The main structural designer or the building component producer drafts the conditions set on the moisture of load bearing timber structures and the necessary weather protection methods so that this can be achieved.

7.3.1 Moisture in the structural design

In heated internal conditions, timber structures are design to service class 1, in which case the mean moisture content is below 12 % (RH 65 %, 20^{o}C).
In sheltered unheated conditions, timber structures are designed to service class 2, in which case the target moisture content should not exceed 20 % (RH 85 %, 20^{o}C).

In Nordic climates, the internal humidity of heated buildings may be very low during winter times. The moisture content of wood may decrease to less than 5 % during the winter and during the fall in may increase to about 12 %. In sheltered unheated conditions the moisture content of wood may vary during the year between 12 – 18 %.

7.3.2 Moisture content of wood during delivery to building site

The moisture content at delivery varies depending on the product:
- Sawn timber is delivered usually at 15 – 25 %, however due to mould growth this should be lower than 20%
- Glue laminated timber is usually delivered at a moisture content of 10 - 12 %,
- Plywood and laminated veneer lumber are delivered at a moisture content of 8 – 10 %

7.3.3 Moisture during construction

Normally during storage and assembly the wood moisture content increases, except for sawn timber which is delivered usually at a high moisture content and this continues to dry on the building site. On the building site, during storage and assembly, the material moisture increase is controlled with weather protection.

The drying of wood, especially with large cross sections, should be carried out slowly so that drying cracks would not develop. Some guidance to drying of large cross sections is given in the reference (in Finnish, 'Puurakenteiden kosteuden hallinta', Koponen 2002).

In the moisture control plan and in the assembly plan, the level of weather protections is given. The different weather protection levels and the moisture contents expected are:

- Protection level 0, **ST0**, no protection
  - moisture content depends on the climate and may not be assigned, to be used only in winter climates and in short durations
- Protection level 1, **ST1**, plastic covering
  - moisture content below 20 %
- Protection level 2, **ST2**, sheltered
  - moisture content below 20%, more reliable than ST1
- Protection level 3, **ST3**, internal conditions or a tent with heating
  - moisture content below 15 %

Table 7.1 The content of the moisture control plan

Moisture control plan • This covers the whole chain from production and building process of the timber structure • This plan is communicated to the personnel on site.	
Responsible	Building developer
Who delivers:	A cooperation between the structural designer (leader), the building contractor, the element designer and the element producer
Who verifies:	The building officials, the building developer, the structural designers and the contractors
Who follows:	The producers of building components and the contractors operating on site.

The moisture control plan is drafted for building projects that are carried out at least partly in external conditions.

1. Basic information of the building project (address and other coordinates of the building site, the person responsible for the construction on site, the main author of the moisture control plan)

2. List of wood products to be used in the construction site

3. The target moisture content of wood and wooden elements at different stages of the industrial production.

4. The target moisture content of wood and wooden elements when delivered to the building site, during assembly and when the building is finalized.

5. Inspections on site and the person responsible for these.

6. Possible sources of moisture in the building site (for instance, rain, snow, ground water etc.)

7. The protection level (ST0-ST3) chosen for the building phase and an estimate on the necessary protection duration.

8. The protection of wood and wooden elements on the building site:
   - storage method and protection of storage
   - protection during assemble (as determined by the protection level),
   - drying methods applied for wood that has gained moisture

9. Risk assessment of moisture in the building project
   - Sensitivity of the project to unfavorable weather
   - Needs on drying duration and how drying conditions are realized
   - Effects on the overall schedule of work on site

10. Moisture measurement plan (measurement method, timetable, documentation and person responsible)

7.4 Assembly plan

The assembly plan is a building project specific document. In the assembly plan, working methods are described for the safe assembly of timber structures. The conditions and requirements set in the moisture control plan have to be taken into account.

The assembly plan, as well as the moisture control plan, has to be compatible with the project description document described earlier.

Table 7.2 Content of the assembly plan

The assembly plan - This plan has to be documented in a written form and is to be available in the building site	
Responsible	Building developer
Who delivers:	The contractor performing the assembly, who is helped by the structural engineer and the main contractor in the building site
Who verifies:	The structural designers and the contractors
Who follows:	The assembly contractors operating on site and the element producers
1. Basic information on building site - Descriptions of building project, - Personnel: The assembly performing contractor and person responsible The main manager on site, main designer and main structural designer, The element designer and element producer - Information on lifting crane: crane type, lifting capacity, operation surface, maximum load of support on ground - Information on element: element types: dimensions and weights, lifting points and methods.	
2. An assessment of the following - The building site fulfils the requirements of the security plans - The stability of the cranes used and their maintenance - The control of entry to the building site - Ground and foundation conditions and safety on site - Any requirements on dimensions and weights of building parts handled on site. - Environment and weather conditions to be considered - Information on neighboring buildings effect on the assembly work and vice versa.	
3. Reception of building elements - Transportation and storage on site, storage method and location - Working schedules on pre-assembly activities - Initial inspection of the elements - Transportation methods of the elements, machinery needed and pathways to be clear	
4. Protection of elements, protection level assigned	
5. Lifting, assembling and assembly order - assembly order per building or storey or building section - Support of elements during assembly,	

	- Protection of reaction and attachment points of elements - The stage when the additional supports are removed - How is the final stability of the assembled structure achieved - Consideration of the moisture control plan on the assembly - Communication with the assembly personnel
6.	Accuracies and tolerances - tolerance class - basic location point for measurements on site
7.	Connection methods and details on assembly
8.	Work safety - safety of falling - Temporary scaffolding, decking or fencing and other security measures
9.	Assessment of fire risks on the building site
10.	Inspections, testing and repair Inspections, testing and repair activities are done on the performed work when compared to the project description structural plan requirements so that the timber structures have the strength and stability and are durable. The inspection to be carried out on the timber structures are: - Inspection of materials and products - Inspection of components and connections and if necessary testing, - Inspections during the process of assembly - Inspection on moisture content and on weather - Inspection on storage and on temporary protections
11.	Approval of the assembly plan by: - the contractor performing the assembly - the structural designer - the element designer - the main contractor on the site
12.	How fault incidents are dealt with - action procedure, security measures and communication

7.5 Tolerances

The tolerances are geometrical deviations from nominal dimension values set on materials, components or elements and on built structures. The numeral value of the tolerances is defined by tolerance classes and permissible deviations are given in the following. The tolerances may be assigned to:
a) Industrial production, where product tolerances are defined before assembly (material, component, element, holes etc.),
b) Building on site, where the tolerances are set on the assembly of these products,
c) Tolerances on connections

The main references are RYL2000, EN 1995-1-1 and CEN product standards.

7.5.1 Tolerance classes for assembly tolerances

1. Tolerance class 1: Structure which demand a very high accuracy on dimension and assembly and where there is a high demand on visual aspects.

2. Tolerance class 2: Residence, commercial and office buildings or similar. This class is the most frequently used class.

3. Tolerance class 3: Hall structures and similar where there is not such a high demand on the accuracies and on visual aspects.

Besides the classes defined above, a tolerance higher or lower may as well be assigned to a specific building project.

7.5.2 Production tolerances

Table 7.3 presents the production tolerances of wood products from nominal values.

Table 7.3. Production tolerances of wood products

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	Thickness, height [mm]	**Width**	**Length**	**Source**
Sawn timber	*1 (EN 336)* a) for thickness and width ≤ 100 mm, (-1 +3) mm b) for thickness and width >100 mm, (-2 +4) mm *Tolerance class 2 (EN 336)* a) for thickness and width ≤ 100 mm, (-1 +1) mm b) for thickness and width > 100 mm, (-1,5 +1,5) mm Undersized lengths are not permitted. Attention: here tolerance class 2 is more demanding than tolerance class 1.			EN 336, The reference moisture content is 20 %. If further information is unavailable, it may be assumed that the width and thickness size increases by 0,25 % for one % moisture content increase from a mc of 20 % to 30 %. Similarly these sizes decrease by 0,25 % for one % moisture content decrease to mc below 20 % . These values may be used for different species.

Laminated veneer Lumber (LVL)	+(0,8 + 0,03 t) mm or -(0,4 + 0,03 t) mm, where t is the nominal thickness	± 2 mm for widths ≤ 400 mm ± 0,5 % for widths > 400 mm	± 5 mm	EN 14374, Distortion of cross section max. 1:50 (equivalent to 1,1° from rectangular), Reference moisture content is 8..12 %
Glulam	for heights ≤ 400 mm +4..-2 mm for heights > 400 mm +1..-0,5 % of nominal value	± 2 mm	for lengths ≤ 2 m ± 2 mm for lengths 2 -20 m ± 0,1 % of nominal value for lengths > 20 m ± 20 mm	EN 390, The reference moisture content is 12 %. If the actual moisture content differs, a corrected size is calculated by equation: $L_{cor} = L_a[l+k(W_{ref}-W_a)]$, where k is the moisture adjusting factor per moisture-% (k = 0,0025 perpendicular to grain and 0,0001 in the grain direction for softwoods and poplar when the moisture content varies between 6..25 %, L_a and L_{ref} are the corrected sizes, W_a and W_{ref} are the actual and reference moisture contents).
Nail plate truss	The truss length and height may vary from the nominal value by 20 mm if the dimension is below 10 m, after which the deviation may be 2 mm per meter. The dimensions of trusses within a batch may vary up to 10 mm from each other.			EN 14250

Table 7.4 shows the production tolerances of wall elements and table 7.5 for roof and floor elements (RYL 2000).

The classification is applied as follows:
- *Class 1:* Elements that are used in residential, office, commercial or related buildings. This is the most often used class.
- *Class 2*: Elements that are used in storage or equivalent buildings.

Table 7.4. Production tolerances for wall elements (RYL 2000), wood moisture content assumed to 15%.

Dimension	**Class 1**	**Class 2**
Width for widths < 2,1 m	± 3 mm	± 5 mm

for widths 2,1...6,0 m for widths > 6,0 m	± 0,15 % ± 10 mm	± 0,25 % ± 20 mm
Height for heights < 3,0 m for heights 3,0...6,0 m for heights > 6,0 m	 ± 3 mm ± 0,15 % ± 10 mm	 ± 5 mm ± 0,25 % ± 20 mm
Thickness (without façade) In attachments Between attachments	 ± 3 mm ± 4 mm	 ± 5 mm ± 6 mm
Cross dimension differences between corners for element widths < 2,1 m for element widths 2,1...6,0 m for element widths > 6,0 m	 ± 4 mm ± 0,15 % ± 15 mm	 ± 7 mm ± 0,25 % ± 28 mm
Position of door and window openings	± 3 mm	± 5 mm

Table 7.5. Production tolerances for roof and floor elements (RYL 2000), wood moisture content assumed to 15%.

Dimension	Class 1	Class 2
Length for lengths ≤6,0 m for lengths > 6,0 m Width for widths < 2,1 m for widths 2,1...6,0 m for widths > 6,0 m	 ± 0,15 % ± 10 mm ± 3 mm ± 0,15 % ± 10 mm	 ± 0,25 % ± 20 mm ± 5 mm ± 0,25 % ± 20 mm
Thickness	± 4 mm	± 6 mm
Cross dimension differences between corners for element lengths ≤ 6,0 m for element lengths > 6,0 m	 ± 0,15 % ± 15 mm	 ± 0,25 % ± 28 mm

7.5.3 Assembly tolerances

The tolerance values given in the following table describe the tolerance allowed in the different tolerance classes (of section 7.5.1) on the structure when compared to its nominal location in the module network. In this way, accumulation of tolerances on structures is not allowed, for example when assembling elements on top of each other.

Table 7.3 Assembly tolerance on timber structures (main reference: RYL 2000, EN 1995-1).

	Maximum deviation allowed		
Tolerance class	**1**	**2**	**3**
Dimension or location			
Wall structure			
Side location of wall	± 3 mm	± 5 mm	± 10 mm
Spacing of wall studs	± 3 mm	± 5 mm	± 10 mm
Size of windows and doors	± 3 mm	± 5 mm	± 10 mm
Location of windows and doors	± 3 mm	± 5 mm	± 10 mm
Distance between two adjacent walls	± 3 mm	± 5 mm	± 10 mm
Straightness of walls[1]	± 1,5 ‰	± 1,5 ‰	± 1,5 ‰
Deviation of the wall frame from a perfect vertical line - height max. 3 m - height over 3 m	 ± 5 mm ± 8 mm	 ± 5 mm ± 8 mm	 ± 5 mm ± 8 mm
Floor structure			
Spacing of floor joist	± 3 mm	± 5 mm	± 10 mm
Dimension of staircase openings	± 3 mm	± 5 mm	± 10 mm
Location of staircase openings	± 3 mm	± 5 mm	± 10 mm
Straightness of the upper and lower edge of floor joist[1]	± 1,5 ‰	± 1,5 ‰	± 1,5 ‰
Deviation of the floor frame from a perfect horizontal line	± 3 mm	± 5 mm	± 10 mm
Roof structure			
Spacing of supporting structures	± 3 mm	± 5 mm	± 10 mm
Straightness of the upper and lower edge of beam[1]	± 1,5 ‰	± 1,5 ‰	± 1,5 ‰
Deviation of the beams from a perfect horizontal line or from the nominal inclination	± 3 mm	± 5 mm	± 10 mm
Columns			
Side location	± 6 mm	± 12 mm	± 20 mm
Spacing	± 6 mm	± 12 mm	± 20 mm
Upper edge height location of columns/supports	± 4 mm	± 8 mm	± 12 mm
Straightness[1]	± 1,5 ‰	± 1,5 ‰	± 1,5 ‰
Deviation from a perfect vertical line - height max. 6 m - height over 6 m	 ± 3 mm ± 4 mm	 ± 5 mm ± 8 mm	 ± 8 mm ± 12 mm

Beams			
Side location	± 6 mm	± 12 mm	± 20 mm
Spacing	± 6 mm	± 12 mm	± 20 mm
Height at support	± 4 mm	± 8 mm	± 12 mm
Straightness[1] and deviation when loaded by self weight	± 1,5 ‰	± 1,5 ‰	± 1,5 ‰
Assembly of wall elements			
Side location	± 5 mm	± 8 mm	± 12 mm
Spacing of adjacent walls	± 5 mm	± 8 mm	± 12 mm
Deviation from a perfect vertical line - height max. 3 m - height over 3 m	 ± 3 mm ± 5 mm	 ± 5 mm ± 8 mm	 ± 8 mm ± 12 mm
Width of element jointing, deviation from nominal value	± 3 mm	± 5 mm	± 8 mm
Indentation of element joints with e timber facade Indentation of the upper element joint	 3 mm 3 mm	 5 mm 5 mm	 8 mm 8 mm
Assembly of floor elements			
Side location	± 5 mm	± 8 mm	± 12 mm
Indentation of element joints on upper and lower edges of floors elements (the indentation must be planned before installation of covering materials)	3 mm	4 mm	4 mm
Assembly of nailplate structures			
Maximum bow of the truss (from the truss plane) on assembly	The maximum bow on assembly is $a_{\mathrm{bow,perm}}$ = 15 mm. The maximum bow of the chords on the whole chord length is $a_{\mathrm{bow,perm}}$ = min(L/300; 50 mm), where L is the chord length.		
Deviation from a vertical line	The maximum vertical deviation $a_{\mathrm{dev,perm}}$ = min(10 mm + H /200; 25 mm), where H is the height of the truss [mm] at the specific point.		

1) 1,5 ‰ from a base length of at least 2 m.

7.5.4 Tolerances for connections

Below are the tolerances set for connections and holes to be drilled for connectors, which have to be met if the general design procedures for the strength and stiffness of the connection are to be used, as EN 1995-1. A special investigation should be carried out for cases where such tolerances cannot be met.

Table 7.4 Tolerances for connections in timber structures.
Allowed deviation from the nominal location if not mentioned otherwise in the structural design, d is the diameter of the connector.

Connection type	Tolerance	Description/base value	Allowed deviation or gap
Nailed connection wood-wood Screwed connection wood-wood	Location of connector	spacing a_1,a_2 [1]	± max(10%; *d*)
		end distance a_3	-0 / +10 mm
		side distance a_4	-*d* / +10 mm
	penetration	Nail head flat with surface	-0 / +3 mm
Nailing plate connection (also screwed)	Location of hole	Holes in the nailing plate	± 3 mm
	Location of nailing plate	in both directions	± 5 mm
Metal framing plates and hangers (approved and industrially produced)	Location of hole	general	± 5 mm
		From contact surface	± 2 mm [9]
	Edge or end distance of connector		- *d*
	Gap to wood surface	Full contact	Skewed gap max. 3 mm
Bolt connection	Location of bolt	Simultaneous drilling [2]	± 5 mm [5]
	Location of hole	Separate drilling	± 1,5 mm [3]
	Tightening	Full contact between members	Skewed gap max. 3 mm
Dowel	Diameter	*d*	-0 / +0,1 mm
	Length	*L*	± 2 mm
	End bevel 30°	Length of bevel 0,15d	± 0,05*d*
Dowel connection	Location of connector [4]	Simultaneous drilling	± 3 mm
	Location of hole [4]	Separate drilling	± 1 mm [6]
	Length of dowel in wood member *t*		- max(2 mm; 0,05*t*) [7]
	Gap of contact	Grooved or battened members	≤ min(3 mm; 0,25t_t) [8]
Incline screw connections	Angle of screw		± 5°
Glued-in rod	Location of rod	Position at wood surface	± 5 mm

Glued-screw connections	Skewness of holes	Drilling length L_a	$\pm L_a/50$
Contact connections	Gap	Contact required	Skewed gap max. 3 mm

[1] In the direction of grain, the nails have to be at least *d* out of line from each other, if $a_1 < 14d$.
[2] Drilling once through all members or using one drilled member as a template
[3] When wood members have 1 mm oversize holes and metal parts have 1,5..2 mm oversized holes.
[4] In both surfaces of all wood members
[5] In the grain direction, the row may be out of line max. 5 mm from each other
[6] When in wood-metal connections have 1 mm oversized holes in metal parts
[7] *t* is the design smooth length in a wood member
[8] Gap between wood surface and metal plate, where t_t is the metal plate thickness
[9] For example the distance of a supporting L-plate from the wood-wood contact surface

Table 7.5 The tolerance of holes for connectors, if no other information is given in the structural design. D is the hole diameter, d is the connector nominal diameter, Lp is the depth of the hole measured from the designed connector head location and L is the nominal length of the connector. Wood here signifies all wood and wood-based panel products.

Connector	Drilled material	Recommended D	Allowed D	L_p
Nail, screw	Metal	d + 1 mm	d + 0,2..1,0 mm	through
Pre-drilled nail [1]	Wood	0,7d	0,5..0,8d	L - 0..5 mm
Pre-drilled wood screw [2]	Wood	0,7d	0,5..0,7d	L - 0..d mm
Lag screw		d 0,7d	d + 0..1 mm [3] 0,60..0,75d [4]	0,4L $\pm$ 5 mm [5] L - 0..d
Dowel[6]	Wood	d	0,95..1,00d	L + 0..5 mm
Dowel [6]	metal	d + 1 mm $\leq$ 1,1d	d + 0,5..1,0 mm $\leq$ 1,1d	through
Bolt, threaded rod	Wood	d + 1 mm	d + 0..1 mm	through
Bolt	Metal	d + 1 mm $\leq$ 1,1d	d + 0,5..2,0 mm $\leq$ 1,1d	through
Glued-in rod	Wood	1,2d	1,15..1,25d	L + 0..5 mm
Glued lag screw	Smooth part in wood Threaded part in wood	d + 1 mm 0,85d	d + 0,5..1,0 mm 0,8..0,9d	$L_s \pm$ 5 mm [7] L - 0..d

1) To be pre-drilled according to design
2) To be pre-drilled according to design or if a non-drill headed screw, with d > 8 mm
3) Oversized hole allowed only for top wood member (Used when the members are drilled separately)
4) Applies to softwood products. Hardwood products (D-strength class) allow D = 0,7..0,85d
5) Partly threaded lag screws according to ISO 1891-25.1, where the thread length is 0,6L
6) If the hole is drilled to wood and metal simultaneously, the allowed D = d + 0,0 mm
7) L_s is the length of the smooth part of the screw

8 STABILITY OF STRUCTURES

8.1 Introduction

Buildings as a unit, as well as individual structures have to be properly braced in order to achieve stability. The design for stability is done keeping in mind the following mechanisms:

- Loss of stability of a structure, which is compressed, buckling of compressed members or lateral torsional buckling of bent beams.
- Falling of a whole building or a mechanism caused by loss of stability of a building frame. This is due to lateral loads and/or eccentricities of vertical loads.

The design for stability is an essential part of the structural design. In this stability design, both during building and final stability have to be considered. (A Finnish guide document for the stability design of timber structures is being prepared).

8.2 Responsibilities for stabilization

The main structural designer has the responsibility that the design for stability of the whole building is carried out. The stability design work may be done by the main designer himself or by the element designer depending on the project organization, this is to be decided in the initial phase of the project and this is also noted to the project description.

The construction work of stabilizing structures, according to the design, is the responsibility of the contractor working on site. The achievement of stability consists of both of the design of bracing for stability and the realization of the bracing structures according to the design. It is mandatory that the realization is done according to the design.

8.3 Stability design

The stability design includes the design for stability in the end-use phase as well as the stability in the various phases of construction. The structure should withstand the external lateral forces as well as eccentricities of vertical forces. Braking and acceleration forces of hall cranes are also regarded as external lateral forces. All lateral forces have to be taken to the foundations by a designed load-path. Additionally, structural parts have to withstand internal forces that may cause partial loss of stability. This loss of stability is avoided by bracing structures. Bracing forces are normally taken within the structural framework and these are not taken to the foundations.

Possible changes or alternative assembly methods which were not considered in the design have to be approved by the main structural designer in advance.

8.4 Stability of a building and bracing

The stability of the whole building is achieved by transmitting all the external lateral forces to the foundations. Figure 8.1 shows a schematic example of this.

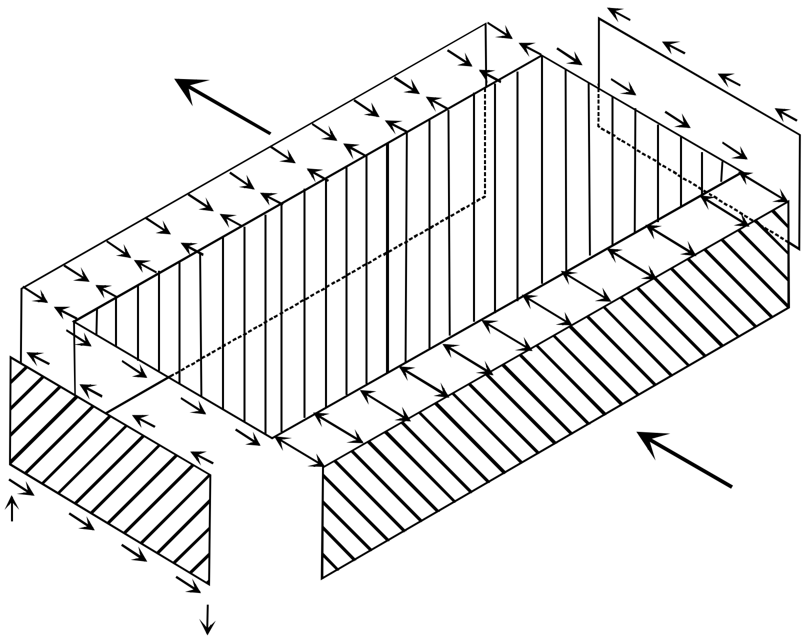

Figure 8.1 Load paths for external forces to foundations.

Figure 8.1 shows how a lateral wind load is transmitted to the lateral wall foundations. In this case the floor slab transmits the forces to the supporting shear walls. These shear walls receive the all lateral loads from the surface area of the top storeys and half of the loads of the same storey, when the wall is assumed to be hinged to the foundations. The rest is assumed to be transferred directly to the foundations. The stiff floor slab transfer the load to the top of the shear walls and form there to the foundations. Vertical anchorage forces are developed in the shear wall ends.

8.5 Bracing

The stability of compressed structural parts is achieved either by designing with sufficient cross sections or by bracing the structure to other supporting structures. The bracing forces are normally taken care of by the structural system and there is no need to transfer this to the foundations. Such a structural system is for example two top chords of trusses which are braced by additional diagonal members to each other and thus prevent the buckling of the compressed top chord.

The bracing structure has to withstand bracing forces and it has to be sufficiently stiff as well. These more detailed requirements are given in design codes, like Eurocode 5. If the bracing structures are not sufficiently stiff, eccentricities of forces may increase the stresses to levels which have not been considered in the design. For instance if the design bracing force against buckling of a member is given as 2 % of the compression force, the deflection of a hinged compressed member may not exceed L/200, where L is the unbraced length of the member.

9 MAINTENANCE MANUAL

For the safe use of timber structures in buildings regarding strength and durability, a building specific maintenance manual is produced, where guidance is given to the necessary service procedures, service intervals and inspections. The maintenance manual is meant to be a guide, with which target conditions and the intended structure life can be met in an economical, energy efficient and reasonable way.

The main responsibility in the drafting of the maintenance manual is with the building developer, who in cooperation with the main designer, structural designers, and material and element producers provides the content for the manual.

The maintenance manual has the following content:

- The main address and contact person information (The main author of the maintenance manual, the partners of the building project, the house manager)
- The service intervals for the structures and appliances, where target intervals for inspection and servicing are given.
- Repair notebook, where all services and repairs are marked
- Service life expectation of main structures
- Internal and external surface materials used
- Surface treatments of wood, where the coating is described along with cleaning and servicing methods
- Target internal climatic conditions
- Moisture control, where the most critical parts and inspections are described regarding moisture in wood and checking.
- Informative comments are drafted on in-service actions as making additional holes on the structures, applying additional hanging loads and on inspection of setting of the structures and foundations.
- Additional guidance on what needs to be considered if the use of the building changes

Further more specific instruction on how to draft maintenance manuals can be found in the website of the ministry of environment (www.ymparisto.fi), as well as in (in Finnish): Puurakennuksen puurakenteiden ja puupintojen käyttöohje ja huoltokirja, Koponen 2002, RT 18-10609 Asuintalojen huoltokirjan rakenne ja sisältö ja RT 18-10610 Asuintalon huoltokirjan laadinta.

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APPENDIX A. DURABILITY OF WOOD

11.1 Introduction

This appendix is based on reference: RIL 120-2004 (Finnish design standard of timber structures), where general information is given on durability and treatment options for wood.

These durability guidelines are given to load bearing timbers structures and to non-load bearing structures where biological deterioration may pass to the load bearing structure. Such structures could be floors of wooden houses. However, these guidelines are recommended to be used also for other non-load bearing structures for safety, economy and practical reasons.

Requirements may be posed on the materials used in a building project on the rot, mould, checking, UV-ray, corrosion, fire protection and treatments to be carried out either in the production facilities or on site.

Treatments may have an effect on strength and stiffness properties of wood. It is known that thermally treated wood the strength is reduced and there is an increase in brittleness.

11.2 Mould and rot in wood

Mould and rot fungi are biological based deterioration. Rot fungi destroy cellulose and lignin, which are the basic strength giving components of wood. Mould and blue stain fungi may grow in wood using only dissolved substances and these do not lower the strength, but these may cause health problems and may be visually disturbing. Therefore these are also of high economical significance. Mould fungi grow only on wood surfaces, but blue stain fungi may also penetrate wood. Blue stain fungi may be prevented with the same methods as rot fungi. Mould fungi prevention may be done with surface coatings, which contains mould inhibitors.

These fungi spread as airborne spores. The fungus first spread on a wood surface and then penetrate the surface with a thread not visible to the naked eye. Mould only becomes visible when new coloured spores are born. Blues stain can be seen also inside wood, when colouring agents are formed in the threads. Only after a very prolonged rot growth, can the fungi be seen on the wood surface.

The following conditions are required for rot fungi to grow:

1. Moisture. The rot fungi growth initiates when wood moisture content exceeds 20 %. The fungus may endure within a drier wood, but then it does not grow or destroy the wood.
2. Oxygen. The fungus needs oxygen in order to nourish.
3. Temperature. The growth of the fungi happens in temperatures between 0..50°C. The growth and rot progression is highest at temperatures of +20..+30°C. If for a moist wood, the temperature is increased to +50 °C or for a dry wood to +100 °C, the fungus dies, but some pores may remain viable.
4. Nutrients. As with any biological organisms, the fungi need different nutrients, as sugars and micronutrients. Wood has these substances by nature, but increasing the

concentrations may accelerate the fungi growth. This may happen for example in certain drying conditions where along with the moisture transfer, sugar and nitrogen compounds are gathered on the wood surface.

11.3 Structural protection

By structural protection it is meant that biological deterioration is minimised by applying a building method or a structural design which prevents or hinders the development of rot in wood. Structural rot prevention may have the following aims:

- Prevention of moisture gain in wood,
- Ensuring that wood has a possibility to dry
- Prevention for the other conditions which are required for rot growth.

From experience it has been observed that from the above list, the negligence of possibility for the wood to dry, has lead to most serious damages.

The effectiveness of structural protection should be assessed, if there is no previous experience on this in certain conditions. In the following cases, assessments are not necessary:

- Wood moisture content is constantly below 20 % or wood is a condition, where the air relative humidity is below RH 85 %. Exceeding these limits temporarily is not harmful if wood is allowed to dry periodically or the temperature is below 0 °C
- Wood is saturated with water and oxygen is thus not present or
- Wood temperature is below +0 °C or over 50 °C.

If structural protection may not be for some reason considered, chemical treatments classified according to standards EN 335 and EN 351 are used. Structural protection should anyhow be sought for, whether chemical treated wood is used or not.

<u>Prevention of moisture gain of wood</u>

Wood may gain moisture from the air (hygroscopic) or by capillary transfer. Wood may as well be moist as the structure is assembled.

Hygroscopic gain of moisture in wood: The mean air relative humidity should be lower than 85 % for temperatures > 0 °C. If this is exceeded wood moisture may increase over the critical value of about 20 %. It is especially hazardous if wood is allowed to gain hygroscopic moisture in places where the ventilation is poor. Such location could be saunas, cellars and crawling spaces. With ground floors, the ground moisture may be prevented utilizing under drains. Most important is however to arrange a proper ventilation.

Capillary gain of moisture in wood: Moisture may penetrate long distances in wood, even if only a small area would be in water contact. Wood may gain capillary moisture, if air moisture is condensed on surfaces, or from rain or other water source enters the structures during building.

Water vapor condenses on surfaces when the temperature decreases below the dew point. The air outlets from heated buildings are very risky since the air is cooled down and large amounts of water may develop. This may be avoided by increasing the air tightness or by avoiding the air cooling by insulation of the air ducts. Condensation is to be considered especially in places with special moisture conditions such as swimming halls and ice skating halls.

When vapor barriers are used in the structure, this should be placed on the side with the high vapor content, normally in the heated side.

The insulation should be built so that no local cold areas develop in the surface. Such areas are prone to condensation.

The use of materials, which absorb and hold water on structures which are at some time in wet conditions, is not recommended. A wooden structure that is even partly in contact with a wet material, especially water or ground contact, cannot be regarded as structural protection nor protected from biological deterioration.

Horizontal building parts should be shaped so that these may dry completely from rain and splash water. In inclined and vertical building part, holes, slots, battens or other attachments should be shaped so that these do not transmit the water into the structure but outwards.

If the wetting is only occasional or if the ventilation is very good, providing a quick drying may also be acceptable as a protection method.

The wood which bought to the building site should be sufficiently dry or it has to be stored so that it may dry fast. Storage should allow air flow between members. Moist wood placed inside structures may deteriorate fast.

Ensuring the drying of wood

The air humidity and temperature conditions should be so that sufficient drying of the wood is possible. The air speed of ventilation should be sufficient to dry the wood in a short duration.

The ventilation air should be dry and preferably slightly cooler than the structure itself. If the ventilated air is warmer, it cools and the air relative humidity increases. If the ventilated air is too cold, the air humidity gets low and this might cause checking.

Drying of wood can be ensured by air ventilation and by the correct physical performance of the structure, including air and vapour permeability’s.

Ventilation: The air moisture content may be lowered with ventilation. Effective ventilation is very important in locations which are occasionally very wet such as bathrooms. In locations which are continuously wet, such as laundries, ventilation cannot be made so effective that it would ensure structural protection of deterioration. Ventilation is very important in locations which next to heated spaces, such as attics and crawl spaces.

Ventilation of structures: The structures should be made ventilated if possible, particularly if the structures get wet at times. On the other hand outdoor cold and humid air should not be passed in too much to avoid other problems.

The air velocity in ventilation can be made sufficient more easily in vertical channels than in horizontal channels. Horizontal ventilation spaces, such as flat roofs, above inner ceilings, floor spaces, should be made of sufficient size and ventilation should be ensured with special methods. All obstacles of ventilation, such as lateral battens under vertical timber facades, should not be continuous.

Permeability of the structure: A wooden structure should not be impermeable from all sides, so that moisture could no escape, if there is a risk of gaining moisture.

Proper building physical performance of the structure is required considering air permeability, moisture diffusion, capillarity, hygroscopic and heat transfer.

For residential and similar buildings the external wall permeability should increase towards the outer wall surface. The heat insulation and wind barrier sheeting together of should be less than 20% in vapour tightness compared to the inner layers of the wall. The façade may be very tight (or impermeable), but it should have a ventilation layer behind.

Limiting other factors for biological deterioration

Oxygen: In practice the only way to keep wood away from oxygen is to keep it continuously under water. Also to some extent, above ground water levels which are wet and air impermeable, may be regarded as lacking oxygen (as foundation piles).

Temperature: If the wood moisture content exceeds 20 % only when the temperature is about
0 °C or below, and the wood dries fast when temperatures are higher, the risk for mould and rot is very small. If the wood temperature rises often to levels where the fungi die, the risk for deterioration is also very minimal.

Nutrients: Earth and dirt's contain nutrients and therefore accelerate the fungi growth. Such contact to wood should be avoided.

Checking: The checking of wood should be avoided as far as possible, since checks collect dirt and water. Timber should be nailed in a manner that the moisture deformations cause minimal checking when gaining moisture (normally heartwood outwards). The timber is sensitive to checking if the heartwood in inside. Surface checking may be also due to fast moisture and temperature variations

Coating: A coating is not enough to prevent oxygen for fungi growth. A tight coating however, slows the moisture variations in wood and decreases checking. A coating should not prevent the drying of wet wood and it should not itself act as a base for fungi. A proper coating does protect the wood from mould fungi.

11.4 Chemical protection

Chemical protection means is used in cases, where biological deterioration (rot, mould, blue stain, insect damages) cannot be ensured with simply by structural protection. The treatments for building use are done the approved preservatives.

Wood species

The species used in industrial impregnation is pine, where the sapwood is permeable. In pine the sapwood is light and permeable as the heartwood is darker and impermeable. The heartwood cannot be impregnated, but this is by nature more resistant to biological deterioration than sapwood. The sapwood is prone to biological deterioration, but this can be totally impregnated. The impregnation may also be partial or only on surface. Spruce may not be impregnated to resist biological deterioration. In the production of treated wood panels, also other species than pine can be used. LVL may only be impregnated if it is cross-veneered, as Kerto-Q.

Preservative

Here only vacuum or pressure impregnated preservatives are considered. These may be classified into three groups as:

- Water-soluble preservatives,
- Creosote oil and
- Oil-soluble preservatives.

Water-soluble preservatives contain normally salts of arsenic, chrome, copper, boron and fluorine compounds. A preservative mix that contains the first three of the above list, bonds into wood chemically and these do not dissolve and flush away with water. The bonding takes a duration of 2..3 weeks in external conditions above 0 °C, but this duration can be decreased with artificial drying. Boron and fluoride compounds however do dissolve, if the wood is in contact with water.

The effect of creosote oil is based on phenol compounds. This does not bond with wood. Creosote oil is not water soluble and therefore it stays in wood and slows moisture variations. The weak points with creosote oil are staining, smell and harmful effect on plants.

The following limitations apply:
- creosote preservative is only allowed in industrial use
- creosote is allowed to be used only in wood structures permanently in soil contact
- other applications are not allowed.

In oil-soluble preservatives the effective agents are dissolved in petrol or in a form of light fuel oil. Effective agents are several. Many oil-soluble preservatives are harmful to plants.

Protection methods

Pressure impregnation is used in cases where the target is to totally impregnate the wood. This is done in a pressurized chamber normally applying water-soluble preservative or creosote oil.

Vacuum impregnation leads normally only to partial impregnation. This is done in a closed chamber applying water- or oil-soluble preservatives.

Surface treatments are done by wetting, spraying or by brushing etc. normally with oil-soluble preservatives. In this case only the surface is protected.

Wood based panels may be treated during the production phase by applying preservatives in the glue or in the wood.

Quality control and classification of chemically treated wood products

The classification and quality control of impregnated timber is carried out according to standards EN 355 and EN 351. The preservatives have to be tested according to standards EN 113 EN 252.

The classification of impregnated wood is based on the penetration depth, the effectiveness of the preservative and the amount of preservative used.

- **Class M** Impregnated wood, where the impregnation penetrates all the way to the heartwood and the preservative is tested for salt water contact.
- **Class A** Impregnated wood, where the impregnation penetrates all the way to the heartwood and the preservative is tested for ground contact.
- **Class AB** Impregnated wood, where the impregnation penetrates all the way to the heartwood and the preservative is tested for external climate.
- **Class B** Impregnated wood, where the impregnation penetrates at least 6 mm into the sapwood. This wood may not be cut or machined after treatment.

Wood based panels are not classified according to these impregnation standards.
The production of all the above mentioned impregnation classes is controlled by an approved quality control scheme. Such rules for treatments against mould and blue stain do not exist at present.

The use of chemically treated wood

Impregnated wood of class M is meant to be used in sea water conditions, where the salt content is over 0,7 % by weight. That would be the southern parts of the Baltic sea and the Oceans.

A minimum of class A impregnated wood is used, when a permanent structure is built to service classes 4 or 5 as defined in standard EN 335. These would be ground and water contact, in cases where the structure is not fully submerged in water at all times. (Note that Eurocode 5(EN 1995:2004) does not consider service classes 4 and 5 as design classes). In service class 3, above ground contact, where there is a risk for biological deterioration; class AB wood products are used.

Class A or AB impregnated wood products are used for example in the following cases:

1. Timber structures in water contact, for example in dams, docks and other marine structures (A-class).
2. Timber structures in ground contact, for example poles and railway sleepers (A-class).
3. Timber structures in contact with moist materials as the contact with a concrete foundation (A-class).
4. Timber structures which are bearing or ensuring safety (A-class) and are exposed to rain as bridges, guard rails, balconies, ladders and stairs (AB-class).
5. Internal structures which are exposed to high humidity's as ice skating halls where class AB wood may also be used.

When there is a risk of biological deterioration of a non-load bearing structure, the use of class A or AB wood products is recommended. This is especially the case in situations where repairing is difficult or costly. Arsenic compounds may not be used in residential buildings.

Class AB or B impregnated wood is normally used in external non-load bearing structures, where rain water does not easily escape as in horizontal or almost horizontal structures.

11.5 Connections in preservative treated wood

When using chemically treated wood in load bearing structures, the possible effects of accelerated corrosion of connections has to be considered.

In service class 3 when using preservative treated wood in load bearing structures the connections have to be made of stainless steel parts and connectors, if other instructions given by a notified body are not given. The basic stainless steel qualities EN 1.4301, AISI 304 or 42 may be used.

In non-load bearing structures, zinc coated connectors, nail and screws, may be used. It should be noted that in such a case the service life of the connectors may be shorter than of the wood. In moist conditions, the zinc layer is to be of thickness at least of G185 , ASTM A123 and A153, that equals to a thickness of at least 90 micrometers.

12 APPENDIX B. CHECKLIST FOR THE STRUCTURAL DESIGN

In the following checklist the structural designer notes:
- The input values used in the structural design or
- what structural designs have been done.

The inspector of the design makes his markings in the respective column.

Table B.1 Checklist of the structural design

Checklist	Designer	Inspector
1. Standards used in the design		
2. The loads used in the design 2.1 Self weights, snow and wind loads 2.2 Live loads 2.3 Accidental loads 2.4 Loading areas 2.5 Loading combinations 2.5 Snow drifting risks 2.6 Dynamic effects 2.7 Effects of moisture and temperature 2.8 Continuity of secondary structures		
3. Load bearing structure 3.1 Beam-column system 3.2 Continuous beams 3.3 Massive beams 3.4 Trusses 3.5 Arches 3.6 other 3.7 Frame 3.8 Cantilevered beams 3.9 Slab 3.10 Steel structures 3. 11 composite structures		
4. Inspection of dimensions 4.1 Spans 4.2 Storage conditions		

5. Stabilisation 5.1 Stability in direction of the main beams 5.2 Stability in perpendicular direction 5.3 Falling, buckling, torsional buckling		
6. Reliability 6.1 Reliability class of the building 6.2 Strength grade of timber products 6.3 Service class 6.4 Load combination 6.5 Fatigue		
7. Limit states 7.1 Ultimate limit state 7.2 Service limit state		
8. Deformations and strains 8.1 Deformation criteria in service limit state 8.2 Vibration and resonance 8.2 Effects of moisture		
9. Special cases 9.1 Size effects 9.2 Falling 9.3 Compression perpendicular to grain 9.4 Holes and notches 9.5 Inclined cut surfaces 9.6 Internal stresses 9.7 Moisture deformations and moisture protection		
10 Connections 10.1 Connection design details 10.2 Quality of connection 10.3 Dimensioning of connections		

11. Reduction of cross section 11.1 Inspection of connection and strengthening 11.2 Holes		
12. Fire 12.1 Cross section analysis 12.2 Performance of connections in fire		
13. Construction plan 13.1 Counselling in structural design 13.2 Realisation of design and distribution 13.3 Inspection routines of design 13.4 Technical descriptions and their inspection 13.5 Distribution list of the project		
14. Additional inspections 14.1 Structural details which have a major effect on the strength and reliability of the building 14.2 Structural details which are unique 14.3 Inspection of treatment of wood in locations vulnerable to biological deterioration 14.4 Protection of steel parts 14.5 Environmental effect		

13 APPENDIX C. CHECKLIST FOR THE ASSEMBLY PLAN

In the following checklist the contractor performing the action notes and approves and the manager responsible on site inspects:
- The reception of building parts received on the building site,
- and their compatibility to the assembly plan and structural design

The inspector of the design makes his markings in the respective column.

Table C.1 Checklist of the assembly plan

Checklist	Performer	Inspector
1. Identification of building parts and materials on site 1.1 Reception of materials 1.2 Inspection of quantity: amount or number 1.3 Inspection of dimensions 1.4 Possible damages caused by transport		
2. Handling of building parts on site 2.1 Inspection of storage location 2.2 Moisture and dirt protection 2.3 Lifting method 2.4 Position of crane 2.5 Lifting capacity of crane		
3. Inspection of assembly plan 3.1 Marking of building parts 3.2 Number of building parts 3.3 Inspection of dimensions of building parts and comparison to structural plan 3.4 Length of building parts 3.5 The quality and finishing of building parts 3.6 Comparison of holes and notches to the structural plan		
4. Inspection during storage 4.1 Height measurements within tolerances 4.2 Other dimensions within tolerances 4.3 Shape within tolerances 4.4 Storage space sufficient 4.5 Proper moisture protection		
5. Stability		

5.1 Temporary bracing and supports 5.2 Supporting needed during assembly 5.3 Stability after assembly of the completed structure		
6. Surface treatments 6.1 Surface treatments on wood and comparison to structural plan 6.2 Colour of wood and comparison to plan 6.3 Surface treatments for corrosion and fire		
7. Additional inspections 7.1 Structural details which have a major effect on the load bearing capacity 7.2 Structural details which are unique 7.3 Inspection of treatment of wood in locations vulnerable to biological deterioration 7.4 Protection of steel parts 7.5 Environmental effect		

14 APPENDIX D. EXAMPLE OF A PROJECT DESCRIPTION

The content of the project description, where a recommendation of the partner responsible to deliver the content is given using the following abbreviations:
Building developer (or representative): BD,
Main designer: MD,
Architectural designer: AD,
Structural designer: SD

Responsible	Building developer	
Who delivers:	The building developer or by his commission the main designer, the structural designer, element designer or any other consultant	
Who verifies:	The main designer, the building officials and the contractors before initiation of building work	
Who follows:	All partners, especially the contractors and element producers.	
Content:		**Version I, II or III** (a recommendation at which latest stage a decision has to be done)
Cover page	• Name and address of building project location: Meilahti Tennis hall Pallokatu 15, 00100 Helsinki, Finland • The name of the main author of the project description: NN • The name of the contact person of the partners: - The building developer: NN - The main designer: MM - The main structural designer: PP - Other designers, RR • Update version and date: REV 1 *List of updates:* - What updates are done compared to last version, and date	
A. Basic information	1. A description of the end-use of the building and the its consequence class, **I MD** *The building serves as a sports hall, mainly for tennis.* *The span of the main arch is 36 m and the building may be regarded as demanding, the consequence class is CC3.* 2. The designed in-service life period of the building and the service intervals, **I BD** *The designed service life of the building is 50 years and the target*	

	service intervals 10 years. 3. Climatic conditions of the building (exterior and interior) , **I AD** *The main hall is heated to a target temperature of 17 °C. The building is partly excavated into the ground rock and the untreated rock wall may affect the indoor air humidity as a source of moisture. The internal conditions of the main hall is service class2 and in the offices service class 1.* 4. The loads applied on the building and other special conditions (snow, wind etc.), **I SD** *The building is designed with a grass thatch, so the self weight is higher than normal. Special conditions also apply to the grass growing on the roof and the protection of the roof from the roots.* 5. The initial survey of building condition report, in cases where the project is a reparation or restoration assignment, **I MD** *This is a new building* 6. The fire class of the building, and other fire requirements set for the building, **I AD** *The building belongs to fire class P1 and it fire performance will be shown using performance based analysis.* 7. Other known requirements set for the building, **I AD** *If the use of the building is changed, this may affect the fire performance. No such preparations are considered in the design.* 8. The initial schedule of the building project, which involves the timing of the following main tasks, **I BD** (This schedule is initial and not binding, it is updated as needed): 8.1 Project plan *The project plan is done in January 2005* 8.2 Preparation of the design work *The L2 design is done in February-March 2005* 8.3 Preparation of the building and call for bids *The call for bids is done in April-June 2005* 8.4 Timing of the decision on the method of building

The full contract for the whole project is sought to establish a frame for the costs

8.5 Design work period

The counselling and coordination of the design work is the responsibility of the building developer. Purchases used by the contractors may involve external design related to delivered building parts, these have to be approved by the building developer and the main designer.

8.6 Construction of elements, assembly and the period of building

The construction work is targeted to start in august 2005

9. A Brief description on the organization of the building project, **II BD**
   9.1 The chosen contract organization

   Full contract, with possible sub-contracting

   9.2 The contract limits of design and building.

   The contracts will be precisely defined in the agreement.

10. Design procedure and the responsibilities of the designer, **II MD**
   10.1 The tasks of the main designer and the skills/experience required

   The main designer in this project is also the main structural designer and the required competence level is AA due to its central location. The main designer assures that all the designs are compatible and that all part designs make up the full system. The main designer is responsible for the stability of the structure and that the designs building parts fit in the structural system.

   10.2 The approval method of subcontracting design work

   If subcontracting of design work is used, this has to be approved by the building developer. The designer is responsible also for the subcontracted design work.

11. The exchange of information and contact methods used in the building project, **II MD**
   11.1 The exchange of information and cooperation among the designers

   A project database is formed, where the building partners have access and where all relevant plans and documents are filed.

   11.4 The method how alterations on the building site are delivered for the

	designer's approval. *The contractors have to draft "as build"-documents and these are to be inspected by the respective designers and the building developer.*
B. Materials and construction products used	1. The construction materials used in the building project. It may be possible to deliver a list of essential materials to be used in a specific building project (wood materials, connectors etc.), in which case the price, the required technical specifications and the availability are considered. If necessary, the requirements on the façade or the roof materials may also be set by the building officials or the building owner and these are then listed here. **I SD** *All materials used have to have specifications or CE-marking and these have to fulfill the material standard and design standard requirements.* *The foundations and underground walls are reinforced concrete structures and elements may also be used.* *The glue laminated timber is to be of at least class GL32 based on the EN standard.* *All metal parts used in timber connections are zinc-coated as stated in the structural design.* *All nails, screws and other connectors are at leas hot galvanized.* 2. The method how the use of alternative materials is approved in case there is a list of materials to be used. **I MD** *The contractor may offer alternative materials to be used if he presents the equivalence of these to the materials stated in the original plan. Such changes have to be approved by the building developer who is assisted by the designer.*
C. Quality requirements on the structural design This is a verbal description on the technical information on the design and	*1.* The loads, the duration classes and the service classes to be used in the design, **I SD** *The main load bearing element is an arch with a constant radius. The roof is however a pitched roof supported above the arches. The snow loads are taken as given for pitched roofs in design codes, as drifting and the non-symmetric load case. The wind load is a given in the codes. The building height is 10 m.* *2.* Schedule, **II MD**

requirements	2.1 Timing of the design work, in comparison to the building on site. *Stage L2 is during February-March 2005* *The contracts to be ready March-April 2005* *The structural design is ready by October 2005, so that the building can be carried out with the plans ready. Inspection of the structural design is done at least when the contracts are signed, during material purchases and before start of building.* 2.2 Inspections to be done on the design *An external inspection on the structural design is carried out simultaneously with the design work and this inspection is finished before the respective building work. The external evaluation report is available before start of building.* 3. The standards and guides to be used in the design and construction (eurocodes), **II SD** *The design is mainly base on the national Finnish building codes. Specific structural parts may also be designed according to the Eurocode if the same standard set is used for the loads and strengths for the particular building part.* 4. A brief description on the requirements set on the structures by the fire class and how these are implemented on the construction, **II SD** *The fire requirements and performance are carried out by a separate performance based analysis and the solutions are presented for the fire and building officials for approval.* 5. A brief description on the structural design, **II SD** 5.1 Foundation conditions and foundation method *The building is founded on solid rock, partly on excavated rock and partly on the natural surface.* 5.2 The load-bearing frame system of the building *The frame system is based on 3 hinged arches which are supported by the foundations on rock. The arches support glue laminated secondary beams, which in turn supports a corrugated steel sheet.* 5.3 The method of stabilizing the structure, during construction and final *The secondary beams support the arch for lateral stability. These are*

	connected directly to the arch except near the support ends. *The lengthwise stability of the building is achieved by the secondary beams at a 2.5 m spacing that are attached to the corrugated steel plate. The roof transfers the load to the long side walls and the foundations. The width wise stability is provided by the glue laminated arches. The stability during assembly is achieved with the secondary beams and temporary bracing* 5.4 The most critical structural connections *The most critical connection in the load bearing structures are the connections of the secondary beams to the arches and the connection of the hinges in the arches.* 5.5 The requirements set on the outer walls of the structure *The external walls in the lengthwise direction are stabilizing and therefore contain internal bracing members* 5.6 Building conditions and any other requirements 6. Requirements set by the main designer, **III MD** on the moisture control plan and assembly plan (which are described later), as: 6.1 Tolerances of the structures 6.2 The stability of the structure in different phases of the construction.

D. Quality requirements on the construction work	1. The method how alterations from the design and quality disputes are dealt with, **I MD** *If alterations are needed or mistakes are found, the plans are corrected and presented to the building developer for approval.* 2. Guidance on how alterations in structural design are dealt with, **I MD** *The structures built may not divert from the structural plan without the approval of the building developer and the structural designer. Such divergences are reported on cost of the proposer and an inspection on the realisation is carried out.* 3. The main tasks of the building developer in the project, **II BD** *The building developer follows that all required official inspections are carried out. The building developer may approve changes in the quality requirements and on the cost effects of these.* 4. A statement on how the partners are able to fulfil the requirements set on the project description, **II BD** 4.1 Competence requirements on the contractor and the management 4.2 Assurance of sufficient resources in line with the project size 4.3 Earlier experience and references *The contractors should reserve a competence level AA class concrete and timber structure building site manager. The contractor presents in the first negotiations the resource plan and the competences of the personnel involved.* 5. Construction methods to be followed:, III SD 5.1 General work guides 5.2 Guidance given from the structural designer 5.3 Guidance for the production of structural parts and elements – external inspections 5.4 Requirements on tolerances 5.5 Specific instructions to be followed in the assembly plan 6. Inspection and test plan on the construction work, **III MD** 6.1 Inspection of the main modular network positions, 6.2 Foundation, frame and final inspections (possibly other inspections) 6.3 Persons responsible for the different inspections
E. Security guidance and requirements	*1.* Initial risk assessment and need of external evaluation, **I SD** The structural designer drafts the initial risk assessment before the design work for buildings that are demanding (long span for instance, A and AA in Finland) for the use of the building officials. At the same time a decision on the need fro an external evaluation of the structural design is

	done. *(Reference (in Finnish) Menettelytavat vaativan rakennushankkeen rakenteellisen turvallisuuden varmistamiseksi, RIL luonnos 15.09.2005)* *The structural design will have an external evaluation* 2. A decision is done whether a full risk analysis needs to be done and at what stage this has to be ready, **II SD** The timing of the external evaluation of the design is also set. The co-operation work of the designer and the evaluator initiates from the beginning of the design work. 3. Other requirements set on the security of the building project, **III BD** The inspections carried out by the structural designer on site and on the fabrication plant for prefab elements are assigned, **III SD** *The main structural designer has to attend all the inspections carried out by the building officials. Inspections are done at least after the following action:* *-The steel reinforcement of the main foundation supporting the arches* *-The arch and the support and top hinge connection model* *- The connection between the secondary beam to the corrugated steel sheet*
F. The requirements set on the moisture control plan	The moisture control plan is drafted on building activities carried out in external conditions. The moisture control plan is done as described in section 7.3. In the project description, the following are drafted: 1. The schedule of the realization of the moisture control plan, **I BD** 2. The person responsible for drafting the moisture control plan, **I BD** *The moisture control plan is made by the contractor based on draft presented by the main structural designer. The contractor presents the plan on initiation of the building site or latest on the opening meeting of the construction.* 3. The inspection of the moisture control plan, who carries it out and when, **I BD** *The moisture control plan is inspected by the structural designer prior to the construction work.* 4. The protection level used in the construction, **I SD** **(**Protection level PL0: no protection, ST1: mobile covering used, ST2:

	temporary roof , ST3: indoor conditions or a full tent protection with heating) *The protection level during construction is ST1* 5. The target moisture content of the wood and wooden elements in the different phases of construction, **II SD**: 5.1 Fabrication phase of elements, 5.2 When delivered to construction site, 5.3 When stored at the construction site 5.4 At the assembly and building phase and the final (during use) 6. Methods of drying wood, if necessary, **II SD**
G. The requirements set on the assembly plan	The assembly plan is require in construction methods where prefabricated building parts are used. The assembly plan is done as described in section 7.4. In the project description, the following are drafted: 1. The schedule of the realization of the assembly plan, **II BD** *The assembly plan is drafted one month prior to assembly* *2.* The person responsible for the drafting of the assembly plan (for instance Element producer or contractor carrying out the assembly), **II BD** *The assembly plan is drafted by the contractor performing the assembly* 3. The inspection of the assembly plan, who carries it out and when, **I BD** *The assembly plan is inspected by the main structural designer before initiation of the construction work.*