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Engineers' Views on Serviceability in Timber Buildings

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Preface

Higher timber buildings are built around the world and the development is moving forward. How to design timber buildings in ultimate limit state is well known, but little focus has been put on the serviceability limit state e.g. deformation, vibrations, and human comfort. This report presents *Engineers' Views on Serviceability in Timber Buildings*, exemplifying knowledge and questions that engineers in the Nordic countries are dealing with when designing mid-rise timber buildings in serviceability limit state.

This report is a part of an ongoing Ph.D. candidate project, which started in 2012 with focus on higher timber buildings and serviceability limit state.

The author gratefully wants to thank all of the respondents for taking their time and answering questions and for their interesting discussions about serviceability limit state in timber structures.

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Abstract

Higher timber buildings are produced around the world. The interest for higher timber buildings has increased. Design in ultimate limit state is well known, but little focus has been put on serviceability limit state especially on higher timber buildings. In this report result from interviews with structural engineers/designers, timber frame suppliers, and development managers are presented. The focus has been on serviceability limit state in mid-rise timber buildings. The experience and knowledge with the respondents varies, which has given a wide perspective of the area. Some of the outcomes are summarised here:

- Stabilisation and stiffness will be an important aspect when it comes to building/designing higher timber buildings. Large deformations both in vertical and horizontal directions can be an issue due to increased weight and wind load respectively but the main focus should be on acceleration and comfort criteria.

- Dynamic properties will according to several respondents be a challenge and several of them questioned how to make dynamic calculations and determine damping properties of a timber building.

- Connections are a crucial link and it is important to find good solutions. In general all respondent argued that connections are the weakest link but the behaviour of the connection is difficult to predict.

- Comfort criteria on timber floors has shown not to be satisfying due to human sensitivity to motion. Pilot projects have shown that stiffer floors are to recommend satisfying human comfort.

- Criteria regarding horizontal deformations were pointed out as missing in Eurocode but best practice was used by several of the respondent. Some criteria regarding horizontal deformation and comfort criteria due to vibration can be found in other standards and was used by some of the respondents. Criteria can also be posed by e.g. a glass supplier.

Higher timber buildings will be built and dynamic properties will be the main design focus. Analyses and measurements of the natural frequencies and the damping of existing buildings are needed to increase knowledge.

Contents

Definitions

There is not an absolute definition of low-rise, mid-rise, high-rise, and tall buildings. Following definitions will be used in this report:

- Low-rise: up to 4 storeys
- Mid -rise : 5-10 storeys
- High-rise: 11-20 storeys
- Tall: > 20 storeys

Introduction

Larger and higher timber buildings are built today, due to the development of technology and increased knowledge. Different building system can be used when building in timber; light frame, massive timber, and beam-and-post systems. Light frame systems are common used in single-family houses, but also in higher residential buildings. Key issues when building higher buildings with timber are horizontal stabilisation, acoustics, and vibrations. Timber structures are light-weight and an important issue is stabilisation against horizontal loads. In the Nordic countries, wind load are the foremost horizontal load that must be taken into account. Earthquakes also constitute a horizontal load and are an issue in other areas of the world, but not in the Nordic region. Movements and deformations that occur from horizontal loads can be unpleasant or even dangerous for the human being (Crocetti et al., 2011). An increasing number of floors accentuate the problem with movements and deformations of the building.

Higher timber buildings are exposed to higher wind load, and due to the low density of timber large horizontal deformations can occur. The wind load can also cause oscillation of the building. The current building regulation in Sweden is Eurocode together with Boverket´s application of the European construction standard. No requirements are set on static horizontal displacement in Eurocode or Boverket´s application. In a previous version of Eurocode from 1989 a requirement for shear walls was H/300 where H is the current height of the building, (Källsner & Girhammar, 2008). In the German DIN-standard (DIN, 1994) according to Källsner & Girhammar, (2008) a more conservative value are used, H/500. The client together with the designer is responsible for setting up limits where no limits are presented.

Expected phenomena that can happen in serviceability limit state and also the consequences and the probability need to be known to decide a limit. Functional requirements need to be satisfied when constructing new buildings. When designing buildings, structural engineers need to consider all requirements. For load bearing structures design both in ultimate limit state and serviceability limit state is made. In the serviceability limit state the building should serve as intended, the function of the building shall be fulfilled. According to Griffis, (1993), serviceability limit state can be grouped into three categories; deformation, motion, and deterioration. It covers functional requirements such as; functionality, user comfort, and appearance. Independent of the structural material the criteria should be fulfilled. Criteria are specified to verify the required performance according to Lüchinger, (1996):

- Deformations
- Vibrations;
- Cracking/stress limitations/fatigue.

Aim

To get a wider perspective of serviceability and the phenomena that can occur when building/designing higher timber buildings interviews were performed. The purpose of the interviews was to gather information about serviceability phenomena in timber structures, especially higher timber buildings. Questions were also asked about how Eurocode is used and how limits in serviceability limit state are set and applied. Focus was put both on global and local effects in serviceability. The results from the interviews are presented in this report.

Method

During the autumn 2014, 9 interviews were performed. The respondents were structural engineers/designers, timber frame suppliers, and development managers. All of the respondents work or have worked with timber and projects with timber as load-bearing structures. The industry experiences among the respondents varied between 3-30 years. Besides residential buildings some of the respondents also worked with warehouses and arenas, bridges, roof structures, and architecture. Three of the interviews were performed face to face at the company and the rest over telephone/skype. The interviews were recorded and notes were taken simultaneously. Due to some technical problems one recorded interview is missing. Afterwards, the author went through the recorded materials and additional notes were taken. The interviews were not fully transcribed. Before the interviews questions were prepared by the author. The questions were used as a basis for discussion and follow-up questions were raised during the interviews. After the interviews different themes were identified and organized in a matrix, see appendix A. In findings chapters each theme is summarised and reflections from the author is presented. The reflections from the author are right aligned in the report. The respondents used different definitions on low-, mid-, and high-rise buildings. In cases were the definitions from the respondents were unclear, the author have afterward interpret the definitions.

Findings

General

All of the respondents were asked about their experience in building/designing higher buildings, especially higher timber buildings. The variation was between 4 - 14 storeys where half of the respondents had experience of designing 6-8 storey timber buildings. One of the respondents mentioned that the current building system at the company is not developed to carry load for a building higher than 10 storeys. To build higher, development of the building system is needed. Feasibility studies on a 20 storey high timber building had been carried out by one of the respondents and from a technical point of view it is possible to construct it. Due to lack of knowledge, one respondent did not design timber buildings higher than 4 storeys.

The knowledge in designing higher timber buildings varies among the respondents. Some of the respondents mention that it is the request from the market and wish from the client that regulates if timber is chosen as a structural material. Also, contractors present a higher tender due to uncertainty among the contractors on constructing with timber.

Some of the respondents said that the load carrying capacity will not be an issue when it comes to higher timber buildings, the ultimate limit state is well known. Instead, the serviceability limit state will be the key issue.

The identified themes from the interviews were:

- Stabilisation
- Stiffness
- Deformations
- Dynamics
- Connections
- Floors
- Criteria

Stabilisation and stiffness

Stabilisation and stiffness was for several of the respondents the first mentioned key issue when designing higher timber buildings, mid-rise and up. Compared to a steel or concrete building the issues (stabilisation and stiffness) will occur already in mid/high-rise timber buildings. A question raised by one of the respondents was; at what height will we get problems regarding stabilisation and stiffness in a timber building, compared to a steel and concrete building? The respondent also argued that; above 16 storeys we will get problems with stabilisation and stiffness when designing timber buildings, special technical solutions and measures will be needed. The stiffness and symmetry of the building was pointed out as an important parameter, it will affect the motions of the building. And a challenge will be to calculate the stiffness for the whole structure. There were questions raised by some of the respondents:

- What stiffness will the building have?
- How do we calculate the stiffness?

One respondent argued that the placement of dead load will be important to prevent uplift and overturn of the building caused by strong wind.

> The phenomena are not special for timber buildings. In timber buildings these phenomena and issue need to be consider already in mid-rise due to low structural weight. The stiffness of the building is dependent on the used building system; light frame, massive timber or beam-and-post system. When choosing building system it is important to know what stiffness the building system has, already in the preliminary design. Depending on the height of the building all building systems will not be suitable for use. Symmetry of the building will increase the stiffness and staircases can also be used to increase the stiffness. Placement of dead load will be important when building higher buildings due to uplift forces and overturn which was mentioned by one of the respondent. Knowledge of the structural behaviour and input stiffness parameters are important when calculating the stiffness of the building system. It is also important to know how different structural elements are connected and how the stiffness of the connections affects the structural behaviour. Calculating the stiffness of whole buildings was mentioned by several respondents as important which is not an easy task.

Deformations

Several of the respondents mention that deformation (both horizontal and vertical) will be an issue when building/designing higher timber buildings. One of the respondent mentions that the use of elastic material (Sylomer) to reduce the flanking transmission between floors contributes to vertical deformations since the material has in some project compressed more than expected. Compression perpendicular to the grain contributes to the vertical deformations since the compressed part of the timber can give settlements in the vertical direction. According to one respondent should vertical and horizontal deformation be in accepted limits but the main focus when it comes to taller buildings will be on acceleration and comfort criteria.

Deformations may occur in horizontal direction since higher buildings will be subjected to higher wind load. The dead load and imposed load will also increase with increased height. Compression perpendicular to the grain might then be an issue for local settlements and should be avoided. Compression perpendicular to the grain belongs to ultimate limit state but in this case it may affect the serviceability limit state and several local settlements could lead to larger deformations and consequences for the building.

Dynamics

Several of the respondents stated that vibrations/motions/dynamic properties will be important and a technical issue when designing higher timber buildings. One of the respondents stated that the natural frequencies will be important in timber buildings at a height of 15-20 storeys. The damping properties of the building will be a challenge; the damping properties are difficult and unclear according to one respondent. The distribution of mass in the building will be important since if influences the dynamic behaviour. Questions raised by the respondents:

- How do we calculate wind load applied to higher buildings?
- How do we calculate the natural frequencies of the building?
- What is the building response?
- How much damping can we expect in the building?
- What comfort criteria should be used in the design?

The response shows decent knowledge and uncertainties about dynamic properties. Knowledge of dynamic properties of timber buildings has not been relevant as of yet since there are not so many high-rise timber buildings built today. Several of the respondents are comfortable to build/design 6-10 storeys but when it comes to dynamic properties several of them don’t know how to handle them. The question is at what height do we need to consider the dynamic properties in a timber building? And what can we learn from steel/concrete structures? The stiffness of the building will be important regarding stabilisation and the overturning behaviour from the wind. More masses may be added to resist the up-lift which will affect the natural frequency. Low frequency should be avoided due to human comfort. Higher stiffness will result in increasing the natural frequency. Damping properties are an important input parameter when dealing with dynamic and since there are few high-rise timber building measured regarding damping, the knowledge about the behaviour are low and uncertain.

Connections

The design solutions of connections were mentioned by several of the respondents as important. Finding good solutions and avoiding compression perpendicular to the grain were mentioned. Connections will be the crucial link and important for the global stiffness of the building. One respondent meant that the flexibility of connections will affect deformations of the system and could lead to large deformations. According to another respondent the building may lose stiffness overtime because of the flexibility of the connections. Depending on flexibility and stiffness of the building system, connections may affect the deformation and dynamic behaviour of the structure. In connections where several dowels are used, the connection will be stiff enough so slip will not occur. It may be possible that slip occurs in connections where different materials are used e.g. between cross-laminated timber and concrete due to different material properties. Questions regarding how the connections will affect the building were raised and it was stated that the stiffness of the connections should be taken into account in the design. Stiffness between structural elements needs to be ensured. In timber buildings where steel rods are used to resist up-lift created by horizontal wind load it is important to have a good solution so the steel rods can be tightened by using solutions that allows the timber to shrink and swell.

The effect of connections is a highlighted area. The global stiffness will vary depending of building system but how will different solutions of connections affect the global stiffness? Is it enough to calculate the stiffness according to Eurocode 5 (2009), to ensure the stiffness of the connection and stiffness’s between structural elements? General assumptions are to use pined connections but the real behaviour is between pinned and rigid. Should the stiffness of the connection be used in commercial software? There are several opinions among the respondents on connections but in general all agreed that connections are the weakest link and the global behaviour is difficult to predict.

Floors

The span of timber floor is limited due to motions/vibrations in the floor. The floor should be rigid enough both to transfer load and satisfy comfort criteria. Three of the respondents reported that todays´ recommendation on comfort criteria for floors is not satisfying due to human sensitivity to motions. Pilot projects have shown that stiffer floors are to recommend since the value in Eurocode 5 (2009), does not give an acceptable solution when compared to the human sensitivity of motions.

One reflection is that the stiffness of the floor may not be the same as calculated. If interaction between several layers of the floor is considered in the calculation the interaction needs to be verified in the built floor. Another aspect is that external factors for example boundary conditions or surrounding structures may affect the stiffness properties of the floor in use.

Criteria

Criteria or limits on horizontal deformations in Eurocode were pointed out as missing by several of the respondents. Some of the respondents used H/500 (H = height of the building) as the global criteria and H/300 or H/250 as local criteria for horizontal deformation. The criteria were not based on any particular source, criteria was mentioned to be found in other national standards and regulations. Regarding acceleration/comfort criteria no guidelines or recommendation could be found in Eurocode. One respondent have used the comfort criteria found in ISO 10137 (2008) – "Bases for design of structures – Serviceability of buildings and walkways against vibration", where comfort criteria for residential buildings and offices are presented. One respondent said that deformation criteria can be given for example by glass suppliers to regulate the acceptable deformation due to damage of the glass.

Several of the respondents raised the following questions:

- What level of deformation is acceptable?
- What comfort criteria due to acceleration is recommendable?
- What is the sensitive of humans regarding vibration?

Both horizontal deformation and acceleration criteria are lacking in today's Eurocode. There are uncertainties of what criteria that should be used and "best practices" are used by the engineers. The sensitivity of humans and how acceleration affects human are important aspects but it is very difficult to measure since all human have various sensitivity to motions. In Eurocode 5 (2009), examples for deflection limits are presented for timber beams. But deflection, deformation and motion criteria should not be specified dependent on material. Recommendations and limits for comfort criteria may be found in SS 460 48 61, a Swedish standard for measuring and guidelines regarding evaluation comfort in buildings, or ISO 6897 (1984) where guidelines for evaluation the response of occupant in buildings at low frequency. According to the Swedish building regulation should comfort criteria presented in ISO 6897, be used. The engineer together with the client is responsible to set up criteria. But when do we need criteria, is it dependent on the height of the building, stiffness of the building or other aspects? Some criteria will be important already at lower buildings levels and some are not related to the height of the building.

Other findings

Subjects raised during the interviews which are not suited under any themes are presented here.

Some respondents mention that when designing, focus should be on the behaviour of the whole structure not on individual elements. Interaction between structural elements should be considered.

One respondent stated that measuring acceleration and deformations should be of value to increase the knowledge and verify the calculated value with measured ones. Since there are few high-rise timber buildings, knowledge sharing was stated as important by several of the respondents. A handbook with examples should be useful.

Compression perpendicular to the grain was mentioned by several of the respondents as a serviceability issue even if it is currently an ultimate limit state issue. Some of the respondents wonder how compression perpendicular to the grain affects the serviceability behaviour.

Special solutions, for example façade elements, may be considered when designing higher buildings to avoid vibrations and noise generated by wind.

Other issues are to satisfy fire and sound requirements. When the building is higher, the fire requirements are tougher independent of material. Preventing sound transfer is always a challenge and is also independent of building height. One respondent mentioned that cracks in sealing layers can occur due to motions in the building; this could lead to water leakage. Cracks in joints between wall and roof are phenomena that also can occur due to motions and settlements. Some of the respondents asked the question: how does creep behaviour of timber affect the structural behaviour of the building?

Considering interaction between structural elements was also raised as important issue under Stabilisation and Stiffness. Measuring acceleration and deformation on one building would give valuable data but will it only reflect that specific building? The question is how can this information be used in other projects? The surrounding structure/interior walls will probably have an effect on the measured data. As already mention should compression perpendicular to the grain be avoided due to vertical deformations and may be consider in serviceability limit state.

Summary

There is important for engineers when designing to have good knowledge of different structural element behaviour and also how the structural elements can be modelled in commercial software. When modelling, boundary conditions and what generalized can be done in the modelled are important to know. There are also important to know material specific properties and if special invention are needed and how to create good technical solutions. Stabilisation and stiffness of the building are key issues when building higher timber buildings. Depending on the height and the geometry of behaviour of the building will vary. Different timber building system will be suitable for different height due to different stiffness properties of structural element. As already mention good technical solutions are needed and for timber compression perpendicular to the grain should be avoided.

Higher building will be subjected to higher wind load and the dynamic properties and response of the building will be important in the design phase. Since higher timber buildings are built and there are plans for higher, dynamic properties needs to be considered. One already raised question are at what height of the building will dynamic properties be important? Since stiffness is one important parameter, floor layout, concept and geometry of the building needs to be considered in an early state of the project. When designing higher buildings the detail design will increase and the prices for the project may then increase. It's important in an early state to know what type of analysis that needs to be carried out. Since there are few reference projects regarding high-rise timber buildings, knowledge in behaviour and dynamical response is lacking and unclear. Analyses of existing timber buildings and measuring natural frequency and damping need to be performed to gather more knowledge.

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Appendix A – Results from the interviews

Defined themes and results from the interviews are presented here.

Theme/respondent	1	2	3	4	5	6	7	8	9
Stabilisation	Stabilisation will be an issue	Stabilisation and stiffness will be an issue already in mid/high-rise timber building compared to steel or concrete building. At what height will we get problem, regarding stabilisation and stiffness, compared to steel and concrete building?		Stabilisation will be an issue.	Stabilisation will be important issue	Elements need to have enough stiffness due to stabilisation.	Stabilisation of the building will be a technical issue	Stabilisation is an issue. Tall buildings will try to overturn in strong winds, hence tension anchorages will be needed. Clever placement of structural elements, so that dead load can counteract the uplift, is important.	
Stiffness	What stiffness has the building? How do we calculate the stiffness?	Stabilisation and stiffness will be an issue already in mid/high-rise timber building compared to steel or concrete building. At what height will we get problem, regarding stabilisation and stiffness, compared to steel and concrete building? Challenge will be to calculate the stiffness of the whole building.	Stiffness and symmetry of the building are to prefer. What stiffness will the building have? How is the stiffness ensured during the whole building life?		What stiffness will the building have?			Achieving the necessary stiffness for tall timber buildings is in many cases not a challenge	The stiffness of the building affects the motions of the building.
Deformation	Deformation will be crucial, both horizontal and vertical	Horizontal deformation will be an issue.			Deformation will be an important issue. In a building several materials can be used and interaction between the materials is hard to know. If you get settlement in one structural element how is that affecting other structural elements and the whole system? Elastic material (sylomer) used to reduce flanking transmission contribute to vertical deformations since they deform more than expected.	Deformations will be an important issue. Compression perpendicular to the grain should count as a serviceability issue since it could lead to settlements of the building.	Elastic material (sylomer) is affecting the deformation. The elastic material is compressed due to high load. Compression perpendicular to the grain is an issue since it affects deformations of the structures	Vertical and horizontal deformations must be acceptable and within limits, but main focus for tall buildings should be on accelerations and comfort criteria	

Theme/respondent	1	2	3	4	5	6	7	8	9
Dynamics	Vibration/dynamic will be a challenge. How do we calculate wind load applied to higher buildings and dynamical properties? What is the building response?		Natural frequencies and dynamical properties will be import about 15- 20 storey. How much damping can we expect? 1 %, 5 %, more or less?			Motions are important. It is not clear how to calculate dynamic properties and wind load.	Motions of the building will be an technical issue. There are different equations for calculate natural frequencies, which should be used? When does a building count as a light respectively heavy structure?	Dynamic properties will be a challenge when designing high buildings. Damping of the structures is difficult and unclear. What comfort criteria should be used? Depending on the geometry of the building wind tunnel test may be suitable. Planning the distribution of the mass in the building influences the dynamic behaviour	
Connections	The design solutions of connections are important, find good solutions and avoid compression perpendicular to the grain. Connections will be the crucial link and important for the global stiffness of the building. The connections should be designed to minimize slip.	Good solutions for tension rods are important to maintain tense during the life time of the building. And maybe have solutions which allow retightening of the rods.	Tension rods need to be retightened due to creep behaviour of the timber. The stiffness of the connections should be taking into account within the design. The building may lose stiffness because of the connections. The stiffness of the connections between structural elements is important to verify. How are the connections affecting the behaviour of the building?		The flexibility of connections will effect deformations of the system and could lead to large deformations. Details solutions of connections are important.	Nail/dowel connections may give small deformation. Bolted connections can give larger deformations that may affect the deformations of the building.	Flexibility of connections may affect the deformation.	Stiffness of connections may affect the deformation and dynamic behaviour of the structure. In connections where several dowels are used, it will be enough stiff so slip will not occur. It may be possible that slip occur in connections where different materials are used	
Floors	What response has the floor? What is the threshold for human comfort?	Today's standard recommendation on floors is maybe to low and the floors are designed for higher frequencies to get a better response.			Due to motions of the floor, limit of span are stated. Pilot studied has also shown that floor calculated according to standard and regulated against the comfort recommendation do not fulfilled the criteria when using it in buildings	Rigid floors are important both for transfer load and comfort criteria.	We want to have stiffer floors since calculations according to standard give a floor with too much motion. The standard is maybe too general.	Timber floors are light, and this can be challenging when it comes to vibrations.	

Theme/respondent	1	2	3	4	5	6	7	8	9
Criteria	What criteria should be fulfilled and what is the human sensitive due to vibrations? What is okay?	Criteria for floors seem not to be accurate. Design solutions with higher natural frequency are preferred. There are criteria from example glass supplier. A deflection limit on L/300 is used so the glass not will break, and it is stated by the glass supplier. By experience some criteria are stated and used as "best practice" at the company. The criteria should be independent of material.	On horizontal deformation, H/500 is used on the global deformation and H/300/H/250 on the local deformation on each floor. It is not expressed in the Eurocode but can be found in other national standards. How mush acceleration is okay?	Regarding motion and deflection on floors, it is not so clear in the standard.	Settlements of the buildings can give consequence such as doors cannot be opened. Requirements should be based on needs. What deformations are okay? What is the human sensitive due to vibrations, what is okay?	Stricter requirements than Eurocode are used on floors to get a better comfort. No comfort criteria on acceleration of the building. Displacement criteria for buildings is missing.	Eurocode is maybe to general when it comes to natural frequencies of floors and requirements. H/500 for horizontal deformation is used and is not based on any particular source, best practice. Criteria of deformation on a steel, concrete or timber beam should be the same independent of material.	Regarding acceleration criteria, we needed to search in other documents beyond the Eurocode standard. In ISO 10137 acceleration criteria can be found. What criteria should be used? Global tolerance is not the summation of local tolerance.	
Other	Design situation will be serviceability limit state. Ultimate limit sate will not be a problem. Challenges will be design calculations and create good technical solutions. When designing, focus should be on the whole structure and not on individual elements. It is the overall solution that will be crucial in the design situation. When it comes to wind load, it will give a large load, does it really occur? How is compression perpendicular to the grain affecting the serviceability limit state? Acoustics /sound performance will be an issue	When do we get permanently damage? Detail solutions of the structure are important. How does the creep behaviour of timber affect the structural behaviour of the building?	The load carrying capacity is easy to achieve, serviceability limit state will be designing. Measuring acceleration and deformation should be good, due to importance of increase the knowledge and verify the measured value with the calculated. Since there are few high-rise timber buildings, knowledge sharing is important. Geometry of the building gives a varying wind load. Creep behaviour of the timber, how does it affect the behaviour of the structure. This is dependent of used material. Compression perpendicular to the grain should be avoided. Higher fire requirements will lead to thicker walls which is more expensive	Problems with cracks during lift and transport of building elements, how to avoid this? Different movements appear when different materials are used and the surface layers are sensitive for movements. Compression perpendicular to the grain should be avoided. Tolerances at the construction site are important. Higher fire requirements. Sound performance	We know how to design in ultimate limit state. We know how to design 4-6 storeys but when it comes to higher buildings knowledge sharing are limited. Too few reference projects. Knowledge sharing is important. Some handbooks should be useful, how to design higher timber buildings, good and bad examples, and about behaviours of the building. Examples on good and bad solutions should be useful, to increase knowledge and don't do the same mistake again. It is important to find good technical solutions. Compression perpendicular to the grain should be avoided The span of floor might be a problem. Sound performance is an issue.	How should the wind load be calculated? How is structural solutions handle? When designing the whole system need to be considered and interaction between elements. Compression perpendicular to the grain should count in serviceability design. Fire requirements will be tougher.	Compression perpendicular to the grain becomes an issue when building higher. By changing regulations to Erucode have given some problem in design phase. Sound performance is an issue. Vibrations from example railways. Humans' sensitive is a challenge.	Feasibility studies have been carried out and show that 15-20 storeys high timber building is possible from a technical point of view. When it comes to higher buildings, special solutions may be needed to avoid vibrations and noises i.e. active dampers, heavy mass in the top of the building, liquids. Technical solutions to fulfil fire requirements Earthquake will be an issue in other countries, but is an accidental design situation. The principles are the same as for wind load, energy dissipation in the structure.	Sound performance is an issue. Motions in sealing layer could lead to water leakage and damage on load bearing elements. Cracks in joints between wall and roof are phenomena that occur, could depend on settlements.