English Summary

Objective

The project will show, that large dimension timber (LDT) can be transformed into value added products for the market of construction timber, if the full potential of the technical properties of LDT is used to meet the technical requests set by the market. Market of construction timber

There are short term and long term trends on the market of construction timber. Technical innovations can only be implemented in the course of long term trends. The market of construction timber is influenced by trends of the entire construction market including for example the development of the new buildings market, the reconstruction market and the house extension market on the demand side, and on the supply side, structural changes of the wood industry sector and import from European countries. In summary, the market situation can be characterized as follows: The demand for construction products on the German market is stable to declining, while the demand for construction products on the European and overseas market is growing. In Germany, older housings will be converted and extended within the next years. Thus, the demand for construction products that can be used in dry shape will increase. Accordingly, the industry has increased their production and their export. Especially products based on European standards like gluelam beams show a considerable increase. Favourable to this development are the stable to falling prices of round wood. Especially LDT will be available in high quantities in the long term and the prices are falling. Industrial round wood prices are rising and the quantity is falling. This can be ascribed to the higher demand for residues from sawmills and from the forest causing price increases, if there are no technical innovations that compensate these increases. Debarked LDT used in saw mills, for example, could deliver residues for the production of value added insulating materials or long fibres for pulp and paper. Requirements for squared timber and beams The requirements for squared timber and beams are given in several technical standards and trading rules. DIN 68365 gives the lowest requirements for regular timber. The use of this older standard for constructions is restricted by construction rules established by the German building authorities. Dry or moist timber for load bearing constructions must be graded according to DIN 4074. DIN 4074 is also the basic grading rule for KVH (finger jointed construction timber). KVH is graded according to a voluntary quality standard set by producers and users of this material. A brief overview of the require- ments according to these two standards is shown in appendix A3. Especially the requirements for dimensional stability, surface quality and load bearing capacity are higher for KVH than for construction timber according to DIN 68365. KVH of strength class C16/C14 would be an economically interesting product for wood frame and panel construction. Unfortunately, there is no tradition to use this product. This product, produced by small saw mills, may also be exported to overseas markets. If squared timber and planks (Table 1 DIN 4074) are glued edgewise or flatwise, the resulting product is called "Balkenschichtholz" (glued laminated construction timber) [DIBt Z-9.1-440]. In this case, squared timber and planks must be graded according to DIN 4074. The minimum grade is "S10" (Appendix A3). According to this, planks used on edge must have a low knot ratio. The slightly higher modulus of elasticity and the dimensioning advan- tages however do not compensate for the higher costs. In this case, machine graded timber in strength class C16/C14 would be an economically interesting product. Since the lamellas of "Balkenschichtholz" have already reached a high quality level, surface qualities only differ with regard to the processing methods. Beams that are only flushed and chamfered are used in non visible constructions, whereas planed beams can be used in visible constructions. Pitch pockets, compression wood or discoloration are tolerated. The requirements for glued laminated timber GLT (DIN 1052) are summarized in appendix A3. GLT, which is up to now nearly exclusively produced from softwood, is graded into four strength classes (GL24 to GL36) and three surface quality classes. The straight beams with standard dimensions are regularly graded into strength class GL24. The surface quality is flushed or planed. GLT with a higher bearing capacity is used in wide spanned roof constructions. The lamellas of GLT are graded according to DIN 4074 with special criterions. Knots in particular are rated different in comparison to squared timber. For this important criterion the requirements for lamellas are lower than for squared timber. Knot diameters in lamellas are related to the flat side, while the smallest knot diameter in squared timber is related to that side where the knot is visible. This means that most of the times narrow-face knots are decisive for the grading. For the machine-grading of boards, not only the knot diameter is used as an indicating parameter, but also the density and the modulus of elasticity are important criterions. This more complex grading method allows for detection of boards with a higher load-bearing capacity (C35M, C40M). Therefore, the strength potential in boards can be detected more efficiently by machine grading than by visual grading. For higher surface grades, pitch pockets, cracks, discoloration and the shape of knots are more precisely defined and limited. Dimensional stability is ensured by the laminated structure of the beams and the surface treatment. Requirements for boards and structural board elements Boards and structural board elements are used in supporting and non supporting constructions. The non supporting boards are used for decorative sheathing or weather protection. The load bearing structural board elements like board plywood are also used as decorative elements in visual constructions [Finnforest Merk 2006), [Binder 2007], [KLH 2006], [DIBt Z-9.1-482], [HMS 2006], [Lingnotrend 2006], [DIBt Z-9.1-574], [DIBt Z-9.1-555], [Brettstapel 2006]. The requirements for surface quality of "Massivholzplatten" (solid wood panels) are given in EN 13017. Boards and lamellas for structural elements are graded more precisely than squared timber in bearing constructions. However, the requirements are not higher. In Europe, for load bearing constructions the national grading rules are in effect. In Germany, DIN 4074 is also in effect for boards. For non supporting elements with visible surfaces, three grading and trading rules are in effect in Germany (DIN 68365, "Nordisches Holz 1994" and EN 1611). There are five to six grades, which are mainly defined by knot ratio and knot shape. The warp and the pitch pockets are often determining factors. DIN 68365 requires sound and small knots, but it is indifferent with regard to warp of the boards. However, "Nordisches Holz 1994", EN 1611 and DIN 4074 have high requirements for this criterion. DIN 4074 evaluates twist very strong, while the trading rule "Nordisches Holz 1994" evaluates bow and cup stronger. These different evaluations are determined by the application of the boards. For example, it is difficult to build a stack of boards from a gluelam beam with twisted boards. Besides, twisted boards have a lower bearing capacity. DIN 4074 does not divide into sound and lose knots, because both types of knots reduce the bearing capacity in the same way. The other grading rules have higher requirements for lose knots than for sound knots. Sound knots remain in the boards after drying and planing while lose knots fall out. Subsequently, a lot of holes remain in the boards. Furthermore, the dark colour of the lose knots is not decorative. All grading rules allow for bigger knot diameters with bigger board dimensions regardless of the shape of the knot. Especially, DIN 4074 and EN 1611 allow for bigger knots in thicker boards. This means that large boards from LDT are better rated than small boards from medium dimension timber. Board stack elements Board stack elements are massive structural floor or wall elements made by upright arranged lamellas (boards, planks or squared timber), connected by mechanical fasteners [Brettstapel 2006]. An approval by the building authorities for board stack elements in Germany and Europe is going to be prepared under the leadership of the Chair for engineered wood construction at the University of Karlsruhe. According to the voluntary quality standard set by producers and users of this material, the minimum grade for lamellas from boards, planks and squared timber, needs to be at least "S10" (DIN 4074). Only 10% of the boards are allowed to have the lower grade "S7". The joints between the boards are an important aspect for board stack elements. The joints depend on the warp of the lamellas. Therefore, the warp of the lamellas is limited. Gaps at the end of the boards are avoided by finger joints. Bow can be avoided by planning, but this causes material losses. Cross laminated timber CLT and parallel laminated timber Boards laminated crosswise (normal case is right angle) in three and more layers joined by glueing or by pegs are called CLT [DIBt Z-9.1-482], [DIBt Z- 9.1-574]. Frequently used numbers of layers are 3, 5, 6 or 9. The minimum grade of the boards has to be "S10" [DIN 4074]. Is the angle between the lamellas zero, the panels look like flat glued laminated beams. These panels are called parallel laminated timber PLT. There is a fundamental difference in the stress distribution over the cross section between cross laminated timber and parallel laminated timber. The cross glued lamellas change the stress progress intermittent. The cross layers do not absorb stress in the longitudinal direction. Therefore, the top layers have to absorb most of the stress in the longitudinal direction. The more layers of equal thickness are used in preparing cross laminated timber with the same thickness, the thinner are the layers and with it the top layers as well. Therefore, the modulus of elasticity of the whole element is decreasing with increasing number of layers. If the top layers have a modulus of elasticity of 10,000 N/mm², the 3-layer-panel has a modulus of elasticity of 9,500 N/mm² and the 9-layer-panel has a modulus of elasticity of 6,400 N/mm² (Fig. 14.46). If the modulus of elasticity of the top layer is 15,000 N/mm², the modulus of elasticity of the whole 3-layer-panel is 14,300 N/mm² and of the whole 9-layer-panel it is 9,200 N/mm². By using a top layer with higher stiffness the loss of stiffness can be balanced. That way it is possible to combine the high dimensional stability of a 9-layer-panel with the high modulus of elasticity of a 3-layer-panel. Lamellas with a high modulus of elasticity are hardly available, so they are not yet used. The layers of cross laminated timber are made of multiple boards joined together. By increasing the width of the panel, the number of joined boards is also increasing and the 5%-fractile is increasing. The 5%-fractile of CLT with a width of one lamella was 27.3 N/mm², with a width of two lamellas it was 29.8 N/mm², with a width of four lamellas it was 31.3 N/mm² and with a width of eight lamellas it was 32.6 N/mm² [Schickhofer 2006]. A similar improvement of the quality can also be achieved for parallel laminated timber (Fig. 14.44), but on a higher level of strength. By joining lamellas, the free length of the edge, which determines the strength by eccentrically located wood defects, is decreasing (Fig. 14.47). Using a slim element with a width of only one board in the top layer, both edges of the board are free. When there are two boards in the top layer, only two of four edges are free. When there are three boards in the top layer again, only two edges are free. For this reason the relative free length of the edge decreases with increasing width of the parallel laminated timber. As the relative free length is decreasing, the 5%-fractile of strength is increasing. This indirect proportionality is shown in Fig. 14.48 by the difference of 1 minus the relative free length of the edge. – Besides, knots on the edges, which are determining the strength, are now balanced by the knot free edge of the ad jointing board. Comment: The "criterion of narrow-face knots" according to paragraph 5.1.3.2 in [DIN 4074] should be used for lamellas of cross laminated timber too. Hence the lamellas of CLT would be treated like lamellas of glued laminated timber GLT. Properties of squared timber and boards made of large dimension timber (LDT). The properties of squared timber and boards made of LDT change according to the sampling height, from butt log to top log of the trees, the pith distance, the origin of the tree and the sawing pattern. Properties from the butt log to the top log The diameter of knots of LDT logs increase by about 200% from the butt log to the top log in 20m height. The knot ratio according to DIN 4074 increases also from the butt log to the top log by about 160% for squared timber and by about 40% for boards. The biggest lose knots are found in the middle log. Hence from this log the quality of timber for visual use is lowest. Boards and planks with moderate sound knots can also be gained in greater tree height. Annual ring width and density of wood are closely related. With increasing tree height up to 20m the annual ring width decreases by about 35%, while the density increases by about 15% [Teischinger 2006]. This increase seems to be small, but it is important for the strength of the boards. In LDT from fir, 1% to 2% of the boards were down graded due to "Schil-ferrisse", a special kind of fissures. These "Schilferrisse" were found in 5m to 10m tree height and close to the pith, where they determine the strength. The number of pitch pockets longer than 20mm increases from the butt log to the top log by about 330%. Hence boards from top logs cannot be used for visible surfaces. Compression wood in softwood LDT increases from butt log to top log by about 100%. Boards with eccentrically located compression wood are crooked and curved alongside. The spiral grain doesn't change with the tree height. The quality of sawn wood decreases with increasing tree height according to the knots, the pitch pockets and the compression wood while the quality increases with increasing density. Top logs deliver boards with sufficient strength, if the boards are machine graded. The quality of their surface is low. The variation of the wood quality from butt log to top log increases the variability of the sawn timber. Grading is an economically interesting method to yield value added products from LDT. Properties from the pith to the bark The diameter of knots increases with the distance from the pith. If this single knot diameter is related to the small side of a squared timber, the resulting knot ratio is increasing with the distance from the pith. This is valid for single abstract knots. In practice, the maximal knot diameter is not always related to the small side but also to the broad side. This statistical effect is increasing with the distance from the pith. Hence the knot ratio according to DIN 4074 for squared timber is decreasing with the distance from the pith by about 20%. The knot ratio of boards results from the sum of the knot diameters on the surface parallel to the edge in a 150mm long section of the board related to the width of the broad side of the board. With increasing distance from the pith (150mm), the probability decreases, that multiple knots appear in a 150mm long section of the board. Hence the knot ratio is decreasing with the distance from the pith by about 50%. The knot area ratio according to the ECE standard decreases by about 35%. The density of the sawn wood is increasing by about 10% while the distance from the pith is increasing by about 150mm. The fibre length increases by about 100%, while the distance from the pith is increasing by about 200mm. The increasing fibre length enables a strong cross-linkage of the fibres. Thus the tear strength is growing. High tear strength also means a higher tensile strength of boards. Bark free chips close to the bark of LDT yields high quality of the pulp or paper. Stiffness and strength of construction timber are related to the knot ratio, the density and the fibre length. Therefore, both properties are increasing with the distance from the pith. The stiffness is measured by non-destructive testing. Together with knot ratio and density the stiffness of the boards determines the machine grade of boards. For example, the ratio of boards of grade C35M according to DIN 4074 from LDT is about 60% and from small diameter timber about 10%. Properties of sawn wood with different origin In Bavarian growth areas of LDT the vegetation period lasts for 130 to 150 days per year. It is shown that wood from growth areas with long vegetation periods have a higher density than wood from growth areas with short vegetation periods. Hence the density and the modulus of elasticity are directly related; the modulus of elasticity of wood from growth areas with long vegetation periods like "Tertiäres Hügelland" is about 20% higher than the modulus of elasticity of wood from the "Molasse-Vorberge". These differences in the MOE can be utilised by machine grading. Properties of sawn wood with different sawing patterns Sawn wood with upright annual rings, have a good dimensional stability and a high ratio between density and modulus of elasticity (Fig. 14.2). Machine grading detects these properties, and the boards and squared timbers are upgraded. Allocation of wood from LDT to the optimal application Increasing diversity of requirements on national and international level faces a similar diversity of technological properties of machine graded timber from LDT. When allocating the possible products from LDT to the new requirements of the market the following list of innovative products (Tab. 14. 2) is obtained. Both for high and low load bearing products new economically interesting products for construction arise, which up to now have very rarely or not at all been manufactured. Construction timber KVH with low bearing capacity can be used for visible or non-visible surfaces for wood frame house construction. Glued laminated timber BSH with high bearing capacity and machine graded lamellas, having loose knots and a grade G4-4 according to EN 1611, may be used in wide spanned roof constructions. The distance between the visitor and the beams is big, so loose knots won't be recognized. In case boards with upright annual rings are used, the straight standard beams with grade GL24 can be used for visible purposes. Glued laminated construction timber BaSH with a medium bearing capacity can be further used for visible or non-visible applications. Machine graded squared timber may have bigger sound knots but will have the required strength. Boards with lower bearing capacity could be used in board stack elements BST for visible and non-visible applications. If the board stack elements are combined with planks with big sound knots (cottage plank) these elements may be used for visible applications. In the section medium bearing capacity cross laminated timber CLT is used as usual for visible or non-visible applications. If the top layers of the block boards BSS are made of sawn wood with upright annual rings, the panels may be used for building sections with high requirements for visible applications. If these top lamellas of the CLT or BSS panels are machine graded and the cross layers are made of hard wood these panels with high bearing capacity can be used for visible applications. Development of market strategies for the new products A good product is not enough. It needs an efficient market strategy to find the right customer (Fig. 14.3). The demand side of the market of new construction products is composed of individual, system and standard manufacturers. They are niche manufacturers, specialists or low-cost leaders. The niche manufacturers are carpenters or free architects which build individual houses or other value added buildings, using glued laminated timber for visible surfaces from the traders. The system manufacturers are medium-sized enterprises. They produce small series of valuable buildings from self-made cross laminated CLT or glued laminated timber GLT from traders. Traders obtain their products from low- cost leaders in the saw mill industry, the GLT-industry or the wood composite industry. Large dimension timber LDT from small private forests is usually sawn by small saw mills. These small saw mills are able to support the individual GLT and CLT manufacturers with high quality timber. These manufacturers produce innovative products and sell it via traders to the carpenters and industrial customers. It is possible to use the trading competence of the medium-sized saw mills. In that way, they could expand their product range with products where they have produced the primary product themselves. To start this process, the results of this project were discussed with representatives of all the companies named above in dialogs at the mills or at trade fair centres or in presentations at sessions of guilds. Furthermore, an internet page with the results is provided. A first step in this process could be achieved at the "Holzforum Allgäu" a cluster of stack holders from the forest, timber and construction sector. Other clusters "Forst-Holz-Bau" will be developed in Bavaria.