

Small diameter round wood observation tower

Peter A. de Vries

(senior researcher)

Wolfgang F. Gard

(senior researcher)

Delft University of Technology

Faculty of Civil Engineering and Geosciences

Timber Structures and Wood Technology

Delft/The Netherlands

Summary

In the centre of a nature reserve situated in the province Drenthe, The Netherlands, a 15-meter high, public accessible wooden observation tower was built. The tower is constructed of slender Larch beams and has a spatial structure based on the geometry of a hyperboloid. The small diameter beams are produced of stems harvested in forest thinnings, which were milled to cylindrical sections. During the drying of round wood, cracks develop along the length of the stem. When making bolted or dowelled joints in such beams, the cracks can lead to severe practical problems. Therefore an alternative jointing principle was developed, that is less sensitive to these cracks. Special elements in the structure are the steel nodes that connect the round wood beams. The detailing of the couplings in the nodes is such that it is possible to disassemble each round wood beam in the structure, and have it replaced easily. This aspect of the nodes is important, as the wood in the tower is not treated with preservatives.

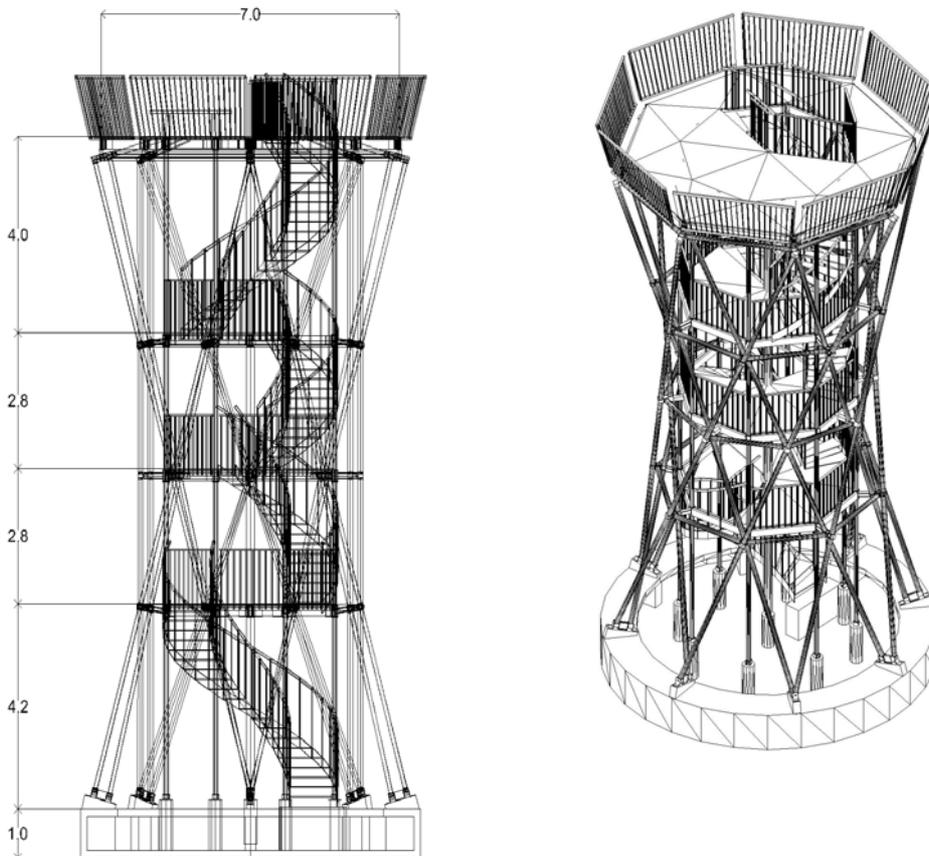
1 Introduction

In the centre of the nature reserve Holmers-Halkenbroek, situated in the province Drenthe, The Netherlands, Tentech designed and engineered a public accessible wooden observation tower. The tower is constructed of slender Larch beams and has a spatial structure based on the geometry of a hyperboloid. A light steel stairway leads the visitor to the top-level platform, approx. 15 m. above the ground. While the wide base of the tower makes sense from a structural point of view, the large area of the upper floor is clearly beneficial for the users of the structure. From the waist of the tower, the shape 'reaches out' to the surroundings. The orientation of the fence on the observation platform once again stresses this. The tower is situated in a silence area and can only be reached by foot or bicycle.

There are two cooperating structural systems, firstly the vertical columns and platform floors that support the stairs and secondly the hyperboloid diagonal structure at the outside of the tower. The floor-column system has a pure vertical bearing constitution, while the outer diagonal structure bears its own weight, some of the floor loading of the top platform and all horizontal forces (lateral and torsion), caused by both wind and horizontal load by persons) on the structure.

The structural concept made it possible to build the tower with very slender beams. The diameter of the poles at the ground level is only 140 mm, with a length of approx. 4 meter, while in the floors above the diameter is only 120 mm.

The shape of the main load bearing system is based on the geometry of a hyperboloid. By this choice, the beams that form the structure are exactly straight over the complete height of the tower.



Drawings preliminary design

A new node system was developed to benefit from this straightness. In the nodes the beams are pin-wise connected in lateral direction. This makes it possible to realize the axial connections between the poles on a standard way. The elements a node consists of are equal for all nodes in the structure. The drawback of the choice of nodes with crossing beams is internal eccentricity in the nodes. This means the transfer of vertical loads on a node leads to torsion forces on the node. These forces have to be accommodated in the foundation of the structure and on the top level of the tower.

2 Building with round wood

The used structural concept made it possible to build the tower with very slender beams. The diameter of the poles at the ground level is only 140 mm, with a length of approx. 4 meter, while in the floors above the diameter is only 120 mm.

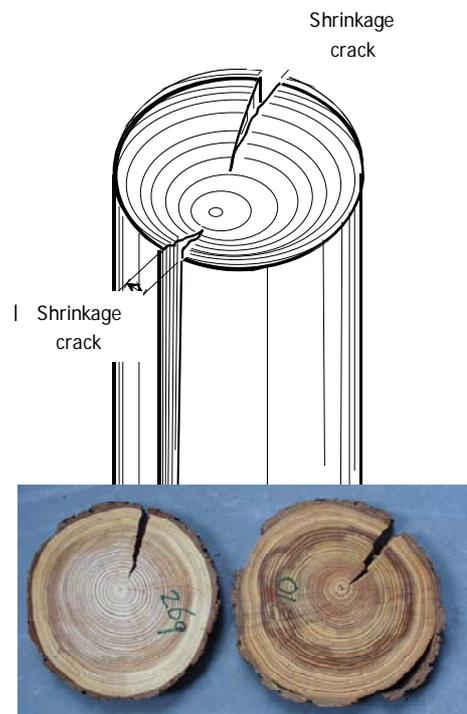
The small diameter beams are produced of wood harvested in forest thinnings. Traditionally in structural applications where round wood from thinnings is used, the stems are debarked. This means the beams are slightly tapered. Milling the stems cylindrical has the disadvantage of losing a large (up to 50%) part of the section. On the other hand however, milling has significant advantages with respect to the design of connections. Furthermore, using cylindrical sections the integration of the round wood stems with other, standard, building elements is much more straightforward. Another advantage of milling is the fact that all sapwood is removed, and stems

consisting of only heartwood remain. This makes it possible to use the Larch beams unpreserved. For the tower all stems were milled cylindrical.

In the Dutch building industry poles from thinnings are hardly used for construction purposes. One of the reasons for this is the fact that no design rules are available for the material. Furthermore construction wood from thinnings is not available via the normal commercial routes. The material requires special selection techniques to ensure high enough strength. Using the results of the EC research project “Small diameter Round wood in Constructions (1996-1999) [1]”, it was possible to select wood with sufficient strength characteristics. Using ring width, maximum knot diameter and maximum initial curvature as selection criteria, the necessary 140 beams (with lengths up to 4.5 m.) were selected from a batch of 180 poles. The EC5 strength class of the round wood was C24 and all beams used have initial curvatures less than or equal to 1/200.

3 Connections

During the drying of the stems cracks develop in the length direction of the beams. In general a stem has one or two of such cracks, present over the full length. The width of these cracks can be considerable (dependent of the diameter, up to 10 mm). While these cracks have negligible influence on the strength of the stem, wide cracks can lead to problems when dowel type fasteners are used. To cope with this problem an innovative connection was developed. This so-called anchor block connection is based on load transfer through a threaded steel rod that is ‘anchored’ in the pole. This results in a wooden beam with on both ends a thread end. The steel anchor block has dimensions that are an order larger than the maximum width of a crack. This ensures the anchorage of the rod to be insensitive for the cracks. The principle of the load transfer mechanism is simple: compression forces are transferred directly by contact pressure through the head plate of the connection, while tension forces are transferred to the anchorage block by the steel rod. From the anchorage block, the force is transferred to the wood by contact pressure and ultimately through shear stress transferred to tension stresses in the centre part of the beam.



beams with axial hole



milled anchor block chambers



*parts of the anchor block connection:
anchor block, threaded rod and head
plate*



assembly of the connection



prestress auxiliary device



*'workmanship' application of
prestress in connections*



fixing the prestress in the wood



*beams ready for assembly in the
tower*

The elements of the connection are assembled under prestress. This way all slip is pulled out, and a stiff connection results, that is well suited to transfer changing tension and compression forces. To be sure of the prestress level in the connection, the prestress is applied externally, using auxiliary tensioning devices. While the external tension is acting on the connection, the head plate is tightened, and the prestress is 'locked' into the connection area of the beam. Certainly in time the prestress level will decrease by creep of the wood, but only a minimal prestress level is enough to ensure a stiff reacting connection.

4 Joint

Based on the anchorage block connection a (patented) jointing technique was developed. In the joints of the tower the beams are connected in both lateral and axial direction. For this joint a so

called chaining block was designed. The chaining block is made out of a cube shaped piece of SHS 120x120x10 profile. In one direction the block has openings to couple it in lateral direction; in the other direction the faces of the block have incisions, leading to a center hole. The faces with the incisions are used to connect the poles in axial direction. The incision enables assembly and disassembly of poles while the chaining blocks are already laterally chained. The poles are slid in the slots and fixed to the chaining block using special locking disks that exactly fit in the centre hole. With a special tool the locking disk is tightened inside the chaining block. The principle of the joint is also applicable for other structural elements, like trusses.



Chaining block



Chaining rod



Tightening of a locking disk inside a chaining block



Partially completed joint

The design of the joint makes it possible to replace beams, without taking the whole structure apart. This is essential, as the use of unpreserved wood may imply replacement of degraded poles during the live cycle of the tower. Should this be necessary, a new pole can be constructed, re-using the steel elements of the anchorage block connection.



locking disk



chaining block with incisions and center holes



mounting of beams on chaining block



axial joint

5 Structural analysis

For the structural design of the elements of the tower a complete model of the tower was built in a structural analysis software package. The eccentricities in the joints of the round wood beams are of key importance on the structural behavior of the tower. Therefore these eccentricities are all in the calculation model.

The eccentricities in the joints and other connection detailing cause bending moments in the round wood beams. The anchorage block joint connections are designed essentially for axial loads, and have only limited bending moment capacity. The extreme slenderness of the beams, large initial curvature of the round wood, high design tension and compression forces and the bending moments that result from the eccentricities in the connections, made it necessary to perform design calculations in which the influence of the initial curvature is accounted for.

Light weight structures like this tower are sensitive to dynamic response of horizontal loading by wind and/or persons. Notably in this case, were also the eccentricity in the nodes has negative influence. To analyze this aspect of the structure, the horizontal deformations of the structure were studied carefully, and calculations were made to verify the dynamic behavior.



Viewing platform Holmers Halkenbroek, Drenthe



Home grown small diameter larch beams. Central steel stairway



Foundation detail



Foundation detail central column

6 Discussion, conclusions and acknowledgements

This project clearly demonstrates that small diameter poles can be used for structural purposes. The connection that was developed enables industrial production of high quality building elements, directly suited for assembly in a structure. Structural analysis of the concept of the tower show that using poles with a diameter of only 140 mm and lengths up to 4 meters towers up to 21 meters high can be built.

The behavior and capacity of the anchorage block joint is dependent on the final prestress level in the connection. Current research at Delft University of Technology concentrates on this aspect. An omission in the current design guidelines is a set of ready to use strength grading rules to select suitable poles. Until practical rules are available for strength grading of small diameter poles, the use of the material for structural applications will remain marginal.

7 References

- [1] A. Ranta-Maunus, 1999, Small diameter Round wood in Constructions.