BenDit – A Polyhedral Sculpture from Bent Wood

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Abstract

BenDit is a sculpture from bent wood, created at the TU Dresden as a demonstrator within the European Interreg project Adhesive Free Timber Buildings. It has a diameter of about 3 meters and is hanging in the atrium of the Biology building on the TU Dresden campus, where it was solemnly inaugurated in June 2020. BenDit is a model of the deltoidal icositetrahedron. Twenty-four identical kite-shaped wooden frames are connected along the edges. The scientific director of the project was Peer Haller from the Institute of Steel and Timber Construction. The design was provided by Daniel Lordick from the Institute of Geometry. This report reflects on the assumptions, research goals, and constraints that led to the final design and which were also driven by the architectural environment and the context of other art objects in the Biology building.

The Research Context

The European Interreg project Adhesive-Free Timber Buildings (AFTB) investigates alternatives to the wasteful and harmful use of toxic adhesives in the manufacturing of Engineered Wood Products (EWPs) by the construction industry [1] and aims to avoid metal joints as well. The subproject at the Technische Universität Dresden (TU Dresden) under supervision of Peer Haller especially tries to make use of bent wood. Bentwood is hygrothermal formed wood and has well-known applications in furniture design, e. g. in the iconic bistro chair by Thonet [2]. The advantages are obvious: it is possible to achieve freely curved forms, which adapt to the flow of forces, without gluing or extensive milling. All it takes is heat, steam, and pressure. Furthermore, the wooden beams can be used up to the full extent of the load-bearing cross-sections and the wood can contribute its naturally grown stability to the construction even after heavy deformations. In addition, certain hardwoods are preferred for bentwood, which so far have hardly been used in construction. Thereby, bentwood promotes near-natural silviculture. Against the background of climate change and the associated decline of spruce, this is definitely a trend-setting effect.

Despite these advantages there are only few examples for large scale applications, e. g. historic ship design. The reason for this is that upscaling is not trivial, as the compression forces in the wood increase exponentially when larger cross-sections are bent. This means that much more powerful machines are required than in the manufacturing of furniture. Such machines are not yet available and consequently there is a lack of experience with large beams in terms of the behavior of the wood and the variation of the results. This led to the need for a demonstrator that is significantly larger than a chair and that is suitable as a proof of concept (Figure 1).

The Shape and Size of the Modules

In the spirit of the research project we concentrated on lightweight structures as a resource for design. A typical solution for wide-span roofs is a grid shell from planar quadrilaterals. We have therefore decided to generate quadrilateral modules as frames, assuming that from such modules a larger structure could be assembled in the future. The modules should be inherently stiff so that we could avoid diagonal cables, which typically stiffen similar structures from glass and steel. Freeform roofs require mostly individually formed quadrilaterals. In this stage of the project we postponed the challenge of custom manufactured frames, for which large machines with flexible bending molds are required – a technology that is not yet available. The first step had to be anyway that we generate a series of identical frames and examine the results with respect to precision and repeatability.

Each frame consists of exactly one piece of wood and uses the entire length of the commercially available four-meter-long pieces of ash from the Lake Constance region. Thus the perimeter of the quadrilaterals was set technically. The frames were dampened and bent at the Swiss company 3R that normally manufactures Davos sledges [3]. At TU Dresden the bent timbers were glued to loops with simple half-lap splice joints that were placed in the middle of a longer edge of each frame. These joints were evenly distributed over the entire structure, so that no two joints ever meet at one edge. We also successfully tested joints that avoid adhesives. Unfortunately, due to the critical hanging position above a common space frequently used by visitors and employees, we had to resort to an already officially approved technical solution this time.

Figure 1: *BenDit (3 meter diameter, about 180 kg, ash) as installed at the TU Dresden. Some of the contributors are visible in the background. Photographer: Lothar Sprenger 2020.*

The Polyhedron

With respect to the range of possible elements we had to develop an object that can be assembled from congruent quadrilaterals and which has enough formal strength to persist as a solitaire within the architectural environment. We decided to deploy a sphere-like polyhedron. There is a short list of possible candidates starting with the cube with its six faces (considered to be trivial). Others are the rhombic dodecahedron with 12 faces and the rhombic triacontahedron with 30 faces. Both have the drawback of highly symmetric quadrilaterals, which look too special compared to typical examples of quadrilaterals in grid shells. In this respect, the deltoidal icositetrahedron with its 24 kite-shaped faces seemed most suitable. The deltoidal icositetrahedron is a member of the polyhedra called "Catalan solids" [4]. As such, it not only has congruent faces, but in addition the dihedral angles are all the same. By the way, an acronym of the Greek name in connection with the verb to bend is the reason for the name BenDit.

The frames are connected with wedge-shaped elements, two at each edge, which, thanks to the constant dihedral angles, makes 96 identical parts. In the center of each wedge there is a metal cylinder with four threads to hold the connecting screws (Figure 2). The 384 black screw heads are a visual accent on the light wood. The whole structure is easily demountable and all parts can be reused. The exact crystal structure of BenDit served as a touchstone for the assembling process, because the polyhedron had to close precisely at the end. Initially we wanted to use wooden nails for the wedge joints. But again, despite good results in testing, for the building permit we were forced to use metal joints instead. Given the size of the frames, the adjusted wedges, and the geometrical structure of BenDit, the result is a diameter of 3 meters.

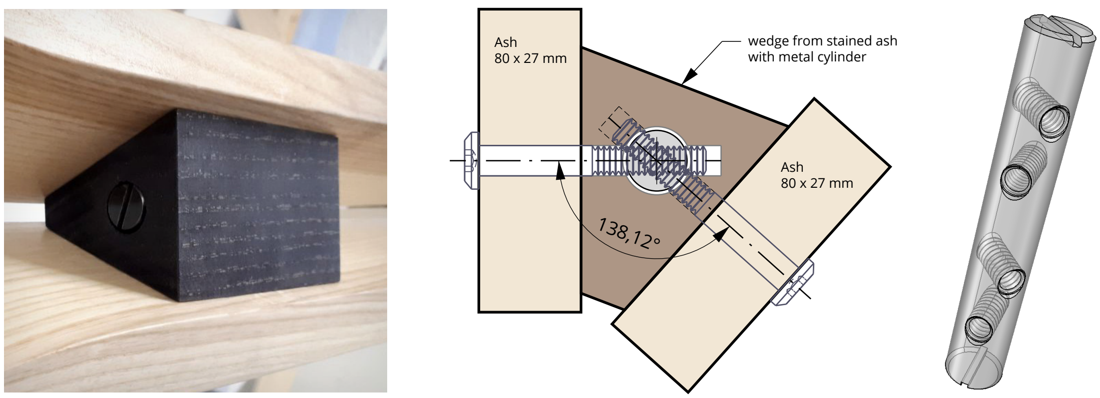


Figure 2: *Left: photograph of a wedge. Center: cross section of the wedge between two frames. Right: rendering of the metal cylinder with four threads to hold the connecting screws.*

Installation at Site

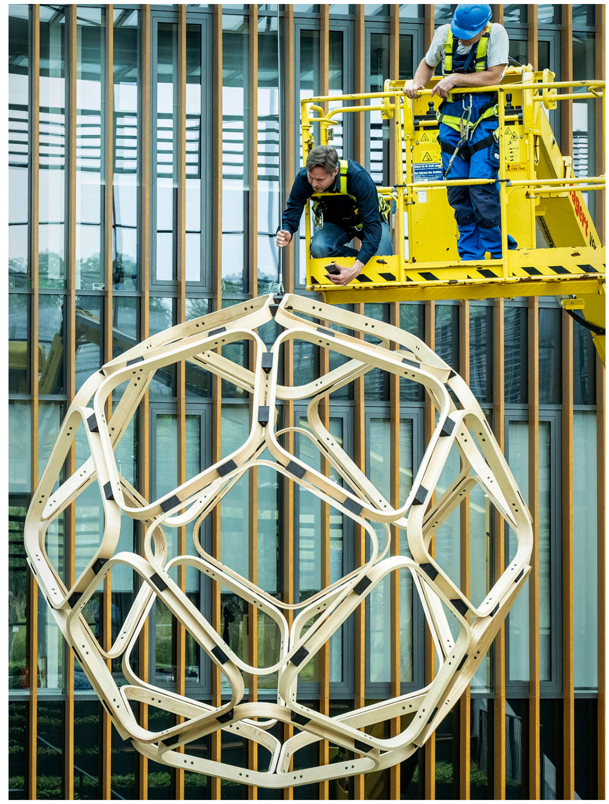
We neither wanted to block a part of the wonderful atrium of the Biology building, nor did we want BenDit to be abused for climbing. The logical consequence was, it had to be suspended from the ceiling. The interior of the atrium already hosts a stepped terrace with plants and two pieces of art. The ceiling provides a large construction grid, into which we wanted to insert BenDit logically. With respect to all given constraints there was only one position in grid and height that was convincing.

The lightness of BenDit, it weighs less than 200 kg, should be emphasized with its ability to rotate with any slight circulation of air. This is why it is suspended from only one 8 mm cable and why there are swivel lifting rings at each end of the cable to avoid any torsion of the strands (Figure 3 a). In fact, BenDit turns very easily with a meditative slowness, which increases the perceptibility of its airy three-dimensionality. The three-fold symmetrical hook, on which BenDit hangs, is milled from a block of aluminum. The axis of rotation is a space diagonal of the inscribed cube with the same symmetry group as BenDit (Figure 3 b).

Summary and Conclusions

BenDit was created in the harmonious interplay of geometric approach, scientific-technical vision, effective use of materials and solid craftsmanship. Bent wood proved to be a suitable starting material for complex structures in a certain size already relevant for applications in buildings. All demands of the research and all requirements of the location had been integrated consequently into one compelling shape that derives much of its power from the interplay of classical symmetry and dynamic expression. With its dissolved edge structure and the rounded corners, it only implies the underlying polyhedron in the sense of the Platonic concept of ideas. Coming from an abstract realm, BenDit gives us a sensual model for the future and, with its warm materiality, blends in with the architecture of the biology building. Wood represents cyclical growth. It has all the characteristics with which we can reconcile technical progress and renewable resources.

(a)



(b)

Figure 3: *Installation of BenDit: (a) Hook, (b) Cable check. Photographers: DL (a), Sven Geise (b).*

Acknowledgements

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References

[1] Adhesive-Free Timber Buildings, Website of the European Interreg project: https://www.nweurope.eu/projects/project-search/towards-adhesive-free-timber-buildings-aftb/.

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[5] Ress, C.: Video documentation of the development of BenDit (2020): www.youtube.com/watch?v=QOwNEqEb3Oo.