STUDIEVERENIGING KOers
CONSTRUCTIEF ONTWERPEN

Kersief

EDITION 114
January 2022

One Million Houses

An opensource housing alternative

WikiHouse

By: Vincent Muller, Wim de Groot, Arthur van Lier, and Pieter van Loon
Co-founder WikiHouseNL, engineer at SHR, engineer at Lüning, editor KOersief

A roof over your head, it should be a human right. A house that fits your needs, custom designed, something to live in, rather than a pile of bricks as investment. WikiHouse is an affordable, bespoke solution for real DIY housing. It is an innovative open-source construction package that is accessible to all.

The concept is simple: you can download a design from the database, mill all the components, and assemble it yourself! Alright, it is not quite that simple yet, but the community is growing quickly and globally. Create your own design or tweak one of the current designs, but make sure to upload your work so that future DIY'ers can use it for their projects.

Wikipedia explains open source as the following: "Open source is source code that is made freely available for possible modification and redistribution. Products include permission to use the source code, design documents, or content of the product." The goal of WikiHouse is to build a database with source documents that enable anyone to design, manufacture, and assemble their own home, as illustrated in *Figure 1*.

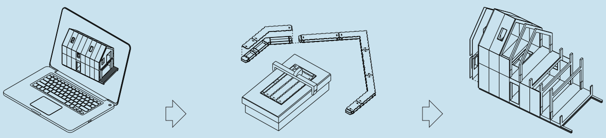

Figure 1: The WikiHouse concept: from design to manufacturing and assembly

The WikiHouse concept, founded by Alastair Parvin in the UK, now contains multiple systems. Each system with its own technical boundaries, its own parameters, and own set of design rules. The common denominator in all this is that all of them consist of 2D timber plates (2440x1220x18 mm^3), which CNC machines can mill to create building blocks of the structure. These building blocks can be manually assembled to form the main structural elements (like portal frames), which in their turn can be combined with the facade plates to become the 3D structure of the design. All this is done with just a few elemental timber connections like the box joints and dowel connections.

One of the implementations of this concept can be found in Almere, where the 'Woningbouwatelier' initiated the first neighborhood consisting of WikiHouses globally. The 'Woningbouwatelier' is an initiative in Almere that promotes innovative and sustainable residential projects. To realize the project the Wren system had been adapted by WikiHouseNL (cofounded by Vincent Muller) to facilitate larger spans. The improved system that can span up to 4.8 meters - 1.2 meters more than its predecessor - has been named Swift. To comply with Dutch codes, the design of Swift has been carefully collaborated with SHR, which provided the structural calculations and tests among others. Finally, a prototype of the system was realized on the BouwExpo in 2017 as a tiny house of 38 m^2. A picture of the finished house can be seen in *Figure 2*.

Technical challenges

When Vincent Muller approached SHR to ask for help developing the Swift system, a lot was still left open. The main parameters were that the system had to be constructed from flat sheet-panels (2440x1220x18mm^3), it should be able to span 4.8 meters, it should provide stability, and from an energy performance perspective, an insulation layer of 300

Figure 2: Tiny house prototype of the Swift

millimeters should be placed around the perimeter of the house. Furthermore, all connections should ideally be based on carpentry joints, or if necessary, screws. But no glue was to be used to keep the system demountable.

For Wim de Groot at SHR, this quickly led to the following basic principle; the structure would be made up of box girders with sufficient height to house the insulation. In this way, a decent amount of moment resistance can be made out of very thin sheeting material. Furthermore, by offsetting the seams in the flanges and webs, an element of 4.8 meters could be made out of sheets of 2.4 meters. *Figure 3* shows the test setup of a 4-point bending test performed at SHR to determine the capacity of the concept. As the red lines indicate, the seams of the web are at 1/3 and 2/3 of the span, whereas the seams of the flanges are near the supports and in the middle of the span. In this way, the box girder as a whole, is never discontinuous, so it can always transfer its bending forces from one sheet to the other. Furthermore, the flange plates were connected by dovetails rather than box joints, so the tensile forces can be transferred over the seam.

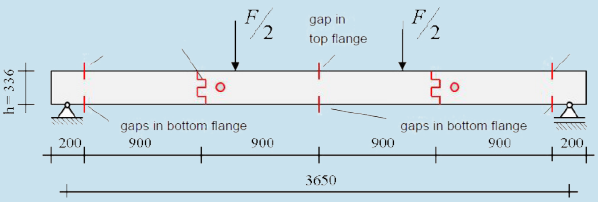

Figure 3: Test setup 4-point bending test

In order to make a stable house, the box girder concept was changed into a box frame (in the shape of the house) with stiff corners. The web plates were made continuous over the corners to ensure moments could be transferred around the corners of the frame, as can be seen in *Figure 4*. In the longitudinal direction of the house, stability is provided by panels that interconnect the portals.

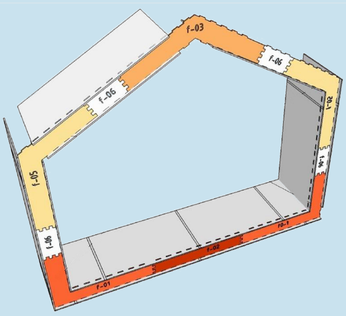

Figure 4: Continuous web-plates for moment-resisting corners

In the end, the tiny house consists out of seven floor boxes with eight portals. *Figure 5* shows a step from the assembly document of the tiny house. The figure clearly shows how the portals are interconnected to provide longitudinal stability. With a width of 1.2 meters, the modules leave plenty of room for window and door openings. With door openings, however, the module wall is considered non-loadbearing since a door opening takes up roughly the entire panel width.

The next stage: two stories

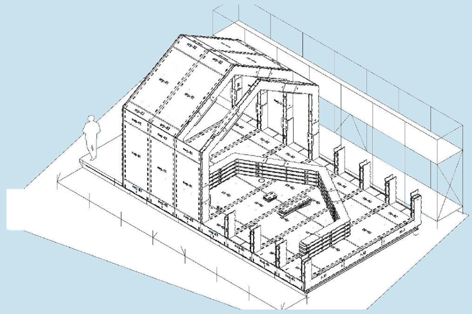

Figure 5: A step from the assembly document of the tiny house

Meanwhile, the next stage of the Wiki-neighborhood has started in Almere. Phase one of this stage, consisting of nine residences, is almost complete. Phase two, an additional 18 dwellings, is being built at the time of writing. These new houses range from 50 m² to 100 m² and most of them have two floors. A part of the new houses are built as row-houses, but the structural elements are being kept separate to keep all the houses modular and demountable.

Since the *Swift* concept was developed as a single-layer structure, the structure's performance had to be recalculated when an extra story was added. This resulted in a design that was off with a unity check of 2.8 in the SLS design as shown in *Figure 6*. The main challenge here was the wind load in the lateral direction, for which the moment-resisting box-frame is ensuring stability. The dwellings are designed as stand-alone villa's and therefore, each house should be able to withstand lateral wind forces on its own. For a single-story WikiHouse, the box-frame has sufficient capacity. However, when an extra story is added, wind forces on the structure increase significantly. This means that the box stiffness had to be almost tripled to suffice. Strength properties should also be increased but to a lesser extent.

Possible design considerations that were pursued within the

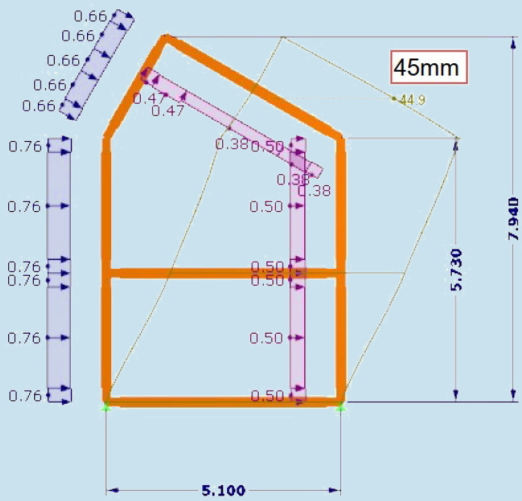

Figure 6: DLUBAL RSTAB calculation of deflection under lateral wind load. Maximum deflection = 8000 / 500 = ~16millimeters; U.C. = 45 / 16 = 2.8

WikiHouse concept were:
Adding extra plywood webs to the box frame.
1. Changing material to birch plywood, which has
2. superior material properties to standard conifer plywood.
Optimization of the joint design.
3. Increase of the total box depth.
4. Adding stability wall panels that would be 'clicked
5. in' to the WikiHouse casco.
In finding a solution within the WikiHouse system

it was difficult to deviate from the standard box lay-up from the SHR tests, since this would mean that the test result would not be valid for the system and new tests should be carried out. For some of these improvements, the section properties of the box could easily be derived. The SHR test was, for instance, carried out on a 600 millimeters wide box, and therefore, adding two extra webs in the center of the span would mean that on a 1.2 meter grid, two boxes would be effectively created and the stiffness and strength would therefore be doubled, see *Figure 7*. Other changes, like increasing the total box thickness and optimizing the joints, have effects that are not easily extrapolated due to the uncertainty in the slip

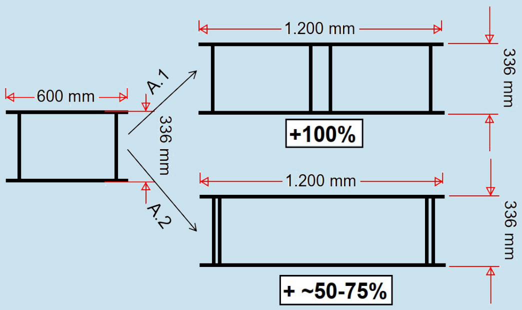

Figure 7: Consideration to increase box properties

factors of the (jig-saw) notches inside and between webs and flanges. New lab tests would therefore be necessary to find a solution that would decrease the U.C. of 2.8 to a respectable value. Unfortunately, these improvements were unrealistic to be carried out in the short time span of the project. Other factors, like ease of construction and weight of separate elements also played a role here.

The solution was therefore found in creating a Glued

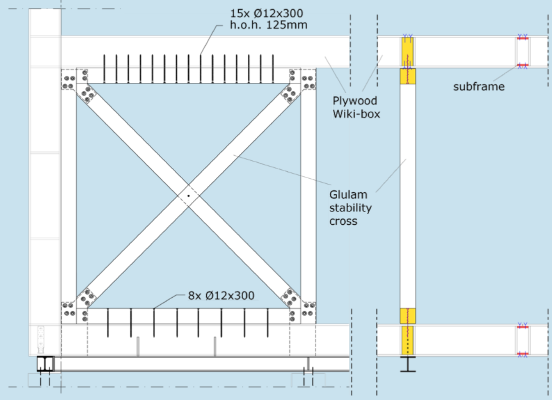

Figure 8: GLT stability frame with connector beam

Laminated Timber (GLT) cross on the bottom floor that is used as a stability frame (*Figure 8*). This cross is directly connected to the steel foundation frame. The first floor is designed as a stiff plate supported by the longitudinal plywood walls and the stability frame. The difficulty here was to implement a more traditional timber construction method into the innovative Wikihouse concept. Because the timber cross would behave much stiffer than the Wikihouse casco, all the stability forces would be directed towards the wall. Furthermore, the floor plate, consisting of 1.2 meter wide modules, had to be properly screwed and tied to let it behave as such. The shear forces in the floor are transferred using a screwed connection between the plywood plates and the subframe (*Figure 8*). The force is transferred towards the GLT cross via a GL beam inside the plywood box. The bending moment in the floor is taken by a steel strip for tension on one side, and through compression on the other side. From the first floor up to the top of the roof, the house would still behave like the 1.0 single layer version.

In the end, a toolbox has been developed for the design process of the Swift, as can be seen in *Figure 9*. The toolbox consists of modules, which can be assembled according to specific design rules to create a design. Installations, as well as interior and exterior finishes, can be chosen freely, as long as it complies to the building codes and local rules. With this, the core concept is achieved; democratization and digitalization of the design and construction process of a house! An easy to use toolbox, for proper DIY house design and building. ◀

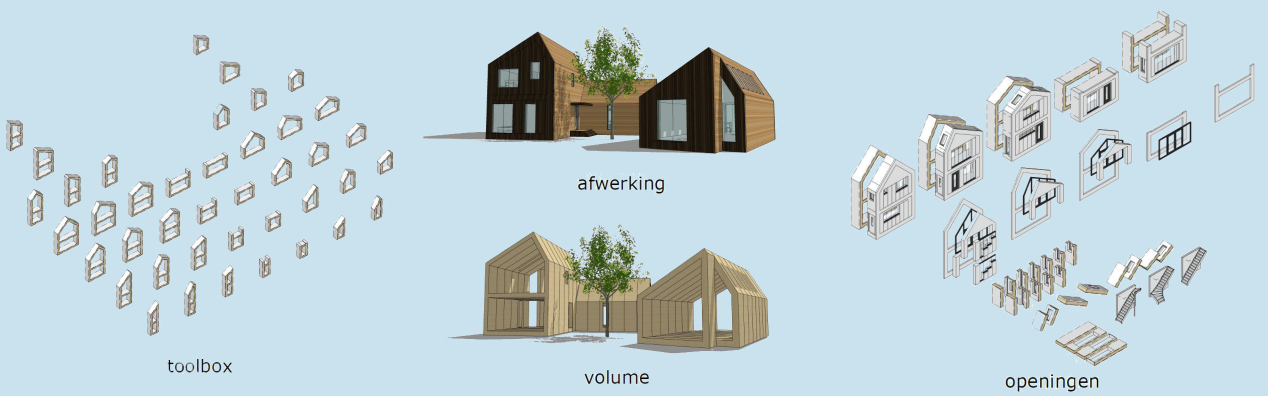

Figure 9: Toolbox of the Swift (a), possible design (b) and openings within the system (c)