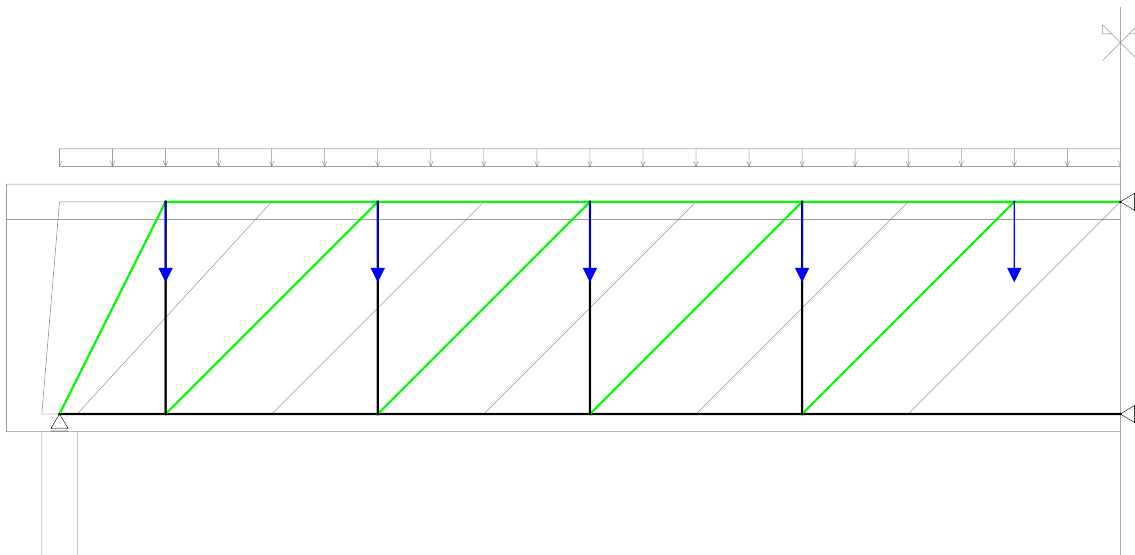


Calculating strut-and-tie models with FACHWERK and FACHWERK3D



Program documentation

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since 2008

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1 The program Fachwerk

1.1 Purpose

FACHWERK is aimed at structural engineers who analyse and design reinforced concrete structures. It intends to simplify the application of discontinuous stress fields and strut-and-tie models. The program calculates strut-and-tie models. It only uses equilibrium conditions. Thus, unlike common programs, it does not assume elastic material behaviour.

If the modelled system is hyperstatic, FACHWERK will nevertheless calculate the forces of the members that are determinate. One can assign forces to the remaining members. If more forces than needed to accomplish a statically determinate system are assigned to members, and the equilibrium condition is not fulfilled, FACHWERK will indicate that the system is inconsistent.

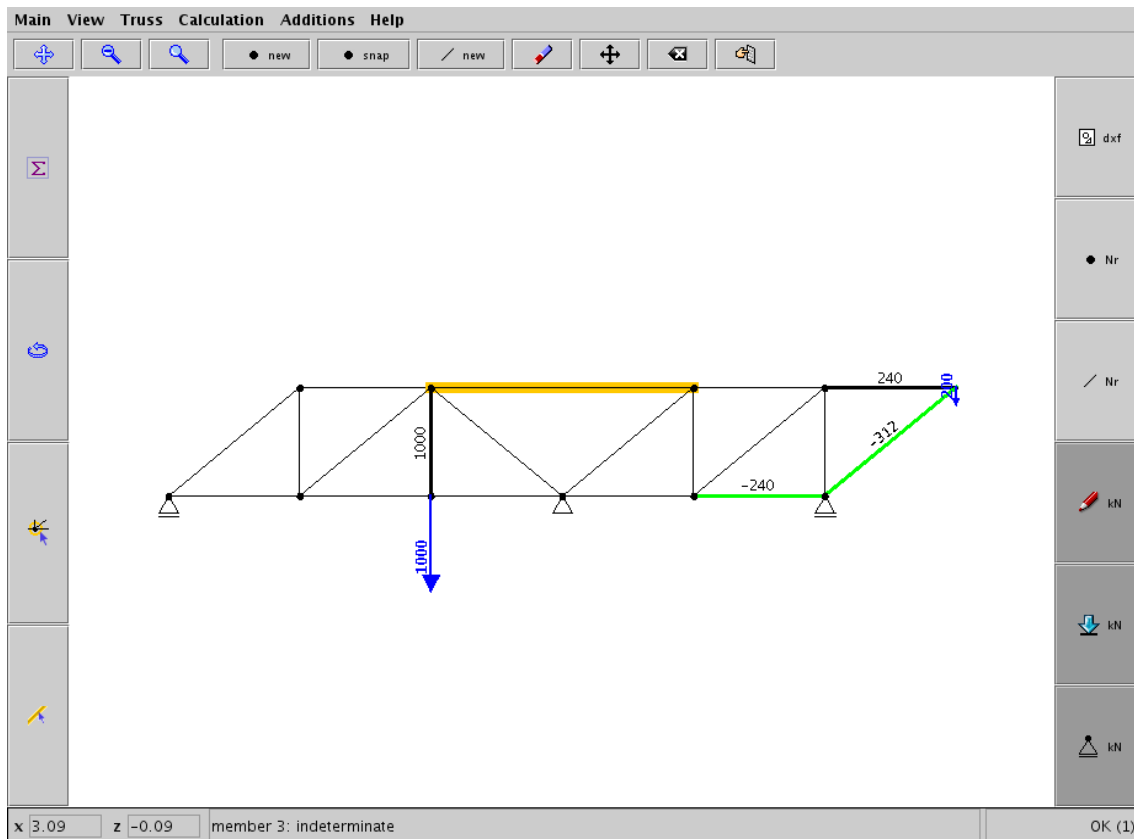


Figure 1: Statically indeterminate model

The example in Fig. 1 shows a strut-and-tie model of a beam with three bearings. The model is statically indeterminate. The members represented by thick lines are determinate: black indicates ones with **tensile** force, green ones under **compression**. The remaining members are still indeterminate (indicated by thin black lines). The number in the status field on the bottom at the right side points out that one of these members can be set.

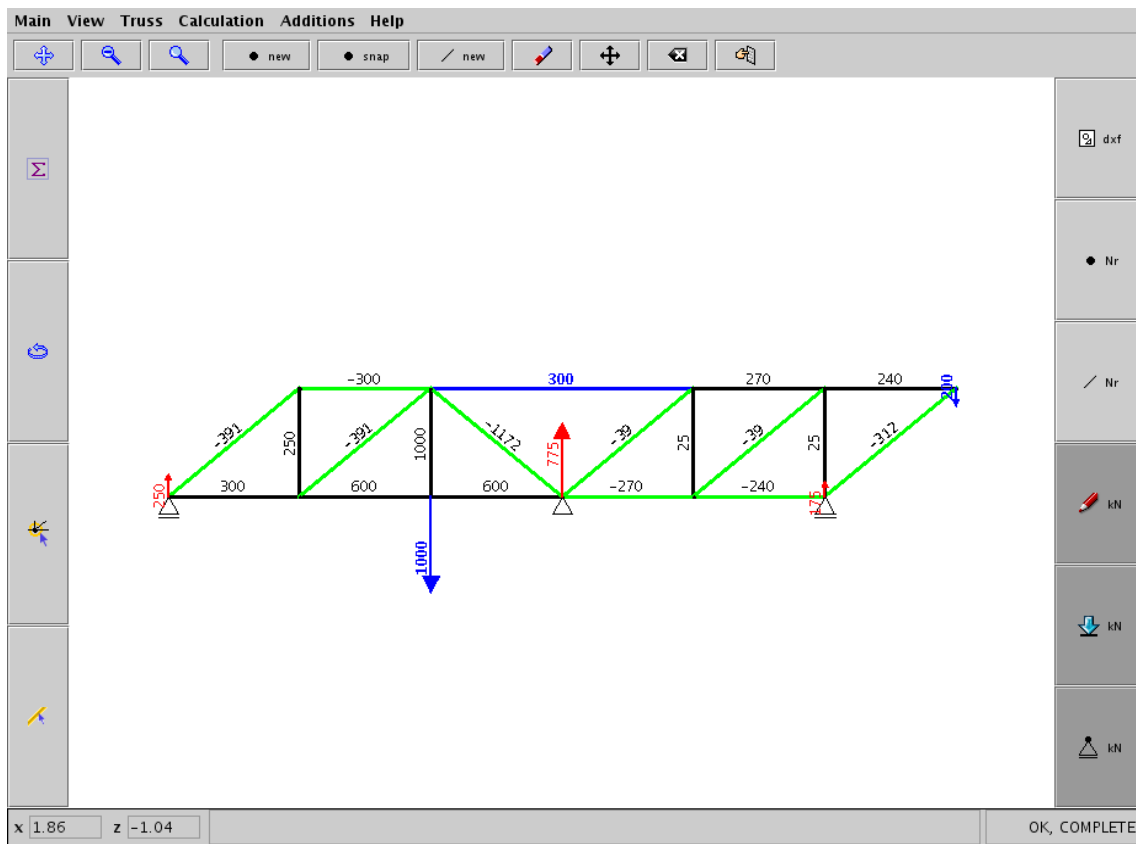


Figure 2: Calculation completed

The selected member (highlighted yellow) shall be **set** to 300 kN. Members with assigned force are drawn in blue colour. Now the calculation can be started again. Figure 2 displays the complete strut-and-tie model, all members are determinate.

1.2 Background

Discontinuous stress field models are suitable for the design and detailing of reinforced concrete structures. The method (based on the theory of plasticity) is graphic and clear. The statical action and the strength can be analysed in a consistent manner [1]. In many cases, this method can easily be applied «by hand». Sometimes, however, a computer program would be helpful to calculate the model. The time saved could be used for the thorough development of stress fields and for the detailing.

To the author's knowledge, there is no publicly available computer program for the calculation of general plane stress fields. A practicable procedure is to first draw the stress field model and then to convert it into a strut-and-tie model. The members of the truss represent the resultants of the compression fields and of the reinforcement. This approach is applicable in many cases.

1.3 Difference to other programs

Every program for frame analysis can calculate trusses and, therefore, is able to find a possible solution that respects the equilibrium conditions. However, there is a problem if the system is statically indeterminate. The common linear-elastic programs calculate the forces according to the rigidity of the members. For the calculation of strut-and-tie models (for reinforced concrete structures) however, the rigidity of the members has no direct meaning and should, consequently, not be used. Instead, one may want to assign the yielding force of a number of reinforcement bars to a tie of the model. This is what FACHWERK is designed for.

1.4 Fachwerk is not suitable for ...

- calculations of deformations.
The program only uses equilibrium conditions. It does not know anything about elastic deformations.
- calculations of bending moments.
The program only knows compressive and tensile forces.
- steel constructions
While FACHWERK can calculate the axial forces of truss beams, there are better suited programs for this purpose.

2.3 No unnecessary bearings or members

FACHWERK allows *unstable*, kinematic models, as long as equilibrium conditions are fulfilled! Supports can be omitted if they are not necessary for equilibrium of the respective load case. Also, there is no need to insert unstressed members.

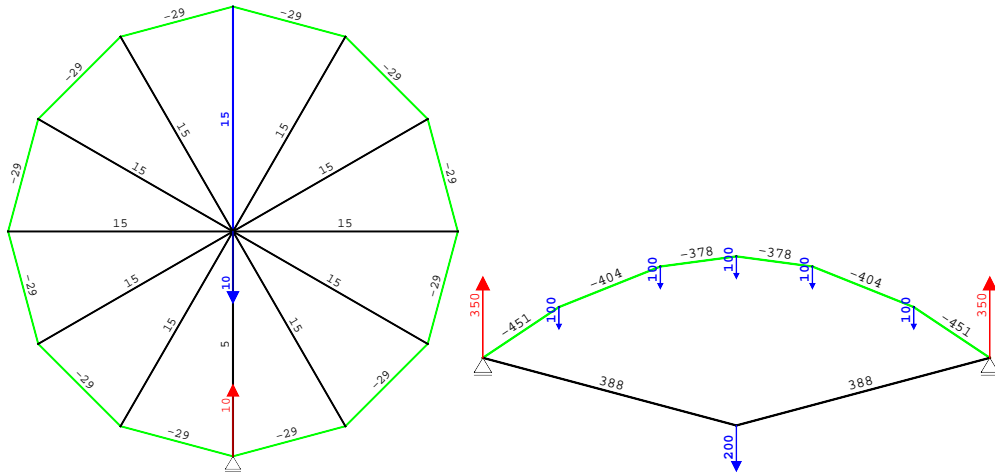


Figure 5: Unstable equilibrium

This feature is quite useful for the calculation of strut-and-tie models, because very often the instability only applies to the model, whereas the real construction is stable. When calculating spatial strut-and-tie models (see chapter 4), the nodes of a concrete web do not have to be supported perpendicularly to web's plane.

2.4 Failure mechanisms

Failure mechanisms are detected and drawn. That way it is easy to find missing members in the model or to prove that a system is kinematic and contradicts equilibrium.

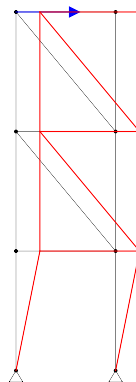


Figure 6: Mechanism

2.5 More features

- norm independent
FACHWERK can be used in conjunction with various construction norms, as the program only applies the equilibrium conditions to the model. Nevertheless, the use of *SI* (metric) units (kN, m) is assumed.
- drawings
Drawings can be displayed in the background of the model. The CAD format *dxf* or the simple text based *bgd* format (see chapter 3.4) are supported.
- print to scale
1:50, 1:100, 1:20
- documentation
A documentation of the model (node coordinates, members, forces, etc.) can be printed easily.
- platform independent
FACHWERK runs on every platform which runs *Java*: Linux, Windows, Mac OS X, Unix
- languages
FACHWERK has been translated to English, German and French.

2.6 Licence GPL

FACHWERK and FACHWERK3D are subject to the *GNU General Public License Version 2*. The text of the licences¹ is distributed together with the program.

All results must be verified carefully in order to state that they are plausible! Therefore, the user must have the appropriate knowledge of statics in order to use the program. The licence disclaims all liability of the author.

2.7 Program development

FACHWERK has been used since 2003. The intended functionality is complete. It is planned to maintain the program (bug fixes, small improvements, etc.). It is recommended to check <http://fachwerk.sourceforge.net> for a new version from time to time.

The program documentation is based on these versions:

- FACHWERK 0.4.4 (March 2016)
- FACHWERK3D 0.4.4 (March 2016)

¹The math library used is subject to its own Open Source licence.

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