

RIGID BODY ON HINGED BARS

This program calculates the forces in the supporting bars which are supporting a rigid body. The analysis is fully 3D. For the 3D presentation a web browser with a VRML plug in is required. The rigid body is possibly loaded in the direction of the six degrees of freedom. The coordinate system is located at the mass centre of the rigid body. The bars are placed between nodes. The first node is the node attached to the rigid body, the other node is the supported end of the bar.

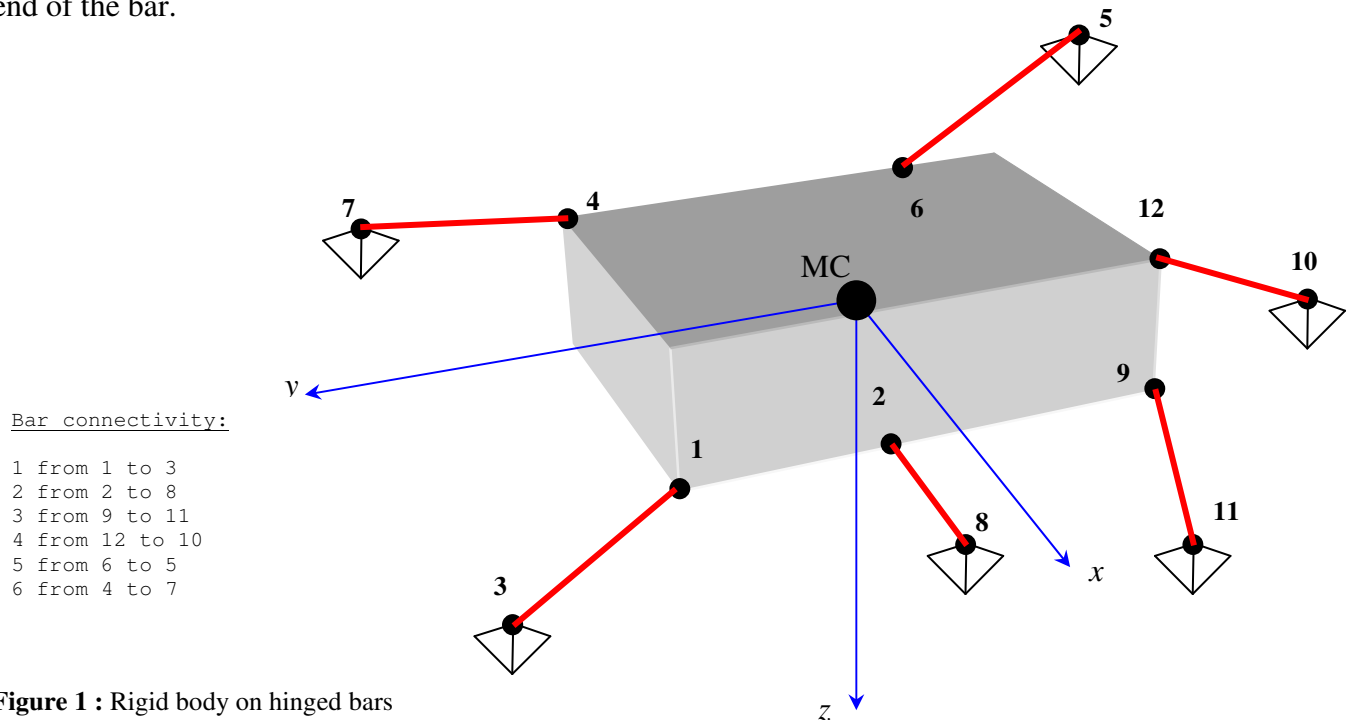


Figure 1 : Rigid body on hinged bars

Each bar can have its own axial stiffness EA . By default the bars use the `type=0` axial stiffness which can only be inputted on the first tab sheet of the program (**Block**).

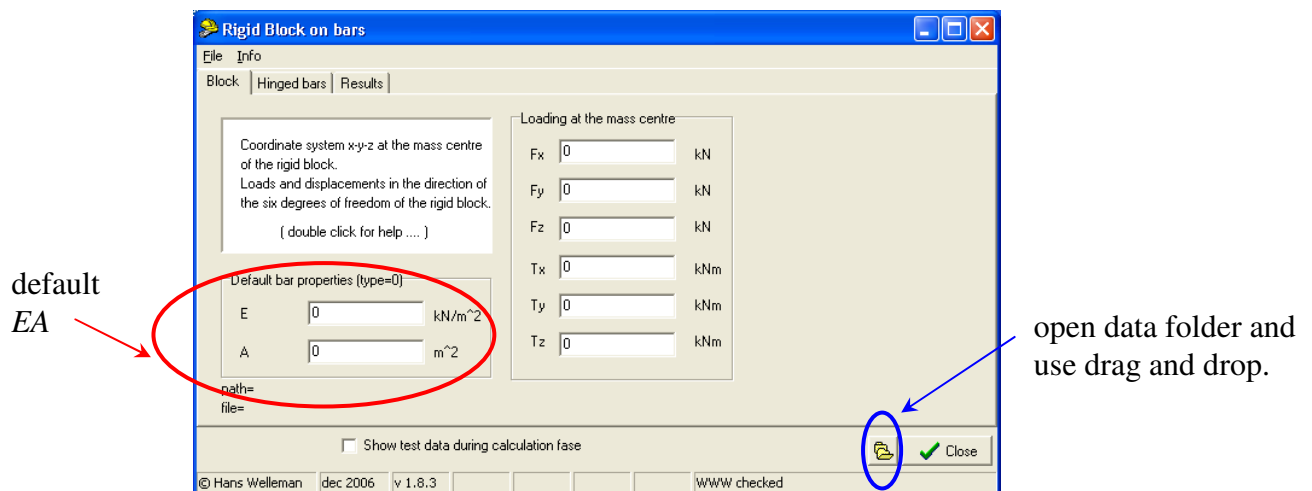


Figure 2 : Block properties and opening screen

On this first tab sheet also the imposed loads on the rigid body can be specified. Previously saved layouts can be loaded or saved with the standard **File** menu options or by opening a data folder by pressing the yellow speed button with the folder icon and using drag and drop capabilities of windows to drop the input files on the application.

Example

To show the capabilities of the program we will examine the following 2D-example in the x - z -plane.

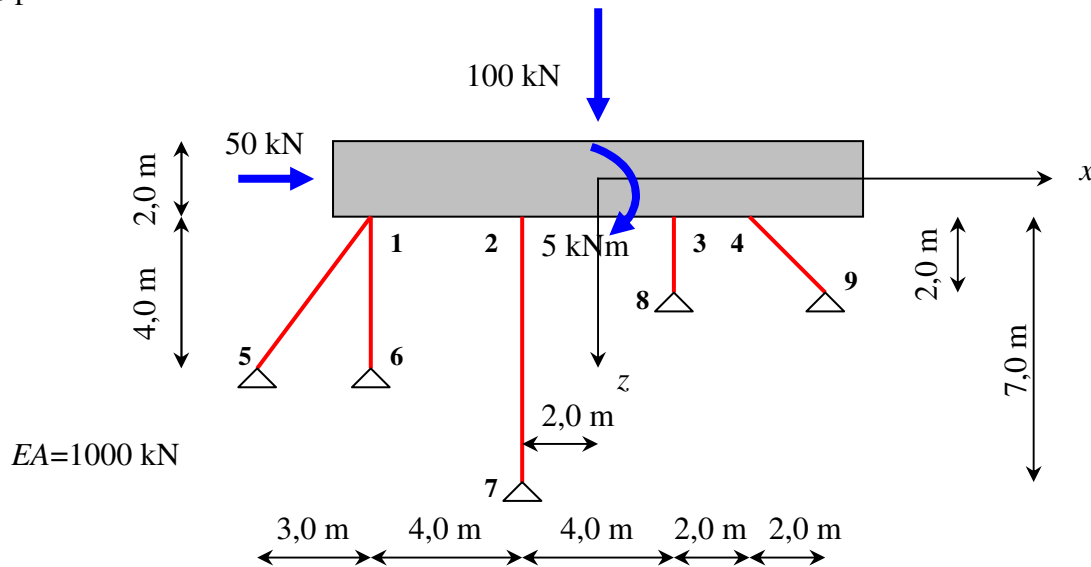


Figure 3 : 2D-example

The loads and the default axial stiffness of the bars can be specified on the first tab sheet (**Block**).

Coordinate system x-y-z at the mass centre of the rigid block. Loads and displacements in the direction of the six degrees of freedom of the rigid block. (double click for help)

Default bar properties (type=0)

E 1000 kN/m²

A 1 m²

path=

file=

Loading at the mass centre

Fx 50 kN

Fy 0 kN

Fz 100 kN

Tx 0 kNm

Ty -5 kNm

Tz 0 kNm

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NOTE:

A positive rotation about the y-axis is from the z - to the x -axis. The applied couple of 5 kNm is therefore negative.

From the figure above the input of the structure can be specified on the second tab sheet (**Hinged bars**).

node X[m] Y[m] Z[m]

1	-6.	0.	1.
2	-2.	0.	1.
3	2.	0.	1.
4	4.	0.	1.
5	-9.	0.	5.
6	-6.	0.	5.
7	-2.	0.	8.
8	2.	0.	3.
9	6.	0.	3.
10			
11			
12			
13			
14			
15			

bar begin node end node type

1	1	5	
2	1	6	
3	2	7	
4	3	8	
5	4	9	
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

type E [kN/m²] A [m²]

0	1000	1
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

View 3D-model (VRML)

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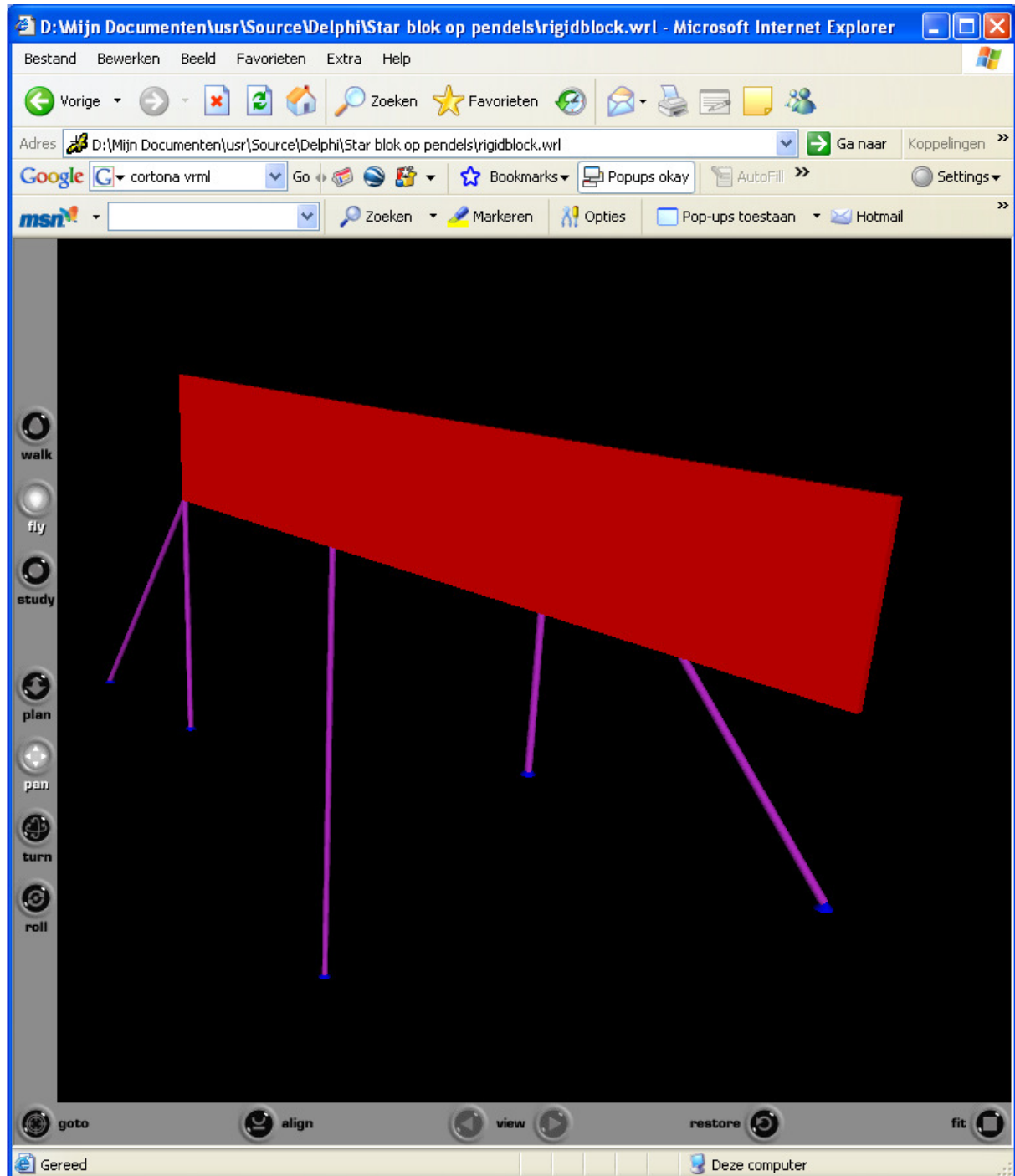
NOTE:

Since all bars use the same (default) axial stiffness no type is required in the bar connectivity table.

If no number is specified a zero is assumed. The EA of **type=0** is taken from the data on the first tab sheet and can only be modified on this first tab sheet.

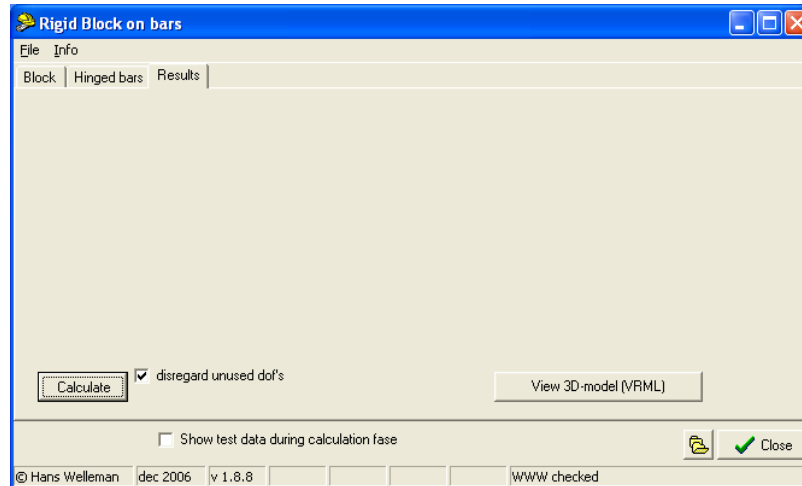
To view and check the model you can press the **View 3D-model (VRML)** button. The model will be exported to a VRML (`rigidblock.wrl`) file which will automatically loaded within the default web browser. The default browser must be Mozilla Firefox with a VRML plug-in installed. A free plug-in is the **Cortona plug-in** which can be downloaded from :

<http://www.cortona3d.com/cortona3d-viewers>

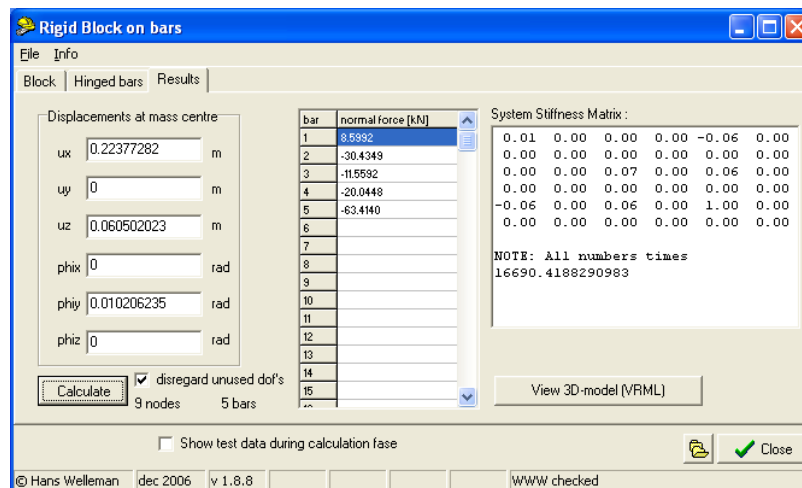


With the button fit at the bottom right the object can be fit to the screen. With the button study you can change with the mouse the view and turn the object upside down.

To find the normal forces in the supporting bars we select the third tab sheet (**Results**).



During the first calculation only the **Calculate** button and two check boxes are visible. After pressing the **Calculate** button the structure is analysed and the results will be shown.

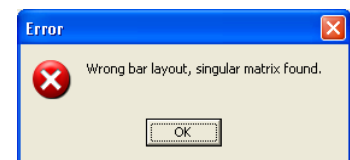


NOTE:

The sign of the normal forces are sensitive to the nodal numbering in the bar elements table. If the **begin** and **end** node are interchanged the sign of the normal force will change. If the correct sign convention is applied the first node should be the node on the block.

On the left side the displacements (and rotations) at the mass centre are shown. In the list the normal forces in the supporting bar elements are shown and on the right the system stiffness matrix is shown. The matrix elements are scaled to the, in absolute sense, largest element. With six degrees of freedom of the rigid body this matrix is always a six by six matrix. Since this is a 2D problem we observe zero rows and zero columns in this matrix (row 2,4,6 and column 2,4,6). If the check box **disregard unused dof's** is marked these rows and columns are disregarded if the corresponding load is also zero.

If the check is not marked during the calculation a warning occurs: With the given bar configuration the stiffness in y- and about the x- and z-axis is not specified. Therefore a mechanism is created if all degrees of freedom's are considered or if a load is specified in an unused degree of freedom.



NOTE : This option should be used only by using your grey cells since it is possible to find the forces in structures which are in fact under different loading conditions swaying structures (mechanisms).

During the calculation the *kinematic* matrix and the *element stiffness* matrix will be displayed if the check box **Show test data during calculation phase** is checked. This will cause a lot of messages so be careful with the use of this option.

Options

The use of the program is straight forward. With the menu option **Info** → **About** some program settings can be changed.

A previous loaded project can be loaded at the start up of the program. Also the automatic update via the internet can be switched off.

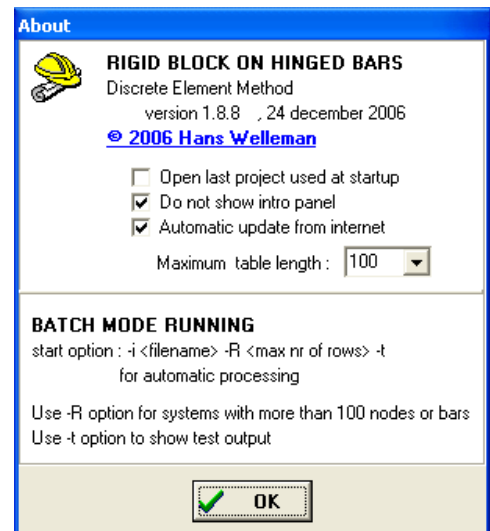
NOTE : By default this option is turned on. If the firewall allows, the user name and machine name are send to the developer for educational purposes only.

Standard all tables allow for 100 lines of input. If more lines are required the number of lines can be increased. The selected options will be stored in an initialisation file

`rigidblock.ini` in the programs root folder. If no data file name is specified `data.PEN` will be used by default and all data will be stored when the program is closed.

The program can also be run in batch mode. This could be handy if in other programs a rigid body should be analysed by calling `rigidblock.exe`. During batch operation no user input is required. Of course this requires a correct input file. All results from the calculation will be written to the input file.

The technical outline of the program is summarised on one page which can be seen with the menu option **Info** → **Technical**.



Technical information

Rigid block on hinged bars

The block on hinged bars has its origin **O** at the mass centre of the block. The hinged end of a supporting bar is attached to the block at a (a_x, a_y, a_z) . The supported end of the bar is denoted with **b** and its coordinates (b_x, b_y, b_z) .

The block has six degrees of freedom located at its centre of gravity.

$$u^T = [u_x, u_y, u_z, \varphi_x, \varphi_y, \varphi_z]$$

The block is loaded by possibly six loads:

$$f^T = [F_x, F_y, F_z, T_x, T_y, T_z]$$

The bar element *i* has its local bar axis from node **b** to **a**. The direction can be denoted with the unity vector *l*:

$$l = \frac{1}{L} \begin{pmatrix} a_x - b_x \\ a_y - b_y \\ a_z - b_z \end{pmatrix} = \begin{pmatrix} l_x \\ l_y \\ l_z \end{pmatrix} \quad \text{with: } |l| = 1.0$$

In which the length *L* of the bar can be found with:

$$L = \sqrt{(a_x - b_x)^2 + (a_y - b_y)^2 + (a_z - b_z)^2}$$

The elongation ϵ_i of a hinged bar can directly be expressed in terms of the six displacements of the block. The relation between the elongation and the displacements is given with the kinematic relation B_i .

$$\epsilon_i = B_i \times u \quad \text{with:}$$

$$B = \begin{bmatrix} l_x & l_y & l_z & -a_x l_y + a_y l_x & a_x l_z - a_z l_x & -a_y l_z + a_z l_y \end{bmatrix}$$

Each elements thus adds to the system stiffness with:

$$K_{system} = K_{system} + B_i^T \times \frac{EA_i}{L_i} \times B_i$$

The displacements of the block can be found by solving:

$$f = K_{system} \times u \quad \text{see footnote } ^1$$

The axial force for an individual hinged bar can be found with:

$$N_i = B_i \times \frac{EA_i}{L_i} \times u$$

¹ Unused degrees of freedoms (with zero stiffness) may be neglected in this system or strictly checked in case of mechanisms. The user can switch this check on or off.

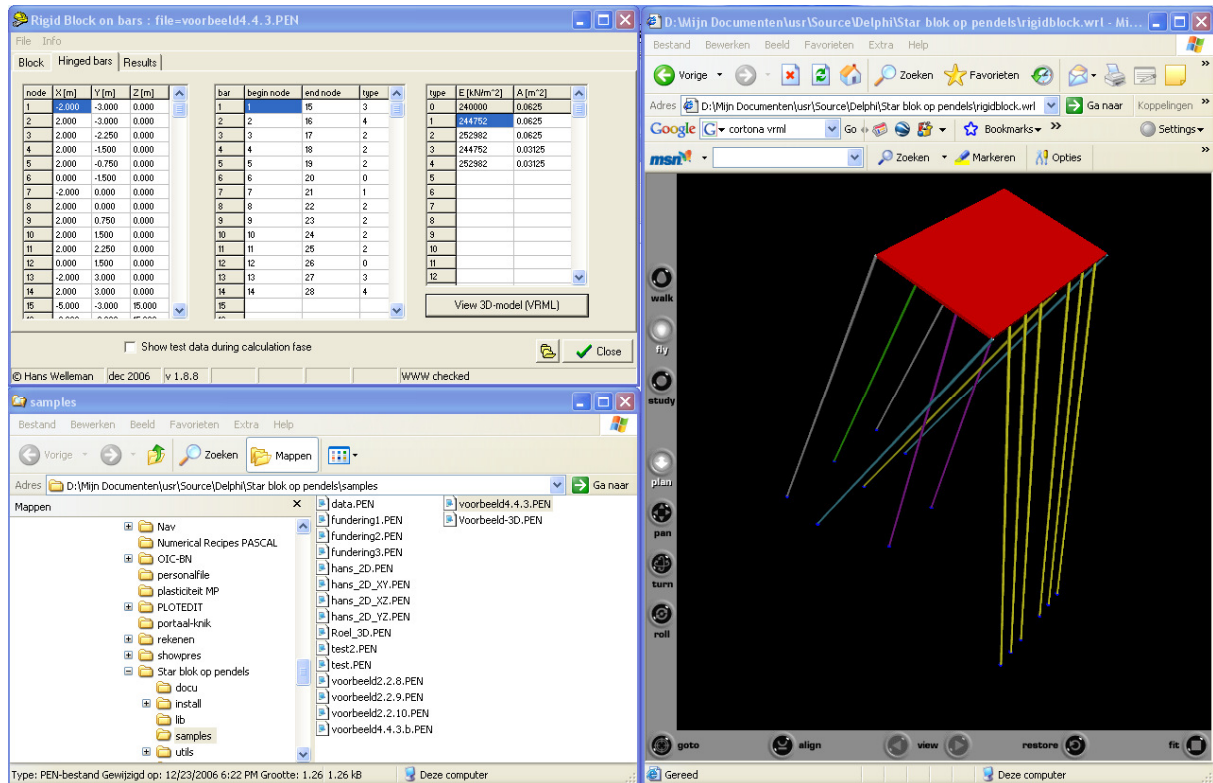
Hans Welleman

2006

Close

WORKING with RIGIDBLOCK

A nice feature of this program is the size it needs on the desktop. If the yellow speed button is activated both the program and the explorer with the content of the data folder can be placed under each other. This leaves room for the web browser to the right of it as can be seen from the figure below.



Opening files is nothing more than dragging the files from the explorer window to the **RigidBlock** program. Pressing the **View 3D-model (VRML)** will redraw the 3D model in the web browser.

NOTE : As can be seen from the above example, each bar type has its own colour.

Note on Windows 7 and Windows 10

- The program is installed in the users AppData\...\w-it\rigidblock folder to avoid blocking problems from the windows UAC.
- The Cortona plug-in works fine in Mozilla Firefox. Other browsers such as Internet Explorer, Edge and Chrome do not support this kind of plug-ins anymore. In order to view the models directly from the program Mozilla Firefox has to be set as the default browser in Windows.