Valentini Bernhard

Smart-Section V 2.01

Calculation routine for cross section values, stress distribution and the core of a cross section or composite cross section on TI89, TI89-Titanium, TI92+, V200

Contents

1 Introduction

Smart-Section V 2.01 is a program for TI89, TI89-Titanium, TI92+ and V200 which calculates cross section values, stress distribution and the core of a cross section or composite cross section. It provides graphic input/output and a tabular view of the results.

Smart-Section V 2.01 contains following files (for TI89/TI89-Titanium, TI92+, V200):

- smartsec.(89z, 9xz, v2z)
- ssec.(89y, 9xy, v2y)
- ssechelp.(89t, 9xt, v2t)
- ssecp01 - ssecp08.(89i, 9xi, v2i)

2 Requirements

- TI89, TI89-Titanium, TI92+ or V200 with AMS-Version 2.05 or higher
- 80kB free RAM

3 Recommendations

- Program "Auto Alpha-Lock Off" from Kevin Kofler (http://kevinkofler.cjb.net) only for TI89

4 Notes and warnings

This program is distributed to help students of civil engineering and other technical fields, but WITHOUT ANY WARRANTY. (The author make no representations or warranties about the suitability of the software, either express or implied. The author are not liable for any damages suffered as a result of using or distributing this software.) Every kind of commercial use is forbidden without the permission of the author.

Certainly there are several bugs within the program. For this reason it's useful to make a backup of your calculator before using it.

Wrong operation can lead to a complete crash of the calculator's system which can only be repaired with a reset (on+2nd+hand). The consequence is that all data on your calculator which is not archived could be deleted.

Therefore you should be careful, especially at the start of using this program.

If you have comments, bug reports or anything else, email Valentini Bernhard (csac7912@uibk.ac.at).

5 Features

- calculation of polygonal cross sections and composite cross sections
- additional use of circle elements
- section generator for cross section types that are often used
- stress distribution of the cross section
- core of the cross section
- input via dialog boxes and graphical or tabular output of the result
- scroll and zoomable drawing area
- scroll and zoomable table
- calculated values:
  - area
  - perimeter of section
  - static moment around y- and z-axis
  - y- and z-coordinate of the center of area
  - angle between the coordinate system and the principal axis
  - moment of inertia around y- and z-axis
  - moment of deviation
  - maximum and minimum moment of inertia
  - radius of gyration on principal axis
  - minimum resistive torque around principal axis
  - point of intersection of the zero-line and the principal-axis
  - stress in x-direction
  - coordinates of the core of the cross section

6 Installation

Transfer all files of you calculator type via link cable to your calculator and archive "ssec.dll", "ssechelp.text" and "ssecp01.pic - ssecp08.pic" - that's all.
When you have a TI89/TI89-Titanium you can install the program "Auto Alpha-Lock Off" from Kevin Kofler (http://kevinkofler.cjb.net) to avoid pressing the alpha button every time you make an input.

7 Starting the program

Write in the command line of the TI-application "Home" the expression "smartsec()".

8 General Notes

The handling of the program is made as easy as possible, so the input of a section can be done very quickly.

Negative numbers you have to input with the "(-)" sign next to the "." at the bottom of the numeric block. You should never make an input with the sign minus "-".

The numbering of the nodes is pretexted by the program. The numbering always starts with "0" and has increment "+1". You should never skip a number. If you want to change the coordinates of a node you can enter them in menu "System → Section node" like the input of a new node.

9 Menu structure

File	System	Generator	Results		View	Info
Save	Input section node	□-Profiles	Section details			Help
Load	Input section circle	⊡-Profiles	Stress distribution	graphic		About
Clear input	Input internal forces	I-Profiles		tabular		
Exit	Input composite section	L-Profiles	Core of section	graphic		
	Node list	T-Profiles		tabular global		
	Circle list	U-Profiles		tabular principal		
	Internal force list	Z-Profiles				
	Composite section list	◎-Profiles				

10 File

10.1 Save

The name of the savefile can't have more signs than eight.
From Smart-Section V 2.00 on savefiles have the ending ".ssec".

10.2 Load

The program now searches for all files with the ending ".ssec". So savefiles from Smart-Section V 1.30 downward can't be loaded anymore.

10.3 Clear input

Clears all data (nodes, circles, internal forces and results).

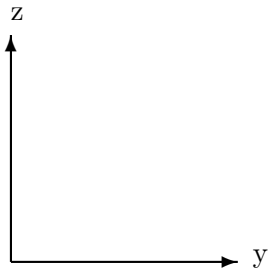
10.4 Exit

Exits the program.

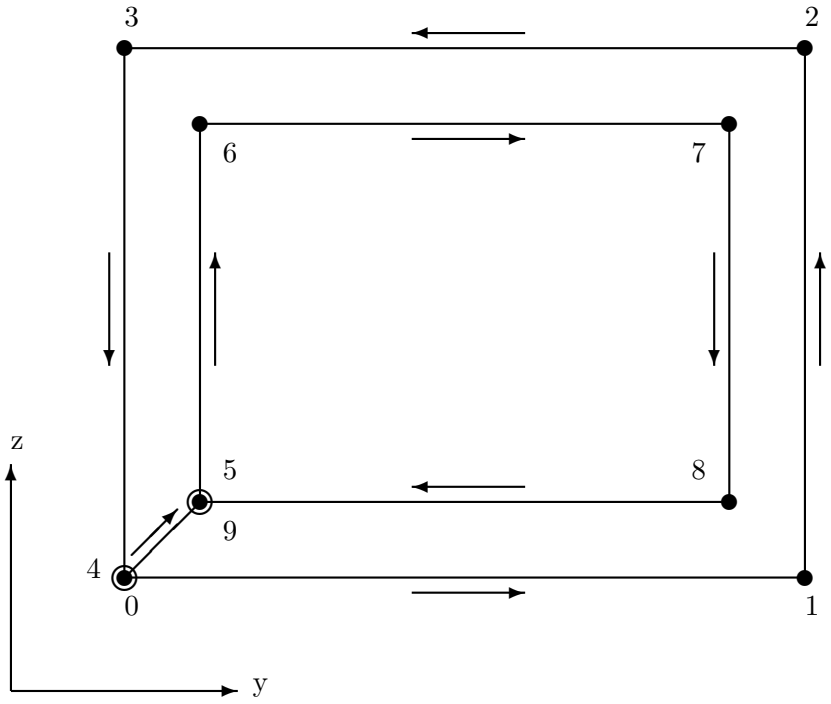
11 System

11.1 Section node

Global system of coordinates [mm] (right hand system):

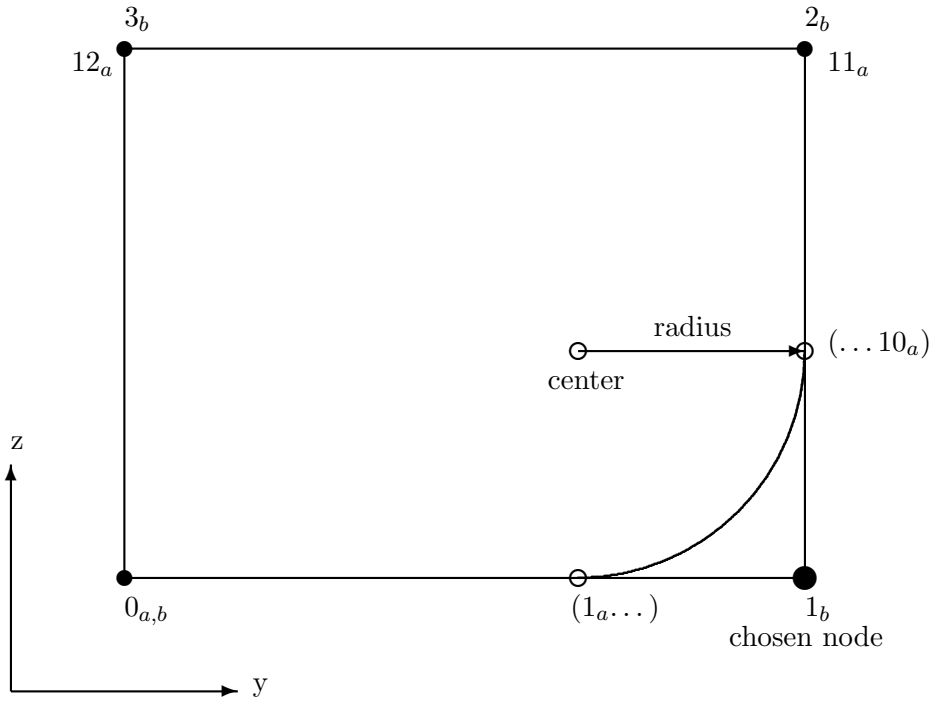


The direction you have to enter the nodes is COUNTER-CLOCKWISE. The section will be closed automatically. If you want to enter a hole you have to enter the nodes clockwise.
You can edit the nodes by overwriting them.



11.2 Section circle

The node you have to choose is the point of intersection of the two tangents of the circle and NOT the center of the circle.
The circle is approximated by nodes every 10°, so the nodes will be renumbered automatically. For a clearer graphic the circle's nodes will never be inscribed. The error of the area through this approximation is about 0,5 percent.



$node_b$ ... before entering circle

$node_a$ ... afterwards

• ... inscribed visible nodes

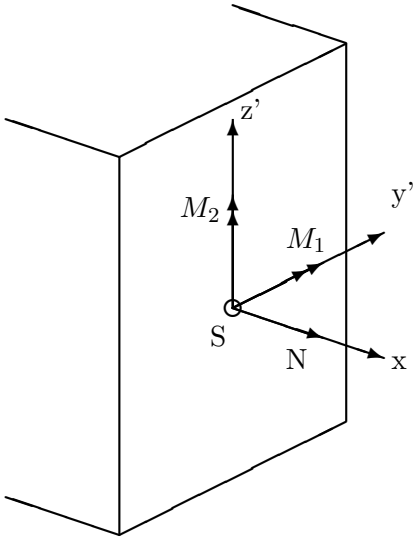
◦ ... not inscribed invisible nodes

11.3 Internal forces

For the stress distribution you have the enter following internal forces:

- N ... axial force in x-direction [N]
- M_1 ... moment around principal y'-axis [Nmm]
- M_2 ... moment around principal z'-axis [Nmm]

They will be deleted every time you change something.

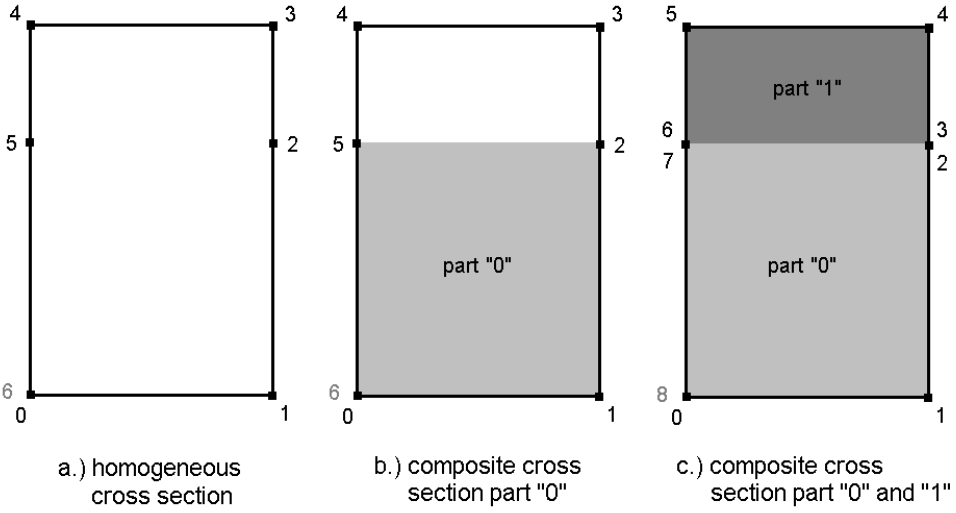


11.4 Input composite section

For each composite cross section part you have to input the elastic modulus E $[N/mm^2]$.

The values of the composite cross section are calculated on the fictive (E-modulus) level of the composite section part "0". For more information take a look at section 13.1.

Example of an input of a composite cross section:



- step 1:
  input cross section with 6 nodes ("0-5"). node number "6" will generated automatically and is invisible. [picture a.)]

- step 2:
  input composite cross section part "0":
  After the input of the E-modulus the input boundary nodes are "0, 1, 2, 5, 6". [picture b.)]

- step 3:
  input composite cross section part "1":
  After the input of the E-modulus the input boundary nodes are "2, 3, 4, 5". [picture b.)]
  The node "2" is split up automatically into node "2 " and "3 ". All nodes with a higher node number will be increased by one. Then the former node "5" (now node "6") is split up automatically into node "6 " and "7 ". Again all nodes with a higher node number will be increased by one. [picture c.)]

During the input of the composite cross section nodes the program will mark every node you choose. So invisible nodes shouldn't be forgotten too easily. EVERY node has to be part of a composite section part - so don't forget one. The invisible last node of the cross section must be chosen too. In the node list you can see which node is already part of the composite cross section.

You can change the E-modulus of a part by overwriting the old one like the input of a new composite cross section part.

11.5 Node list

The input nodes are listed there.

The tabular outputs (node list, circle list, force list, section details, stress distribution and core of section) are scroll and zoomable.

Controls:

- ↑↓←→ ... scroll the table in one of these directions
- +/− ... zoom the table (and font)
- 2nd ... move to row number one
- Esc ... cancel the table

11.6 Circle list

The input circles are listed there.

11.7 Force list

The input internal forces are listed there.

11.8 Composite section list

The input composite cross sections are listed there.

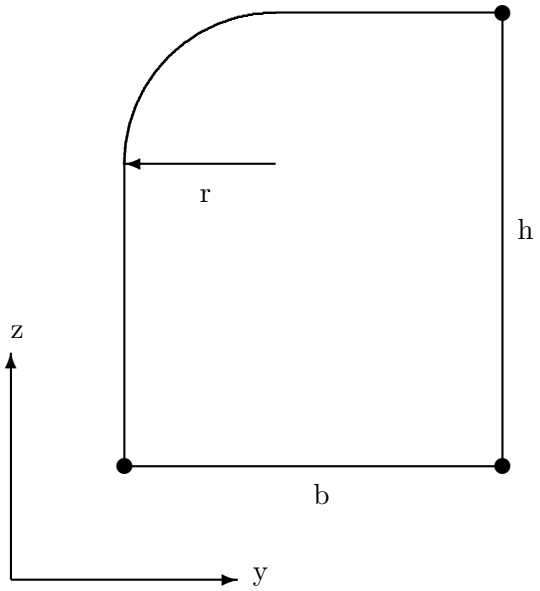
12 Generator

The section generator was made for cross section types that are often used. They are:

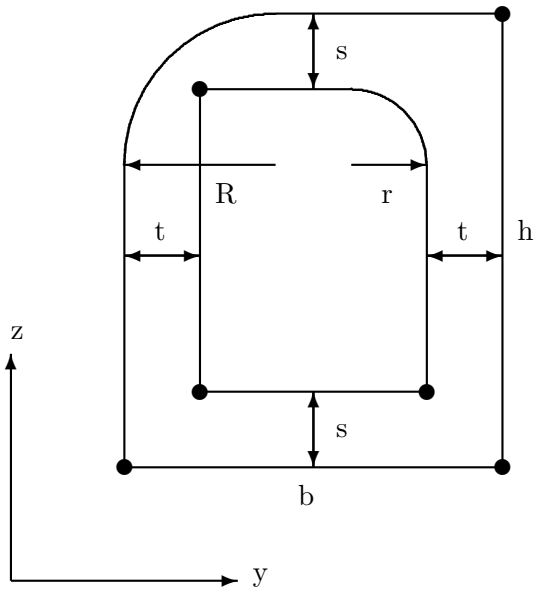
- □-Profiles
- ⊡-Profiles
- I-Profiles
- L-Profiles
- T-Profiles
- U-Profiles
- Z-Profiles
- ◎-Profiles

You can edit the nodes of the profiles afterwards in menu "System → Section node" like the input of a new node.
The radius of all profiles except the ◎-profiles can be zero.

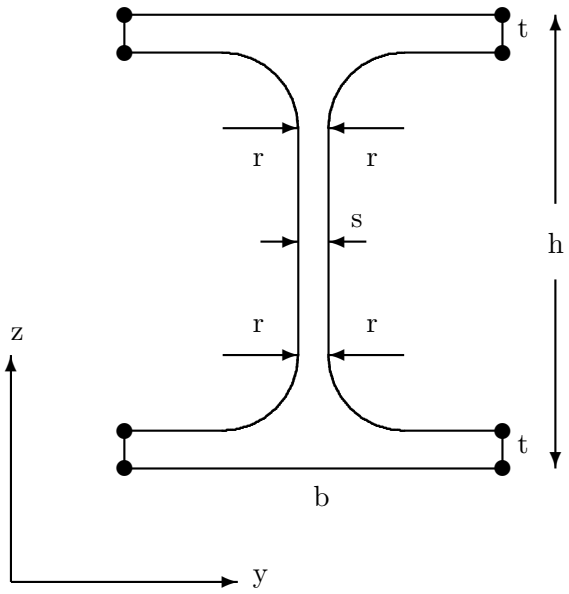
12.1 □-Profiles



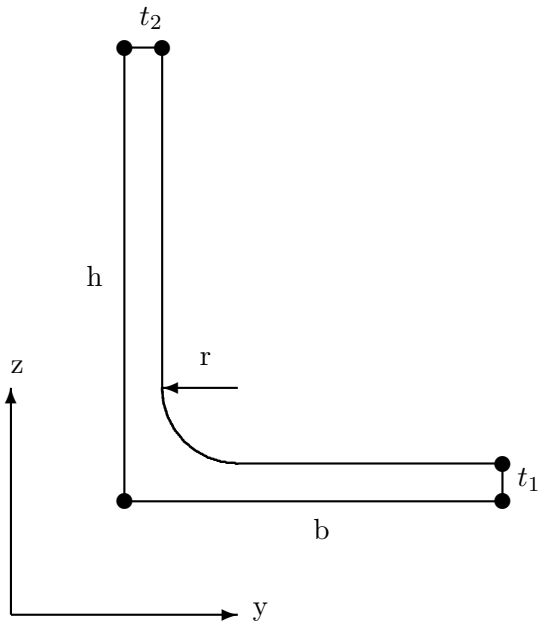
12.2 ⊡-Profiles



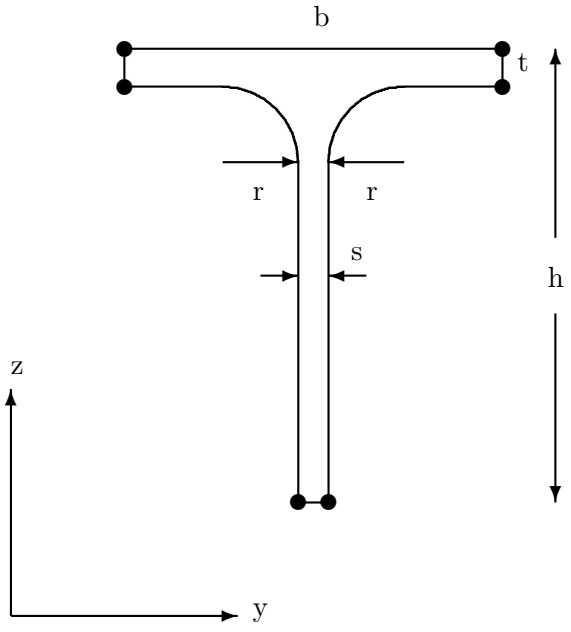
12.3 I-Profiles



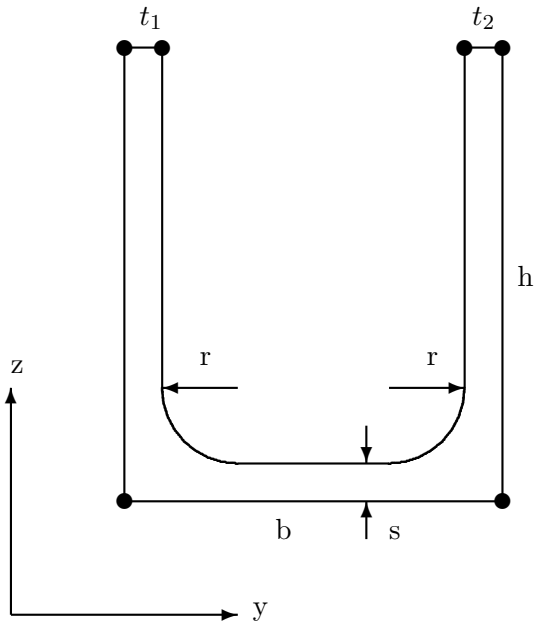
12.4 L-Profiles



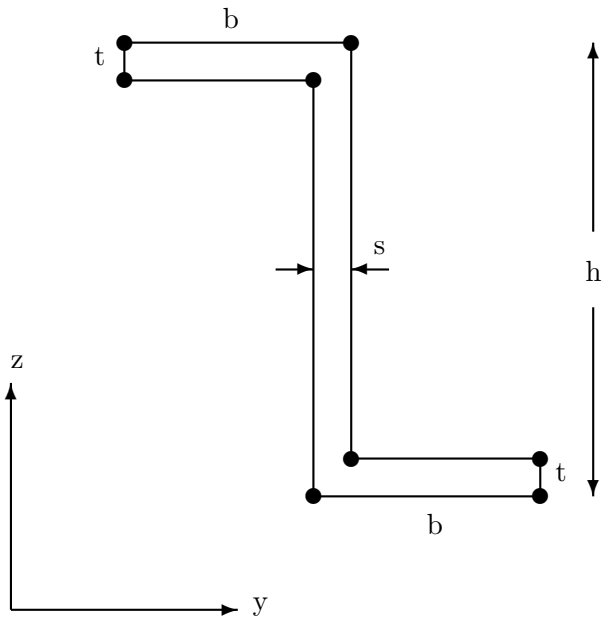
12.5 T-Profiles



12.6 U-Profiles

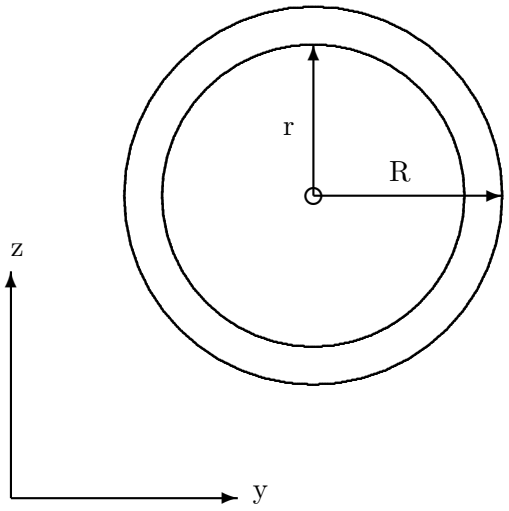


12.7 Z-Profiles



12.8 ◎-Profiles

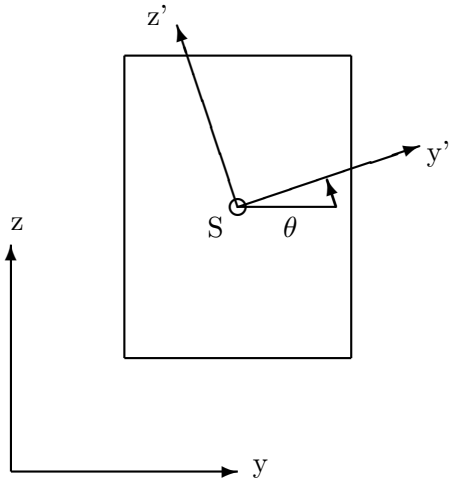
The outer radius "R" must always be larger than the inner radius "r". You can make a full circle without hole when you enter "0" for "r".
The circle will be approximated by a polygon with 72 nodes (5° division). The error of the area through this approximation is about 0,13 percent and the error of the moment of inertia about 0,25 percent.



13 Results

13.1 Section details

Principal axis definition:



If a composite cross section is input, the section details will show the results of the homogeneous cross section (only one material) and the composite cross section (different materials).
The values of the composite cross section are on the fictive (E-modulus) level of the composite section part "0". So all values of the composite section parts "0" to "i" are multiplied with the factor n_i.

- E ... elastic modulus of the composite cross section part $[N/mm^2]$

$$n_i = \frac{E_i}{E_0}. \tag{1}$$

Used formulas for the section details:

- A ... area $[mm^2]$

$$A = \int_A dA \tag{2}$$

- U ... perimeter of section (outer and inner with all connecting lines) $[mm]$

$$U = \int_{border} ds \tag{3}$$

- S_y ... static moment around y-axis $[mm^3]$

$$S_y = \int_A z\,dA \tag{4}$$

- S_z ... static moment around z-axis $[mm^3]$

$$S_z = \int_A y\,dA \tag{5}$$

- y_S ... global y-coordinate of the center of area [mm]

$$y_S = \frac{S_z}{A} \tag{6}$$

- z_S ... global z-coordinate of the center of area [mm]

$$z_S = \frac{S_y}{A} \tag{7}$$

- Theta (Θ) ... angle between the global coordinate system and the principal y'-axis [rad]

$$\Theta = \frac{1}{2} \arctan\left(-\frac{2I_{yz}}{I_y - I_z}\right) \tag{8}$$

- I_y ... moment of inertia around y-axis [mm^4]

$$I_y = \int_A z^2 dA \tag{9}$$

- I_z ... moment of inertia around z-axis [mm^4]

$$I_z = \int_A y^2 dA \tag{10}$$

- I_{yz} ... moment of deviation [mm^4]

$$I_{yz} = \int_A yz dA \tag{11}$$

- I_1 ... maximum moment of inertia [mm^4]

$$I_1 = \frac{I_y + I_z}{2} + \sqrt{\left(\frac{I_y - I_z}{2}\right)^2 + I_{yz}^2} \tag{12}$$

- I_2 ... minimum moment of inertia [mm^4]

$$I_2 = \frac{I_y + I_z}{2} - \sqrt{\left(\frac{I_y - I_z}{2}\right)^2 + I_{yz}^2} \tag{13}$$

- i_1 ... radius of gyration on z'-axis [mm]

$$i_1 = \sqrt{\frac{I_1}{A}} \tag{14}$$

- i_2 ... radius of gyration on y'-axis [mm]

$$i_2 = \sqrt{\frac{I_2}{A}} \tag{15}$$

- n_1 ... point of intersection of the zero-line and the y'-axis [mm]

$$n_1 = -\frac{i_2^2}{e_1} \tag{16}$$

$$e_1 = -M_2/N \tag{17}$$

- n_2 ... point of intersection of the zero-line and the z'-axis [mm]

$$n_2 = -\frac{i_1^2}{e_2} \tag{18}$$

$$e_2 = M_1/N \tag{19}$$

- $W_1(+z')$ ... minimum resistive torque around y'-axis with positive z' value $[mm^3]$
  $z'_{pos,max}$ ... maximum positive coordinate on the principal z'-axis of one node [mm]

$$W_1 = \frac{I_1}{z'_{pos,max}} \tag{20}$$

- $W_1(-z')$ ... minimum resistive torque around y'-axis with negative z' value $[mm^3]$
  $z'_{neg,max}$ ... maximum negative coordinate on the principal z'-axis of one node [mm]

$$W_1 = \frac{I_1}{z'_{neg,max}} \tag{21}$$

- $W_2(+y')$ ... minimum resistive torque around z'-axis with positive y' value $[mm^3]$
  $y'_{pos,max}$ ... maximum positive coordinate on the principal y'-axis of one node [mm]

$$W_2 = \frac{I_2}{y'_{pos,max}} \tag{22}$$

- $W_2(-y')$ ... minimum resistive torque around z'-axis with negative y' value $[mm^3]$
  $y'_{neg,max}$ ... maximum negative coordinate on the principal y'-axis of one node [mm]

$$W_2 = \frac{I_2}{y'_{neg,max}} \tag{23}$$

13.2 Stress distribution

The stress distribution from the internal forces will be calculated and shown for each node.

In the graphic output of the stress distribution the view-mode (section 14) is automatically turned on.

Used formula for the stress distribution:

- σ_x ... stress in x-direction $[N/mm^2]$
  y' ... coordinate on the principal y'-axis [mm]
  z' ... coordinate on the principal z'-axis [mm]

$$\sigma_x = \frac{N}{A} + \frac{M_1}{i_1^2 A} z' - \frac{M_2}{i_2^2 A} y' \tag{24}$$

13.3 Core of section

The core of the section is that area where a axial force has to be placed, when the section should only have tensile or compression forces. It is calculated by all zero-lines which touch the cross section.
The tabular output will be done in the global coordinate system ("tabular global") or in the principal-axis coordinate system ("tabular principal").

The calculation of a full circle can take up to 25 seconds and a circle with hole up to 45 seconds on TI89 and TI92+. So you should consider this when you start the calculation, because there is no option to stop it.

In the graphic output of the core of section the view-mode (section 14) is automatically turned on.

Used formula for the core of the section:

- e_1 ... coordinate on the principal y'-axis [mm]
  y'_N ... point of intersection of the principal y'-axis with a tangent of the section [mm]

$$e_1 = -\frac{i_2^2}{y'_N} \tag{25}$$

- e_2 ... coordinate on the principal z'-axis [mm]
  z'_N ... point of intersection of the principal z'-axis with a tangent of the section [mm]

$$e_2 = -\frac{i_1^2}{z'_N} \tag{26}$$

14 View

When you enter the view-mode you can scroll and zoom the drawing area. Only in the view-routine and in the numeric output four color grayscale is turned on.

Controls:

- ↑↓←→ ... scroll in one of these directions
- +/− ... zoom in and out
- 2nd ... center the section to the area
- Esc ... cancel the view-mode

15 Info

15.1 Help

Shows a list of short cuts used in the section details.
Explains how to input nodes, circles, internal forces and a composite cross section.
Shows the control-keys for the view-mode and tables.

15.2 About

Prints some information about the program.

16 Developer

- Valentini Bernhard [csac7912@uibk.ac.at]

Web site: http://homepage.uibk.ac.at/∼csac7688/

17 Thanks

- Urich Christian as a former developer
- the TIGCC Team for making it possible to program in C (http://tigcc.ticalc.org)
- the TICT (TI-Chess Team) for their ExtGraph library (http://tict.ticalc.org)
- all beta testers (especially Luigi Pagano)
- Elisabeth Nägele for the proof-reading (of Smart-Section V1.00)
- Pablo Lasheras for the Spanish translation

18 History

- Smart-Section V 2.01:
  - 29.10.2004 - update
    * bug with additional circles fixed
      (found by: Niklas Fritz)
    * memory lag in tabular output of the results fixed
    * Spanish version available (translated by: Pablo Lasheras)
- Smart-Section V 2.00:
  - 21.09.2004 - update
    * bugs in core and perimeter of section fixed
    * composite cross section added
    * pictures for section generator added
    * new save and load routine
    * new help
- Smart-Section V 1.30:
  - 29.08.2004 - update
    * calculation error with resistive torques fixed
      (found by: Luigi Pagano)
    * parameters "minimum resistive torque around principal axis" modified
    * additional parameters "perimeter of section" added
    * help added
    * input lists for nodes, circles and internal forces
- Smart-Section V 1.20:
  - 15.08.2004 - update
    * scroll and zoomable table in four color grayscale
    * additional parameters "maximum resistive torque around principal axis" added
    * graphic zero-line
- Smart-Section V 1.10a:
  - 13.06.2004 - update
    * calculation error with internal loads which were not between -32768N(mm) and 32767N(mm) fixed
      (values were restricted to integer instead of double)
      (found by: Bernhard Valentini)

- Smart-Section V 1.10:
  - 07.06.2004 - update
    - new and faster drawing routine
    - scroll and zoomable drawing area in four color grayscale
    - much faster core calculation routine
    - English and German version available
- Smart-Section V 1.00:
  - 08.02.2004 - final release
    - new section types added to the section generator
    - stress distribution added
    - core of section added
- Smart-Section V 0.01:
  - 03.01.2004 - first release

References

[Mang/Hofstetter (2000)] H. Mang and G. Hofstetter, *Festigkeitslehre*, Springer Verlag, Wien, 2000.

[Falter (1992)] B. Falter, *Statikprogramme für Personalcomputer*, 4.Auflage, Werner Ingenieur Texte, Düsseldorf, 1992.