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Smart-Stress V1.00

Calculation routine for stress, strain and elastic material tensors, yield and failure functions of different yield and failure hypothesis on TI89, TI89-Titanium, TI92+, V200

Contents

1 Introduction

Smart-Stress is a program for TI89, TI89-Titanium, TI92+ and V200 which calculates stress, strain and elastic material tensors, yield and failure functions of different yield and failure hypothesis. It provides graphic input/output and a tabular view of the results.

2 Features

- calculation of different elastic material parameters
- yield hypothesis: Tresca, von Mises, Mohr-Coulomb and Drucker-Prager
- failure hypothesis: Rankine
- Mohr's circle graphic
- input via dialog boxes and graphical or tabular output of the result
- scroll and zoomable graphics
- scroll and zoomable tables
- calculated values:
  - hydrostatic and deviatory stress and strain tensor
  - principal stress and strain values and vectors
  - principal shear stress values and stress components normal to them
  - yield and failure functions

3 Requirements

- TI89, TI89-Titanium, TI92+ or V200 with AMS-Version 2.05 or higher
- 60kB free RAM
- Program "HW3Patch" to run the program on TI89-Titanium (You can download it from Kevin Koflers' homepage http://kevinkofler.cjb.net.)

4 Recommendations

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

5 Files

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

1. launcher:
   - smartstr.(89z, 9xz, v2z)
2. dll:
   - sstress.(89y, 9xy, v2y)
3. text file:
   - sstrhelp.(89t, 9xt, v2t)

6 Installation

Transfer all files of you calculator type via link cable to your calculator and archive following files:

1. sstr.dll
2. sstrhelp.text

- that's all. All files must be in one folder.

When you have a TI89-Titanium install the program "HW3Patch" on your calculator.

When you have a TI89 or TI89-Titanium you can install the program "Auto Alpha-Lock Off" 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 "smartstr()".

8 General Notes

The handling of the program is made as easy as possible, so the input of all tensors and parameters 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 “-“.

NO INPUT IS AUTOMATICALLY SET “0“.

9 Notes and warnings

This program is distributed to help students of civil engineering and other technical fields, but WITHOUT ANY WARRANTY. (The authors make no representations or warranties about the suitability of the software, either express or implied. The authors 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 authors.

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 (bernhard.valentini@smart-programs.org) or visit the forum on our web site http://www.smart-programs.org/.

10 Menu structure

File	Create	Edit	Calc.	Results	Info
New	Stress tensor	List	Calculate σ	Stress tabular	Help
Save	Strain tensor	Edit	Calculate ε	Mohr's circle	About
Open	Material tensor	Delete		Strain tabular	
Exit	Yield hypothesis			Mat. tensor tabular	
				Yield hyp. tabular	

Table 1: *Menu structure*

11 File

11.1 New

Clears all data (stress, strain and elastic tensors, yield parameters and results).

11.2 Save

The name of the savefile can't have more signs than eight.
All savefiles have the ending ".sstr".

11.3 Open

The program searches for all files with the ending ".sstr".

11.4 Exit

Exits the program.

12 Create

The available data is shown on the screen. So it should be easy to keep the survey of the input stress, strain and material tensors and the input yield function.
For the stress and strain tensor their state (three-dimensional or plane stress state) is also output.

12.1 Stress tensor

12.1.1 Theory

Global system of coordinates (right hand system) with the positive directions of the stress tensor:

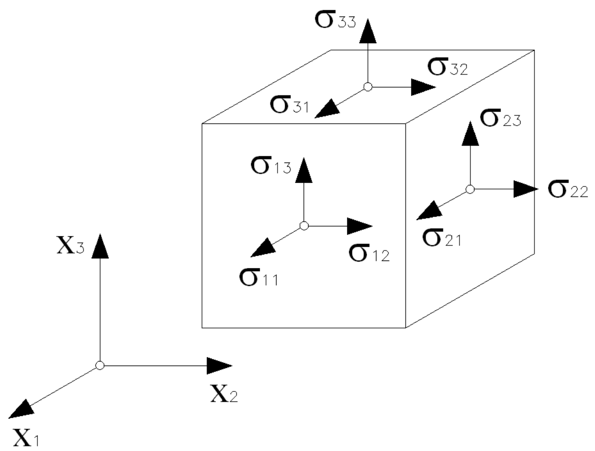

Figure 1: *Positive directions of the stress tensor*

The symmetric stress tensor σ_{ij} can be split up into hydrostatic σ_{hyd} and a deviatory part σ_{dev}.

$$\begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{21} & \sigma_{22} & \sigma_{23} \\ \sigma_{31} & \sigma_{32} & \sigma_{33} \end{bmatrix} = \underbrace{\begin{bmatrix} \sigma^m & 0 & 0 \\ 0 & \sigma^m & 0 \\ 0 & 0 & \sigma^m \end{bmatrix}}_{hydrostatic} + \underbrace{\begin{bmatrix} \sigma_{11} - \sigma^m & \sigma_{12} & \sigma_{13} \\ \sigma_{21} & \sigma_{22} - \sigma^m & \sigma_{23} \\ \sigma_{31} & \sigma_{32} & \sigma_{33} - \sigma^m \end{bmatrix}}_{deviatory} \tag{1}$$

or in index typing

$$\sigma_{ij} = \underbrace{\sigma^m \delta_{ij}}_{hydrostatic} + \underbrace{s_{ij}}_{deviatory} \qquad , i, j = 1, 2, 3 \tag{2}$$

with

$$\sigma^m = \frac{1}{3}(\sigma_{11} + \sigma_{22} + \sigma_{33}) = \frac{1}{3}I_1^\sigma \tag{3}$$

The unit of the stress tensor and its components is $[N/mm^2]$.

The principal stress components σ can be found by solving the eigenvalue problem

$$|\sigma_{ij} - \sigma\delta_{ij}| = 0 \tag{4}$$

$$-\sigma^3 + I_1^\sigma\sigma^2 - I_2^\sigma\sigma + I_3^\sigma = 0 \tag{5}$$

with the invariants of the stress tensor

$$\begin{aligned} I_1^\sigma &= \sigma_{11} + \sigma_{22} + \sigma_{33}, \\ I_2^\sigma &= \begin{vmatrix} \sigma_{22} & \sigma_{23} \\ \sigma_{32} & \sigma_{33} \end{vmatrix} + \begin{vmatrix} \sigma_{11} & \sigma_{13} \\ \sigma_{31} & \sigma_{33} \end{vmatrix} + \begin{vmatrix} \sigma_{11} & \sigma_{12} \\ \sigma_{21} & \sigma_{22} \end{vmatrix}, \\ I_3^\sigma &= \begin{vmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{21} & \sigma_{22} & \sigma_{23} \\ \sigma_{31} & \sigma_{32} & \sigma_{33} \end{vmatrix}. \end{aligned} \tag{6}$$

The principal stress components are sorted from biggest to smallest.

$$\sigma_1 \geq \sigma_2 \geq \sigma_3 \tag{7}$$

The eigenvector to each eigenvalue shows the direction of the principal stress components in the global coordinate system.

The three principal shear stress components are

$$\tau_1 = \left|\frac{\sigma_2 - \sigma_3}{2}\right|, \quad \tau_2 = \left|\frac{\sigma_3 - \sigma_1}{2}\right|, \quad \tau_3 = \left|\frac{\sigma_1 - \sigma_2}{2}\right|. \tag{8}$$

Normally the planes with principal shear stress aren't free from stress normal to these planes. So these values are

$$\sigma_{nn}^{(1)} = \frac{\sigma_2 + \sigma_3}{2}, \quad \sigma_{nn}^{(2)} = \frac{\sigma_3 + \sigma_1}{2}, \quad \sigma_{nn}^{(3)} = \frac{\sigma_1 + \sigma_2}{2}. \tag{9}$$

12.1.2 Input

You have to input the components of upper triangular stress tensor. The lower one is symmetric to the upper one, so you share time during the input. The unit of the stress tensor is $[N/mm^2]$.

The program itself scans the stress tensor whether it's a three-dimensional or a plane stress state. For example a plane stress state in the x_1/x_2-plane is specified by

$$\sigma_{33} = \sigma_{31} = \sigma_{32} = 0. \tag{10}$$

12.2 Strain tensor

12.2.1 Theory

The positive directions of the strain tensor are the same as in the stress tensor, see section 1 on page 5.

The symmetric strain tensor ϵ_{ij} can be split up into volumetric ϵ_{vol} and a deviatory part ϵ_{dev}.

$$\begin{bmatrix} \epsilon_{11} & \epsilon_{12} & \epsilon_{13} \\ \epsilon_{21} & \epsilon_{22} & \epsilon_{23} \\ \epsilon_{31} & \epsilon_{32} & \epsilon_{33} \end{bmatrix} = \underbrace{\begin{bmatrix} \epsilon^m & 0 & 0 \\ 0 & \epsilon^m & 0 \\ 0 & 0 & \epsilon^m \end{bmatrix}}_{volumetric} + \underbrace{\begin{bmatrix} \epsilon_{11} - \epsilon^m & \epsilon_{12} & \epsilon_{13} \\ \epsilon_{21} & \epsilon_{22} - \epsilon^m & \epsilon_{23} \\ \epsilon_{31} & \epsilon_{32} & \epsilon_{33} - \epsilon^m \end{bmatrix}}_{deviatory} \tag{11}$$

or in index typing

$$\epsilon_{ij} = \underbrace{\epsilon^m \delta_{ij}}_{volumetric} + \underbrace{e_{ij}}_{deviatory} \qquad , i, j = 1, 2, 3 \tag{12}$$

with

$$\epsilon^m = \frac{1}{3}(\epsilon_{11} + \epsilon_{22} + \epsilon_{33}) = \frac{1}{3}\epsilon^{vol} = \frac{1}{3}I_1^\epsilon \tag{13}$$

The unit of the strain tensor and its components is [-].

The principal strain components ϵ can be found by solving the eigenvalue problem

$$|\epsilon_{ij} - \epsilon\delta_{ij}| = 0 \tag{14}$$

$$-\epsilon^3 + I_1^\epsilon \epsilon^2 - I_2^\epsilon \epsilon + I_3^\epsilon = 0 \tag{15}$$

with the invariants of the strain tensor

$$
\begin{aligned}
I_1^\epsilon &= \epsilon_{11} + \epsilon_{22} + \epsilon_{33}, \\
I_2^\epsilon &= \begin{vmatrix} \epsilon_{22} & \epsilon_{23} \\ \epsilon_{32} & \epsilon_{33} \end{vmatrix} + \begin{vmatrix} \epsilon_{11} & \epsilon_{13} \\ \epsilon_{31} & \epsilon_{33} \end{vmatrix} + \begin{vmatrix} \epsilon_{11} & \epsilon_{12} \\ \epsilon_{21} & \epsilon_{22} \end{vmatrix}, \\
I_3^\epsilon &= \begin{vmatrix} \epsilon_{11} & \epsilon_{12} & \epsilon_{13} \\ \epsilon_{21} & \epsilon_{22} & \epsilon_{23} \\ \epsilon_{31} & \epsilon_{32} & \epsilon_{33} \end{vmatrix}.
\end{aligned} \tag{16}
$$

The principal strain components are sorted from biggest to smallest.

$$\epsilon_1 \geq \epsilon_2 \geq \epsilon_3 \tag{17}$$

The eigenvector to each eigenvalue shows the direction of the principal strain components in the global coordinate system.

12.2.2 Input

You have to input the components of upper triangular strain tensor. The lower one is symmetric to the upper one, so you share time during the input. The unit of the strain tensor is [-].

The program itself scans the strain tensor whether it's a three-dimensional or a plane strain state. For example a plane strain state in the x_1/x_2-plane is specified by

$$\epsilon_{33} = \epsilon_{31} = \epsilon_{32} = 0. \tag{18}$$

12.3 Material tensor

12.3.1 Theory

From HOOKE's law

$$\sigma_{ij} = C_{ijkl}\epsilon_{kl} \tag{19}$$

we get the elastic or material stiffness tensor **C** with unit $[N/mm^2]$. The material stiffness tensor is symmetric with

$$
\begin{aligned}
C_{ijkl} &= C_{jikl}, \\
C_{ijkl} &= C_{ijlk}.
\end{aligned} \tag{20}
$$

The inverse of the material stiffness tensor is also symmetric and called material compliance tensor

$$\mathbf{D} = \mathbf{C}^{-1} \tag{21}$$

with unit $[mm^2/N]$.

The material tensor can be described with following material parameters:

1. Elastic modulus: E
2. Poisson ratio: ν
$$0 \leq \nu \leq 0.5 \tag{22}$$
3. Shear modulus:
$$G = \frac{E}{2(1+\nu)} \tag{23}$$
4. Compression modulus:
$$K = \frac{E}{3(1-2\nu)} \tag{24}$$
5. LAME's material parameter:
$$\lambda = \frac{E\nu}{(1+\nu)(1-2\nu)} \tag{25}$$

For isotropic materials HOOKE's law is

$$\begin{pmatrix} \epsilon_{11} \\ \epsilon_{22} \\ \epsilon_{33} \\ 2\epsilon_{12} \\ 2\epsilon_{23} \\ 2\epsilon_{31} \end{pmatrix} = \underbrace{\begin{bmatrix} \frac{1}{E} & -\frac{\nu}{E} & -\frac{\nu}{E} & 0 & 0 & 0 \\ & \frac{1}{E} & -\frac{\nu}{E} & 0 & 0 & 0 \\ & -\frac{\nu}{E} & \frac{1}{E} & 0 & 0 & 0 \\ & & & \frac{1}{G} & 0 & 0 \\ & & & & \frac{1}{G} & 0 \\ symm. & & & & & \frac{1}{G} \end{bmatrix}}_{\mathbf{D}=\mathbf{C}^{-1}} \begin{pmatrix} \sigma_{11} \\ \sigma_{22} \\ \sigma_{33} \\ \sigma_{12} \\ \sigma_{23} \\ \sigma_{31} \end{pmatrix} \tag{26}$$

or in index typing

$$\epsilon_{ij} = \frac{1+\nu}{E}\sigma_{ij} - \frac{\nu}{E}\delta_{ij}\sigma_{kk}. \tag{27}$$

The inverse of this equation is

$$\begin{pmatrix} \sigma_{11} \\ \sigma_{22} \\ \sigma_{33} \\ \sigma_{12} \\ \sigma_{23} \\ \sigma_{31} \end{pmatrix} = \underbrace{\frac{E(1-\nu)}{(1+\nu)(1-2\nu)} \begin{bmatrix} 1 & \frac{\nu}{1-\nu} & \frac{\nu}{1-\nu} & 0 & 0 & 0 \\ & 1 & \frac{\nu}{1-\nu} & 0 & 0 & 0 \\ & & 1 & 0 & 0 & 0 \\ & & & \frac{1-2\nu}{2(1-\nu)} & 0 & 0 \\ & & & & \frac{1-2\nu}{2(1-\nu)} & 0 \\ symm. & & & & & \frac{1-2\nu}{2(1-\nu)} \end{bmatrix}}_{\mathbf{C}} \begin{pmatrix} \epsilon_{11} \\ \epsilon_{22} \\ \epsilon_{33} \\ 2\epsilon_{12} \\ 2\epsilon_{23} \\ 2\epsilon_{31} \end{pmatrix} \quad (28)$$

or in index typing

$$\sigma_{ij} = \frac{E}{1+\nu}\left(\epsilon_{ij} + \frac{\nu}{1-2\nu}\epsilon_{kk}\delta_{ij}\right), \quad (29)$$

$$\sigma_{ij} = K\epsilon^{vol}\delta_{ij} + 2Ge_{ij}, \quad (30)$$

$$\sigma_{ij} = \lambda\epsilon^{vol}\delta_{ij} + 2G\epsilon_{ij}. \quad (31)$$

12.3.2 Input

In the program you can decide which parameters you input for the isotropic material tensors. Following combinations are available:

- E $[N/mm^2]$ and ν [-]
- E $[N/mm^2]$ and G $[N/mm^2]$
- G $[N/mm^2]$ and ν [-]
- G $[N/mm^2]$ and K $[N/mm^2]$
- G $[N/mm^2]$ and λ $[N/mm^2]$

12.4 Yield hypothesis

12.4.1 Theory

Four yield and one failure hypothesis have been implemented in the program to specify the mechanic criterion of the material in a specific point.

- yield hypothesis:
  - Tresca
  - von Mises
  - Mohr-Coulomb
  - Drucker-Prager
- failure hypothesis:

– Rankine

1. Tresca yield hypothesis:

   The maximal shear stress is decisive for yield in a specific point of the material.
   The Tresca yield hypothesis needs only one material parameter f_y (yield stress).
   The yield function is

   $$f(\boldsymbol{\sigma}) = \sigma_{max} - \sigma_{min} - f_y. \tag{32}$$

2. von Mises yield hypothesis:

   The energy of distortion is decisive for yield in a specific point of the material.
   The von Mises yield hypothesis also needs only one material parameter f_y (yield stress).
   The yield function is

   $$f(\boldsymbol{\sigma}) = \sqrt{\sigma_{ij}\sigma_{ij}} - \sqrt{\frac{2}{3}} f_y \tag{33}$$

   or

   $$f(\boldsymbol{\sigma}) = \tau_{okt} - \sqrt{\frac{2}{3}} \tau_y \tag{34}$$

   with

   $$\tau_{okt} = \frac{1}{3}\sqrt{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}, \tag{35}$$

   $$\tau_y = \frac{f_y}{\sqrt{3}}. \tag{36}$$

3. Mohr-Coulomb yield hypothesis:

   The maximal shear stress is decisive for yield in a specific point of the material. But according to Coulomb's law of friction the shear stress σ_{nt} depends on the stress σ_{nn} normal to this plane.

   $$|\sigma_{nt}| = f(\sigma_{nn}) \tag{37}$$

   The Mohr-Coulomb yield hypothesis needs two material parameter c (cohesion) and ϕ (friction angle).
   The yield function is

   $$f(\boldsymbol{\sigma}) = \frac{\sigma_{max}}{f_t} - \frac{\sigma_{min}}{f_c} - 1 \tag{38}$$

with

$$f_t = \frac{2c\cos\phi}{1+\sin\phi}, \tag{39}$$

$$f_c = \frac{2c\cos\phi}{1-\sin\phi}. \tag{40}$$

4. DRUCKER-PRAGER yield hypothesis:

   This yield hypothesis is an extension to the VON MISES yield hypothesis. The maximal octahedron shear stress is decisive for yield in a specific point of the material. But according to COULOMB's law of friction the octahedron shear stress τ_{okt} depends on the stress σ_{okt} normal to this plane.
   The DRUCKER-PRAGER yield hypothesis also needs two material parameter μ (friction coefficient) and f_y (yield stress).
   The yield function is

$$f(\boldsymbol{\sigma}) = \tau_{okt} + \mu\sigma_{okt} - \frac{2}{3}\tau_y \tag{41}$$

   or

$$f(\boldsymbol{\sigma}) = \sqrt{\sigma_{ij}\sigma_{ij}} + \frac{\mu}{\sqrt{3}}I_1^\sigma - \sqrt{2}\tau_y \tag{42}$$

   with

$$\sigma_{okt} = \frac{1}{3}(\sigma_1+\sigma_2+\sigma_3) = \sigma^m = \frac{1}{3}I_1^\sigma, \tag{43}$$

$$\tau_{okt} = \frac{2}{3}\tau_y. \tag{44}$$

5. RANKINE failure hypothesis:

   The maximal stress is decisive for failure in a specific point of the material.
   The RANKINE failure hypothesis needs one material parameter for tension f_t (yield tension) and one for compression f_c (yield compression).
   The yield or failure function is for tensile

$$f(\boldsymbol{\sigma}) = \sigma_1 - f_t, \quad \sigma_1 > 0, \tag{45}$$

   and compression

$$f(\boldsymbol{\sigma}) = |\sigma_3| - f_c, \quad \sigma_3 < 0. \tag{46}$$

12.4.2 Input

First you have to choose which yield or failure hypothesis you want to use. Then you have to input the material parameters for the chosen hypothesis.

- Tresca:
  f_y $[N/mm^2]$
- von Mises:
  f_y $[N/mm^2]$
- Mohr-Coulomb:
  c $[N/mm^2]$ and ϕ [rad]
- Drucker-Prager:
  f_y $[N/mm^2]$ and μ [-]
- Rankine:
  f_t $[N/mm^2]$ and f_c $[N/mm^2]$

13 Edit

13.1 List

The input stress, strain and material tensor and yield parameters are listed there.

The tabular outputs 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

13.2 Edit

You can edit the input stress, strain and material tensor and yield parameters with this routine.

13.3 Delete

You can delete all input data with this routine.

14 Calculation

14.1 Calculate σ

When you have input the strain and material tensor this routine will calculate the stress tensor with Hooke's law

$$\sigma_{ij} = C_{ijkl}\epsilon_{kl}. \tag{47}$$

14.2 Calculate ϵ

When you have input the stress and material tensor this routine will calculate the strain tensor with

$$\epsilon_{ij} = D_{ijkl}\sigma_{kl}. \tag{48}$$

15 Results

All tabular outputs are scroll and zoomable. The controls are described in section 13.1.

When you enter the graphic outputs you can scroll and zoom the drawing area. Only in the graphic and numeric output four color grayscale is turned on.

Controls:

- $\uparrow\downarrow\leftarrow\rightarrow$ ... scroll in one of these directions
- $+/-$ ... zoom in and out
- 2nd ... center the graphic to the area
- Esc ... cancel the graphic mode

15.1 Stress tabular

The stress tensor components will be calculated like in section 12.1.1 shown.

Following results are output:

- stress tensors:
  - σ ... stress tensor $[N/mm^2]$
  - σ_{hyd} ... hydrostatic stress tensor $[N/mm^2]$
  - σ_{dev} ... deviatory stress tensor $[N/mm^2]$
- σ_1, σ_2, σ_3 ... principal stresses and their eigenvectors $[N/mm^2]$
- τ_1, τ_2, τ_3 ... principal shear stresses $[N/mm^2]$ with $\sigma^{(1)}$, $\sigma^{(2)}$, $\sigma^{(3)}$ ... stress components normal to the principal shear stress planes $[N/mm^2]$

15.2 Mohr's circle

The MOHR's circles with it's main components

- σ_1, σ_2, σ_3 ... principal stresses $[N/mm^2]$
- τ_1, τ_2, τ_3 ... principal shear stresses $[N/mm^2]$

is shown there.

15.3 Strain tabular

The strain tensor components will be calculated like in section 12.2.1 shown.

Following results are output:

- strain tensors:
  - ϵ ... strain tensor [-]
  - ϵ_{vol} ... volumetric strain tensor [-]
  - ϵ_{dev} ... deviatory strain tensor [-]
- ϵ_1, ϵ_2, ϵ_3 ... principal strains and their eigenvectors [-]

15.4 Material tensor tabular

The material tensor components will be calculated like in section 12.3.1 shown.

Following results are output:

- material tensors components:
  - E ... elastic modulus $[N/mm^2]$
  - ν ... poisson ratio [-]
  - G ... shear modulus $[N/mm^2]$
  - K ... compression modulus $[N/mm^2]$
  - λ ... LAME's material parameter $[N/mm^2]$
- material tensor:
  - **C** ... elastic or material stiffness tensor $[N/mm^2]$
  - **D** ... material compliance tensor $[mm^2/N]$

15.5 Yield hypothesis tabular

The yield function will be calculated like in section 12.4.1 shown.

Following results are output:

- input yield hypothesis and parameters
- $f(\boldsymbol{\sigma})$ ... yield function $[N/mm^2]$

16 Info

16.1 Help

Shows a list of short cuts used in sections 15.1, 15.3 and 15.4.
Also shows the control-keys for the graphic mode (section 15) and tables (section 13.1).

16.2 About

Prints some information about version and developer of the program and address of the homepage.

17 Developer

- Valentini Bernhard (bernhard.valentini@smart-programs.org)

Web site: http://www.smart-programs.org/

18 Thanks

- the TIGCC Team for making it possible to program in C (http://ticalc.ticalc.org)
- the TICT (TI-Chess Team) for their ExtGraph library (http://tict.ticalc.org)
- Christof Neuhauser for mathematic support

19 History

- Smart-Section V1.00:
  - 24.08.2005 - first release
    - new, save and load function added
    - distinction between three-dimensional and plane stress and strain state implemented
    - Mohr's circle improved
    - help file added
- Smart-Section V0.10 Beta 2:
  - 14.08.2005 - update
    - strain and material tensor implemented
    - list, edit and delete functions implemented
    - calculation routine for stress and strain implemented
    - tabular output of strain and material tensor results implemented
    - Mohr's circle improved
    - manual added
- Smart-Stress V0.10 Beta 1:
  - 05.08.2005 - first beta release
    - stress tensor implemented
    - five yield hypothesis implemented
    - Mohr's circle implemented
    - tabular output of stress and yield results implemented

References

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

List of Figures

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