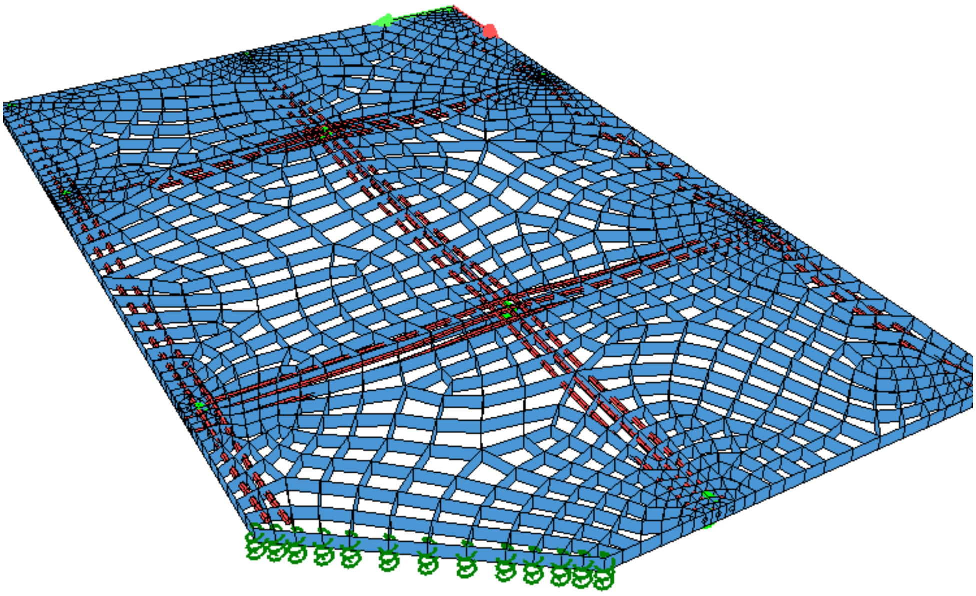

Quick Start Guide to the Input and Analysis of Prestressed Slabs with SOFiSTiK Software

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SSD 10.64-23 / SOFiPLUS(-X) 16.4/17.1-16

1. Scope

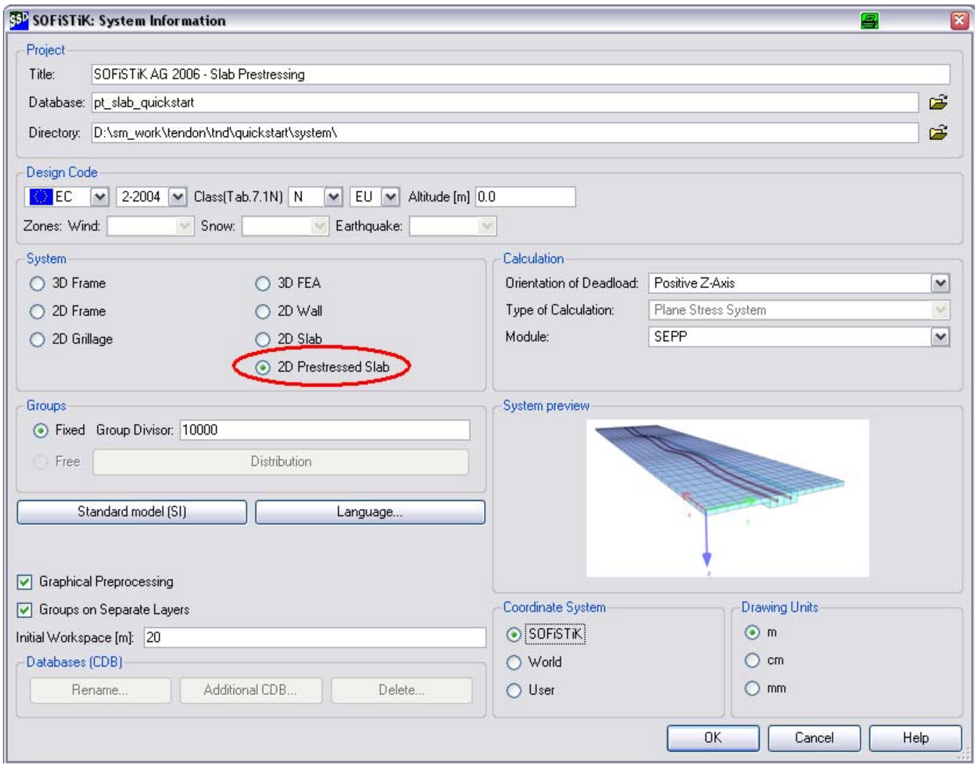
Slab prestressing provides an economical way to decrease the amount of required reinforcement (ULS) while allowing for larger spans with slender slabs and better structural performance regarding crack and deflection control. For similar economical graphical input and FEA analysis, SOFiSTiK software offers special features within the Structural Desktop SSD and SOFiPLUS. In the following quick start guide the different tasks and features will be explained briefly.

Required versions: SSD 10.64-23 or higher for analysis / SOFiPLUS(-X) 16.4/17.1-16 or higher for the graphical input.

2. System 2D Prestressed Slab and SSD Tasks for Slab Prestress

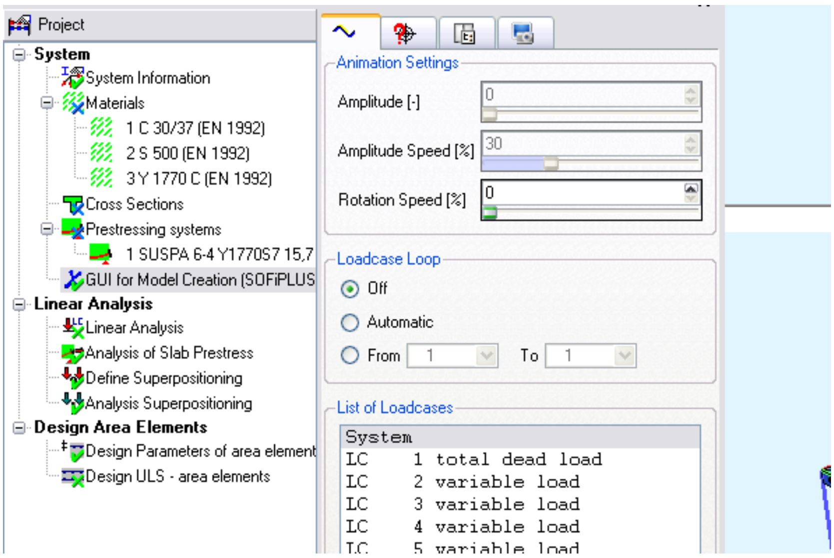
When starting a new project, the System Information dialogue offers a new system type: 2D Prestressed Slab. This system type allows for plane slab systems including membrane effects and varying slab thicknesses with eccentric elements.

> For 3D structures and inplane restraints use the 3D FEA system type



Picture 1: System Information dialogue for example project

After confirming the project settings, the SSD task tree offers two special tasks:



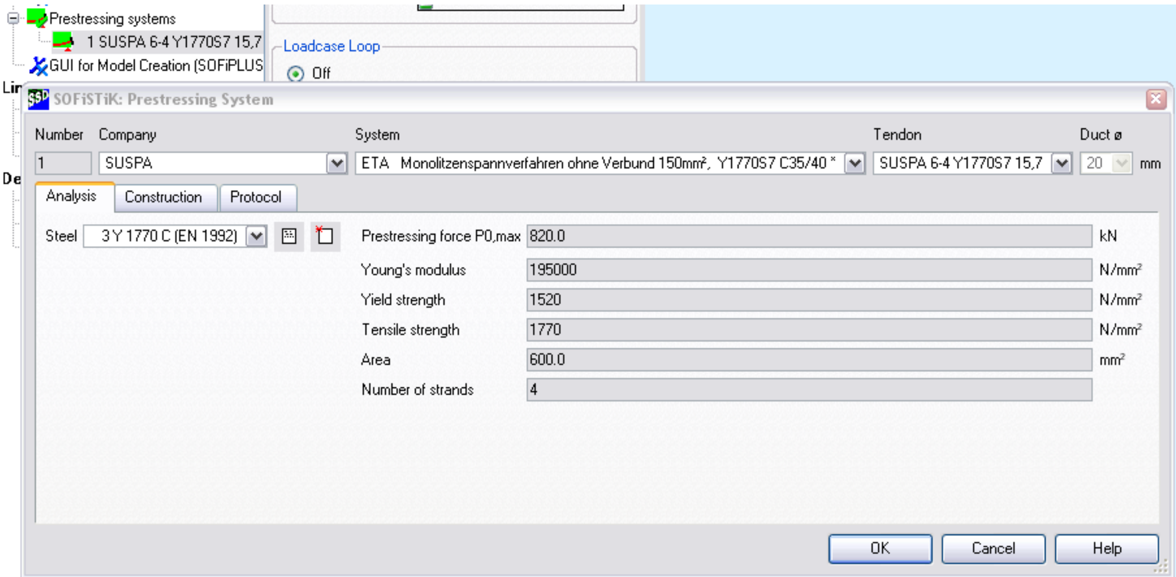
Picture 2: Task Tree for 2D Prestressed Slab system

- **Task: Prestressing System**

The Task Prestressing System provides the possibility to select various predefined prestressing systems which are provided by the software. A preselection is performed according to the defined design code of the project.

The textfile **tendon.tab** in the sofistik.23 folder contains the PT systems library

Individual prestressing systems can be defined by the user generating the file tendon_usr.tab



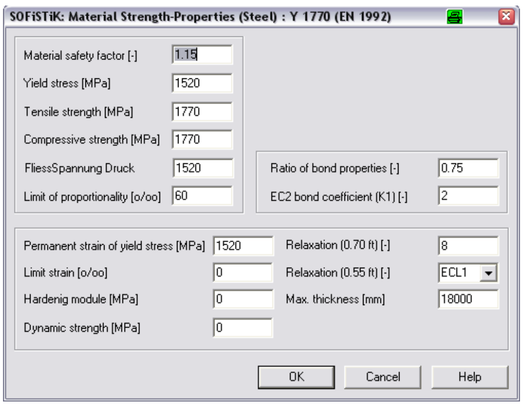
Picture 3: Task Prestressing System with example system selected

Example System: SUSPA/DSI® Monostrands 150 mm² acc. ETA-03/0036:

Company: SUSPA
System: ETA Monolitzenspannverfahren ohne Verbund 150mm²
Tendon: SUSPA 6-4 Y 1770 (Pack of 4 Monostrands)

Check of the prestressing force:
P0, max: with **ft0.1k** = **1520 N/mm²** = 0.9*1520 N/mm² * 600 mm²= **820 kN**

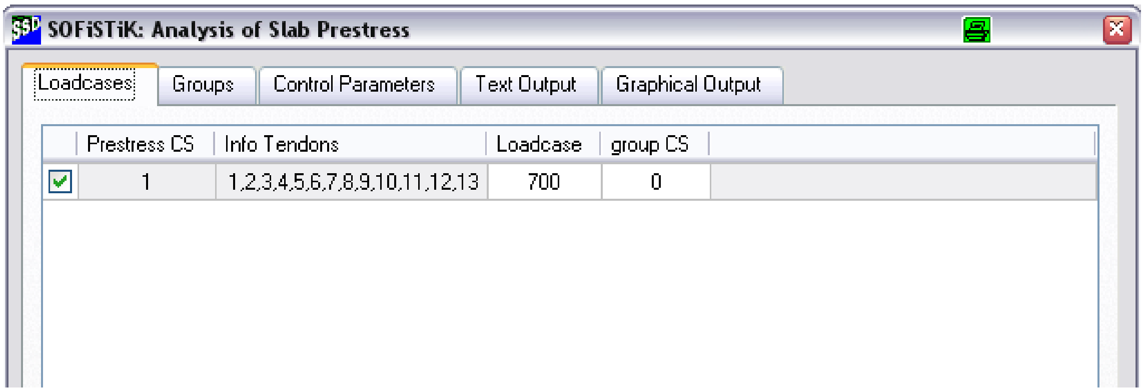
The corresponding prestressing steel Y1770 (EN1992) can be generated in advance using the Task: Materials or directly in the Prestressing System Task:



- **Task: Analysis of Slab Prestress**

The Task Analysis of Slab Prestress computes the resulting forces for existing slab tendons, per default the loadcase number 700 and the action P is assigned to the results.

Construction stages and further control parameters can be assigned using this task, the Graphical Output contains e.g. tendon stresses.

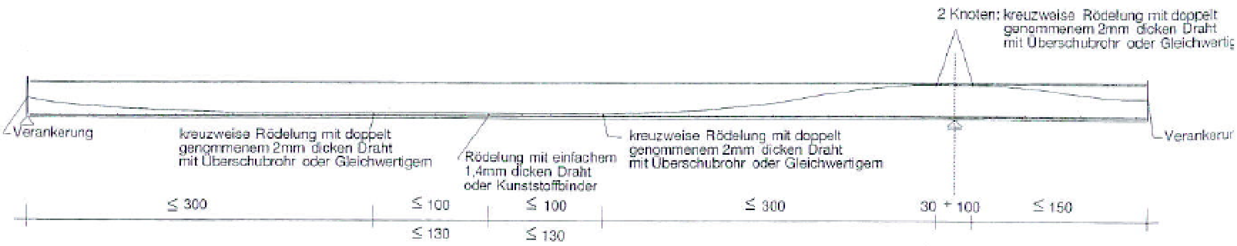


Picture 4: Task Analysis of Slab Prestress

3. Graphical Input of Tendons with SOFiPLUS(-X)

The tendons layout can be defined easily within the graphical pre-processor SOFiPLUS(-X), the tendons are generated in ground view, computation of the complete tendon layout including friction loss calculation is performed during the 'Export' (Meshing) of the system.

Only important boundary conditions, as support lines, stop lines, distance of tendons to the concrete faces and e.g. the transition lengths of the free tendon layout (Freie Spanngliedlage[1]) have to be specified by the user.



Picture 5: Freie Spanngliedlage (Free Tendon Layout) [1]

- **SOFiPLUS Toolbox: Prestressing**

The input of tendons and their layout is done in SOFiPLUS using the Toolbox Prestressing. Three icons for the input of three elements: Input of Tendons, Input of Support Lines and

[1] *Maier, K.; Wicke, M.;* Die freie Spanngliedlage. Beton- und Stahlbetonbau 95, 2000, Heft 2 Pp.: 62

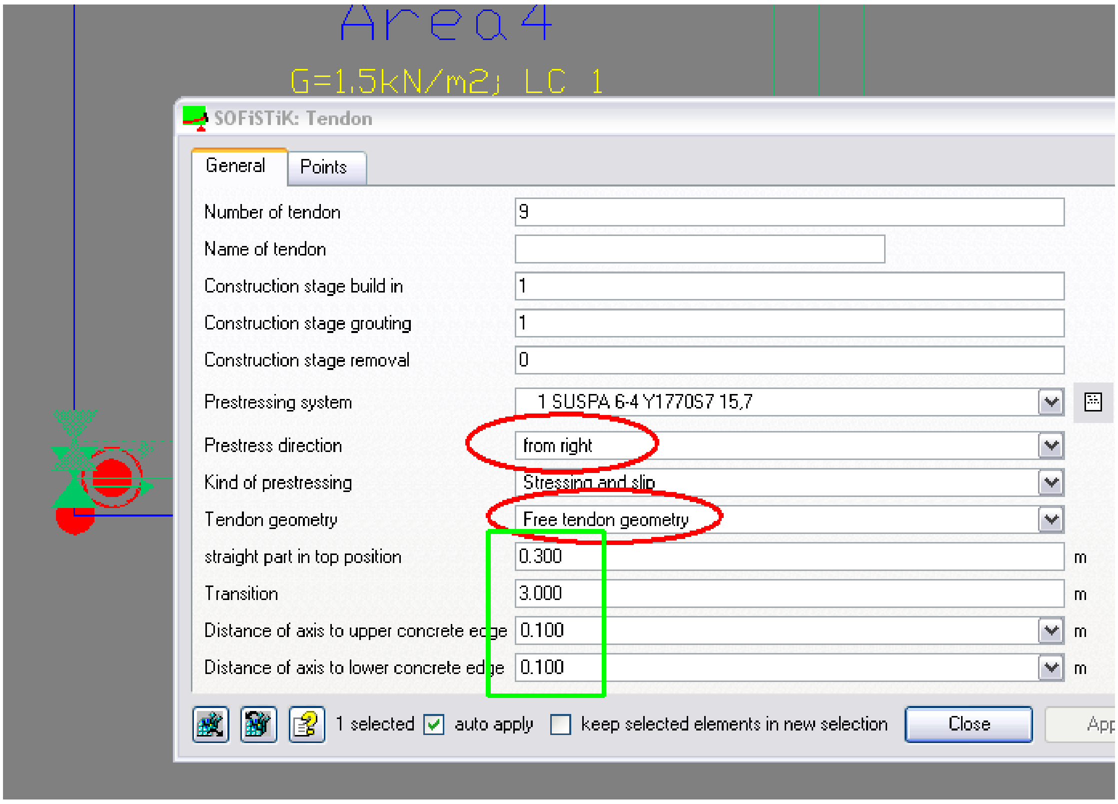
Input of so called Stop Lines are available, their input options and the modification of existing elements is explained below.

 **Input of Tendon**	**Task:** Generates new Tendons in ground view **Options:** • AutoCAD lines and polylines without kinks can be directly transferred into tendons • Points picked generate straight tendons parallel to the global x- or y-Axis • Tendons along a side of the structure are best generated using the ‘distribute along line’ option • Skew layouts are possible using user coordinate systems (UCS) **Modification of tendons:** The tendon dialogue opens with a double-click on one or more selected tendon elements
 **Input of Support Line**	**Task:** Generates support lines which define the height of tendon elements crossing the line **Options:** • Direct input of support lines • Curved object can be transferred into support lines **Modification of support lines:** The properties (i.e. distance of tendon from concrete face along line) of a support line are edited using the AutoCAD properties dialogue
 **Input of Stop Line**	**Task:** Generates stop lines out of AutoCAD objects which cause the intersecting tendons to end **Options:** • Selection of Lines etc. to become a stop line **Modification of support lines:** The stop line objects are copied in a separate layer, modification is possible in the same way as for all AutoCAD objects

- **SOFiPLUS Tendon Dialogue**

Double clicking on one or more selected tendon elements opens the SOFiPLUS Dialogue Tendon, here the necessary input for tendon parameters is possible.

The arrow on one end of the tendon indicates the **'left'** end



Picture 6: Tendon dialogue

- **Prestress direction:** Definition of active and passive anchor side
- **Kind of prestressing**
- **Tendon geometry:** Free tendon geometry or cubic spline geometry can be selected
- **Straight part in top position:** Length of the straight part over highpoints (colums etc.), ***only for free tendon layout***
- **Transition:** Transition length of the free tendon layout, ***only for free tendon layout***
- **Distances of axis to upper and lower concrete edge**

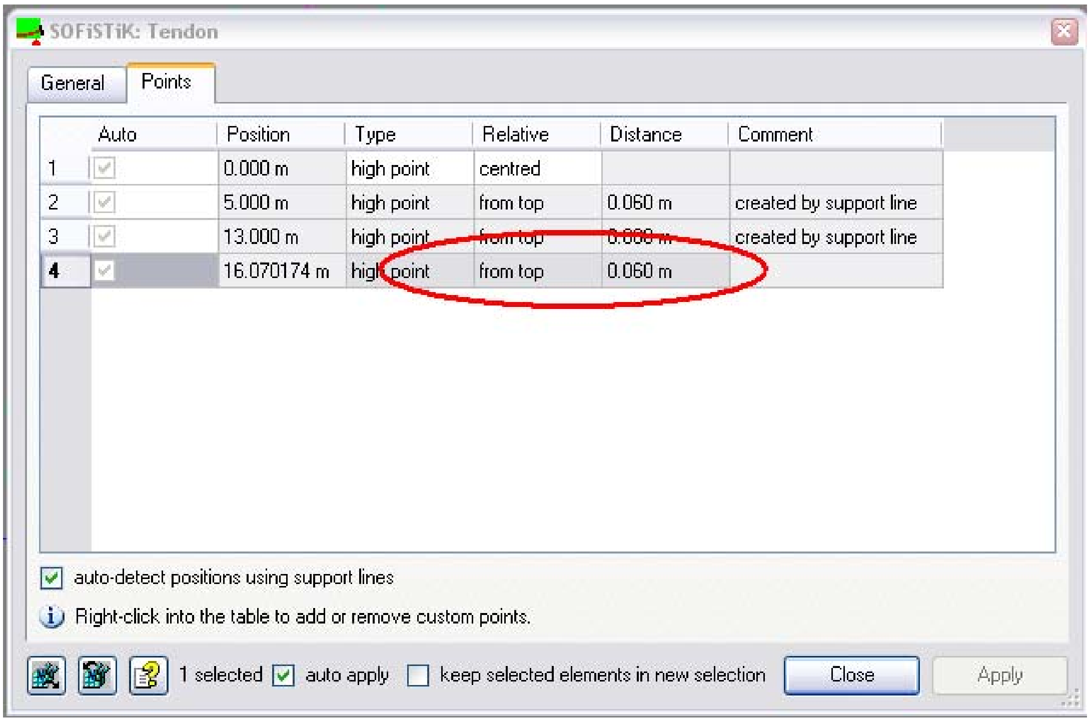
Der sich unter der Annahme der Biegelinie nach der linearen Stabtheorie ergebende Zusammenhang zwischen der Anhebung e und der Freien Durchhangslänge l von

$$l = \sqrt[4]{\frac{72 \cdot E \cdot I \cdot (e_1 + e_2)}{g}}$$

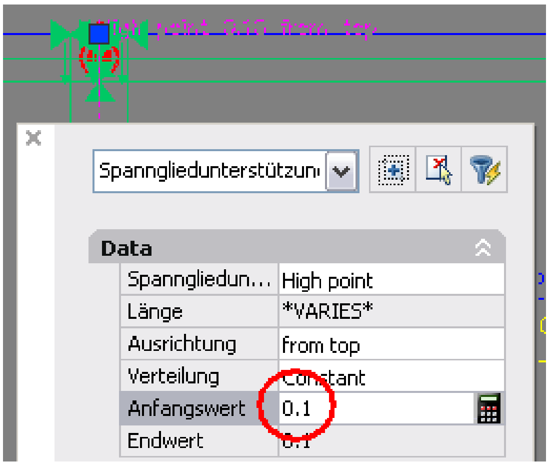
ergibt für die Monolitze F150 mit I = 269,2 mm^4, E = 195000 N/mm^2, g = 13,03 N/m

$$l = 130{,}504 \cdot \sqrt[4]{e_1 + e_2} \qquad e_1, e_2, l\,[\mathrm{cm}]\,.$$

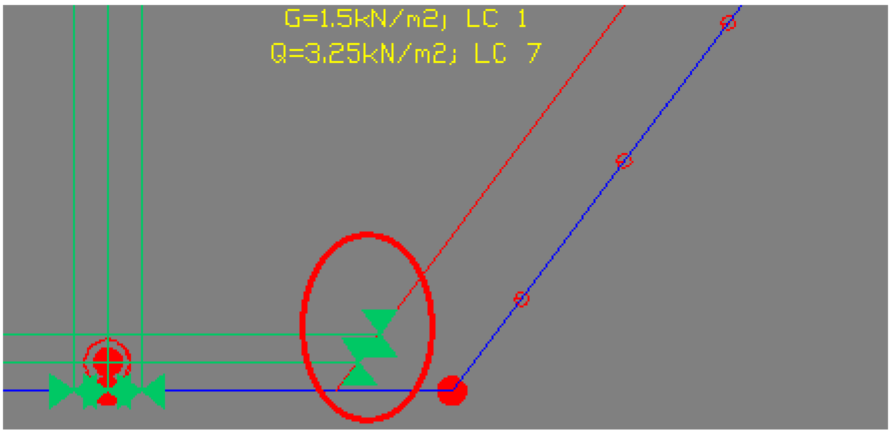
Picture 7: Formula for transition lenght [1]



Picture 8: The Points tab allows for geometry modification of single tendons



Picture 9: Input of tendon distance for a support line

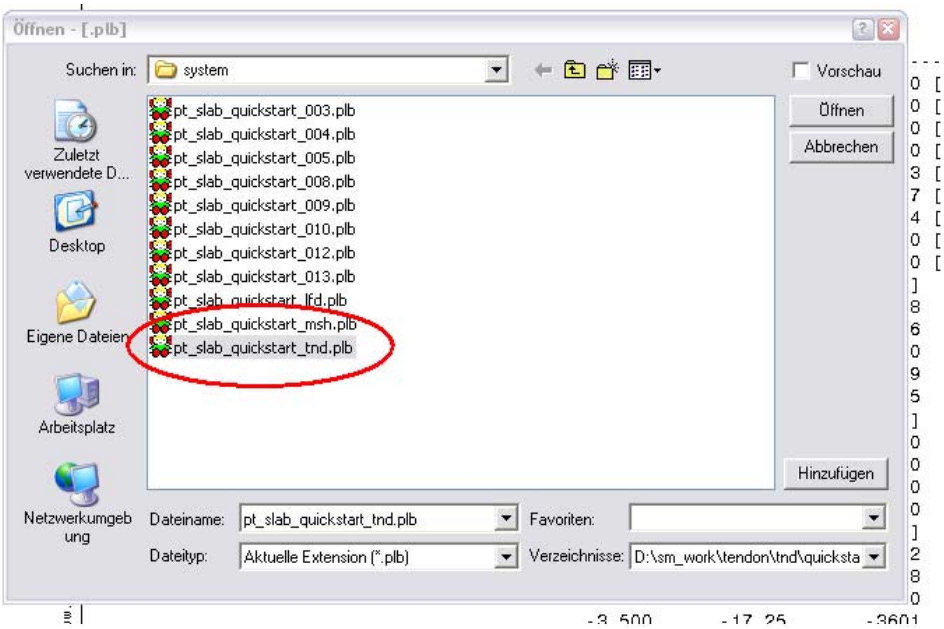


Picture 10: Stop Line (red line)

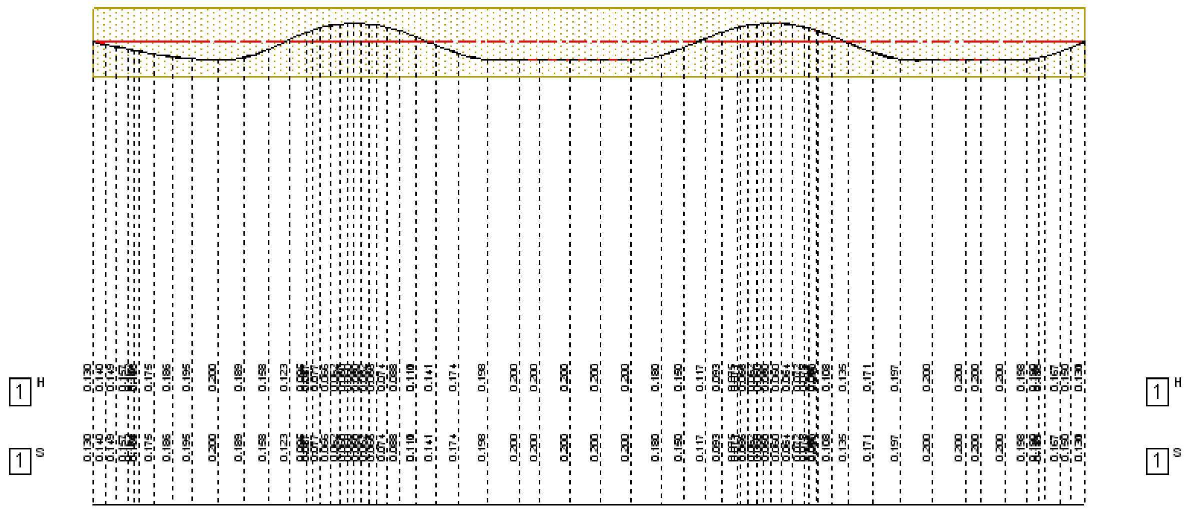
4. Analysis and Post Processing

After the definition of the tendons with SOFiPLUS, the SSD is used to control the further analysis and the post processing, the Task Linear Analysis is used to calculate all loadcases except prestress, here the aforementioned Task Analysis of Slab Prestress is employed. The reports of all calculation steps are managed using the URSULA button of the SSD, further reference on the SSD can be found via Menu 'Help' Quick Reference.

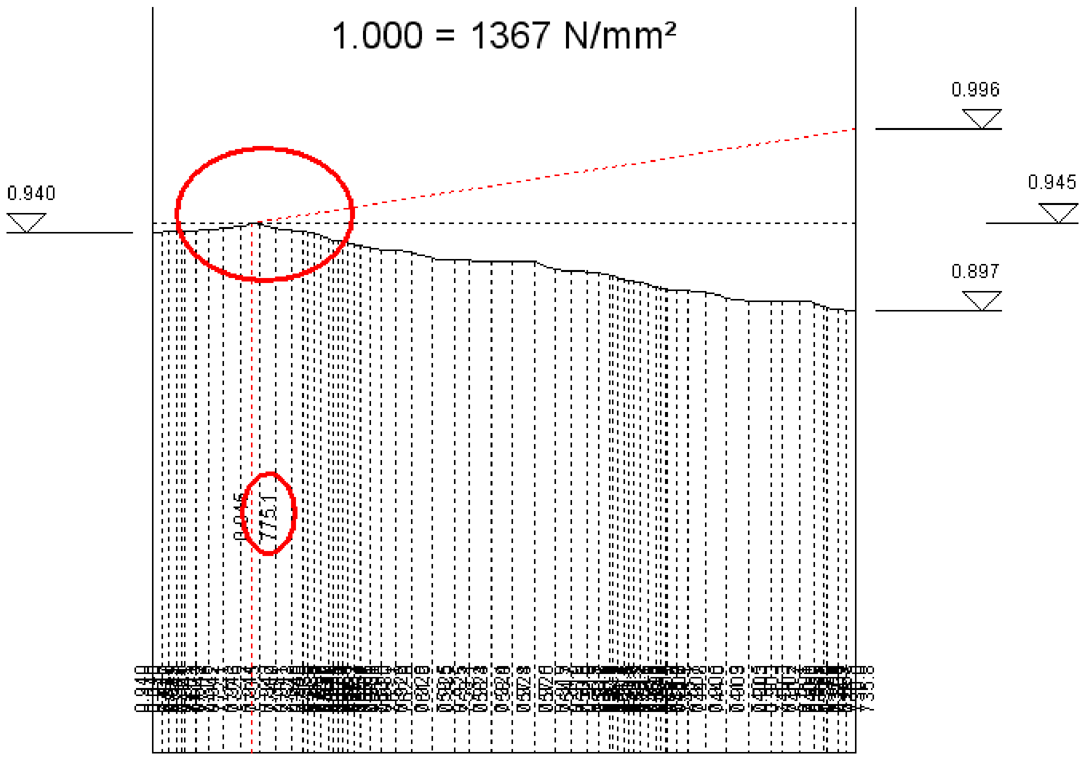
> The complete tendons friction calculation results are available as <projectname>_tnd.plb via the Menu 'Open' of URSULA



Picture 11: Report of tendon calculation

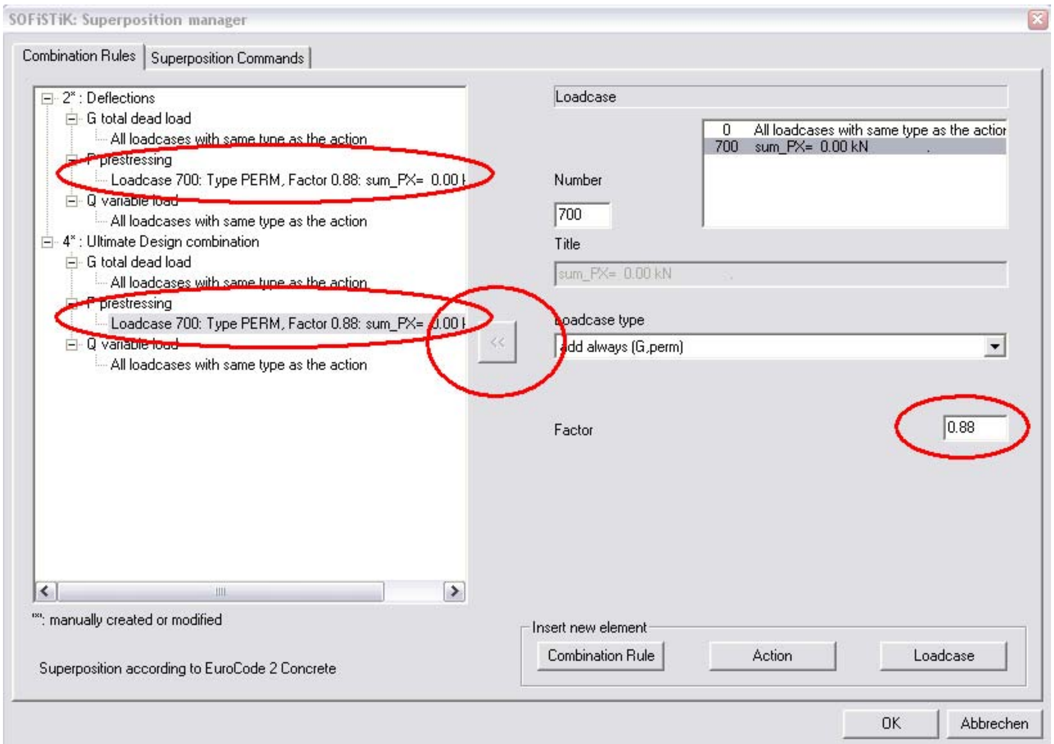


Picture 12: Tendon axis of free tendon layout



Picture 13: Tendon stresses (dashed line: Pm0,max=0.945*P0,max=0.85*1520 N/mm²); Maximum tendon force indicated red.

For simplified consideration of creep, shrinkage and relaxation losses, the Task Define Superpositioning is used to assign a factor (e.g. 0.88 for 12% CSR losses) to the prestressing loadcase in the automatically generated loadcase combinations (e.g. EC2-2004, ULS and SLS combination).



Picture 14: Factor for simple CSR consideration

The design in ULS and SLS of the prestressed slab is carried our using the standard design Tasks: Design ULS/SLS – area elements.

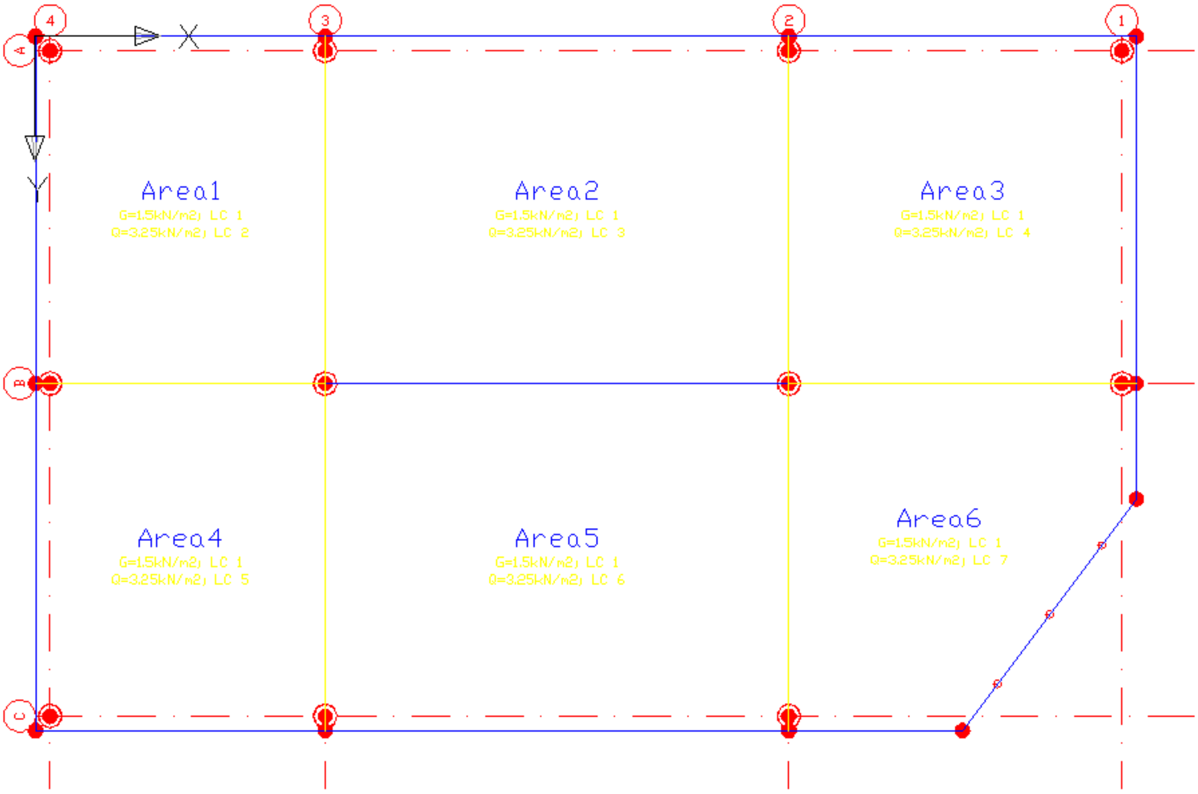
Remark on punching design for prestressed slabs:

Using BEMESS 11.90-23 the inclination and force of tendons crossing the punching area is automatically detected and considered in the punching design and checks, the mean compressive stress sigma-cd is considered for EC2-2004 and DIN 1045-1, selecting extensive text output for punching the prestress reduction force Vpd and the individual contributions can be checked.

```
Punching Design (EC 2 1992-1-1:2004(E))
Node number          =      1          X= 5.000 [m]       Y= 6.000 [m]
Max. shear force V-ULS= 705.9 [kN]     LC=  2102  via QUAD connecting forces
prestress reduct.  Vpd= 188.0 [kN]    V-ED= 517.9 [kN]    in perimeter    1
    12.0 [o/o] loss of prestress due to creep and shrinkage are included in Vpd.
dz/ds=inclination, alpha=horizontal deviation, dVPD=shear force positive=relieve
perimeter   1 :
       tendon no.   2 ZV= 675.0 [kN] dz/ds=0.020 alpha= 0.000 [°] dVPD=  13.2 [kN]
          2. cut      ZV= 673.0 [kN] dz/ds=0.022 alpha= 0.000 [°] dVPD=  14.7 [kN]
       tendon no.   4 ZV= 658.5 [kN] dz/ds=0.023 alpha= 0.000 [°] dVPD=  15.4 [kN]
          2. cut      ZV= 656.5 [kN] dz/ds=0.023 alpha= 0.000 [°] dVPD=  15.4 [kN]
       tendon no.   7 ZV= 676.4 [kN] dz/ds=0.027 alpha= 9.010 [°] dVPD=  18.2 [kN]
          2. cut      ZV= 674.0 [kN] dz/ds=0.025 alpha= 8.569 [°] dVPD=  16.8 [kN]
       tendon no.   8 ZV= 676.4 [kN] dz/ds=0.027 alpha= 9.010 [°] dVPD=  18.2 [kN]
          2. cut      ZV= 674.0 [kN] dz/ds=0.025 alpha= 8.569 [°] dVPD=  16.8 [kN]
       tendon no.  10 ZV= 658.5 [kN] dz/ds=0.023 alpha= 15.91 [°] dVPD=  14.8 [kN]
          2. cut      ZV= 656.5 [kN] dz/ds=0.023 alpha= 15.91 [°] dVPD=  14.8 [kN]
       tendon no.  11 ZV= 658.5 [kN] dz/ds=0.023 alpha= 15.91 [°] dVPD=  14.8 [kN]
          2. cut      ZV= 656.5 [kN] dz/ds=0.023 alpha= 15.91 [°] dVPD=  14.8 [kN]
                                                                     ===========
                                                                      188.0 [kN]
perimeter   2 :
       tendon no.   2 ZV= 675.7 [kN] dz/ds=0.035 alpha= 0.000 [°] dVPD=  24.0 [kN]
       tendon no.   4 ZV= 659.4 [kN] dz/ds=0.043 alpha= 0.000 [°] dVPD=  28.1 [kN]
          2. cut      ZV= 655.6 [kN] dz/ds=0.043 alpha= 0.000 [°] dVPD=  27.9 [kN]
       tendon no.   7 ZV= 677.3 [kN] dz/ds=0.050 alpha= 5.567 [°] dVPD=  33.5 [kN]
          2. cut      ZV= 673.1 [kN] dz/ds=0.046 alpha= 5.222 [°] dVPD=  30.7 [kN]
       tendon no.   8 ZV= 677.3 [kN] dz/ds=0.050 alpha= 5.567 [°] dVPD=  33.5 [kN]
          2. cut      ZV= 673.1 [kN] dz/ds=0.046 alpha= 5.222 [°] dVPD=  30.7 [kN]
       tendon no.  10 ZV= 659.4 [kN] dz/ds=0.043 alpha= 10.47 [°] dVPD=  27.6 [kN]
          2. cut      ZV= 655.6 [kN] dz/ds=0.043 alpha= 10.47 [°] dVPD=  27.4 [kN]
       tendon no.  11 ZV= 659.4 [kN] dz/ds=0.043 alpha= 10.47 [°] dVPD=  27.6 [kN]
          2. cut      ZV= 655.6 [kN] dz/ds=0.043 alpha= 10.47 [°] dVPD=  27.4 [kN]
                                                                     ===========
                                                                      318.4 [kN]
Circular column      dS= 0.400 [m]
Plate thickness h-slab= 0.260 [m]    depth 0.220 [m]
1. perimeter at  2.0*d= 0.440 [m]    utot= 4.021 [m]       u= 4.021 [m]
Min.reinforc. as-upper=  7.09 [cm2/m]  (Min.design-moment-> inner column)
Normal stress sigma-cd= -1.19 [MPa]
Tension reinforc. as >=  9.68 [cm2/m] mue=  0.44 [o/o]  Vrd1= 148.1 [kN/m]
 v-Sd = 1.15*V/u      = 148.1 [kN/m]    <= 148.1 [kN/m]
No punching shear reinforcement necessary.
In the critical punching zone at least      9.68 [cm2/m]
tension reinforcement is required
```

Picture 15: Extensive BEMESS output for punching design with tendons

5. Example System



Example Slab System according EC2-2004	
Lx = 5/8/6 m and	**Ly = 6/6m**
Columns:	**diameter 40cm/ heigth 3m/ C 30/37**
Slab thickness:	**t = 26 cm**
Concrete:	**C 30/37**
Rsteel:	**S 500**
Prestressing steel:	**S Y1770**
Concrete cover:	**3 cm**
Permanent loads:	**automatic selfweight + 1.5kN/m²**
Live loading:	**3.25kN/m²**