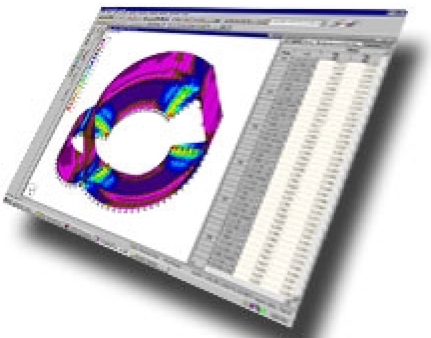
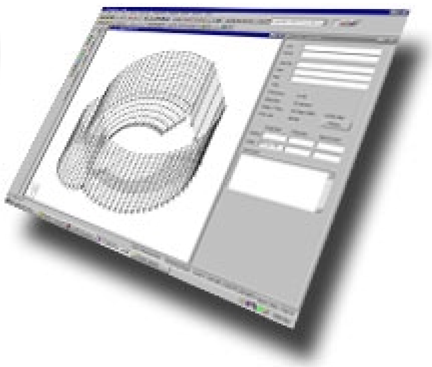
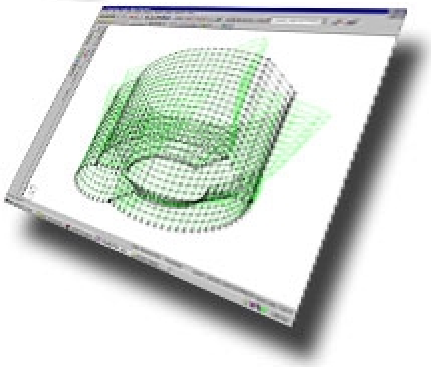
STAAD.Pro

NS 3472 / NPD







NS 3472 / NPD

September 2001 1994

S T E E L D E S I G N - C O D E C H E C K

DESIGN PARAMETER
THEORY MANUAL
TABULATED RESULTS

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1 Introduction

This user manual presents a description of the design basis, parameters and theory applied to STAAD.Pro for performing code checks according to NS 3472 ref. [1] and NPD ref. [5].

The code checks include:

- stability check (buckling)
- lateral buckling check
- yield check (von Mises)
- stability check including local plate buckling of un-stiffened pipe walls according to NPD

The code check is available for the following cross-section types:

- wide flange profiles (HEA, HEB, IPE etc.)
- pipe (OD xx ID xx)
- tube (RHS, HUP)
- channel
- angle type
- rectangular massive box (prismatic)
- user table (wide flange, I-sections, tapered I, tube, channel and RA angle)

The code check is not available for the following cross-section types:

- Double angles
- Tapered tubes
- Prismatic sections with too few section parameters defined
- Other sections that are not in the 'available' list above

Please note the following:

- NS 3472 and NPD code checking covered in this document are available through two separate STAAD.Pro Code check packages.
- This document is not a lecture in use of NS 3472 or NPD. This document explains how, and which parts of, the Norwegian steel codes that have been implemented in STAAD.Pro.
- When L-sections are used, the Code Check requires RA angle definition.
- Weld design is not included in the Norwegian code checks.
- The prismatic section defined in the code check (rectangular massive box) is not identical to the general prismatic profile defined in the STAAD.Pro analysis package.

EDR does not accept any liability for loss or damage from or in consequence for use of the program.

Nomenclature:

NS - refers to NS 3472 ref. [1]
NS2 - refers to NS 3472 ref. [6]
NPD - refers to NPD94 ref. [5]

2 Basis for code checking

2.1 General

This section presents general information regarding the implementation of the Norwegian codes of practice for structural steel design. This manual describes the procedures and theory used for both NS and NPD.

In general NS is used for all cross sections and shapes listed in section 1 of this manual. An exception is the treatment and check of pipe members in framed structures. NS does not give specific details about the treatment of pipes. Section 3.4 explains how this is adopted when NS is selected for code checking.

The NPD however have a more thorough check of pipe members, and consider the effect of local buckling of the pipe wall in conjunction with the stability check. In addition, the NPD code gives joint capacity formulae for brace to chord connections for pipe members.

The design philosophy and procedural logistics are based on the principles of elastic analysis and ultimate limit state design. Two major failure modes are recognized:

- failure by overstressing
- failure by stability considerations

The following sections describe the salient features of the design approach. Members are proportioned to resist the design loads without exceeding the characteristic stresses or capacities and the most economic section is selected on the basis of the least weight criteria. It is generally assumed that the user will take care of the detailing requirements like the provision of stiffeners and check the local effects like flange buckling, web crippling, etc.

The user is allowed complete control over the design process through the use of the parameters listed in Table 2.1. Default values of parameters will yield reasonable results in most circumstances. However, the user should control the design and verify results through the use of the design parameters.

2.2 Calculation of Forces and Bending Moments

Elastic analysis method is used to obtain the forces and moments for design. Analysis is done for the primary loading conditions and combinations provided by the user. The user is allowed complete flexibility in providing loading specifications and using appropriate load factors to create necessary load combinations.

2.3 Members with Axial Forces

For tension only members, axial tension capacity is checked for the ultimate limit stress. For compression members, axial compression capacity is checked in addition to lateral buckling and ultimate limit stress. The largest slenderness ratio (λ) shall not be greater than 250 according to NS 11.7 Stability is checked as per the procedure of NS 12.3. The buckling curves of NS fig. 3 have been incorporated into the STAAD.Pro code check. The coefficient α (as per NS Table 10) can be specified in both directions through the use of parameters CY and CZ. In the absence of parameters CY and /or CZ, default α- value will be according to NS table 11.

2.4 Members with Axial Force and Bending Moments

For compression members with bending, interaction formulae of NS table 12.3.4.2 are checked for appropriate loading situation. All compression capacities are calculated per the procedure of NS 12.3.

The equivalent moment factor β is calculated using the procedure of NS table 12. Two different approaches are used depending upon whether the members can sway or not. Conditions for sidesway and transverse loading can be specified through the use of parameters SSY and SSZ. For members that cannot sway, without transverse loading, coefficients β are calculated and proper dimensioning moments are used in the interaction formulae.

2.5 Lateral Buckling

Lateral torsional buckling is checked as per the procedure of NS 12.3.4. The procedure for calculation of ideal buckling moment for sections with two axis of symmetry has been implemented. The coefficient can be provided by the user through the use of parameter CB. In the absence of CB, a value of 1.0 will be used. Torsional properties for cross-sections (torsional constant and warping constant) are calculated using formulae from NS 3472. This results in slightly conservative estimates of torsional parameters. The program will automatically select the maximum moment in cases where M_{yd} is less than M_{zd}.

2.6 Von Mises Yield Criterion

Combined effect of axial, bending, horizontal/vertical shear and torsional shear stress is calculated at 13 sections on a member and up to 9 critical points at a section. The worst stress value is checked against yield stress divided by appropriate material factor.
The von Mises calculates as:

$$\sigma_j = \sqrt{\left(\sigma_x + \sigma_{by} + \sigma_{bz}\right)^2 + 3\left(\tau_x + \tau_y + \tau_z\right)^2} \le \frac{f_y}{\gamma_m}$$

2.7 Material Factor and nominal stresses

The design resistances are obtained by dividing the characteristic material strength by the material factor.

NS 3472: The material factor default value is 1.10. Other values may be input with the MF parameter. The nominal stresses should satisfy $\sigma_j \le \frac{f_y}{\gamma_m} = f_d$

NPD: The general requirement is $\sum S\left(F_i \gamma_{fi}\right) \le R_k / \left(\gamma_m \cdot \gamma_{mk}(S)\right)$ according to NPD 3.1.1. For stability the NPD 3.1.1 and 3.1.3 requires that the structural coefficient is considered.

$$S_d \le f_{kd} = \frac{f_k}{\gamma_m \cdot \gamma_{mk}\left(S_d\right)}$$

where

S_d = reference stress or load effect resultant
f_k = characteristic capacity
f_{kd} = design capacity
γ_m = material coefficient

γ_{mk} = structural coefficient

γ_m is default set to 1.10.
γ_{mk} shall be equal to 1.0 for frames. For pipe members γ_{mk} is a function of the reduced slenderness. In the STAAD.Pro implemented NPD code this is calculated automatically.

2.8 Code checking according to NPD

The following parts of Chapter 3 in the NPD guidelines have been implemented.

a) Control of nominal stresses. (NPD 3.1.2).
b) Buckling of pipe members in braced frames, including interaction with local shell buckling (NPD 3.2.2, 3.2.3).
c) Buckling of un-stiffened closed cylindrical shells, including interaction with overall column buckling (NPD 3.4.4, 3.4.6, 3.4.7 and 3.4.9).
d) Joint capacity check for gap as well as for overlap joints (NPD 3.5.2).

Check b) provides the unity check based on the beam-column buckling interaction formulae in NPD 3.2.2. The interaction between global and local buckling due to axial load and hydrostatic pressure is accounted for through computation of an axial characteristic capacity to replace the yield stress inn the beam-column buckling formulae.

Note that check b) handles members subjected to axial loads, bending moments and hydrostatic pressure. In other words, check b) assumes that stresses resulting from shear and torsion are of minor importance, e.g. in jacket braces.

Check c) provides the unity check based on the stability requirement for un-stiffened cylindrical shells subjected to axial compression or tension, bending, circumferential compression or tension, torsion or shear. The unity check refers to the interaction formulae in NPD 3.4.4.1. The stability requirement is given in NPD 3.4.7.

2.9 Aluminium Check

STAAD.Pro performs stability check on aluminium alloys according to buckling curve in ECCS (European recommendation for aluminium alloy structures1978). It is possible to select heat-treated or non heat-treated alloy from the parameter list in the STAAD.Pro input file.

For heat-treated use CY=CZ=0.1590, and for non heat-treated use CY=CZ=0.2420.

Tracks 1.0 and 9.0 print buckling curve H for heat- treated, and buckling curve N for non-heat-treated. The yield check is the same as for steel.

Table 2.1 Design parameters

STAAD.Pro **STEEL DESIGN- CODE CHECK**			
PARAMETER NAME	**DEFAULT VALUE**	**DESCRIPTION**	**REFERENCE**
BEAM	0.0 **Note: must be set to 1.0**	Parameter **BEAM 1.0 ALL** tells the program to calculate von Mises at 13 sections along each member, and up to 8 points at each section. (Depends on what kind of shape is used.)	Sec. NS 12.2.2
CODE	none	NS3472 for NS, NPD for NPD (NOR may also be used for both)	
CY CZ	Default see NS 3472	Buckling curve coefficient, α about local z-axis (strong axis). Represent the a, a_0, b, c, d curve.	Fig. NS 3 Sec. NS 12.2 NS Table 11
BY	1.0	Buckling length coefficient, β, for weak axis buckling (y-y) (NOTE: BY > 0.0)	Fig. NS 3 Sec. NS 12.3
BZ	1.0	Buckling length coefficient, β, for strong axis buckling (z-z) (NOTE: BZ > 0.0)	Fig. NS 3 Sec. NS 12.3
FYLD	235	Yield strength of steel, f_y (St37) [N/mm^2]	Tab. NS 3
MF	1.1 (NS3472) 1.15 (NPD)	Material factor / Resistance factor, γ_m	Sec. NS 10.4.2 Sec. NPD 3.1
UNL	Member length	Effective length for lateral buckling calculations (specify buckling length). Distance between fork supports or between effective side supports for the beam	Sec. NS 12.3
CB	1.0	Lateral buckling coefficient, Ψ. Used to calculate the ideal buckling moments, M_{vi}	Sec. NS2 A5.5.2 Fig. NS2 A5.5.2a)-e)
SSY	0.0	0.0 = No sidesway. β calculated. > 0.0 = Sidesway in local y-axis weak axis β=SSY	Sec. NS 12.3.4 Tab. NS 12 Sec. NPD 3.2.1.4
SSZ	0.0	0.0 = No sidesway. β calculated. > 0.0 = Sidesway in local z-axis strong axis β=SSYβ=SSY	Sec. NS 12.3.4 Tab. NS 12 Sec NPD 3.2.1.4
CMY	1.0	Water depth in meters for hydrostatic pressure calculation for pipe members	Valid for the NPD code only
CMZ	0.49	α_{LT} for sections in connection with lateral buckling	Sec. NS 12.3.4 Fig. NS 6.

TRACK	0.0	0.0 = Supress critical member stresses. 1.0 = Print all critical member stresses, i.e. DESIGN VALUES 2.0 = Print von Mises stresses. 9.0 = Large output, 1 page for each member. See section 7 and Appendix A for complete list of available TRACKs and print examples.	
RATIO	1.0	Permissible ratio of the actual to allowable stresses.	Sec. NS 12.3.4.2
DMAX	100.0 [cm]	Maximum allowable depth of steel section.	
DMIN	0.0 [cm]	Minimum allowable depth of steel section.	

The parameter CMY will, when given with negative value, define an inside pressure in pipe members. The pressure corresponds to given water depth in meters.

The parameter CB defines the ϕ value with respect to calculation of the ideal lateral buckling moment for single symmetric wide flange profiles, ref. NS app. 5.2.2.

EXAMPLE:
(Used at the end of the input file)

```
* Code check according to NS3472
 UNIT MMS NEWTON
 PARAMETERS
 CODE NS3472
 BEAM 1.0 ALL
 FYLD 340 ALL
 MF  1.10 ALL
 CY  0.49 MEMB 1
 CZ  0.49 MEMB 1
 BY  0.9  MEMB 1
 BZ  0.7  MEMB 1
 SSY 1.42  MEMB 1
 SSZ 1.45  MEMB 1
 CB  0.9  MEMB 1
 RATIO 1.0 ALL
 TRACK 9.0 ALL
 UNIT KNS METER
 LOAD LIST 1
 CHECK CODE MEMB 1
 FINISH
```

3 Stability check according to NS 3472

3.1 General description

The stability check is based on the assumption that both ends of the member are structural nodes. Buckling lengths and results for member with joints between the structural nodes have to be evaluated in each separate case.
Effects from local buckling or external hydrostatic pressure on pipes and tubes are not included.

The general stability criteria is: (ref. NS 12.3)

Buckling : $\boxed{n_{max} + k_z \cdot m_z + k_y \cdot m_y \le 1}$

Lateral buckling : $\boxed{\frac{n}{\chi_y} + k_{LT} \cdot \frac{m_z}{\chi_{LT}} + k_y \cdot m_y \le 1}$

$i = z, y$ $\quad n_{max} = \frac{n}{\chi_{min}} \qquad n = \frac{N_f}{N_d} \qquad \chi_{min} = \min(\chi_z, \chi_y) \qquad \chi_i = \frac{N_{kd.i}}{N_d}$

$$k_i = 1 - \mu_i \cdot \frac{n}{\chi_i \cdot \gamma_m} \le 1.5 \qquad \mu_i = \overline{\lambda_i} \cdot (2 \cdot \beta_{Mi} - 4) \le 0.9$$

β_M ref. NS Tab. 12

$$k_{LT} = 1 - \mu_{LT} \cdot \frac{n}{\chi_y \cdot \gamma_m} \le 1.0 \qquad \mu_{LT} = 0.15 \cdot \left(\overline{\lambda_y} \cdot \beta_M - 1\right) \le 0.9$$

$$\overline{\lambda_i} = \frac{\lambda_i}{\lambda_1} \qquad \lambda_i = \frac{L_{ki}}{i_i} \qquad \lambda_1 = \pi \cdot \sqrt{\frac{E}{f_y}}$$

$$\chi_i = \frac{1}{\phi + \sqrt{\phi^2 - \left(\overline{\lambda}\right)^2}} \qquad \phi = 0.5 \cdot \left[1 + \alpha \cdot \left(\overline{\lambda} - 0.2\right) + \left(\overline{\lambda}\right)^2\right]$$

α ref. NS Tab. 10 & 11

$$\chi_{LT} = \frac{1}{\phi_{LT} + \sqrt{\phi_{LT}^2 - \left(\overline{\lambda_{LT}}\right)^2}}$$

$\phi_{LT} = 0.5 \cdot \left[1 + \alpha \cdot \left(\overline{\lambda}.LT - 0.4\right) + \left(\overline{\lambda}.LT\right)^2\right]$ $\quad \alpha$ ref. NS sec. 12.3.4.1

$\overline{\lambda_{LT}} = \sqrt{\frac{W_z \cdot f_z}{M_{cr}}} \qquad M_{cr} = \psi \cdot M_{vio}$ $\quad \psi$ ref. NS2 A5.5.2 a)-d)

$$M_{vio} = \frac{\pi}{L} \cdot \sqrt{E \cdot I_z \cdot G \cdot I_T} \cdot \sqrt{1 + \frac{\pi^2}{L^2} \cdot \frac{E \cdot C_w}{G \cdot I_T}}$$

3.2 Determination of β_z and β_y

3.2.1 Lateral sidesway not prevented, NS 12.3

Code check input parameters SSZ and SSY must be given values > 0.0 for beams with movable end joints and beams with transverse loads between joints. The parameter equals the equivalent moment factor β ref. NS sec. 12.3.4.2 and Tab. 12.

β_y=SSY
β_z=SSZ

3.2.2 Lateral sidesway prevented, NS 12.3

Code check input parameters SSZ and SSY ≡ 0 for beams with unmovable end joints without transverse loads between joints. The equivalent moment factor β (for z and y) is calculated dependant on moment distributions as shown in Fig. 3.1.

Figure 3.1 β for different moment distributions

Momentdiagram	β_M (β_{LT})
M_1  ψM_1 $-1 \le \psi \le 1$	$\beta_{M,\psi} = 1{,}8 - 0{,}7\,\psi$

3.3 Lateral buckling

The Ideal lateral buckling moment is calculated according to NS2 A5.5.2

$$M_{vi} = \psi \cdot M_{vio} = \psi \cdot 1.95 \frac{E}{L}\sqrt{I_y \cdot I_x}\ \sqrt{1 + \frac{\pi^2 \cdot 2.6}{L^2}\frac{C_w}{I_x}}$$ concern double symmetric

cross sections where ψ is given in NS fig. A5.5.2, (input parameter CB), L = member length for lateral buckling (input parameter UNL), C_w and I_x , see section 5. For single symmetric cross sections, the ideal lateral buckling moment is

$$M_{vix} = \phi \cdot \frac{\pi^2 EI_y}{L^2}\sqrt{(\frac{5a}{\pi^2} + \frac{r_x}{3} - y_s)^2 + C^2} - (\frac{5a}{\pi^2} + \frac{r_x}{3} - y_s)$$ where

$$C^2 = \frac{C_w + 0{,}039 L^2 I_T}{I_y}$$ and a is distance from profile CoG to point where the load is acting, assumed to be on top flange. The φ parameter (ref NS fig. A5.5.2.g) is controlled by the input parameter CB.

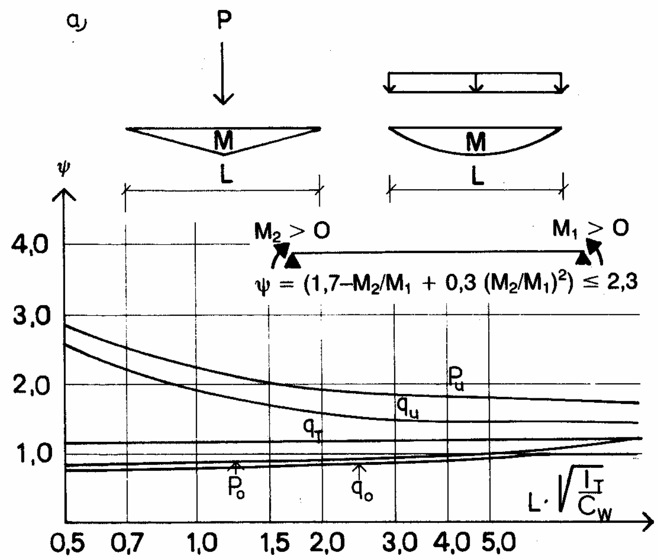


Fig. A5.5.2a ψ-koeffisienter for enkel bjelke

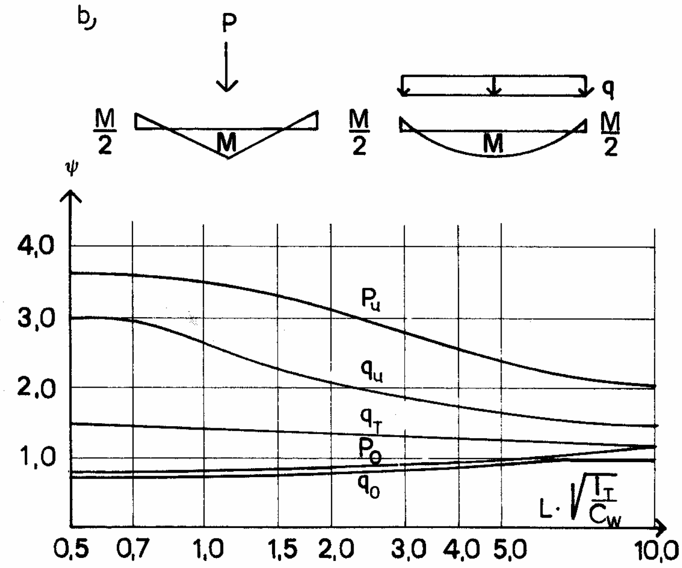


Fig. A5.5.2b ψ-koeffisienter for delvis innspent bjelke

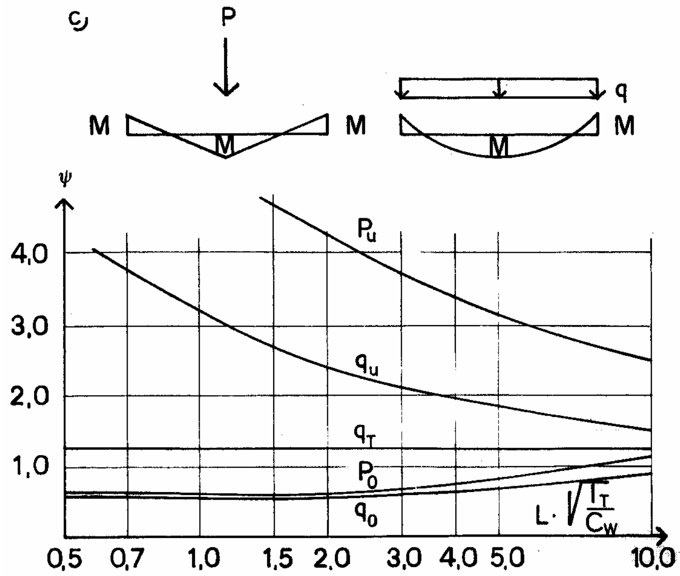


Fig. A5.5.2c ψ-koeffisienter for tilnærmet fullt innspente bjelker

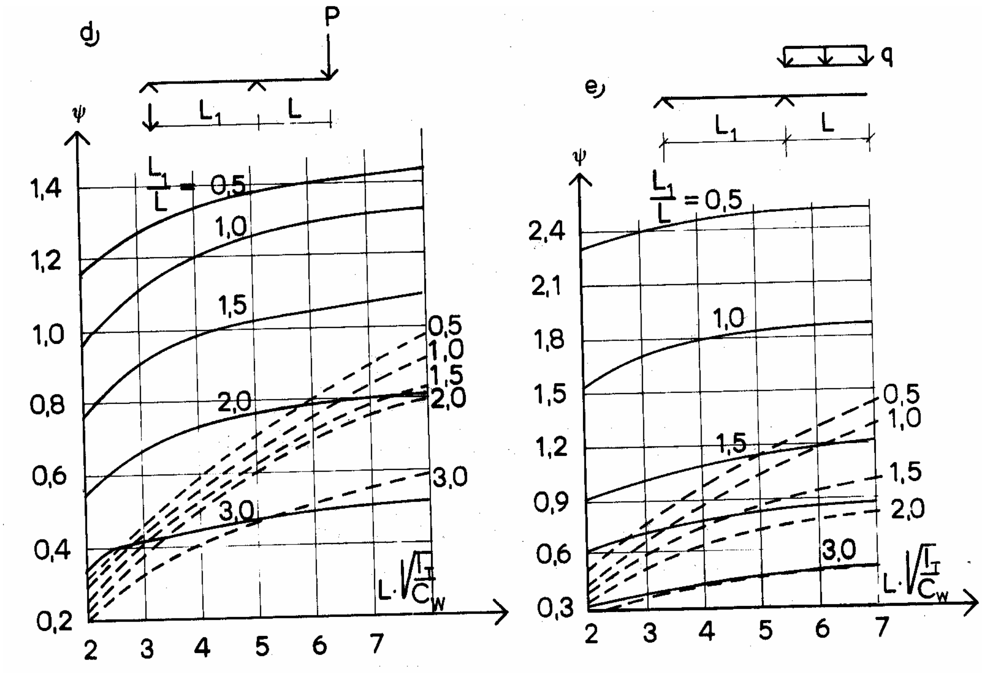


Fig. A5.5.2d og e ψ-koeffisienter for utraget bjelke med enkel last og fordelt last. Stiplede kurver gjelder last på overflens.

3.4 Stability check of pipe members

The stability criteria applied for members with pipe cross section is:

$$IR = \frac{N}{N_{kd}} + \sqrt{\left(\frac{\overline{M}_z}{M_d\left(1 - \frac{N}{N_{Ezd}}\right)}\right)^2 + \left(\frac{\overline{M}_y}{M_d\left(1 - \frac{N}{N_{Eyd}}\right)}\right)^2} \leq 1.0$$

where

$$\frac{N}{N_{kd}} = \max of\left(\frac{N}{N_{kzd}}, \frac{N}{N_{kyd}}\right)$$

$\overline{M}_z$ and $\overline{M}_y$ is given in NS 5.4.2.

For the print output option TRACK 9.0 $K_E \equiv 1.0$ and $M_{vd} \equiv M_d$

3.5 Angle profiles type RA (reverse angle)

The axial contribution to the total interaction ratio is checked according to the modified EECS-method, see NS A5.4.

The stability criterion is:

$$\mathrm{IR} = \frac{N}{N_{kd}} + \frac{\overline{M}_y}{M_{yd}\left(1 - \frac{N}{N_{Eyd}}\right)} + \frac{\overline{M}_z}{M_{zd}\left(1 - \frac{N}{N_{Ezd}}\right)} \leq 1.0$$

$$\frac{N}{N_{kd}} \quad = \quad \text{max of} \left(\frac{N}{N_{kzd}}, \frac{N}{N_{kyd}}\right)$$

N_{kyd} and N_{kzd} are found from NS 3472 fig. 5.4.la C-curve

for y- and z-axis respectively.

$$\overline{\lambda}_{eff} = 0.60 + 0.57\overline{\lambda} \qquad \text{for } \overline{\lambda} \leq \sqrt{2}$$

$$\overline{\lambda}_{eff} = \overline{\lambda} \qquad \text{for } \overline{\lambda} > \sqrt{2}$$

$$\overline{\lambda} = \frac{\lambda_k}{\pi}\sqrt{\frac{f_y}{E}}$$

$$\lambda_k = \frac{l_k}{i}$$

$$i = \sqrt{\frac{I}{A}}$$

Possible lateral buckling effects and torsional buckling (NS A5.4.5) is not included in the code check. This has to be evaluated by the user separately.

3.6 Stability check of members with tapered section

Stability of members with tapered cross section is calculated as described in section 3.1. The cross section properties used in the formulae are calculated based on the average profile height. (I.e. I_z, I_y values are taken from the middle of the member.)

3.7 Lateral buckling for tension members

When compressive stress caused by large bending moment about strong axis is greater than tension stress from axial tension force, lateral buckling is considered as defined below.

$$\sigma_a = \frac{N}{A} \quad \text{(+ tension , - compression)}$$

$$\sigma_{bz} = \frac{\pm M_z}{W_z}$$

$$M_{warp} = 0 \qquad \text{for } \sigma_a + \sigma_b \geq 0 \ \text{(tension)}$$

$$M_{warp} = |\sigma_a + \sigma_{bz}|\, W_z \qquad \text{for } \sigma_a + \sigma_b < 0 \ \text{(compression)}$$

$$IR = \frac{M_{warp}}{M_{vd}} + \frac{M_{y,\max}}{M_{yd}} \leq 1.0$$

4 Stability check according to NPD

4.1 Buckling of pipe members

Tubular beam-columns subjected to compression and lateral loading or end moments shall be designed in accordance with NPD 3.2.2

$$\sigma_c \gamma_{mk} + \mathrm{B}\sigma_b^{\ *} + \sqrt{\left(B_z \sigma_{bz}\right)^2 + \left(B_y \sigma_{by}\right)^2} \leq \frac{f_y}{\gamma_m}$$

where

$\sigma_c = \dfrac{N}{A} =$ axial compressive stress

γ_{mk} = structural coefficient

B = bending amplification factor = $\dfrac{1}{1-\mu}$

B is the larger of B_z and B_y

B_z = bending amplification factor about the Z-axis

B_y = bending amplification factor about the Y-axis

$$\mu = \frac{\sigma_c}{f_E}$$

$$f_E = \frac{\pi^2 E}{l_k^{\ 2}} i^2$$

$$i = \sqrt{\frac{I}{A}}$$

l_k = kl

k = effective length factor

$$\sigma_b{}^* = \sigma_c \left(\frac{f_y}{f_k} - 1\right)\left(1 - \frac{f_k}{\gamma_m f_E}\right)$$

f_k = characteristic buckling capacity according to NS fig. 5.4.1a, curve A.

4.1.1 Interaction with local buckling, NPD 3.2.3

If the below conditions are not satisfied, the yield strength will be replaced with characteristic buckling stress given in NPD 3.4.

a) members subjected to axial compression and external pressure

$$\frac{d}{t} \leq 0{,}5\sqrt{\frac{E}{f_y}}$$

b) members subjected to axial compression only

$$\frac{d}{t} \le 0{,}1\frac{E}{f_y}$$

4.2 Calculation of buckling resistance of cylinders

The characteristic buckling resistance is defined in accordance with NPD 3.4.4

$$f_k = \frac{f_y}{\sqrt{1+\overline{\lambda}^4}}$$

where

$$\overline{\lambda}^2 = \frac{f_y}{\sigma_j}\left[\frac{\sigma_{ao}}{f_{ea}} + \frac{\sigma_{b0}}{f_{eb}} + \frac{\sigma_{p0}}{f_{ep}} + \frac{\tau}{f_{e\tau}}\right]$$

$$\sigma_j = \sqrt{(\sigma_a + \sigma_b)^2 - (\sigma_a + \sigma_b)\sigma_p + \sigma_p{}^2 + 3\tau^2}$$

$$\sigma_{a0} = \begin{cases} 0 & \sigma_a \ge 0 \\ -\sigma_a & \sigma_a \langle 0 \end{cases}$$

$$\sigma_{b0} = \begin{cases} 0 & \sigma_b \ge 0 \\ -\sigma_b & \sigma_b \langle 0 \end{cases}$$

$$\sigma_{p0} = \begin{matrix} 0 & \sigma_p \ge 0 \\ \sigma_p & \sigma_p \langle 0 \end{matrix}$$

σ_a = design axial stress in the shell due to axial forces (tension positive)

σ_b = design bending stress in the shell due to global bending moment (tension positive)

$\sigma_p = \sigma_\Theta$ = design circumferential stress in the shell due to external pressure (tension positive)

τ = design shear stress in the shell due to torsional moments and shear force.

f_{ea}, f_{eb}, f_{ep} and $f_{e\tau}$ are the elastic buckling resistances of curved panels or circular cylindrical shells subjected to axial compression forces, global bending moments, lateral pressure, and torsional moments and/or shear forces respectively.

4.3 Elastic buckling resistance for un-stiffened, closed cylinders

The elastic buckling resistance for un-stiffened closed cylinders according to NPD 3.4.6 is:

$$f_e = k\frac{\pi^2 E}{12(1-v^2)}\left(\frac{t}{l}\right)^2$$

where k is a buckling coefficient dependent on loading condition, aspect ratio, curvature, boundary conditions, and geometrical imperfections. The buckling coefficient is:

$$k = \psi\sqrt{1+\left(\frac{p\xi}{\psi}\right)^2}$$

The values of ψ, ζ and *p* are given in Table 4.1 for the most important loading cases.

Table 4.1 Buckling coefficients for un-stiffened cylindrical shells

	ψ	ζ	p
Axial stress	1	0,702 Z	$0{,}5\left(1+\frac{r}{150t}\right)^{-0,5}$
Bending	1	0,702Z	$0{,}5\left(1+\frac{r}{300t}\right)^{-0,5}$
Torsion and shear force	5,34	$0{,}856Z^{3/4}$	0,6
Lateral pressure	4	$1{,}04\sqrt{Z}$	0,6
Hydrostatic pressure	2	$1{,}04\sqrt{Z}$	0,6

The curvature parameter is defined by

$$\mathrm{Z} = \frac{1^2}{rt}\sqrt{1-v^2}$$

For long shells the elastic buckling resistance against shear stresses is independent of shell length. For cases with $\frac{1}{r}\rangle 3{,}85\sqrt{\frac{r}{t}}$ the elastic buckling resistance may be taken as:

$$f_{e\tau} = 0{,}25\mathrm{E}\left(\frac{t}{r}\right)^{3/2}$$

For long shells and pressure vessels, the elastic buckling resistance against uniform lateral pressure is independent of length.

For cases with $\frac{l}{r}\rangle 2{,}25\sqrt{\frac{r}{t}}$, the elastic buckling resistance may be taken as:

$$f_{ep} = 0{,}25\mathrm{E}\left(\frac{t}{r}\right)^2$$

4.4 Stability requirements

The stability requirement for curved panels and un-stiffened cylindrical shells subjected to axial compression or tension, bending, circumferential compression or tension, torsion or shear is given by NPD 3.4.7:

$\sigma_j \leq f_{kd}$

where the design buckling resistance is

$$f_{kd} = \frac{f_k}{\gamma_m \cdot \gamma_{mk}}$$

4.5 Column buckling, NPD 3.4.9

For long cylindrical shells it is possible that interaction between shell buckling and overall column buckling may occur because second-order effects of axial compression alter the stress distribution as compared to that calculated from linear theory. It is necessary to take this effect into account in the shell buckling analysis when the reduced slenderness of the cylinder as a column exceeds 0,2 according to NPD 3.4.4.1.

σ_b shall be increased by an additional compressive stress which may be taken as:

$$\Delta\sigma = \mathrm{B}\sigma_a\left(\frac{f_y}{f_k} - 1\right)\left(1 - \frac{f_k}{f_e}\right) + (\mathrm{B} - 1)\sigma_b$$

where

$$\overline{\mathrm{B}} = \frac{1}{1-\mu}$$

$$\overline{\lambda} = \sqrt{\frac{f_y}{f_e}}$$

$$f_e = \frac{\pi^2 \mathrm{E}}{\lambda^2}$$

λ = slenderness of the cylinder as a column.
B, σ_a, σ_b and μ are calculated in accordance with NPD 3.2.2.

5 Yield check

The yield check is performed at member ends and at 11equally spaced intermediate sections along the member length.

At each section the following forces are applied:

F_X max. axial force along member
F_Y actual shear in local y-direction at section
F_Z actual shear in local z-direction at section
M_X max. torsional moment along member
M_Y actual bending about local y-axis at section
M_Z actual bending about local z-axis at section

For all profiles other than angle sections absolute values of the stresses are used. For double symmetric profiles there will always be one stresspoint.

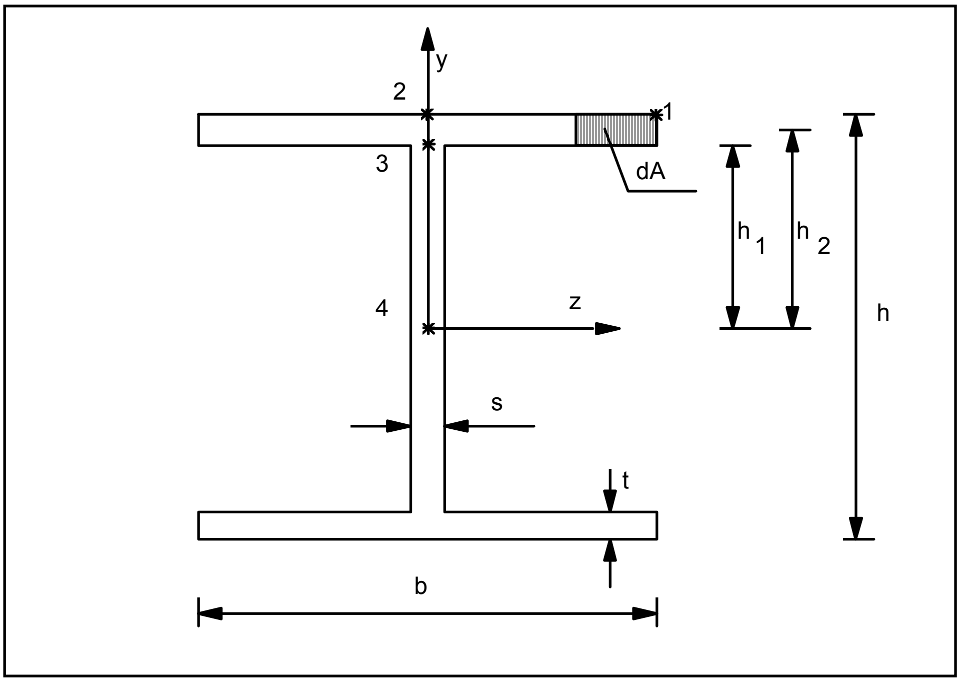
The stresses are calculated in several stress points at each member section. At each stress point the von Mises stress is checked as follows:

$$\sigma_j = \sqrt{\sigma_{tot}^2 + \sigma_p^2 - \sigma_{tot} \cdot \sigma_p + 3\left(\tau_x + \tau_y + \tau_z\right)^2} \le \frac{f_y}{\gamma_m}$$

where $\sigma_{tot} = \left| \sigma_x + \sigma_{by} + \sigma_{bz} \right|$ and σ_p stress from hydrostatic pressure

5.1 Double symmetric wide flange profile

The von Mises stress is checked at 4 stress points as shown in figure below.



Section properties

A_X , I_X , I_y and I_Z are taken from STAAD.Pro database

$A_y = h \cdot s$ Applied in STAAD.Pro print option PRINT MEMBER STRESSES

$A_z = \frac{2}{3} b \cdot t \cdot 2$ $\tau_y = \frac{F_y}{A_y}, \tau_z = \frac{F_Z}{A_z}$

A_y and A_Z are not used in the code check

$C_w = \frac{(h-t)^2 b^3 t}{24}$ ref. NS app. C3

$T_y = dA \cdot z$
$T_z = dA \cdot y$

General stress calculation

$$\sigma = \sigma_x + \sigma_{by} + \sigma_{bz} = \frac{F_x}{A_x} + \frac{M_y}{I_y} z + \frac{M_z}{I_z} y$$

$$\tau = \tau_x + \tau_y + \tau_z = \frac{M_x}{I_x} c + \frac{V_y T_z}{I_z t} + \frac{V_z T_y}{I_y t}$$

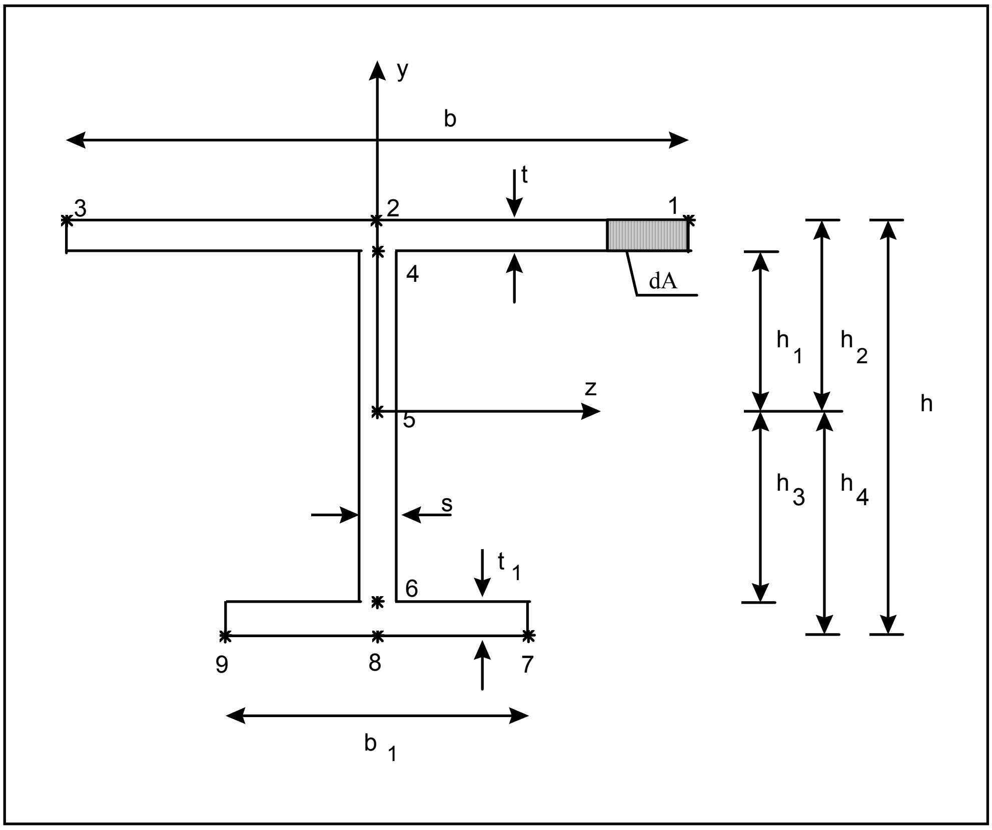
Stress calculation at selected stress points

Point no.	σ_x	σ_{by}	σ_{bz}	τ_x	τ_y	τ_z
1	$\frac{F_x}{A_x}$	$\frac{M_y}{I_y}\cdot\frac{b}{2}$	$\frac{M_z}{I_z}\cdot\frac{h}{2}$	$\frac{M_x}{I_x}$ t	0	0
2	$\frac{F_x}{A_x}$	0	$\frac{M_z}{I_z}\cdot\frac{h}{2}$	$\frac{M_x}{I_x}$ t	$\frac{F_y}{I_z}\ \frac{bth_2}{2t}$	$\frac{F_z}{I_y}\ \frac{tb^2}{8t}$
3	$\frac{F_x}{A_x}$	0	$\frac{M_z}{I_Z}h_1$	$\frac{M_x}{I_x}$ s	$\frac{F_y}{I_z}\ \frac{bth_2}{s}$	0
4	$\frac{F_x}{A_x}$	0	0	$\frac{M_x}{I_x}$ s	$\frac{F_y}{I_z}\ \frac{(bth_2+0.5h_1^2 s)}{s}$	0

In general wide flange profiles are not suitable for large torsional moments. The reported torsional stresses are indicative only. For members with major torsional stresses a separate evaluation has to be carried out. Actual torsional stress distribution is largely dependent on surface curvature at stress point and warping resistance.

5.2 Single symmetric wide flange profile and tapered section

The von Mises stress is checked at 9 stress points as shown in figure below.



Section properties

A_X , I_X , I_y and I_Z are taken from STAAD.Pro database, except for tapered sections where these values are calculated for each section checked. (I.e. I_z, I_y values are taken from the middle of the member.)

$A_y = h \cdot s$ Applied in STAAD.Pro print option PRINT MEMBER STRESSES

$A_z = \frac{2}{3}(b \cdot t + b_1 \cdot t_1)$ $\tau_y = \frac{F_y}{A_y}, \tau_z = \frac{F_Z}{A_z}$

A_y and A_Z are not used in the code check

$$C_w = \frac{b^3 t \cdot b_1^3 t_1 \cdot (h - t/2 - t_1/2)^2}{12(b^3 t + b_1^3 t_1)}$$ ref. NS app. C3

$T_y = dA \cdot z$
$T_z = dA \cdot y$

General stress calculation

$$\sigma = \sigma_x + \sigma_{by} + \sigma_{bz} = \frac{F_x}{A_x} + \frac{M_y}{I_y} z + \frac{M_z}{I_z} y$$

$$\tau = \tau_x + \tau_y + \tau_z = \frac{M_x}{I_x} c + \frac{V_y T_z}{I_z t} + \frac{V_z T_y}{I_y t}$$

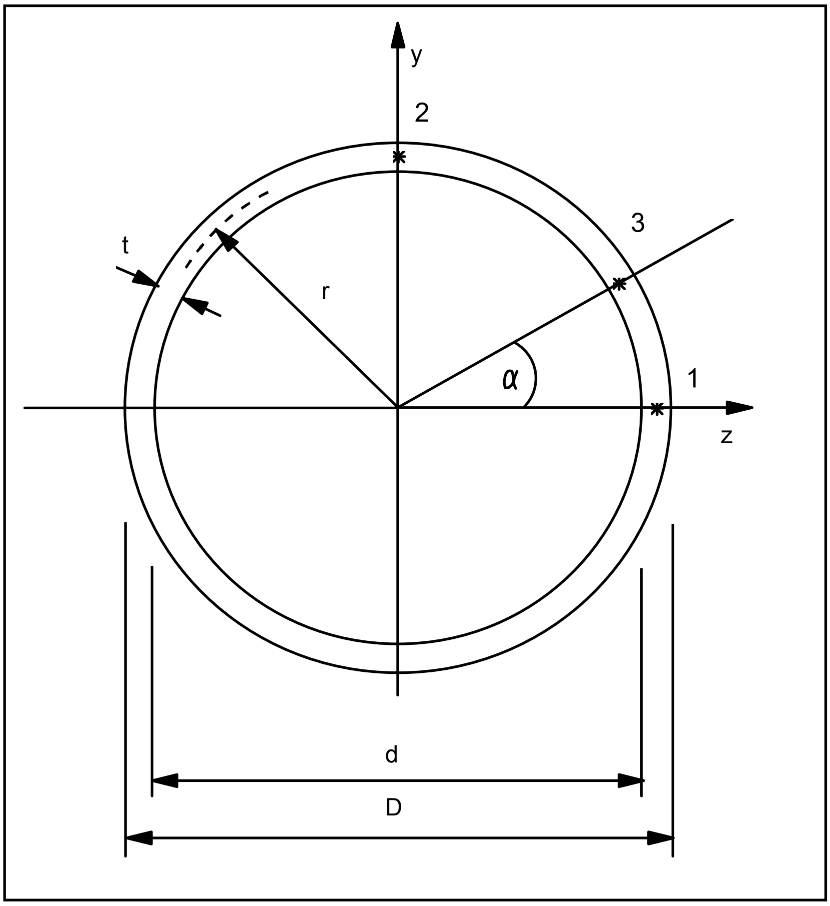
Stress calculation at selected stress points

Point no.	σ_x	σ_{by}	σ_{bz}	τ_x	τ_y	τ_z
1	$\frac{F_x}{A_x}$	$-\frac{M_y}{I_y}\frac{b}{2}$	$\frac{M_z}{I_z}h_2$	$\frac{M_x}{I_x}t$	0	0
2	$\frac{F_x}{A_x}$	0	$\frac{M_z}{I_z}h_2$	$\frac{M_x}{I_x}t$	$\frac{F_y}{I_z}\frac{bt(h_1+t/2)}{2t}$	$\frac{F_z}{I_y}\frac{tb^2}{8t}$
3	$\frac{F_x}{A_x}$	$\frac{M_y}{I_y}\frac{b}{2}$	$\frac{M_z}{I_z}h_2$	$\frac{M_x}{I_x}t$	0	0
4	$\frac{F_x}{A_x}$	0	$\frac{M_z}{I_Z}h_1$	$\frac{M_x}{I_x}s$	$\frac{F_y}{I_z}\frac{bt(h_1+t/2)}{s}$	0
5	$\frac{F_x}{A_x}$	0	0	$\frac{M_x}{I_x}s$	$\frac{F_y}{I_z}\frac{\left(bt(h_1+t/2)+05h_1^2 s\right)}{s}$	0
6	$\frac{F_x}{A_x}$	0	$-\frac{M_z}{I_Z}h_3$	$\frac{M_x}{I_x}s$	$\frac{F_y}{I_z}\frac{b_1t_1(h_3+t_1/2)}{s}$	0
7	$\frac{F_x}{A_x}$	$-\frac{M_y}{I_y}\frac{b_1}{2}$	$-\frac{M_z}{I_z}h_4$	$\frac{M_x}{I_x}t_1$	0	0
8	$\frac{F_x}{A_x}$	0	$-\frac{M_z}{I_z}h_4$	$\frac{M_x}{I_x}t_1$	$\frac{F_y}{I_z}\frac{b_1t_1(h_3+t_1/2)}{2t_1}$	$\frac{F_z}{I_y}\frac{t_1b^2}{8t_1}$
9	$\frac{F_x}{A_x}$	$\frac{M_y}{I_y}\frac{b_1}{2}$	$-\frac{M_z}{I_z}h_4$	$\frac{M_x}{I_x}t_1$	0	0

In general wide flange profiles are not suitable for large torsional moments. The reported torsional stresses are indicative only. For members with major torsional stresses a separate evaluation has to be carried out. Actual torsional stress distribution is largely dependent on surface curvature at stress point and warping resistance.

5.3 Pipe profile

The von Mises stress is checked in 3 stress points as shown in figure below.



<u>Section properties</u>

$$d = D - 2t$$

$$r = 0.5\,(D-t)$$

$$\alpha = \tan^{-1} \frac{M_z}{M_y}$$

$$A_x = \frac{\pi}{4} (D^2-d^2)$$

$$A_y = A_z = 0.5A_x$$

$$I_x = 2I_z = \frac{\pi}{32} (D^4-d^4)$$

$$I_y = I_z = \frac{\pi}{64} (D^4-d^4)$$

Note!
In the STAAD.Pro analysis package slightly different values are used for A_y , A_z and I_x , however this has insignificant influence on the force distribution.

$A_Y = A_z = 0.6A_x$

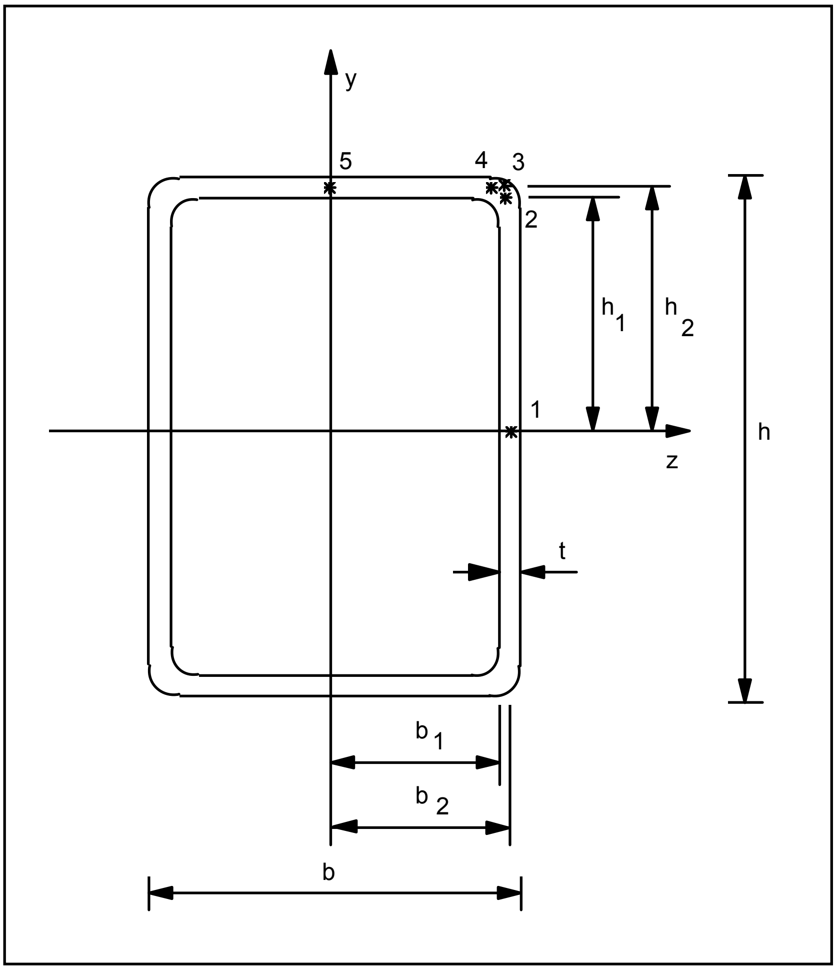
$I_x = 2\pi R^3 t$

Stress calculation at selected stress points

Point no.	σ_x	σ_{by}	σ_{bz}	τ_x	τ_y	τ_z
1	$\frac{F_x}{A_x}$	$\frac{M_y}{I_y} \cdot r$	0	$\frac{M_T}{I_x} \cdot r$	$\frac{F_y}{0.5A_x}$	0
2	$\frac{F_x}{A_x}$	0	$\frac{M_z}{I_z} \cdot r$	$\frac{M_T}{I_x} \cdot r$	0	$\frac{F_z}{0.5A_x}$
3	$\frac{F_x}{A_x}$	$\sigma_b = \frac{\sqrt{M_y^2 + M_z^2}}{I_z} r$		$\frac{M_T}{I_x} \cdot r$	$\tau = \frac{\sqrt{F_y^2 + F_z^2}}{0.5A_x}$	

5.4 Tube profile

Tube sections are rectangular or quadratic hollow uniform profiles. Critical stress is checked at 5 locations as shown in figure below.



Section properties

A_X , I_X , I_Y and I_Z are taken from STAAD.Pro database.

$A_y = 2ht$ Similar as for wide flange profiles, see sec. 5.2

$A_z = 2\cdot\frac{2}{3}\ bt$ A_y and A_Z are not used in code checks.

$C_w = \frac{b^2h^2t}{24}\frac{(h-b)^2}{(h+b)}$ ref. NS app. C3.

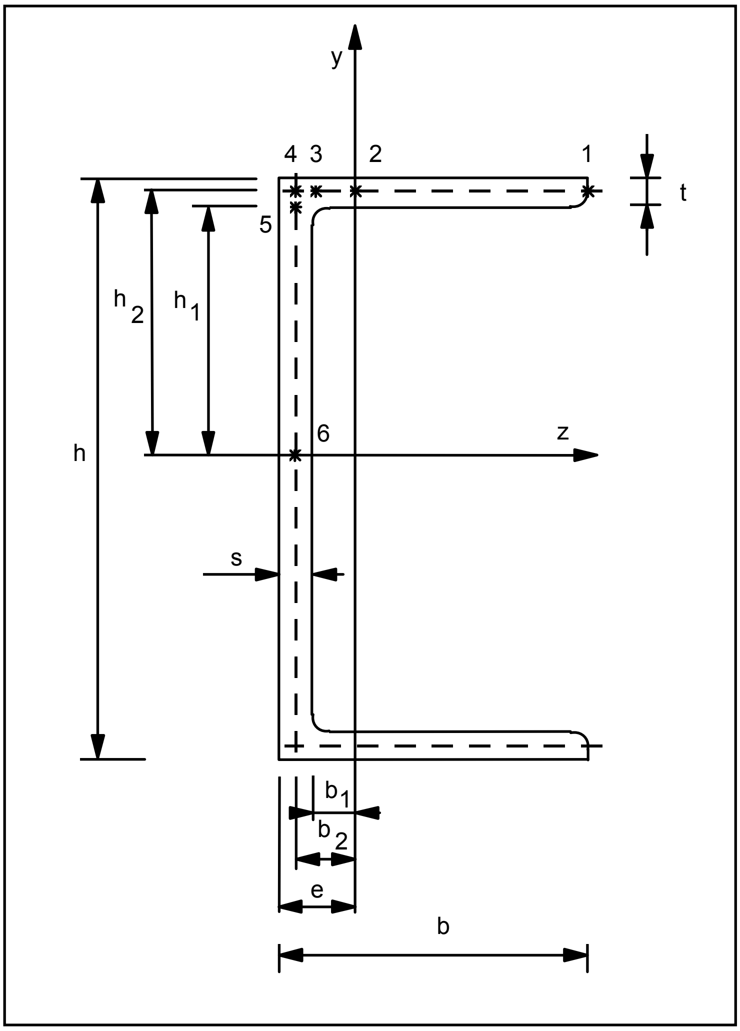
Stress calculation at selected stress points

Point no.	σ_x	σ_{by}	σ_{bz}	τ_x	τ_y	τ_z
1	$\frac{F_x}{A_x}$	$\frac{M_y}{I_y} b_2$	0	$\frac{M_x(h-t)(b-t)}{I_x(h+b-2t)}$	$\frac{F_y}{I_z} \frac{bth_2 + th_1^2}{2t}$	0
2	$\frac{F_x}{A_x}$	$\frac{M_y}{I_y} b_2$	$\frac{M_z}{I_z} h_1$	$\frac{M_x(h-t)(b-t)}{I_x(h+b-2t)}$	$\frac{F_y}{I_z} \frac{bth_2}{2t}$	$\frac{F_z}{I_y} \frac{2h_1tb_2}{2t}$
3	$\frac{F_x}{A_x}$	$\frac{M_y}{I_y} b_2$	$\frac{M_z}{I_z} h_2$	$\frac{M_x(h-t)(b-t)}{I_x(h+b-2t)}$	$\frac{F_y}{I_z} \frac{2b_2th_2}{2t}$	$\frac{F_z}{I_y} \frac{2h_2tb_2}{2t}$
4	$\frac{F_x}{A_x}$	$\frac{M_y}{I_y} b_1$	$\frac{M_z}{I_z} h_2$	$\frac{M_x(h-t)(b-t)}{I_x(h+b-2t)}$	$\frac{F_y}{I_z} \frac{2b_1th_2}{2t}$	$\frac{F_z}{I_y} \frac{htb_2}{2t}$
5	$\frac{F_x}{A_x}$	0	$\frac{M_z}{I_z} h_2$	$\frac{M_x(h-t)(b-t)}{I_x(h+b-2t)}$	0	$\frac{F_z}{I_y} \frac{htb_2 + tb_1^2}{2t}$

The general stress formulation is given in sec. 5.2.

5.5 Channel profile

For channel profiles the von Mises stress is checked at 6 locations as shown in figure below.



<u>Cross section properties</u>

A_X , S_Y , S_Z , I_X , I_Y and I_Z are taken from STAAD.Pro database.

$A_y = 2ht$ Similar as for wide flange profiles, see sec. 5.2

$A_z = 2 \cdot \frac{2}{3} bt$ A_Y and A_Z are not used in code checks

$$e = b - \frac{I_y}{S_y}$$

$$x = h - t$$

$$y = b - \frac{s}{2}$$

$$C_w = \frac{x^2 y^3 t}{12} \frac{(2xs + 3yt)}{(xs + 6yt)}$$ ref. [4] tab. 21, case 1

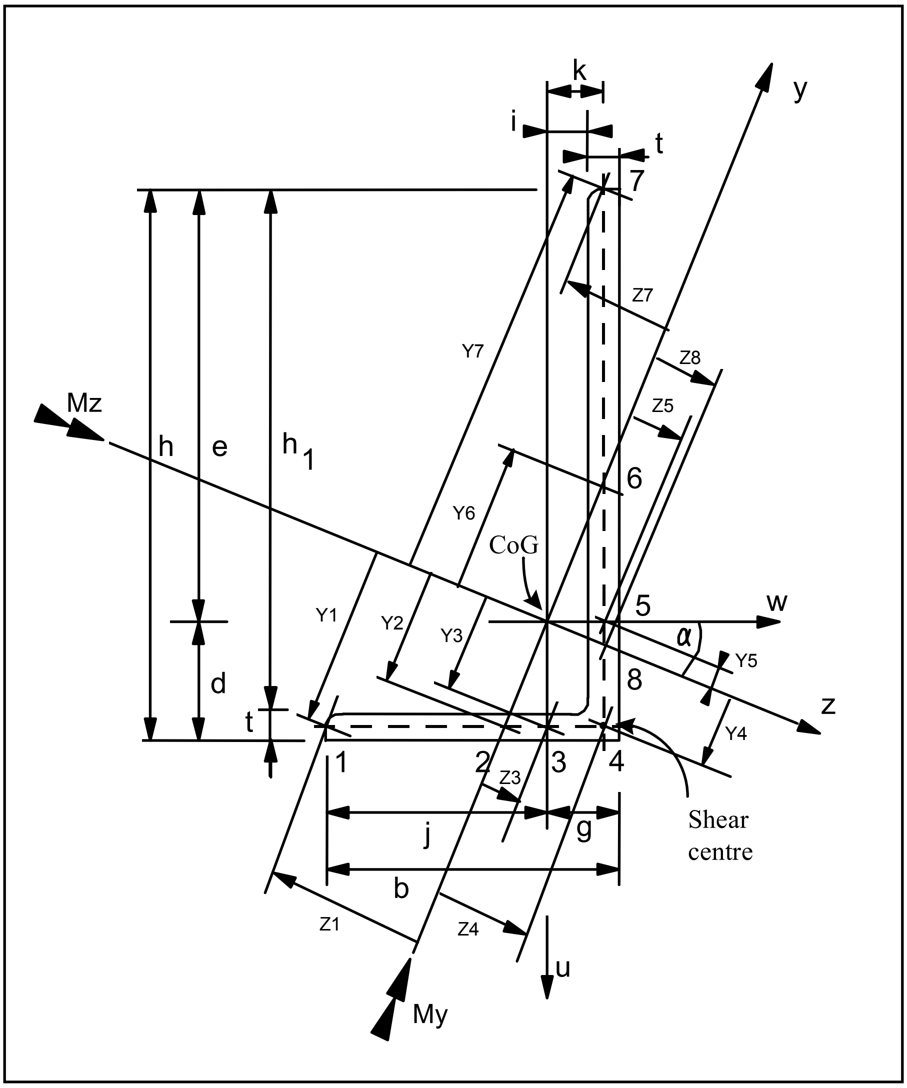
Stress calculations at selected stress points.

Point no.	σ_x	σ_{by}	σ_{bz}	τ_x	τ_y	τ_z
1	$\frac{F_x}{A_x}$	$\frac{M_y}{I_y}$ (b-e)	$\frac{M_z}{I_z}$ h_2	$\frac{M_x}{I_x}$ t	0	0
2	$\frac{F_x}{A_x}$	0	$\frac{M_z}{I_z}$ h_2	$\frac{M_x}{I_x}$ t	$\frac{F_y}{I_z} \frac{(b-e)t \cdot h_2}{t}$	$\frac{F_z}{I_y} \frac{0.5(b-e)^2 t}{t}$
3	$\frac{F_x}{A_x}$	$\frac{M_y}{I_y}$ b_1	$\frac{M_z}{I_z}$ h_2	$\frac{M_x}{I_x}$ t	$\frac{F_y}{I_z} \frac{(b-s)th_2}{t}$	$\frac{F_z}{I_y} \frac{(b-S)t\{0.5(b+s)-e\}}{t}$
4	$\frac{F_x}{A_x}$	$\frac{M_y}{I_y}$ b_2	$\frac{M_z}{I_z}$ h_2	$\frac{M_x}{I_x}$ t	$\frac{F_y}{I_z} \frac{(b-0.5s)th_2}{t}$	$\frac{F_z}{I_y} \frac{\left(b-\frac{5}{2}\right)t\left\{0.5\left(b+\frac{s}{2}\right)-e\right\}}{t}$
5	$\frac{F_x}{A_x}$	$\frac{M_y}{I_y}$ b_2	$\frac{M_z}{I_z}$ h_1	$\frac{M_x}{I_x}$ s	$\frac{F_y}{I_z} \frac{bth_2}{s}$	$\frac{F_z}{I_y} \frac{bt\left(\frac{b}{2}-e\right)}{s}$
6	$\frac{F_x}{A_x}$	$\frac{M_y}{I_y}$ b_2	0	$\frac{M_x}{I_x}$ s	$\frac{F_y}{I_z} \frac{bth_2+0.5sh_1^2}{s}$	0

The general stress formulation is given in sec. 5.2.

5.6 Angle profile type RA (reverse angle)

For angle profiles the von Mises check is checked at 8 stress points as shown in figure below.



Axes y and z are principal axes.
Axes u and w are local axes.

<u>Cross section properties</u>

A_X , I_X , I_y and I_Z are taken from STAAD.Pro database

$A_y = \frac{2}{3}\,ht$ Applied in STAAD.Pro print option PRINT MEMBER STRESSES

$A_z = \frac{2}{3}\,bt$ $\tau_y = \frac{F_x}{A_y}, \tau_z = \frac{F_z}{A_z}$

and A_Z are not used in the code check.

$h_2 = 0.5\,h_1 + t$

f = h_1-e

d = $$\frac{th_1h_2 + 0.5t^2b}{A_x}$$

g = $$\frac{t^2h_1 + tb^2}{2A_x}$$

I_u = $$\frac{h_1t^3}{12} + htk^2 + \frac{tb^3}{12} + tb\left(\frac{b}{2} - g\right)^2$$

I_w = $$\frac{th_1^3}{12} + h_1t(h_2 - d)^2 + \frac{bt^3}{12} + bt(d - 0.5t)^2$$

I_{uw} = $$\frac{\left(d - \frac{1}{2}\right)t}{2}\left(g^2 - j^2\right) - \frac{kt}{2}\left(e^2 - f^2\right)$$

α = $$0.5\tan^{-1}\left(\frac{2I_{uw}}{I_u - I_w}\right)$$

<u>Section forces</u>

The section forces from the STAAD.Pro analysis are about the principle axis y and z. The second moment of area (T_y Λ T_Z):

T_y = A Z
T_z = A Y

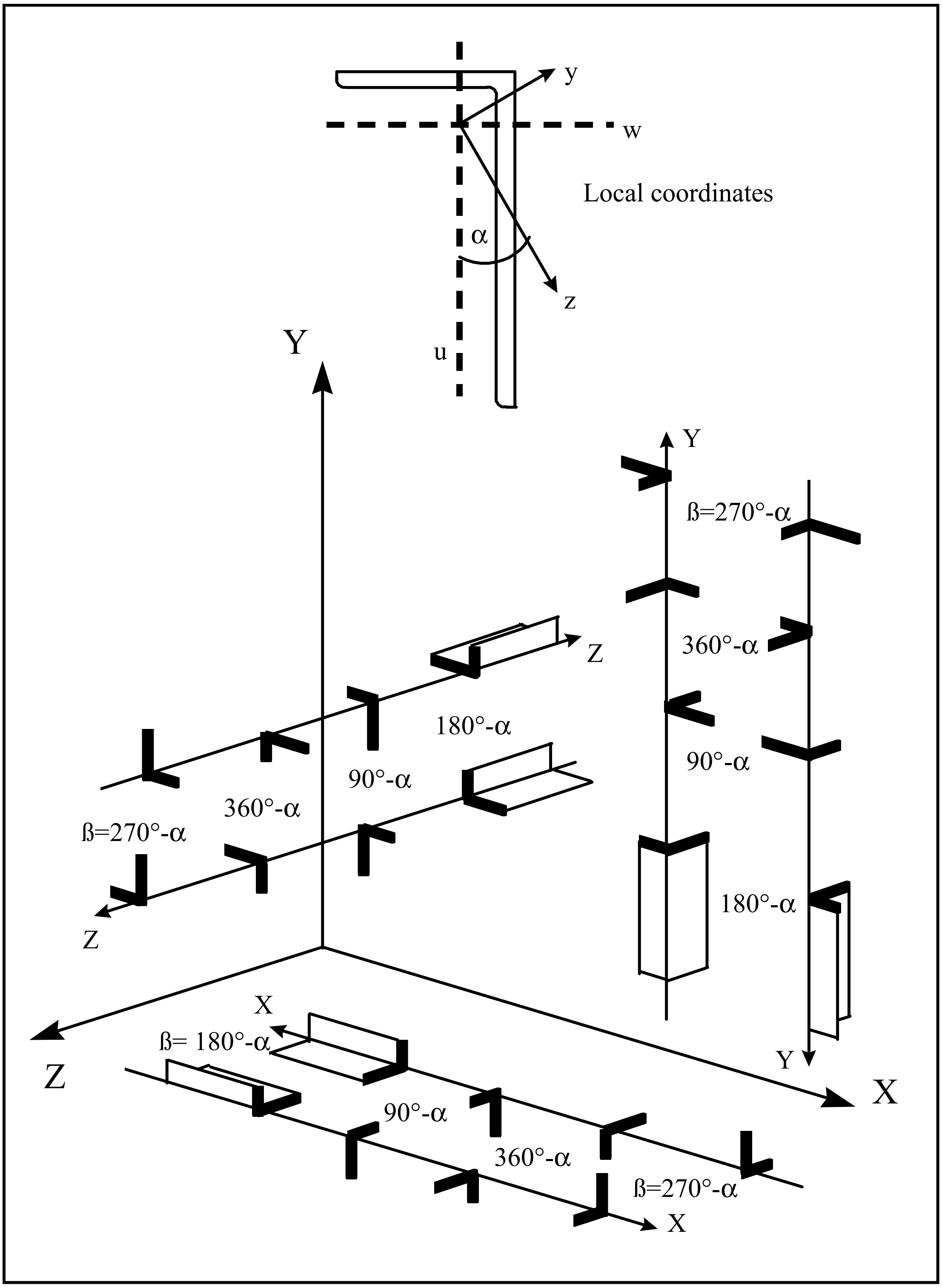
Stress calculation at selected stress points

Point no.	σ_x	σ_{by}	σ_{bz}	τ_x	τ_y	τ_w
1	$\frac{F_x}{A_x}$	$-\frac{M_y Z1}{I_y}$	$-\frac{M_z Y1}{I_z}$	$\frac{M_x}{I_x}t$	0	0
2	$\frac{F_x}{A_x}$	0	$-\frac{M_z Y2}{I_z}$	$\frac{M_x}{I_x}t$	$\frac{F_y T_z}{I_z t}$	$\frac{F_z T_y}{I_y t}$
3	$\frac{F_x}{A_x}$	$\frac{M_y Z3}{I_y}$	$-\frac{M_z Y3}{I_z}$	$\frac{M_x}{I_x}t$	$\frac{F_y T_z}{I_z t}$	$\frac{F_z T_y}{I_y t}$
4	$\frac{F_x}{A_x}$	$\frac{M_y Z4}{I_y}$	$-\frac{M_z Y4}{I_z}$	$\frac{M_x}{I_x}t$	$\frac{F_y T_z}{I_z t}$	$\frac{F_z T_y}{I_y t}$
5	$\frac{F_x}{A_x}$	$\frac{M_y Z5}{I_y}$	$\frac{M_z Y5}{I_z}$	$\frac{M_x}{I_x}t$	$\frac{F_y T_z}{I_z t}$	$\frac{F_z T_y}{I_y t}$
6	$\frac{F_x}{A_x}$	0	$\frac{M_z Y6}{I_z}$	$\frac{M_x}{I_x}t$	$\frac{F_y T_z}{I_z t}$	$\frac{F_z T_y}{I_y t}$
7	$\frac{F_x}{A_x}$	$-\frac{M_y Z7}{I_y}$	$\frac{M_z Y7}{I_z}$	$\frac{M_x}{I_x}t$	$\frac{F_y T_z}{I_z t}$	$\frac{F_z T_y}{I_y t}$
8	$\frac{F_x}{A_x}$	$\frac{M_y Z8}{I_y}$	0	$\frac{M_x}{I_x}t$	0	0

An additional torsional moment is calculated based on:
$M_T = F_y \ Z4$
$M_T = F_z \ Y4$
This torsion moment is included in M_x if F_y and F_Z exist.

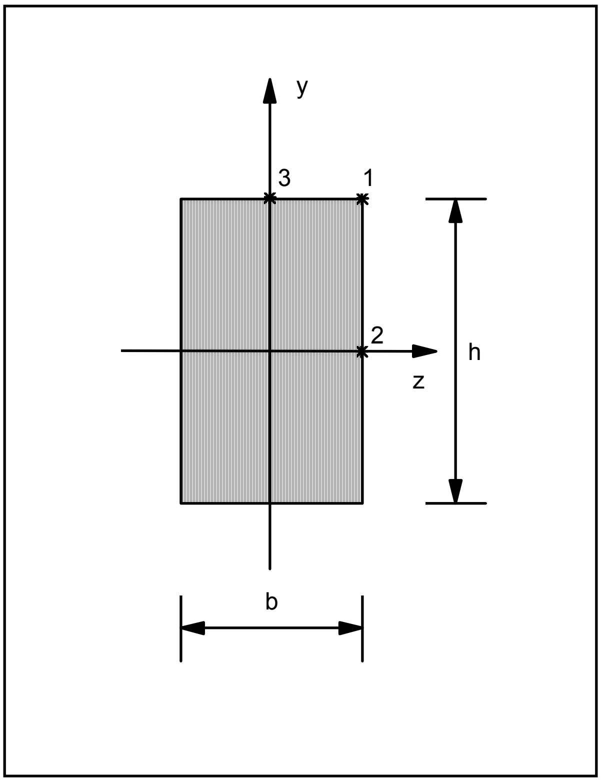
Beta-rotation of equal & unequal legged angles

(Note: the order of the joint numbers in the member incidence command specifies the direction of the local x-axis.)



5.7 Rectangular massive box (prismatic)

Code check of the general purpose prismatic cross section defined in the STAAD.Pro analysis package is not available. The prismatic section is assumed to be a rectangular massive box and the von Mises stress is checked at 3 locations as shown in figure below.



Note that 'b' may not be much greater than 'h'.

If that is the case, define the member with h>b and Beta angle 90^o instead.

Section properties

A_X , A_Y , A_Z , I_X , I_Y , I_Z , b and h are given by the user, see STAAD.Pro Reference Manual, sec. 5.19.2

(b = ZD , h = YD)

$$C_w = \frac{1}{24}\frac{b}{2}\frac{(h-b)^2}{h+b}h^2b^2$$ ref. NS app. C3.

General stress calculation

$$\sigma = \sigma_x + \sigma_{by} + \sigma_{bz} = \frac{F_x}{A_x} + \frac{M_y}{I_y}z + \frac{M_z}{I_z}y$$

$$\tau = \tau_x + \tau_y + \tau_z = \tau_{x,max}\left(\frac{c}{b}\right)^2 + \frac{V_y}{A_y} + \frac{V_z}{A_z}$$

$$\tau_{x,max} = \frac{M_x\left(1.5h + 0.9b\right)}{o.5h^2 b^2}$$

ref. [4] tab. 20, case 4 at midpoint the largest side i.e. point 2

<u>Stress calculation at selected stress points</u>

Point no.	σ_x	σ_{by}	σ_{bz}	τ_x	τ_y	τ_z
1	$\frac{F_x}{A_x}$	$\frac{M_y}{I_y} \quad \frac{b}{2}$	$\frac{M_z}{I_z} \quad \frac{h}{2}$	$\tau_{x,\max} \frac{b^2}{b^2 + h^2}$	0	0
2	$\frac{F_x}{A_x}$	$\frac{M_y}{I_y} \quad \frac{b}{2}$	0	$\tau_{x,\max}$	$\frac{F_y}{A_y}$	0
3	$\frac{F_x}{A_x}$	0	$\frac{M_z}{I_z} \quad \frac{h}{2}$	$\tau_{x,max} \frac{b^2}{h^2}$	0	$\frac{F_z}{A_z}$

6 Tubular joint check, NPD 3.5

For pipe members, punching shear capacity is checked in accordance with the NPD sections 3.5.1 to 3.5.2, except 3.5.2.4. The chord is defined as the member with the greater diameter in the joint. If the diameters are the same the programme selects the member with the greater thickness of the two. The chord members must be collinear by 5 degrees.

The punching shear run sequence is performed in two steps. The programme will first identify all tubular joints and classify them as T type joints (TRACK99). The joints to be checked will be listed in a file specified in the CODE NPD parameter list, below called GEOM1. This file is used as input in the second run. The file is an editable ACSII file saved under the file name given in the CODE NPD parameter. The TRACK parameter is then set to 98 which directs the program to read from the file GEOM1 file and use it as input to the second run, i.e. the joint capacity checking. The programme will check the capacity for both chord members entering the joint. The local y and z moments will be transformed into the plane defined by the joint itself and the far end joints of the brace and chord, defined as in- and out-of plane moments.

The ASCII file should be edited to reflect the correct classification of the joints, gap, can or stub dimensions, yield stress and other geometric options if required. The programme will not change the brace or chord definition if this is changed or modified in the input file GEOM1. See Appendix A page xx for GEOM1 example file.

Joint classification parameters in the file GEOM1 are:

KO K joint overlapped
KG K joint with gap
TY T or Y joint
X X joint

Input example for the classification run.

```
*CLASSIFICATION OF JOINTS, TRACK 99
UNITS MM NEWTON
PARAMETER
CODE NPD GEOM1
FYLD 350 ALL
TRACK 99 ALL
BEAM 1.0 ALL
CHECK CODE ALL
```

6.1 Static strength of tubular joints

The basic consideration is the chord strength. The required chord wall thickness shall be determined when the other dimensions are given.

The following symbols are used:

T = Cord wall thickness
t = Brace wall thickness
R = Outer radius of chord
r = Outer radius of brace
Θ = Angle between chord and considered brace
D = Outer diameter of chord

d = Outer diameter of brace
a = Gap (clear distance) between considered brace and nearest load-carrying brace measured along chord outer surface
ß = r/R
γ = R/T
g = a/D
f_y = Yield stress
Q_f = Factor
Q_g = See table 6.1
Q_u = See table 6.1
$Q_ß$d = See table 6.1
N = Design axial force in brace
M_{IP} = Design in-plane bending moment in brace
M_{OP} = Design out-of plane bending moment in brace
N_k = Characteristic axial load capacity of brace (as governed by the chord strength)
M_{OPk} = Characteristic out-of-plane bending moment capacity of brace (as governed by the chord strength)
σ_{ax} = Design axial stress in chord
σ_{IP} = Design in-plane bending stress in chord
σ_{OP} = Design out-of-plane bending stress in chord

This section gives design formulae for simple tubular joints without overlap and without gussets, diaphragms or stiffeners. Tubular joints in a space frame structure shall satisfy:

$$N \leq \frac{N_k}{\gamma_m} \quad \text{where}$$

$$N_k = Q_u Q_f \frac{f_y T^2}{\sin\Theta}$$

Q_u is given in Table 6.1. Q_f is a factor to account for the nominal longitudinal stress in the chord.

$$Q_f = 1{,}0 - 0{,}03\gamma A^2 \quad \text{where}$$

$$A^2 = \frac{\sigma_{ax}^{\ 2} + \sigma_{IP}^{\ 2} + \sigma_{OP}^{\ 2}}{0{,}64 f_y^{\ 2}}$$

Table 6.1 Values for Q_u

Type of joint and geometry	Type of load in brace member		
	Axial	In-plane bending	Out-of-plane bending
T and Y	2,5+19ß	$5{,}0\sqrt{\gamma}\beta$	$\frac{3.2}{1-0.81\beta}$
X	(2,7+13ß)$Q_ß$		
K	0,90(2+21ß)Q_g		

$$Q_\beta = \frac{0,3}{\beta(1-0,833\beta)} \qquad \text{for ß} > 0,6$$

$$Q_\beta = 1,0 \qquad \text{for ß} \le 0,6$$

$$Q_g = 1,8 - 0,1a / T \qquad \text{for } \gamma \le 20$$

$$Q_g = 1,8 - 4g \qquad \text{for } \gamma > 20$$

but in no case shall Q_g be taken as less than 1,0.

When $\beta \ge 0,9$, Q_f is set to 1,0. This is also applicable for moment loading. For cases with tension in the chord, Q_f is set to 1.0. This is also applicable for moment loading.

The brace end moments shall be accounted for in the following cases:

a) Out-of-plane bending moment when $\beta > 0,85$
b) When the brace acts as a cantilever
c) When the rotational stiffness of the connection is considered in the determination of effective buckling length, and / or the structural coefficient $\gamma_{mk} = 1.00$ for the beam-column design of the brace or chord. See Section 3.1.3.

The characteristic capacity of the brace subjected to in-plane bending moment shall be determined by:

$$\mathrm{M}_{IPk} = Q_u Q_f \frac{d f_y T^2}{\sin\Theta}$$ where Q_u is given in Table 6.1 and

$Q_f = 1,0 - 0,045\gamma A^2$

The characteristic capacity of the brace subjected to out-of-plane bending moment shall be determined by:

$$\mathrm{M}_{OPk} = Q_u Q_f \frac{d f_y T^2}{\sin\Theta}$$ where Q_u is given in Table 6.1 and

$Q_f = 1,0 - 0,021\gamma A^2$

For combined axial and bending loads in the brace, the following interaction equation should be satisfied:

$$\frac{\mathrm{N}}{\mathrm{N}_k} + \left(\frac{\mathrm{M}_{IP}}{\mathrm{M}_{IPk}}\right)^2 + \frac{\mathrm{M}_{OP}}{\mathrm{M}_{OPk}} \le \frac{1}{\gamma_m}$$

For overlapping tubular joints without gussets, diaphragms, or stiffeners, the total load component normal to the chord, N_N, shall not exceed

$$N_N = \frac{N_k}{\gamma_m}\frac{l_1}{l}\sin\Theta + \frac{2 f_y t_w l_2}{\sqrt{3}\gamma_m}$$

where (see NPD fig. 3.10)

l_l = circumference for that portion of the brace in contact with the chord (actual length)
l = circumference of brace contact with chord, neglecting presence of overlap
N_k = characteristic axial load capacity of brace
t_w = the lesser of the throat thickness of the overlapping weld or the thickness t of the thinner brace
l_2 = length as shown in NPD fig. 3.10

The above formula for the capacity of overlapping joints is valid only for K joints, where compression in a brace is essentially balanced by tension in brace(s) in the same side of the joint.

7 Tabulated results / TRACKs

This section presents a table with the various TRACKs available with respect to print out from the code check. Example prints and explanation to the information / heading given on the print out is given in Appendix A.

Table 7.1 Available TRACKs

TRACK no.	Description
0	Brief print of member utilizations (2 lines for each member) sorted with highest utilized members first
1	Based on TRACK 3 with additional information regarding stability factors and capacities
2	Simple print of stresses, incl von Mises stress
3	Brief print of member utilizations (2 lines for each member)
9	Comprehensive print with detailed information about member and member utilization(one page for each member)
99	Used in connection with tubular joint check according to NPD. This TRACK identifies tubular joints to be checked and classifies all members entering the joint as T connection
98	Used in connection with tubular joint check according to NPD. This TRACK performs the joint capacity check
49	Prints member end forces for members entering each joint (at the end of the member connected to the joint)
31	Prints maximum and minimum member end forces (axial force defines max and min) at member end 1
32	Prints maximum and minimum member end forces (axial force defines max and min) at member end 2

Appendix A

Tracks for member code checking

TRACK = 0.0

```
                           NS3472 (VERSION 96016.00)
                           UNITS ARE  KNS  AND   METE

 MEMB          FX               MYs        MYm        MYe        MYb   RATIO  LOAD
            TABLE               MZs        MZm        MZe        MZb   COND   DIST
===============================================================================
     21      154.18 C           1.8         .5         .7         .8   1.00     11
      FAIL  PIP 300X10       -185.5      -98.5       10.3      116.0    VMIS   .00
     84         .28 T        -211.1      313.7      191.6      311.7   1.00     11
            TUBRHSBEAM       -764.7    -1666.4      777.1     1666.4    VMIS   .57
     99      783.66 C            .4         .2         .0         .2    .92     11
            PRISHANGOFF      2480.6     1240.8         .0     1488.8    STAB   .00
    111      299.78 T         -13.2      -17.5       21.8       18.4    .86     11
            PIP 600X15       -426.9      262.5     -951.8      400.3    VMIS  3.46
    125      310.50 T         -21.8      -24.3       26.9       24.8    .82     11
            PIP 600X30        951.8     1350.4    -1749.0     1430.1    VMIS  2.00
    133     2690.57 C            .0        5.4      -10.8        6.5    .74     11
            PIP 600X30           .0      589.8    -1179.7      707.8    VMIS  1.15
     31      164.29 C            .8        -.6        1.9         .8    .71     11
            PIP 300X10         13.0       71.3     -128.6       82.9    VMIS  2.17
    123      699.97 C          -7.6       -6.5        5.4        6.7    .62     11
            PIP 600X15       -618.4     -541.7      465.0      557.0    VMIS   .00
```

SYMBOL	**DESCRIPTION TRACK 0.0**	**UNIT**
MEMB	- Member number	
FX	- Axial force in the member (T= tension, C=compression)	kN
MYs	- Start moment about y-axis	kNm
MYm	- Mid moment about y-axis	kNm
MYe	- End moment about y-axis	kNm
MYb	- Buckling moment about y-axis	kNm
RATIO	- Interaction ratio	
LOAD	- The critical load case number	
TABLE	- Section type (HE, IPE, TUBE etc.)	
MZs	- Start moment about z-axis	kNm
MZm	- Mid moment about z-axis	kNm
MZe	- End moment about z-axis	kNm
MZb	- Buckling moment about z-axis	kNm
COND	- Critical condition	
DIST	- Distance from the start of the member to the critical section	m

NB! Myb and Mzb are the design moments used for max unity ratio.

TRACK = 1.0

```
                            NS3472 (VERSION 96016.00)
                            UNITS ARE  KNS  AND   METE

 MEMB          FX                MYs        MYm        MYe        MYb    RATIO  LOAD
             TABLE               MZs        MZm        MZe        MZb    COND   DIST
===============================================================================
   111       299.78 T          -13.2      -17.5       21.8       18.4    .86      11
             PIP 600X15       -426.9      262.5     -951.8      400.3    VMIS  3.46
 |-----------------------------------------------------------------------------|
 | CURVE St A  Wk A  Beta Z   .80       Beta Y   .80       FYLD= 345. N/MM2    |
 | NKYD=.827E+4 KN   NKZD=.827E+4 KN   NEYD=.271E+6 KN   NEZD=.271E+6 KN     |
 | MYD =.118E+4 KNM  MZD =.118E+4 KNM  MVD =.118E+4 KNM  LAMBDA=   13.37      |
 | STRONG IR =  .000 WEAK IR =  .000   VON MISES =  .860 LATBUCK=  .786       |
 |-----------------------------------------------------------------------------|
   112       377.68 T          -13.8      -11.8        9.8       12.2    .28      13
             PIP 600X15        224.1      -17.7      259.5      103.8    VMIS  2.83
 |-----------------------------------------------------------------------------|
 | CURVE St A  Wk A  Beta Z   .80       Beta Y   .80       FYLD= 345. N/MM2    |
 | NKYD=.827E+4 KN   NKZD=.827E+4 KN   NEYD=.405E+6 KN   NEZD=.405E+6 KN     |
 | MYD =.118E+4 KNM  MZD =.118E+4 KNM  MVD =.118E+4 KNM  LAMBDA=   10.94      |
 | STRONG IR =  .000 WEAK IR =  .000   VON MISES =  .276 LATBUCK=  .185       |
 |-----------------------------------------------------------------------------|
   113        11.61 T          -18.4      -16.4       14.3       16.8    .27      11
             PIP 600X15        -43.3      132.9     -309.1      168.2    LATB  3.46
 |-----------------------------------------------------------------------------|
 | CURVE St A  Wk A  Beta Z   .80       Beta Y   .80       FYLD= 345. N/MM2    |
 | NKYD=.827E+4 KN   NKZD=.827E+4 KN   NEYD=.271E+6 KN   NEZD=.271E+6 KN     |
 | MYD =.118E+4 KNM  MZD =.118E+4 KNM  MVD =.118E+4 KNM  LAMBDA=   13.37      |
 | STRONG IR =  .000 WEAK IR =  .000   VON MISES =  .267 LATBUCK=  .275       |
 |-----------------------------------------------------------------------------|
   114       366.02 C          -13.2      -11.3        9.3       11.6    .45      11
             PIP 600X15       -224.8      120.9     -466.5      190.0    VMIS  2.83
 |-----------------------------------------------------------------------------|
 | CURVE St A  Wk A  Beta Z   .80       Beta Y   .80       FYLD= 345. N/MM2    |
 | NKYD=.827E+4 KN   NKZD=.827E+4 KN   NEYD=.405E+6 KN   NEZD=.405E+6 KN     |
 | MYD =.118E+4 KNM  MZD =.118E+4 KNM  MVD =.118E+4 KNM  LAMBDA=   10.94      |
 | STRONG IR =  .206 WEAK IR =  .206   VON MISES =  .452 LATBUCK=  .000       |
 |-----------------------------------------------------------------------------|
```

SYMBOL	**DESCRIPTION TRACK 1.0**	**UNIT**
CURVE St	- Buckling curve about Strong axis	
CURVE Wk	- Buckling curve about Weak axis	
Beta Z	- Buckling length factor about z-axis	
Beta Y	- Buckling length factor about y-axis	
FYLD	- Allowable yield strength	N/mm^2
NKYD	- Factored buckling strength/ resistance about y-axis	kN
NKZD	- Factored buckling strength/ resistance about z-axis	kN
NKD	- Axial capacity	kN
NEYD	- Euler buckling resistance for compression members about y- axis	kN
NEZD	- Euler buckling resistance for compression members about z-axis	kN
MYD	- Moment capacity about y-axis	kNm
MZD	- Moment capacity about z-axis	kNm
MVD	- Lateral buckling moment	kNm
LAMBDA	- $\lambda = \frac{L_k}{i}$	
STRONG IR	- Interaction Ratio for buckling about strong axis	
WEAK IR	- Interaction Ratio for buckling about weak axis	
VON MISES	- Interaction Ratio for von Mises	
LATBUCK	- Interaction Ratio for lateral buckling	

TRACK = 2.0

```
                              NS3472 (VERSION 96016.00)
                              UNITS ARE  mm AND    N

 MEMB          Sx              Sby        Sbz        Stot      Spmx      Svm     LOAD
            TABLE              Ty         Tz         Tto       Spmn     POINT    DIST
================================================================================
   111        10.87 T         242.0        .0       252.9        .0  257.90     11
            PIP 600X15         28.9        .0          .3        .0     3     3.46
   112        13.70 T          66.0        .0        79.7        .0   82.70     13
            PIP 600X15         12.4        .0          .3        .0     3     2.83
   113          .42 T          78.7        .0        79.1        .0   80.18     11
            PIP 600X15          7.4        .0          .2        .0     3     3.46
   114        13.28 C         118.6        .0       131.9        .0  135.52     11
            PIP 600X15         17.7        .0          .3        .0     3     2.83
   115        68.71 C          18.8        .0        87.5        .0   87.66     11
            PIP 200X8           1.0        .0         2.3        .0     3      .00
   116        66.13 T          37.9        .0       104.0        .0  105.91     11
            PIP 200X8           1.1        .0        10.3        .0     3     5.13
   117        63.29 T          47.5        .0       110.8        .0  110.84     11
            PIP 200X8           1.7        .0          .4        .0     3      .00
   118        85.64 C          39.8        .0       125.4        .0  125.43     11
            PIP 200X8           1.2        .0          .2        .0     3     6.20
   119        90.54 C          21.4        .0       111.9        .0  111.96     14
            PIP 200X8           1.0        .0          .6        .0     3      .00
   120        94.89 T          24.7        .0       119.6        .0  119.61     14
            PIP 200X8           1.2        .0          .3        .0     3     5.23
   121        79.98 C          43.7        .0       123.6        .0  123.68     11
            PIP 200X8           1.3        .0          .2        .0     3     6.20
```

SYMBOL	DESCRIPTION TRACK 2.0	UNIT
MEMB	- Member number	
Sx	- Axial stress in the member (T= tension, C=compression)	N/mm^2
Sby	- Stress from moment about y-axis	N/mm^2
Sbz	- Stress from moment about z-axis	N/mm^2
Stot	- Sum of Sx + Sby + Sbz	N/mm^2
Spmx	- Currently not in use	
Spmn	- Currently not in use	
Svm	- von Mises stress	N/mm^2
Ty	- Stress from shear force in y direction	N/mm^2
Tz	- Stress from shear force in z direction	N/mm^2
Tto	- Total shear stress used in von Mises calculation	N/mm^2
TABLE	- Section type (HE, IPE, TUBE etc.)	
POINT	- Location in cross section with max von Mises stress	
LOAD	- Governing load condition	
DIST	- Distance from the start of the member to the critical section	m

Note:

Do not use TRACK = 2.0 in connection with the SELECT OPTIMIZED or SELECT MEMBER / ALL commands.

TRACK = 3.0

```
                         NS3472 (VERSION 96016.00)
                         UNITS ARE  KNS  AND   METE

 MEMB          FX            MYs        MYm        MYe        MYb   RATIO  LOAD
             TABLE           MZs        MZm        MZe        MZb   COND   DIST
===============================================================================
   111        299.78 T      -13.2      -17.5       21.8       18.4  .86      11
             PIP 600X15    -426.9      262.5     -951.8      400.3   VMIS  3.46
   112        377.68 T      -13.8      -11.8        9.8       12.2  .28      13
             PIP 600X15     224.1      -17.7      259.5      103.8   VMIS  2.83
   113         11.61 T      -18.4      -16.4       14.3       16.8  .27      11
             PIP 600X15     -43.3      132.9     -309.1      168.2   LATB  3.46
   114        366.02 C      -13.2      -11.3        9.3       11.6  .45      11
             PIP 600X15    -224.8      120.9     -466.5      190.0   VMIS  2.83
   115        331.57 C       -4.1         .3       -2.0        1.7  .33      11
             PIP 200X8        -.5        1.0       -2.5        1.3   STAB   .00
   116        319.14 T       -1.9        -.6       -3.3        1.4  .35      11
             PIP 200X8        -.4        3.7       -7.8        4.5   VMIS  5.13
   117        305.44 T         .0        -.3         .5         .3  .37      11
             PIP 200X8       10.6        -.8        9.9        5.3   VMIS   .00
   118        413.31 C         .1        -.3         .6         .3  .50      11
             PIP 200X8        4.4       -1.1        8.8        4.6   STAB  6.20
   119        436.94 C       -4.5         .2       -2.1        1.9  .41      14
             PIP 200X8       -1.6         .0       -1.7         .7   STAB   .00
   120        457.92 T       -3.7        -.7       -5.1        2.0  .40      14
             PIP 200X8        1.7        -.2        2.1         .8   VMIS  5.23
   121        385.99 C        -.2        -.1         .0         .1  .48      11
             PIP 200X8        6.0        -.8        9.7        5.0   STAB  6.20
```

SYMBOL	DESCRIPTION TRACK 3.0	UNIT
MEMB	- Member number	
FX	- Axial force in the member (T= tension, C=compression)	kN
MYs	- Start moment about y-axis	kNm
MYm	- Mid moment about y-axis	kNm
MYe	- End moment about y-axis	kNm
MYb	- Buckling moment about y-axis	kNm
RATIO	- Interaction ratio	
LOAD	- The critical load case number	
TABLE	- Section type (HE, IPE, TUBE etc.)	
MZs	- Start moment about z-axis	kNm
MZm	- Mid moment about z-axis	kNm
MZe	- End moment about z-axis	kNm
MZb	- Buckling moment about z-axis	kNm
COND	- Critical condition	
DIST	- Distance from the start of the member to the critical section	m

TRACK 3: Member results sorted by member number.

TRACK = 9.0

Member in tension:

```
DETAILS FOR CODECHECK ACCORDING TO NS3472
                                 (VERSION 96016.00)
          MEMBER NO            :    111
          MEMBER TYPE          : PIPE     SECTION PIP 600X15
          GOVERING LOADCASE    :   11

               MEMBER PROPERTY             UNITS CM
               ---------------
               Ax    :     275.7     iy    :      20.7
               Ay    :     137.8     iz    :      20.7
               Az    :     137.8     Sy    :    3933.5
               Ix    :  236010.1     Sz    :    3933.5
               Iy    :  118005.0     Iw    :        .0
               Iz    :  118005.0     Lw    :     345.9

               MATERIAL DATA               UNITS NEWTON MMS
               ---------------
               E     :      204960.     Gamma :     1.150
               Fy    :   344.966        Fd    :   299.970
               FORCES                      UNITS KNEWTON METERS
               ---------------
               Fx     :    299.78 T
               Msz    :   -426.86          Msy   :   -13.176
               Mmz    :    262.48          Mmy   :   -17.508
               Mez    :   -951.82          Mey   :    21.840
               LATERAL BUCKLING
               --------
               Mlatbuck:   670.43
               Mvd     :  1179.90
               IRtot   :      .786
               YIELD CHECK
               -----------
               STRESS : NEW MMS            FORCES: KNEW METERS
               STRESS AT POINT :   3       FORCES AT SECTION   3.459
               sigax  :    10.873          Fx    :   299.778 T
               sigb   :   242.016          Fy    :   398.539
               tau    :    28.914          Fz    :     2.505
               tors   :      .305          Mx    :     2.398
               sige   :   257.904          My    :    21.838
               IR     :      .860          Mz    :  -951.695

               Governing interaction ratio               .860
```

Member in compression:

```
DETAILS FOR CODECHECK ACCORDING TO NS3472
                       (VERSION 96016.00)
MEMBER NO            :    114
MEMBER TYPE          : PIPE     SECTION PIP 600X15
GOVERING LOADCASE    :   11

     MEMBER PROPERTY            UNITS CM
     ---------------
     Ax    :     275.7     iy    :      20.7
     Ay    :     137.8     iz    :      20.7
     Az    :     137.8     Sy    :    3933.5
     Ix    :  236010.1     Sz    :    3933.5
     Iy    :  118005.0     Iw    :        .0
     Iz    :  118005.0     Lw    :     282.9

     MATERIAL DATA              UNITS NEWTON MMS
     ---------------
     E     :      204960.     Gamma   :     1.150
     Fy    :   344.966        Fd      :   299.970
     lamfy :    76.577        Gamma mk:     1.000
     BUCKLING PARAMETERS        UNITS KNEWTON METERS
     -------------------
     STRONG AXIS           WEAK AXIS              LATERAL BUCKLING
     L     :     2.829     L     :     2.829     L     :     2.829
     beta  :      .800     beta  :      .800     ny    :     1.000
     lambda:    10.939     lambda:    10.939     n     :     1.500
     lambb :      .143     lambb :      .143     Mvd   :  1179.903
     curve :      A        curve :      A
     Fk/Fy :     1.000     Fk/Fy :     1.000
     Nkd   :  8269.398     Nkd   :  8269.398
     NEd   :405254.700     NEd   :405254.700
     Md    :  1179.903     Md    :  1179.903
     KE    :     1.000     1/KE  :     1.000
     Factor:      .999     Factor:      .999
     FORCES                     UNITS KNEWTON METERS
     ---------------
     STRONG AXIS           WEAK AXIS
     Fx     :   366.025 C   Fx    :   366.025 C
     Ms     :  -224.840     Ms    :   -13.205
     Mm     :   120.851     Mm    :   -11.253
     Me     :  -466.542     Me    :     9.300
     beta   :     -.482     beta  :      .704
     m      :      .407     m     :      .882
     Mb     :   189.989     Mb    :    11.643
     IRx    :      .044     IRx   :      .044
     IRm    :      .161     IRm   :      .161
     IRtot  :      .206     IRtot :      .206

     YIELD CHECK
     -----------
     STRESS : NEW MMS           FORCES: KNEW METERS
     STRESS AT POINT :   3      FORCES AT SECTION   2.829
     sigax  :    13.276         Fx    :   366.025 C
     sigb   :   118.618         Fy    :   244.366
     tau    :    17.729         Fz    :    -1.380
     tors   :      .260         Mx    :     2.044
     sige   :   135.525         My    :     9.299
     IR     :      .452         Mz    :  -466.480

     Governing interaction ratio               .452
```

Member in compression (pipe - NPD):

```
DETAILS FOR CODECHECK ACCORDING TO NPD94
                                 (VERSION 96016.00)
          MEMBER NO           :      1
          MEMBER TYPE         : PIPE      762x  19 mm
          GOVERING LOADCASE   :    2

          UNITS [properties: cm][stesses:new mms][forces:kn me]
          -- PROPERTIES --
          D/t    :      40.0     Iy Iz :  306983.8     Ly    :    3074.8
          Ax     :     444.6     Sy Sz :    8057.3     Lz    :    3074.8
          Ay Az :     222.3     iy iz :      26.3     By    :        .7
          Ix    :  613967.7     Z     :  124263.4     Bz    :        .6

          -- MATERIAL --
          E     :   209979.     Fy    :      366.     Gamma m :     1.150
          lamfy :       91.     Fd    :      318.     Gamma mk:     1.000

          -- SHELL BUCKLING --
          -- Section npd 3.4.6.1 --
          fea :    2984.5 feb :    3076.4 fet :     528.2 fep :     131.2
          -- Section npd 3.4.4.1 --
          La  :      .350 Lb  :      .345 Lt  :      .632 Lp  :     1.670
          Ga  :     1.047 Gb  :     1.045 Gt  :     1.135 Gp  :     1.250
          Fk  :   365.952
          -- Section npd 3.4.7 --
          Sigj:     278.7 SECT:       1.0 Irshell      .876
          -- Section npd 3.4.9.2 --
          Bendingmoment stress in 3.4.4.1 increased by dsigb :    91.430
          d/t    40.0 >    12.0 interaction npd 3.2.3 a
          -- BEAM COLUMN BUCKLING --
          -- Section npd 3.4.4.1 --
          La  :      .350 Lb  :      .345 Lt  :      .632 Lp  :     1.670
          Ga  :     1.047 Gb  :     1.045 Gt  :     1.135 Gp  :     1.250
          Fa  :     249.6 Sect:       1.0
          -- Section ns3472 5.4.1 --
          lbz :    67.872 lbbz:      .745 crvz:  A    FkFy z:      .826
          lby :    78.404 lbby:      .860 crvy:  A    FkFy y:      .759
          -- Section npd 3.2.2 --
          SIGa  :     162.6     SIGby :       8.2     SIGbz :      32.2
          fE    :   337.131
          B     :     1.932     By    :     1.932     Bz    :     1.566
          SIGb* :      26.3     SIGbuc:     266.4     Irb   :     1.227
          -- Section npd 3.2.2.1 (ns3472 5.4.2) --
             z axis                          y axis
          Fx     :  7231.114 C       Fx    :  7231.114 C
          Ms     :   -87.503         Ms    :    28.677
          Mm     :  -154.416         Mm    :    36.766
          Me     :  -297.803         Me    :    87.503
          beta   :     -.294         beta  :     -.328
          m      :      .482         m     :      .469
          Mb     :   259.566         Mb    :    66.179
          -- Section npd 3.1.2 --
          Stress at point :   3      Forces at section  30.748
          sigax  :   162.614         Fx    :  7231.114 C
          sigb   :    38.519         Fy    :    46.293
          tau    :     2.156         Fz    :    12.386
          tors   :      .000         Mx    :      .000
          sigp   :    30.166         My    :    87.491
          sige   :   187.912         Mz    :  -297.764
          Irj fy :      .590         HSpres:     1.508

               Governing interaction ratio              1.227
```

Tracks for joint capacity code checking

TRACK = 99

```
$JOINT BRACE CHORD     D    T     d    t   GAP  FYc   FYb THETA  TW THETAT JTYPE
  1020  1016  1015   420.  15.  400.  15.    0. 340.  340.  90.   0.  0.   TY
  1020  1016  1017   420.  15.  400.  15.    0. 340.  340.  90.   0.  0.   TY
  2010  1016  1010   500.  20.  400.  15.    0. 340.  340.  45.   0.  0.   TY
  2010  1016  2010   500.  20.  400.  15.    0. 340.  340.  45.   0.  0.   TY
  2000  1017  1000   500.  20.  420.  15.    0. 340.  340.  45.   0.  0.   TY
  2000  1017  2000   500.  20.  420.  15.    0. 340.  340.  45.   0.  0.   TY
  1020  1018  1015   420.  15.  400.  15.    0. 340.  340.  90.   0.  0.   TY
  1020  1018  1017   420.  15.  400.  15.    0. 340.  340.  90.   0.  0.   TY
  2000  2015  1000   500.  20.  400.  15.    0. 340.  340.  40.   0.  0.   TY
  2000  2015  2000   500.  20.  400.  15.    0. 340.  340.  40.   0.  0.   TY
  3010  2015  2010   500.  20.  400.  15.    0. 340.  340.  40.   0.  0.   TY
  3010  2015  3010   500.  20.  400.  15.    0. 340.  340.  40.   0.  0.   TY
  3010  3015  2010   500.  20.  400.  15.    0. 340.  340.  40.   0.  0.   TY
  3010  3015  3010   500.  20.  400.  15.    0. 340.  340.  40.   0.  0.   TY
  2000  2005  1000   500.  20.  400.  10.    0. 340.  340.  90.   0.  0.   TY
  2000  2005  2000   500.  20.  400.  10.    0. 340.  340.  90.   0.  0.   TY
  2010  2005  1010   500.  20.  400.  10.    0. 340.  340.  90.   0.  0.   TY
  2010  2005  2010   500.  20.  400.  10.    0. 340.  340.  90.   0.  0.   TY
  3000  3005  2000   500.  20.  400.  10.    0. 340.  340.  90.   0.  0.   TY
  3000  3005  3000   500.  20.  400.  10.    0. 340.  340.  90.   0.  0.   TY
  3010  3005  2010   500.  20.  400.  10.    0. 340.  340.  90.   0.  0.   TY
  3010  3005  3010   500.  20.  400.  10.    0. 340.  340.  90.   0.  0.   TY
  2210  1215  1210   500.  20.  400.  15.    0. 340.  340.  45.   0.  0.   TY
  2210  1215  2210   500.  20.  400.  15.    0. 340.  340.  45.   0.  0.   TY
  2210  2215  1210   500.  20.  400.  15.    0. 340.  340.  40.   0.  0.   TY
  2210  2215  2210   500.  20.  400.  15.    0. 340.  340.  40.   0.  0.   TY
  3200  2215  2200   500.  20.  400.  15.    0. 340.  340.  40.   0.  0.   TY
  3200  2215  3200   500.  20.  400.  15.    0. 340.  340.  40.   0.  0.   TY
  3200  3215  2200   500.  20.  400.  15.    0. 340.  340.  40.   0.  0.   TY
  3200  3215  3200   500.  20.  400.  15.    0. 340.  340.  40.   0.  0.   TY
  2200  2205  1200   500.  20.  400.  10.    0. 340.  340.  90.   0.  0.   TY
  2200  2205  2200   500.  20.  400.  10.    0. 340.  340.  90.   0.  0.   TY
```

TRACK = 98

NPD 94 TUBULAR JOINT CHECK (VERSION 96016.00)
UNITS ARE mm

JOINT	CHORD	Dc	Tc	BRACE	db	tb	TYPE	LOAD	RATIO
1020	1015	420.0	15.0	1016	400.0	15.0	TY	3	.143
1020	1017	420.0	15.0	1016	400.0	15.0	TY	3	.143
2010	1010	500.0	20.0	1016	400.0	15.0	TY	3	.049
2010	2010	500.0	20.0	1016	400.0	15.0	TY	3	.048
2000	1000	500.0	20.0	1017	420.0	15.0	TY	3	.548
2000	2000	500.0	20.0	1017	420.0	15.0	TY	3	.586
1020	1015	420.0	15.0	1018	400.0	15.0	TY	3	.099
1020	1017	420.0	15.0	1018	400.0	15.0	TY	3	.099
2000	1000	500.0	20.0	2015	400.0	15.0	TY	3	.450
2000	2000	500.0	20.0	2015	400.0	15.0	TY	3	.481
3010	2010	500.0	20.0	2015	400.0	15.0	TY	3	.527
3010	3010	500.0	20.0	2015	400.0	15.0	TY	3	.498
3010	2010	500.0	20.0	3015	400.0	15.0	TY	3	.338
3010	3010	500.0	20.0	3015	400.0	15.0	TY	3	.320
2000	1000	500.0	20.0	2005	400.0	10.0	TY	3	.107
2000	2000	500.0	20.0	2005	400.0	10.0	TY	3	.113
2010	1010	500.0	20.0	2005	400.0	10.0	TY	3	.177
2010	2010	500.0	20.0	2005	400.0	10.0	TY	3	.170
3000	2000	500.0	20.0	3005	400.0	10.0	TY	3	.168
3000	3000	500.0	20.0	3005	400.0	10.0	TY	3	.167
3010	2010	500.0	20.0	3005	400.0	10.0	TY	3	.183
3010	3010	500.0	20.0	3005	400.0	10.0	TY	3	.174
2210	1210	500.0	20.0	1215	400.0	15.0	TY	3	.945
2210	2210	500.0	20.0	1215	400.0	15.0	TY	3	.518
2210	1210	500.0	20.0	2215	400.0	15.0	TY	3	1.146
2210	2210	500.0	20.0	2215	400.0	15.0	TY	3	.617
3200	2200	500.0	20.0	2215	400.0	15.0	TY	3	.575
3200	3200	500.0	20.0	2215	400.0	15.0	TY	3	.579
3200	2200	500.0	20.0	3215	400.0	15.0	TY	3	.232
3200	3200	500.0	20.0	3215	400.0	15.0	TY	3	.234
2200	1200	500.0	20.0	2205	400.0	10.0	TY	3	.183
2200	2200	500.0	20.0	2205	400.0	10.0	TY	3	.177
2210	1210	500.0	20.0	2205	400.0	10.0	TY	3	1.402
2210	2210	500.0	20.0	2205	400.0	10.0	TY	3	.262
3200	2200	500.0	20.0	3205	400.0	10.0	TY	3	.210
3200	3200	500.0	20.0	3205	400.0	10.0	TY	3	.212
3210	2210	500.0	20.0	3205	400.0	10.0	TY	3	.223
3210	3210	500.0	20.0	3205	400.0	10.0	TY	3	.223
2000	1000	500.0	20.0	1315	400.0	15.0	TY	3	.522
2000	2000	500.0	20.0	1315	400.0	15.0	TY	3	.558
2000	1000	500.0	20.0	2315	400.0	15.0	TY	3	.463
2000	2000	500.0	20.0	2315	400.0	15.0	TY	3	.495
3200	2200	500.0	20.0	2315	400.0	15.0	TY	3	.519
3200	3200	500.0	20.0	2315	400.0	15.0	TY	3	.523
3200	2200	500.0	20.0	3315	400.0	15.0	TY	3	.309
3200	3200	500.0	20.0	3315	400.0	15.0	TY	3	.311
2200	1200	500.0	20.0	2305	400.0	10.0	TY	3	.259
2200	2200	500.0	20.0	2305	400.0	10.0	TY	3	.238
2000	1000	500.0	20.0	2305	400.0	10.0	TY	3	.154
2000	2000	500.0	20.0	2305	400.0	10.0	TY	3	.171
3200	2200	500.0	20.0	3305	400.0	10.0	TY	3	.163
3200	3200	500.0	20.0	3305	400.0	10.0	TY	3	.164
3000	2000	500.0	20.0	3305	400.0	10.0	TY	3	.159
3000	3000	500.0	20.0	3305	400.0	10.0	TY	3	.159

Special prints (not code check)

TRACK = 49

NS3472 JOINT OUTPUT (VERSION 95015.01.)
UNITS ARE KNS AND METE

JOINT	LOAD	MEMBER	FX	FY	FZ	MZ	MY	MZ
1	12	1	46.8C	142.0	156.0	72.3	38.8	-31.7
		8	9.5C	51.6	-13.0	4.4	-28.2	-109.4
		107	193.5T	33.8	-146.5	10.6	-181.7	27.3
2	12	1	46.8C	-140.7	-156.0	-72.3	88.8	-83.9
		2	110.8C	22.7	-.1	-.2	-11.8	82.0
		9	156.1T	118.0	-64.0	1.9	-76.9	-72.5
3	12	2	110.8C	22.2	.1	.2	11.4	-82.8
		3	47.3C	-140.1	-158.7	-68.3	-86.7	84.2
		10	158.6T	117.8	63.5	-1.4	75.3	-68.0
4	12	3	47.3C	141.3	158.7	68.3	-43.1	30.9
		4	19.1C	51.6	13.0	-4.4	26.9	-107.4
		108	192.9T	-34.3	-139.6	-16.2	-175.6	-26.5
5	12	4	19.1C	-44.8	-13.0	4.4	30.3	-104.8
		5	1.2T	47.4	119.8	-69.3	43.3	-16.8
		109	92.2C	-11.8	-138.9	-13.0	-174.1	12.4
6	12	5	1.2T	-48.6	-119.8	69.3	54.7	-22.4
		6	64.6T	-22.6	278.3	278.5	149.3	21.1
		10	158.6T	-71.2	-63.5	1.4	204.0	-347.8
7	12	6	64.6T	-22.3	279.4	279.2	-151.5	-20.5
		7	.7T	-49.1	-123.3	65.1	-53.0	22.4
		9	156.1T	-71.4	64.0	-1.9	-204.5	-344.3
8	12	7	.7T	47.8	123.3	-65.1	-47.8	17.2
		8	9.5C	-44.8	13.0	-4.4	-29.2	-102.8
		110	92.6C	12.4	-132.8	18.7	-167.8	-12.8
9	12	11	218.4T	81.6	27.7	75.1	2.3	-94.9
		18	101.5T	48.6	-3.1	-7.8	-8.7	-101.8
		107	200.7T	-33.8	146.5	-10.6	-201.5	-115.7
		111	549.0T	-169.9	3.6	3.4	20.5	221.7
		115	333.3C	.3	2.2	-.2	3.9	-1.0
		117	40.2C	1.1	.0	.1	.1	-2.5

TRACK = 31

```
                           MAX MIN OUTPUT FOR END NO:    1
                           UNITS ARE  KNS  AND   METE

 MEMBER  LOAD      FX            FY         FZ         MZ         MY         MZ
===============================================================================
     1   11      67.6C      153.8      155.2       71.9       38.2      -61.3
         16    -116.3T       60.0       -3.7         .1        1.2     -181.9
         11      67.6C      153.8      155.2       71.9       38.2      -61.3
         10        .9C         .1         .0         .0         .0        -.1
         13      48.0C      142.0      156.0       72.3       38.8      -31.6
         16    -116.3T       60.0       -3.7         .1        1.2     -181.9
         13      48.0C      142.0      156.0       72.3       38.8      -31.6
          1       3.0C       36.3         .3        -.2        -.1        9.0
         14       1.1C       96.6       77.1       41.7       39.2      -58.8
          3     -12.4T       29.1       45.2       24.7      -23.1       30.2
          4     -81.9T        7.5       -2.6         .1        -.6      103.1
         16    -116.3T       60.0       -3.7         .1        1.2     -181.9
```

TRACK = 32

```
                    MAX MIN OUTPUT FOR END NO:   2
                    UNITS ARE  KNS  AND   METE

 MEMBER  LOAD      FX           FY         FZ         MZ         MY         MZ
==============================================================================
     1    11      67.6C     -152.5     -155.2      -71.9       88.7      -64.0
          16    -116.3T      -58.7        3.7        -.1       -4.2      133.4
          10        .9C        -.1         .0         .0         .0         .1
          11      67.6C     -152.5     -155.2      -71.9       88.7      -64.0
          16    -116.3T      -58.7        3.7        -.1       -4.2      133.4
          13      48.0C     -140.8     -156.0      -72.3       88.8      -84.0
           1       3.0C      -35.4        -.3         .2        -.2       20.3
          13      48.0C     -140.8     -156.0      -72.3       88.8      -84.0
          13      48.0C     -140.8     -156.0      -72.3       88.8      -84.0
           2      14.7C      -56.0      -91.8      -42.8      -52.3       31.6
          16    -116.3T      -58.7        3.7        -.1       -4.2      133.4
           4     -81.9T       -7.5        2.6        -.1        2.7      -97.0
```

8 References

[1] NS 3472 3.utg. 2001
Prosjektering av stålkonstruksjoner
Beregning og dimensjonering

[2] STAAD.Pro Technical Reference Manual, Release 2002

[3] NS 3472 1.utg. 1973
Prosjektering av stålkonstruksjoner
Beregning og dimensjonering

[4] Roark &Young`s 5th edition

[5] NPD utg. 1994
Veiledning om utforming, beregning og dimensjonering av stålkonstruksjoner. Sist endret 1. oktober 1993.

[6] NS 3472 2.utg.1984
Prosjektering av stålkonstruksjoner
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