name1 = Truss1

name2 = K − joint

loadcase = Fatigue

location = Support1

name = JohnSmith

```
2020-10-20 22:58:43
```

Uniplanar SHS/RHS K-Joints with Overlap

CIDECT DESIGN GUIDE 8

The purpose of this worksheet is to determine the allowable stresses at the K-Joints of the trusses.

The CIDECT 8 design guide is adopted. It can be downloaded at: https://www.cidect.org/design-guides/

INPUT GEOMETRY

Excerpt 1: Notation

Chord Size

$b0 = 350.0\ mm$ (Width of Chord)

$h0 = 350.0\ mm$ (Height of Chord)

$t0 = 20.0\ mm$ (Thickness of Chord)

Brace size

$b1 = 300.0\ mm$ (Width of Brace)

$h1 = 300.0\ mm$ (Height of Brace)

$t1 = 16.0\ mm$ (Thickness of Brace)

Parameters to determine Brace Angle

$e = -110.000\ mm$ (Eccentricity)

$chordspacing = 2.000\ m$ (Spacing between Legs for determining brace angle)

$L_{chord} = 6.000\ m$ (Height of legs for determining brace angle)

$div_{chord} = 4$ (no diagonal braces for determining brace angle)

INPUT LOADING

Excerpt 2: Load Conditions

$P_{chord} = 100.000\ kN$ (Axial Force +ve Compression)

$P_{brace} = 50.000\ kN$ (Axial Force +ve Tension)

$M_{ip_{chord}} = 10.000\ kN \cdot m$ (Moment In-Plane on Chord (Column of Gantry))

$M_{op_{chord}} = 10.000\ kN \cdot m$ (Moment Out-of-Plane on Chord (Column of Gantry))

$M_{op_{brace}} = 10.000\ kN \cdot m$ (Moment Out-of-Plane on Brace (Between gantry columns))

CAPACITY

$deltaF = deltaF \cdot Pa = 24.300\ MPa \cdot Pa = 24.300\ MPa$ (Allowable fatigue stress after SCF applied)

SCF ASSUMED

CIDECT 8 does not cover out of plane bending of SHS/RHS sections.

Out of plane SCF's are defined manually below.

$SCF_{ch_{op}} = 2.0$ (Min recommended Sec 5 and Appendix C)

$SCF_{br_{op}} = 2.0$ (Min recommended Sec 5 and Appendix C)

Parameters

$\beta = \frac{b1}{b0} = \frac{300.0\ mm}{350.0\ mm} = 8.6 \times 10^{-1}$ (Ratio of brace to chord width, where 0.35 <= beta <= 1.0)

$\gamma = \frac{b0}{2 \cdot t0} = \frac{350.0\ mm}{2 \cdot 20.0\ mm} = 8.8$ (Ratio of chord width to 2*thickness, where 10 <= 2*omega <= 35)

$\tau = \frac{t1}{t0} = \frac{16.0\ mm}{20.0\ mm} = 0.8$ (Ratio of brace to chord thickness, where 0.25 < tau <= 1.0)

Truss Overlap Calculations

Determine bracing centreline length between intersection points

Excerpt 3: Overlap Calculation

$$\begin{aligned} h_{truss} &= chordspacing + 2 \cdot e \\ &= 2.000\ m + 2 \cdot -110.000\ mm \\ &= 1.780\ m \quad \text{(Height of truss adjusted by eccentricity.)} \end{aligned}$$

$$\begin{aligned} l_{truss} &= \frac{L_{chord}}{div_{chord}} \\ &= \frac{6.000\ m}{4} \\ &= 1.500\ m \quad \text{(Length of truss (projection of brace onto the chord))} \end{aligned}$$

$$\begin{aligned} \theta &= \arctan\left(\frac{h_{truss}}{l_{truss}}\right) \\ &= \arctan\left(\frac{1.780\ m}{1.500\ m}\right) \\ &= 8.706 \times 10^{-1} \quad \text{(Angle between chord and brace)} \end{aligned}$$

$p = \frac{h1}{\sin(\theta)} = \frac{300.000\ mm}{\sin(8.706 \times 10^{-1})} = 392.317\ mm$ (Projected width of brace)

$x = \frac{0.5 \cdot h0 + e}{\tan(\theta)} = \frac{0.5 \cdot 350.000\ mm + -110.000\ mm}{\tan(8.706 \times 10^{-1})} = 54.775\ mm$ (Projection of Intersection)

$q = p - 2 \cdot x = 392.317\ mm - 2 \cdot 54.775\ mm = 282.766\ mm$ (Overlap Projection)

$Ov = \frac{q}{p} = \frac{282.766\ mm}{392.317\ mm} = 7.208 \times 10^{-1}$ (Overlap, where 50% <= Ov <= 100%)

Check Parameter within Allowable

```
beta:
Check 0.86 <= 1
Util = 0.86
Check 0.86 >= 0.35
Util = 0.41
PASS

2*gamma:
Check 17.50 <= 35
Util = 0.50
Check 17.50 >= 10
Util = 0.57
PASS

tau:
Check 0.80 <= 1.0
Util = 0.80
Check 0.80 >= 0.35
Util = 0.44
PASS

theta:
Check 49.88 <= 60
Util = 0.83
Check 49.88 >= 30
Util = 0.60
PASS

Ov:
Check 0.72 <= 1.0
Util = 0.72
Check 0.72 >= 0.5
Util = 0.69
PASS

e/h0:
Check -0.31 <= 0.25
Check -0.31 >= -0.55
PASS
```

Section Properties

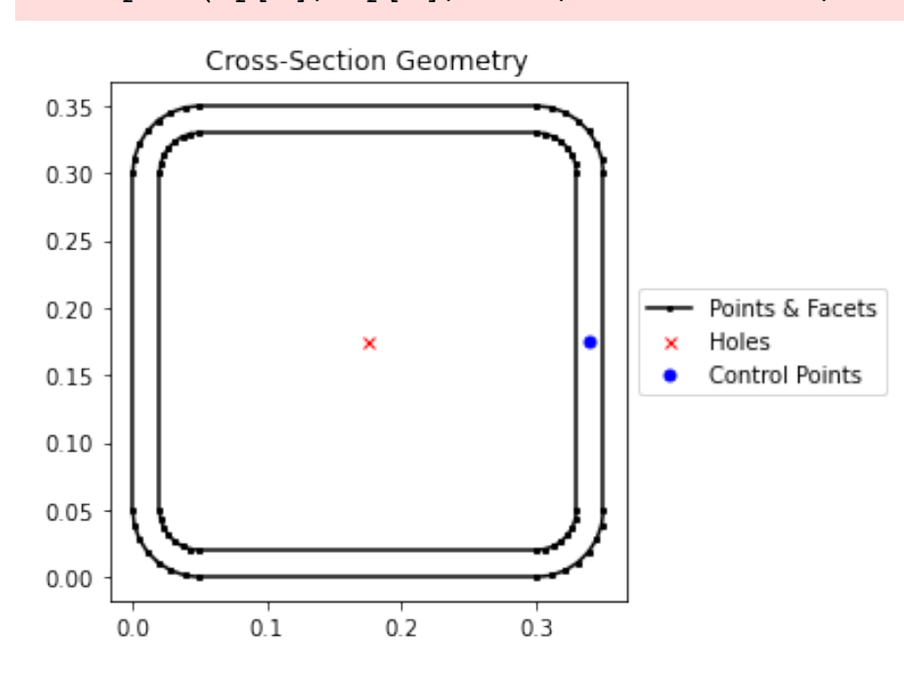
The following section calculates the SHS properties:

- 2nd moment of area in 2 directions.
- area

This is to enable determining the external fibre stresses:

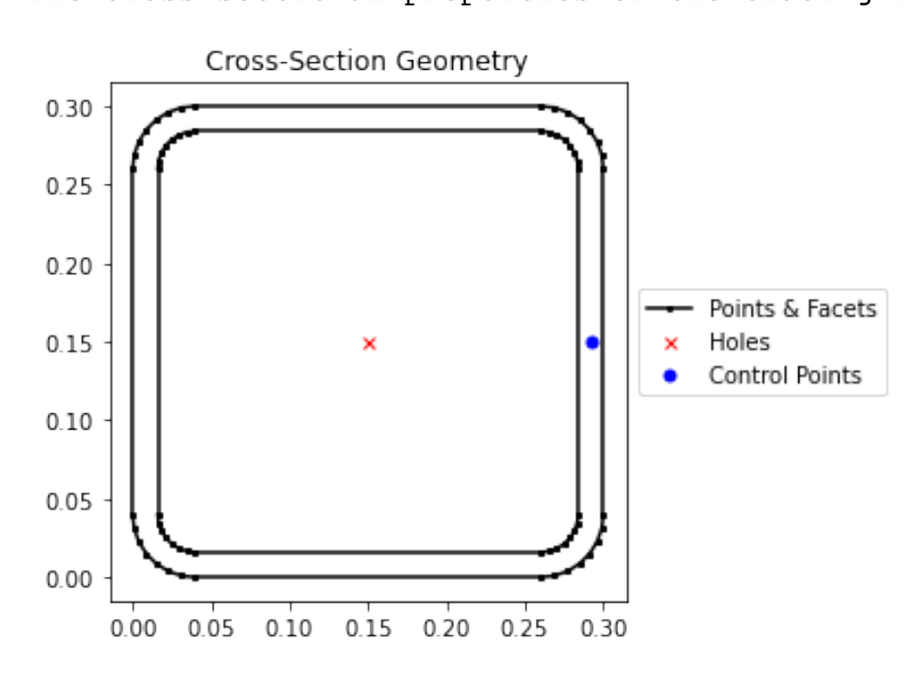
```
The cross sectional properties of the chord member:
```

```
/Users/michaellisitsa/opt/miniconda3/envs/mywork1/lib/python3.8/site-packages/sectionproperties/pre/sections.py:304: MatplotlibDeprecationWarning: Case-insensitive properties were deprecated in 3.3 and support will be removed two min
or releases later
  ax.plot(h[0], h[1], 'rx', markerSize=5, label='Holes')
/Users/michaellisitsa/opt/miniconda3/envs/mywork1/lib/python3.8/site-packages/sectionproperties/pre/sections.py:311: MatplotlibDeprecationWarning: Case-insensitive properties were deprecated in 3.3 and support will be removed two min
or releases later
  ax.plot(cp[0], cp[1], 'bo', markerSize=5,
```




```
SHS chord:
Area=2.50e-02 m^2
Ixx=4.39e-04 m^4
Iyy=4.39e-04 m^4
```

```
The cross sectional properties of the bracing member:
```




```
SHS Brace:
Area=1.73e-02 m^2
Ixx=2.25e-04 m^4
Iyy=2.25e-04 m^4
```

SCF Calculations

The follow calculations determine the Stress Concentration Factors (SCF) for each:

- LC1 chord -> $SCF_{ch,ax}$
- LC1 brace -> $SCF_{b,ax}$
- LC2 chord -> $SCF_{ch,ch}$

Excerpt 4: E.3 SCF Locations

SCF_{chax} Calculation

$$\begin{aligned} SCF_{chaxpt1} &= \left(0.5 + 2.38 \cdot \beta - 2.87 \cdot (\beta)^2 + 2.18 \cdot \beta \cdot Ov + 0.39 \cdot Ov - 1.43 \cdot \sin(\theta)\right) \\ &= \left(0.5 + 2.38 \cdot 8.571 \times 10^{-1} - 2.87 \cdot \left(8.571 \times 10^{-1}\right)^2 + 2.18 \cdot 8.571 \times 10^{-1} \cdot 7.208 \times 10^{-1} + 0.39 \cdot 7.208 \times 10^{-1} - 1.43 \cdot \sin(8.706 \times \right. \\ &= 9.658 \times 10^{-1} \end{aligned}$$

$$\begin{aligned} SCF_{chaxpt2} &= \left((2 \cdot \gamma)^{0.29} \cdot (\tau)^{0.7} \cdot (Ov)^{(0.73 - 5.53 \cdot \sin(\theta)**2)} \cdot (\sin(\theta))^{((-0.4) - 0.08 \cdot Ov)}\right) \\ &= \left((2 \cdot 8.75)^{0.29} \cdot (0.8)^{0.7} \cdot \left(7.208 \times 10^{-1}\right)^{(0.73 - 5.53 \cdot \sin(8.706 \times 10^{-1})**2)} \cdot \left(\sin\left(8.706 \times 10^{-1}\right)\right)^{((-0.4) - 0.08 \cdot 7.208 \times 10^{-1})}\right) \\ &= 5.035 \end{aligned}$$

$$\begin{aligned} SCF_{chax} &= SCF_{chaxpt1} \cdot SCF_{chaxpt2} \\ &= 9.658 \times 10^{-1} \cdot 5.035 \\ &= 4.863 \quad \text{(Balanced Loading condition Chord Forces)} \end{aligned}$$

SCF_{bax} Calculation

$$\begin{aligned} SCF_{baxpt1} &= 0.15 + 1.1 \cdot \beta - 0.48 \cdot (\beta)^2 - \frac{0.14}{Ov} \\ &= 0.15 + 1.1 \cdot 8.571 \times 10^{-1} - 0.48 \cdot \left(8.571 \times 10^{-1}\right)^2 - \frac{0.14}{7.208 \times 10^{-1}} \\ &= 0.546 \end{aligned}$$

$$\begin{aligned} SCF_{baxpt2} &= (2 \cdot \gamma)^{0.55} \cdot (\tau)^{(-0.3)} \cdot (Ov)^{((-2.57) + 1.62 \cdot \beta**2)} \cdot (\sin(\theta))^{0.31} \\ &= (2 \cdot 8.75)^{0.55} \cdot (0.8)^{(-0.3)} \cdot \left(7.208 \times 10^{-1}\right)^{((-2.57) + 1.62 \cdot 8.571 \times 10^{-1}**2)} \cdot \left(\sin\left(8.706 \times 10^{-1}\right)\right)^{0.31} \\ &= 7.462 \end{aligned}$$

$$\begin{aligned} SCF_{bax} &= SCF_{baxpt1} \cdot SCF_{baxpt2} \\ &= 0.546 \cdot 7.462 \\ &= 4.074 \quad \text{(Balanced Loading condition Brace Forces)} \end{aligned}$$

SCF_{chch} Calculation

$$\begin{aligned} SCF_{chch} &= 1.2 + 1.46 \cdot \beta - 0.028 \cdot (\beta)^2 \\ &= 1.2 + 1.46 \cdot 8.571 \times 10^{-1} - 0.028 \cdot \left(8.571 \times 10^{-1}\right)^2 \\ &= 2.431 \end{aligned}$$

3.3 Nominal Stress Ranges

Nominal stresses are obtained by getting the principal and outer fiber bending stresses of each element defined in Sec 3.3.

σ_{chord}

Balanced LC

$$\begin{aligned} \sigma_{chord1P} &= SCF_{chax} \cdot \frac{P_{brace} \cdot \cos(\theta)}{chord.area \cdot (m)^2} \\ &= 4.863 \cdot \frac{50.000\ kN \cdot \cos\left(8.706 \times 10^{-1}\right)}{chord.area \cdot (m)^2} \\ &= 6.271\ MPa \end{aligned}$$

Unbalanced LC

$$\begin{aligned} \sigma_{chord2P} &= SCF_{chch} \cdot \frac{P_{chord} - P_{brace} \cdot \cos(\theta)}{chord.area \cdot (m)^2} \\ &= 2.431 \cdot \frac{100.000\ kN - 50.000\ kN \cdot \cos\left(8.706 \times 10^{-1}\right)}{chord.area \cdot (m)^2} \\ &= 6.595\ MPa \end{aligned}$$

Bending Moment

$y_{ip_{chord}} = \frac{h0}{2} = \frac{350.000\ mm}{2} = 175.000\ mm$ (Dist from NA to top/bottom of brace)

$y_{op_{chord}} = \frac{b0 - b1}{2} = \frac{350.000\ mm - 300.000\ mm}{2} = 25.000\ mm$ (Dist from NA to left/right of brace)

$$\begin{aligned} \sigma_{chordM_{ip}} &= SCF_{chch} \cdot \frac{M_{ip_{chord}} \cdot y_{ip_{chord}}}{chord.ixx \cdot (m)^4} \\ &= 2.431 \cdot \frac{10.000\ kN \cdot m \cdot 175.000\ mm}{chord.ixx \cdot (m)^4} \\ &= 9.690\ MPa \end{aligned}$$

$$\begin{aligned} \sigma_{chordM_{op}} &= SCF_{ch_{op}} \cdot \frac{M_{op_{chord}} \cdot y_{op_{chord}}}{chord.iyy \cdot (m)^4} \\ &= 2.0 \cdot \frac{10.000\ kN \cdot m \cdot 25.000\ mm}{chord.iyy \cdot (m)^4} \\ &= 1.139\ MPa \end{aligned}$$

Chord Total

$$\begin{aligned} \sigma_{chord} &= \sigma_{chord1P} + \sigma_{chord2P} + \sigma_{chordM_{ip}} + \sigma_{chordM_{op}} \\ &= 6.3\ MPa + 6.6\ MPa + 9.7\ MPa + 1.1\ MPa \\ &= 23.7\ MPa \end{aligned}$$

```
Sigma_chord capacity:
Check 23694948.19 <= 24300000.0
Util = 0.98
PASS
```

Brace Stresses

σ_{brace}

Balanced LC

$$\begin{aligned} \sigma_{braceP} &= SCF_{bax} \cdot \frac{P_{brace}}{brace.area \cdot (m)^2} \\ &= 4.074 \cdot \frac{50.000\ kN}{brace.area \cdot (m)^2} \\ &= 11.795\ MPa \end{aligned}$$

Bending Moment

$z_{op_{brace}} = \frac{b1}{2} = \frac{300.000\ mm}{2} = 150.000\ mm$

$\sigma_{braceM_{op}} = SCF_{br_{op}} \cdot M_{op_{brace}} \cdot \frac{z_{op_{brace}}}{brace.iyy \cdot (m)^4} = 2.0 \cdot 10.000\ kN \cdot m \cdot \frac{150.000\ mm}{brace.iyy \cdot (m)^4} = 13.312\ MPa$

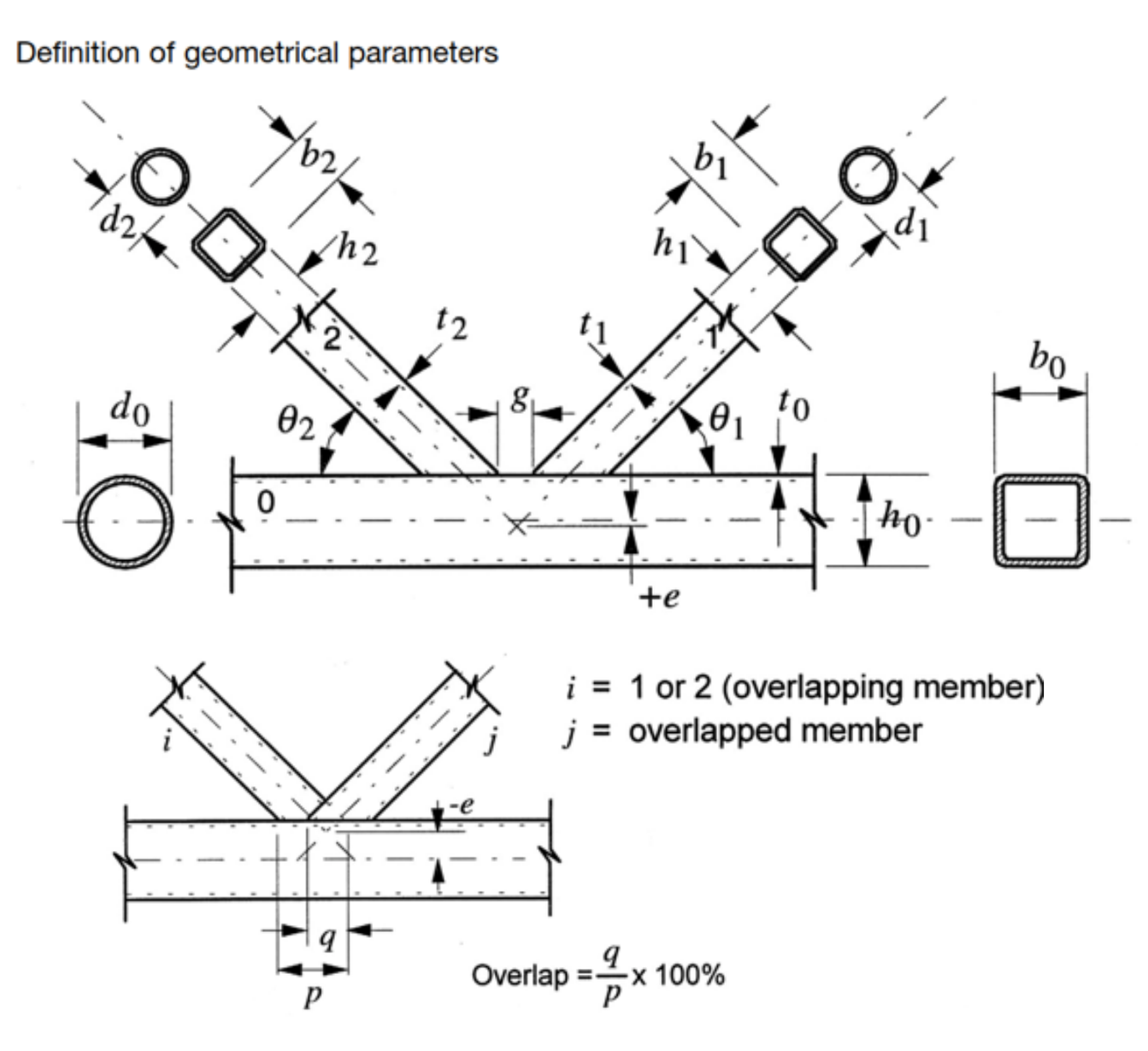
Brace Total

$$\begin{aligned} \sigma_{brace} &= \sigma_{braceP} + \sigma_{braceM_{op}} \\ &= 11.795\ MPa + 13.312\ MPa \\ &= 25.107\ MPa \end{aligned}$$

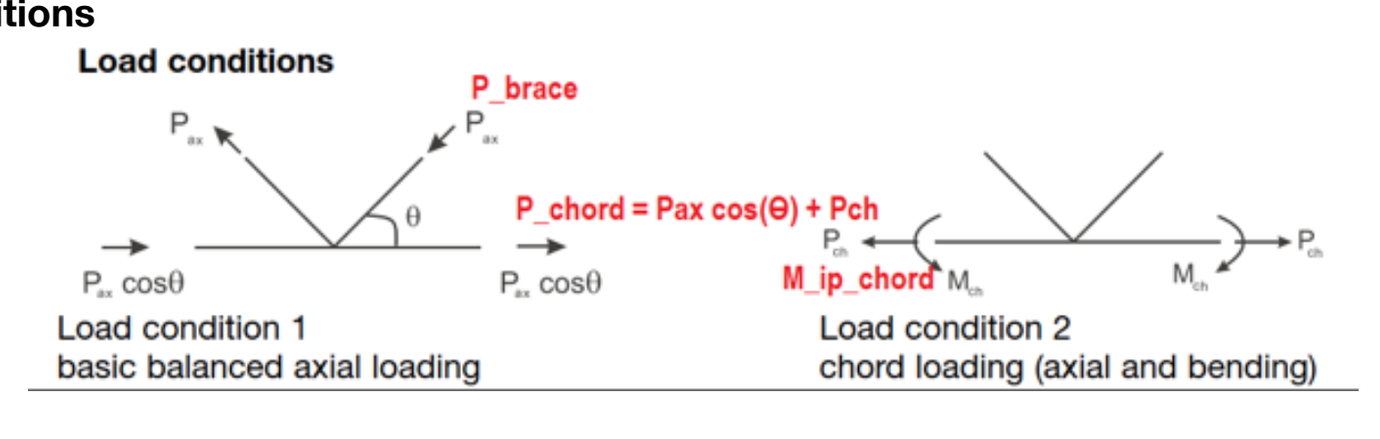
```
Sigma_brace capacity:
Check 25107040.62 <= 24300000.0
Util = 1.03
FAIL
```

RELEVANT CLAUSES

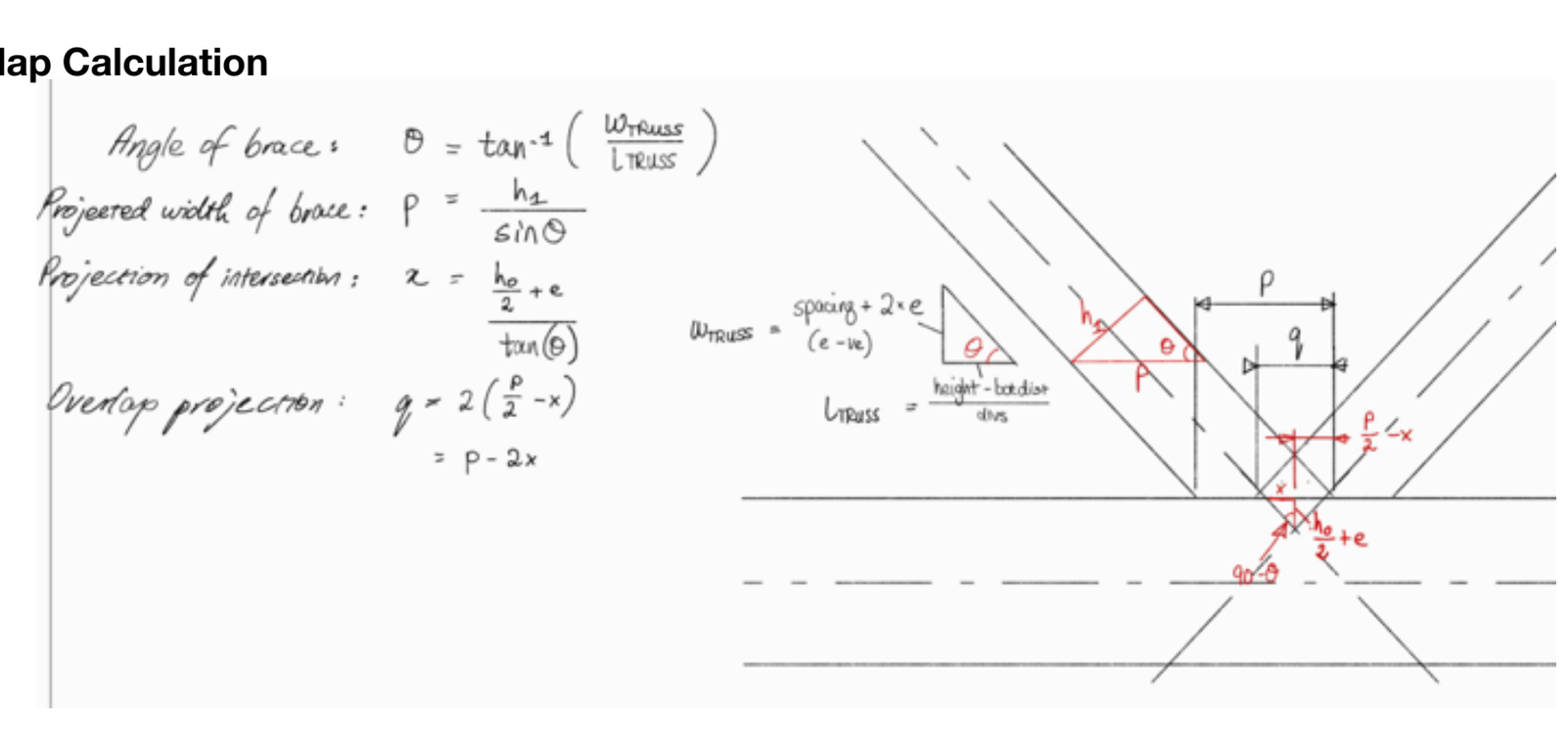
Excerpt 1: Notation



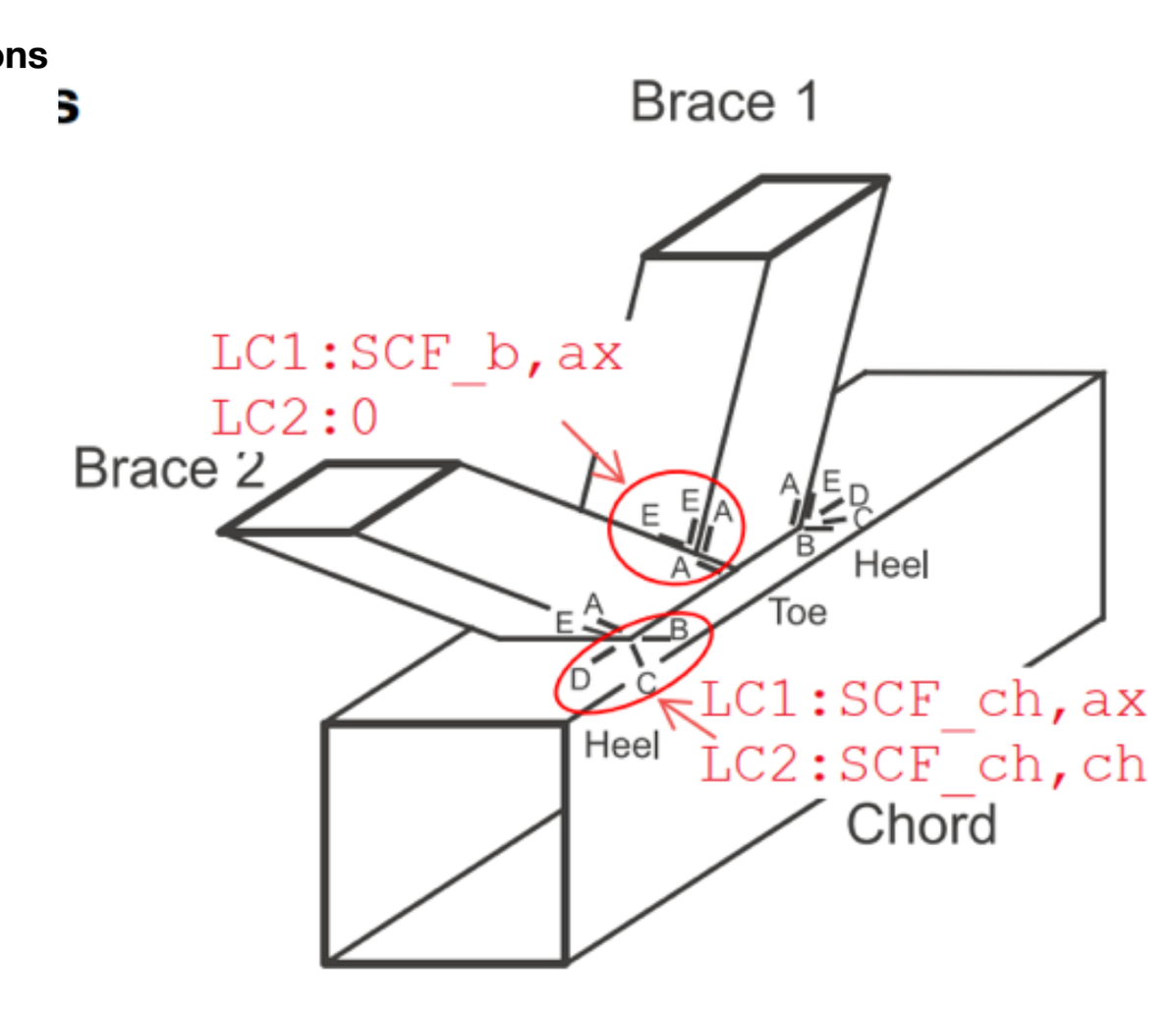
Excerpt 2: Load Conditions



Excerpt 3: Overlap Calculation



Excerpt 4: E.3 SCF Locations



SUMMARY

Geometry Check Summary

```
beta:
Check 0.86 <= 1
Util = 0.86
Check 0.86 >= 0.35
Util = 0.41
PASS

2*gamma:
Check 17.50 <= 35
Util = 0.50
Check 17.50 >= 10
Util = 0.57
PASS

tau:
Check 0.80 <= 1.0
Util = 0.80
Check 0.80 >= 0.35
Util = 0.44
PASS

theta:
Check 49.88 <= 60
Util = 0.83
Check 49.88 >= 30
Util = 0.60
PASS

Ov:
Check 0.72 <= 1.0
Util = 0.72
Check 0.72 >= 0.5
Util = 0.69
PASS

e/h0:
Check -0.31 <= 0.25
Check -0.31 >= -0.55
PASS
```

Stress Check Summary

```
Sigma_chord capacity:
Check 23694948.19 <= 24300000.0
Util = 0.98
PASS

Sigma_brace capacity:
Check 25107040.62 <= 24300000.0
Util = 1.03
FAIL
```