STANDARDS

The calculations are carried out in accordance with:


For all NDPs (Nationally Determined Parameter) in the Eurocodes the recommended values are used.

NDP’s are as follows:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\gamma_1$</th>
<th>$\gamma_2$</th>
<th>$\alpha_{ct}$</th>
<th>$\alpha_{ct}$</th>
<th>$c_{Rd,c}$</th>
<th>$v_{\min}$</th>
<th>$k_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended value</td>
<td>1.5</td>
<td>1.15</td>
<td>1.0</td>
<td>1.0</td>
<td>0.12</td>
<td>0.035$f_{ck}^{1/2}$</td>
<td>0.15</td>
</tr>
</tbody>
</table>

**Table 1: NDP-s in EC-2.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\gamma_{M0}$</th>
<th>$\gamma_{M1}$</th>
<th>$\gamma_{M2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended value</td>
<td>1.0</td>
<td>1.0</td>
<td>1.25</td>
</tr>
</tbody>
</table>

**Table 2: NDP-s in EC-3.**

QUALITIES

Concrete grade C35/45:

- $f_{ck} = 35.0$ MPa
- $f_{cd} = \alpha_{ct} f_{ck}/\gamma_1 = 1.35/1.5 = 23.3$ MPa
- $f_{ct} = \alpha_{ct} f_{ck,0.05}/\gamma_1 = 1.20/1.5 = 1.46$ MPa
- $f_{bd} = 2.25 \eta_1 \eta_2 f_{ctd} = 2.25 \times 0.7 \times 1.0 = 2.3$ MPa

- $\eta_1$ is a coefficient related to the quality of the bond condition and the position of the bar during concreting
  - 1.0 for condition of good bond
  - 0.7 for all other cases and for bars in structural elements built with slipforms

- $\eta_2$ is related to bar diameter
  - 1.0 for $\phi \leq 40$ mm (NDP)
  - $(140 - \phi)/100$ for $\phi > 40$ mm

$\eta_1 = 0.7$ coefficient related to bond condition
$\eta_2 = 1.0$ coefficient related to bar diameter

$D_{lb} = 0.5 \text{ in} = 12.7 \text{ mm}$ Use #4 Rebar

$F_{bd} = 2.25 \eta_1 \eta_2 f_{ctd} = 335.037$ psi Design Bond Stress
Reinforcement B500C:
\[ f_{yd} = \frac{f_y}{\gamma_s} = \frac{500}{1.15} = 435 \text{ MPa} \]
\[ f_{yd} := \frac{500 \text{ MPa}}{1.15} = 63059.886 \text{ psi} \]
Design Yield Strength of Reinforcement

Structural steel S355:
Tension: \[ f_{yd} = \frac{f_y}{\gamma_{md}} = \frac{355}{1.0} = 355 \text{ MPa} \]
Compression: \[ f_{yd} = \frac{f_y}{\gamma_{md}} = \frac{355}{1.0} = 355 \text{ MPa} \]
Shear: \[ f_{sd} = \frac{f_y}{[\gamma_{md}V_3]} = \frac{355}{(1.0\cdot V_3)} = 205 \text{ MPa} \]
\[ f_{yd,ts} := \frac{355 \text{ MPa}}{1.0} = 51488.397 \text{ psi} \]
Design Tension Stress of Tube Steel
\[ f_{yd,ts} := \frac{355 \text{ MPa}}{1.0} = 51488.397 \text{ psi} \]
Design Compression Stress of Tube Steel
\[ f_{sd,ts} := \frac{355 \text{ MPa}}{1.0\cdot V_3} = 29726.84 \text{ psi} \]
Design Shear Stress of Tube Steel

**DIMENSIONS**

Inner tube: HUP 100x50x6, Cold formed, S355
Outer tube: HUP 120x60x4, Cold formed, S355

**LOADS**

Vertical ultimate limit state load = \( F_V = 100 \text{kN} \).
\[ F_V := 100 \text{kN} = 22.481 \text{ kip} \]
**F_v** = External force on the inner tube

\( R_{1i}, R_{2i} \) = Internal forces between the inner and outer tubes.  
\( R_1, R_2, R_3 \) = Support reaction forces the outer tube.

g = distance to the middle plane of the anchoring stirrups in front of the unit.

---

**Equilibrium equations of the inner tube:**

1): \( \sum M = 0 \):  
\[ F_v(L_1-b-e) - R_{1i}(L_1-b-a-g-e) = 0 \]

2): \( \sum F_y = 0 \):  
\[ F_v - R_{1i} + R_{2i} = 0 \]

**Assuming Nominal Values:**

\[
\begin{align*}
L_1 & = 295 \text{ mm} & a & = 75 \text{ mm} & b & = 35 \text{ mm} & g & = 40 \text{ mm} & e & = 10 \text{ mm} \\
L_1 & = 11.614 \text{ in} & a & = 2.953 \text{ in} & b & = 1.378 \text{ in} & g & = 1.575 \text{ in} & e & = 0.394 \text{ in}
\end{align*}
\]

**Results:**

\[
\begin{align*}
R_{1i} & = \frac{100 kN \cdot (295 - 35 - 10) mm}{(295 - 35 - 75 - 40 - 10) mm} = 185.2 kN \\
R_{2i} & = 185.2 kN - 100 kN = 85.2 kN \\
R_{1i} & = \frac{F_v \cdot (L_1 - b - e)}{(L_1 - b - a - g - e)} \\
R_{2i} & = R_{1i} - F_v
\end{align*}
\]

\[
\begin{align*}
R_{1i} & = 185.185 \text{ kN} & R_{1i} & = 41.631 \text{ kip} \\
R_{2i} & = 85.185 \text{ kN} & R_{2i} & = 19.15 \text{ kip}
\end{align*}
\]
Exact distribution of forces depends highly on the behavior of the outer tube. Both longitudinal bending stiffness and local transverse bending stiffness in the contact points between the inner and the outer tubes affects the equilibrium. Two situations are considered:

1) Rigid outer tube.

Outer tube rotates as a stiff body. This assumption gives minimum reaction force at $R_{ij}$ and maximum reaction force at $R_2$. $R_3$ becomes zero. (The force $R_3$ will actually be negative, but since no reinforcement to take the negative forces is included at this position, it is assumed to be zero.)

Equilibrium equations of the outer tube:

1): $\sum M=0$: $$ (R_{11} - R_1) \cdot (L - 3\text{-}g\cdot d) - (R_{21} - R_3) \cdot (L - 3\text{-}g\cdot c\cdot d) = 0$$

2): $\sum F_y=0$: $$ R_2 + R_3 + R_{11} - R_{21} = 0$$

Assuming Nominal Values:

$L := 348 \text{ mm}$ $c := L_1 - b - a - g - e = 135 \text{ mm}$ $g := 40 \text{ mm}$ $e := 10 \text{ mm}$ $d := 10 \text{ mm}$

$L = 13.701 \text{ in}$ $c = 5.315 \text{ in}$ $g = 1.575 \text{ in}$ $e = 0.394 \text{ in}$ $d = 0.394 \text{ in}$

Assume $R_{31} := 0 \text{ kip}$ per discussion above

$$(185.2 - R_1) \cdot (348 - 3 - 40 - 10) - (85.2 - 0) \cdot (348 - 3 - 40 - 135 - 10) = 0$$

$54634 - 295R_1 - 13632 = 0$

$R_1 = \frac{41002}{295} = 139 \text{ kN}$

Given

$$(R_{11} - R_1) \cdot (L - 3\text{-}g\cdot d) - (R_{21} - R_3) \cdot (L - 3\text{-}g\cdot c\cdot d) = 0$$

$R_{11} := \text{Find}(R_{11})$ $R_{11} = 138.983 \text{ kN}$ $R_{11} = 31.245 \text{ kip}$

$$R_2 = R_1 + R_{21} - R_{11} - R_3 = 139 + 85.2 - 185.2 = 39 \text{ kN}$$

$$R_{21} := R_{11} + R_{21} - R_{11} - R_3$$ $R_{21} = 38.983 \text{ kN}$ $R_{21} = 8.764 \text{ kip}$
2) Outer tube without bending stiffness. No forces transferred to outer tube at the back of inner tube.

This assumption gives maximum reaction forces $R_1$ and $R_3$. $R_2$ becomes zero. The forces follow directly from the assumption: $R_2 = R_3 = R_{12}$ and $R_2 = 0$

$$R_1 = 185.2 \text{kN}$$

$$R_2 = 0 \text{kN}$$

$$R_3 = 85.2 \text{kN}$$

$$R_{12} = R_{11} \quad R_{12} = 185.185 \text{kN} \quad R_{12} = 41.631 \text{kip}$$

$$R_{22} = 0 \text{kip}$$

$$R_{32} = R_{21} \quad R_{32} = 85.185 \text{kN} \quad R_{32} = 19.15 \text{kip}$$

The magnitude of the forces will be somewhere in between the two limits, and the prescribed reinforcement ensures integrity for both situations. Reinforcement is to be located at the assumed attack point for support reactions.

**Use Maximum Reactions considering both assumptions**

$$R_1 := \max(R_1) \quad R_1 = 185.185 \text{kN} \quad R_1 = 41.631 \text{kip}$$

$$R_2 := \max(R_2) \quad R_2 = 38.983 \text{kN} \quad R_2 = 8.764 \text{kip}$$

$$R_3 := \max(R_3) \quad R_3 = 85.185 \text{kN} \quad R_3 = 19.15 \text{kip}$$

**Reinforcement Necessary to anchor the unit to concrete**

**Eurocode Equations**

Reinforcement for $R_1 = 185.185 \text{kN}$

Reinforcement $R_1$: $A_{s1} = R_1 / f_{yd} = 185.2 \text{kN} / 435 \text{MPa} = 426 \text{ mm}^2$

Select 2-Ø12 = 2x2x113 =452 mm$^2$

Capacity selected reinforcement: $R = 452 \text{ mm}^2 \cdot 435 \text{ MPa} = 196.6 \text{kN}$

$$A_{s1} = \frac{R_1}{f_{yd}} \quad A_{s1} = 425.926 \text{ mm}^2$$

**Bar Size**

$$N_{reqd} := \left\lceil \frac{A_{s1}}{A_{sb\text{ metric size metric}}} \right\rceil$$

$$N_{reqd} = 2$$

**Bars Required**

$$N_{reqd} \left( A_{sb\text{ metric size metric}} \cdot 2 \cdot f_{yd} \right) = 196.522 \text{ kN}$$

**Capacity of Supplied Reinforcing**

TSS101.xmcd
Reinforcement Design for RVK 101

Reinforcement for $R_3 = 85.185 \text{kN}$

Reinforcement $R_3$: $A_3 = \frac{R_3}{f_yd} = 85.2 \text{kN}/435 \text{MPa} = 196 \text{mm}^2$

Select $\varnothing 12 = 1\times2\times113 = 226 \text{mm}^2$

Capacity selected reinforcement: $R = 226 \text{ mm}^2 \cdot 435 \text{MPa} = 98.3 \text{kN}$

$$A_3 = \frac{R_3}{f_yd} = 195.926 \text{ mm}^2 \quad \text{Bar Size} \quad \text{size:metric} := 12$$

Bars Required

$$N_{reqd} := \text{ceil} \left( \frac{A_3}{A_{\text{bar,metric size:metric}}} \right)$$

$$N_{reqd} = 1$$

Capacity of Supplied Reinforcing

$$N_{reqd} \left( A_{\text{bar,metric size:metric}} \right)^2 f_yd = 98.261 \text{kN}$$

Reinforcement for $R_2 = 38.983 \text{kN}$

Reinforcement $R_2$: $A_2 = \frac{R_2}{f_yd} = 39 \text{kN}/435 \text{MPa} = 89 \text{ mm}^2$

Select $\varnothing 12 = 1\times2\times113 = 226 \text{ mm}^2$

Capacity selected reinforcement: $R = 226 \text{ mm}^2 \cdot 435 \text{MPa} = 98.3 \text{kN}$

$$A_2 = \frac{R_2}{f_yd} = 89.661 \text{ mm}^2 \quad \text{Bar Size} \quad \text{size:metric} := 12$$

Bars Required

$$N_{reqd} := \text{ceil} \left( \frac{A_2}{A_{\text{bar,metric size:metric}}} \right)$$

$$N_{reqd} = 1$$

Capacity of Supplied Reinforcing

$$N_{reqd} \left( A_{\text{bar,metric size:metric}} \right)^2 f_yd = 98.261 \text{kN}$$

US equivalent Equations

Reinforcement for $R_1 = 41.631 \text{ kip}$

Rebar Yield Strength $f_y := 60 \text{ ksi}$

Strength Reduction Factor for rebar in tension $\phi_t := 0.9$

$$A_1 = \frac{R_1}{\phi_t f_y} = 0.771 \text{ in}^2 \quad \text{Bar Size} \quad \text{size} := 4$$

Bars Required

$$N_{reqd} := \text{ceil} \left( \frac{A_1}{A_{\text{bar size}}} \right)$$

$$N_{reqd} = 2$$

Capacity of Supplied Reinforcing

$$N_{reqd} \left( A_{\text{bar size}} \right)^2 \phi_t f_y = 43.2 \text{ kip}$$

Reinforcement for $R_3 = 19.15 \text{ kip}$

Rebar Yield Strength $f_y := 60 \text{ ksi}$

Strength Reduction Factor for rebar in tension $\phi_t := 0.9$

$$A_3 = \frac{R_3}{\phi_t f_y} = 0.355 \text{ in}^2 \quad \text{Bar Size} \quad \text{size} := 4$$

Bars Required

$$N_{reqd} := \text{ceil} \left( \frac{A_3}{A_{\text{bar size}}} \right)$$

$$N_{reqd} = 1$$

Capacity of Supplied Reinforcing

$$N_{reqd} \left( A_{\text{bar size}} \right)^2 \phi_t f_y = 21.6 \text{ kip}$$

Reinforcement for $R_2 = 8.764 \text{ kip}$

Rebar Yield Strength $f_y := 60 \text{ ksi}$

Strength Reduction Factor for rebar in tension $\phi_t := 0.9$

$$A_2 = \frac{R_2}{\phi_t f_y} = 0.162 \text{ in}^2 \quad \text{Bar Size} \quad \text{size} := 4$$

Bars Required

$$N_{reqd} := \text{ceil} \left( \frac{A_2}{A_{\text{bar size}}} \right)$$

$$N_{reqd} = 1$$

Capacity of Supplied Reinforcing

$$N_{reqd} \left( A_{\text{bar size}} \right)^2 \phi_t f_y = 21.6 \text{ kip}$$
Width \( W_{\text{inTube}} := 100 \text{ mm} \)

Height \( H_{\text{inTube}} := 50 \text{ mm} \)

Tube Steel Yield Strength \( F_{yts} := 50 \text{ ksi} \)

**Eurocode Equations**

**Shear Capacity of Tube Steel**

**Ultimate Shear**

\[
\phi V_{ts} := f_{yd,ts} \cdot 2 \cdot t_{in} \cdot (d_{in})
\]

\( F_v = 100 \text{ kN} \)

\( F_v = 22.481 \text{ kip} \)

**Moment Capacity of Tube Steel**

**Ultimate Moment @ Location of zero shear**

\[
\text{ZeroShear} = \text{root}\left( \frac{V_u}{X} \right), \text{ZeroShear} = 4.654 \text{ in} \quad \text{M}_{u,\text{zero}} := \left| M_u(\text{ZeroShear}) \right| \quad \text{M}_{u,\text{zero}} = 85.498 \text{ in kip}
\]

**Supplied Plastic Section Modulus**

\( Z_{\text{supplied}} = 29200 \text{ mm}^3 \)

\( Z_{\text{supplied}} = 1.782 \text{ in}^3 \)

\( \phi M_p := f_{yd,ts} \cdot Z_{\text{supplied}} \)

\( \phi M_p = 91.747 \text{ in kip} \)
US equivalent Equations

Shear Capacity of Tube Steel

Ultimate Shear

\[ F_v = 22.481 \text{ kip} \]
\[ F_v = 100 \text{ kN} \]
\[ F_v = 22.481 \text{ kip} \]

\[ \phi V_{ts} = 0.9 \cdot 0.6 \cdot F_{yts} \cdot 2 \cdot t_{in} \]
\[ \phi V_{ts} = 111.695 \text{ kN} \]
\[ \phi V_{ts} = 25.11 \text{ kip} \]

Moment Capacity of Tube Steel

Ultimate Moment @ Location of zero shear

\[ M_{u, \text{zero}} = |M_d(\text{ZeroShear})| \]
\[ M_{u, \text{zero}} = 85.498 \text{ in-kip} \]

Supplied Plastic Section Modulus

\[ Z_{supplied} = 1.782 \text{ in}^3 \]
\[ \phi M_p = 0.9 \cdot F_{yts} \cdot Z_{supplied} \]
\[ \phi M_p = 80.185 \text{ in-kip} \]

Plastic Section Modulus not satisfied for US Code Equivalent, reduce Design Strength to

\[ F_v = 21.3 \text{ kip} \]

Moment Capacity of Tube Steel

Ultimate Moment @ Location of zero shear

\[ M_{u, \text{zero}} = |M_d(\text{ZeroShear})| \]
\[ M_{u, \text{zero}} = 80.056 \text{ in-kip} \]

Supplied Plastic Section Modulus

\[ Z_{supplied} = 1.782 \text{ in}^3 \]
\[ \phi M_p = 0.9 \cdot F_{yts} \cdot Z_{supplied} \]
\[ \phi M_p = 80.185 \text{ in-kip} \]

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