Input data:

Input data

Geometry - Concrete

$btop := 590$ $htop := 140$

$ytop := \frac{htop}{2} = 70$

$Itop := \frac{btop \cdot htop^{3}}{12} = 1,3491 \cdot 10^{8}$ $Wtop := \frac{btop \cdot htop^{2}}{6} = 1,9273 \cdot 10^{6}$

$Atop := btop \cdot htop = 82600$

Material - Concrete - C20/25

$Etop := 24900$ $Gtop := 13000000000$ $fck := 20$

Geometry - Timber

$bbot := 590$ $hbot := 20$

$Abot := bbot \cdot hbot = 11800$ $dl := 40$

$Ibot := \frac{bbot \cdot hbot^{3}}{12} = 3,9333 \cdot 10^{5}$

$ybot := \frac{hbot}{2} + dl = 50$

Material - Timber - C24

$Em0 := 11000$

$Ebot := Em0$ $Gbot := 690000000$ $Ebotinf := Eminf$

Material - connections

$Econ := 11000$ $Gcon := 690000000$

Geometry - connections

$lef := 100$

Reinforcement

$ds := 8$ $nb := 6$

$As1 := nb \cdot \pi \cdot \frac{ds^{2}}{4} = 301,5929$ $d1 := htop - \frac{ds}{2} = 136$

$Kser := 850000$ $d2 := 50$

$Ku := 570000$

$bconser := \sqrt[4]{\frac{12 \cdot Kser \cdot \left(\left(ytop \right)^{3} + \left(ybot \right)^{3} \right)}{3 \cdot Econ}} = 109,6688$

$hconser := bconser$ $Iconser := \frac{bconser^{4}}{12}$ $Aconser := bconser^{2}$

Span length

$Lt := 5000$ $nEdof := 6$ $dtb := ytop + ybot = 120$

$qser := -1$

$ks := 1,2$

Rod position

$nn := 5$

connection distance $d := \frac{Lt}{nn} = 1000$

$nPN := nn + 1$ $nPE := nPN - 1$

Define connector position

$$conns := \begin{bmatrix} 1000 \\ 2000 \\ 3000 \\ 4000 \end{bmatrix}$$

MOMENT-CURVATURE

Concrete C20/25 $fcm := 28$ $fck := 20$ $\alpha c := 0,85$ $\gamma c := 1,5$

$Ecm := 30000$ $fctk := 1,5$ $Ec := 24900$ $fctm := 2,2$

$\varepsilon c1 := 0,002$ $\varepsilon cu := 0,0035$ $fctd := \frac{fctk}{\gamma c} = 1$ $fcd := \alpha c \cdot \frac{fck}{\gamma c} = 11,3333$

Steel $fyk := 450$ $\gamma s := 1,15$ $Es := 200000$

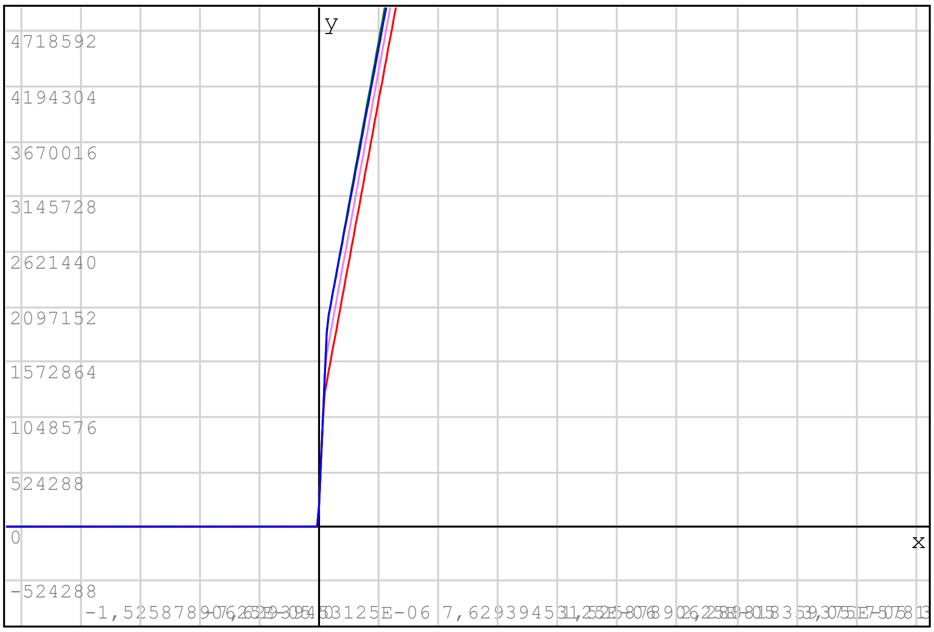
$fyd := \frac{fyk}{\gamma s} = 391,3043$ $\varepsilon e := \frac{fyd}{Es} = 0,002$

$$M(\chi ; N ; yn) := \left| \begin{array}{l} x1 := \frac{As1 \cdot fyd + N}{0,8 \cdot btop \cdot fcd} \\ z := d1 - \frac{x1}{3} \\ M1 := \left(As1 \cdot fyd \cdot z + N \cdot \left(yn - \frac{x1}{3} \right) \right) \\ \chi e := \frac{\varepsilon e}{d1 - x1} \\ Mcr := fctd \cdot Wtop + N \cdot \left(yn - \frac{htop}{2} \right) \\ \chi cr := \frac{fctd \cdot Wtop + N \cdot \left(yn - \frac{htop}{2} \right)}{Ec \cdot Itop} \\ \text{if } \left((\chi \geq 0) \wedge (\chi < \chi cr) \right) \end{array} \right.$$

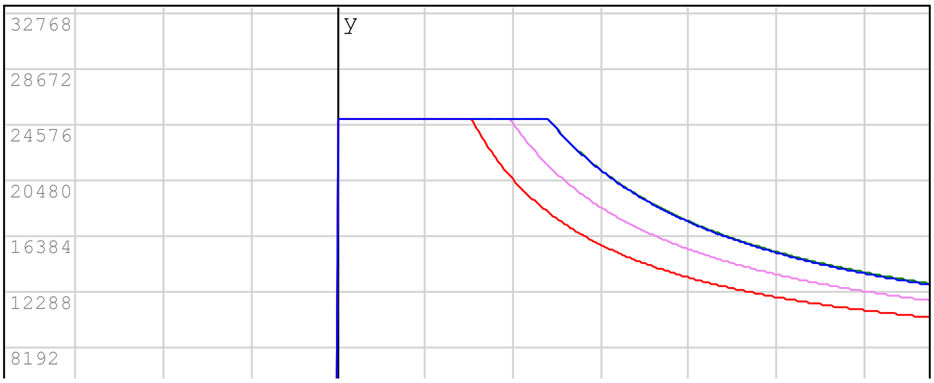
$$\begin{array}{l} \quad \dfrac{Mcr \cdot \chi}{\chi cr} \\ \text{else if } (\chi \geq \chi cr) \wedge (\chi \leq \chi e) \\ \quad Mcr \cdot \left(1 - \dfrac{\chi - \chi cr}{\chi e - \chi cr}\right) + M1 \cdot \dfrac{\chi - \chi cr}{\chi e - \chi cr} \\ \text{else if } \chi > \chi e \\ \quad M1 \\ \text{else} \\ \quad 0 \end{array}$$

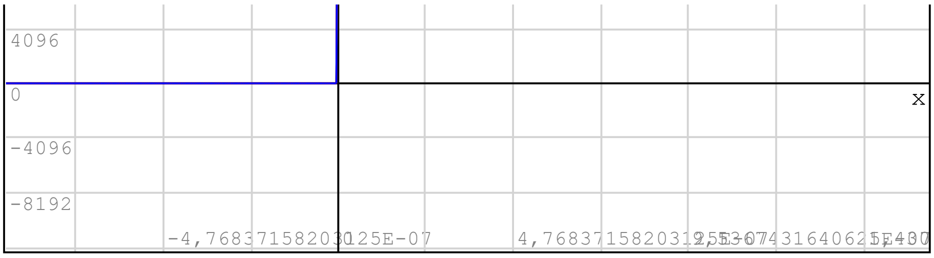
$$E(\chi ; N ; yn) := \frac{M(\chi ; N ; yn)}{\chi \cdot Itop}$$

$$E\left(\frac{fctd \cdot Wtop}{Ec \cdot Itop} ; 0 ; 0\right) = 24900$$



$$\begin{cases} M(x ; 0 ; 0) \\ M(x ; 10000 ; 0) \\ M(x ; 10000 ; ytop) \\ M\left(x ; 10000 ; \dfrac{ytop}{2}\right) \end{cases}$$





$$\begin{cases} E(x;0;0) \\ E(x;10000;0) \\ E(x;10000;ytop) \\ E\left(x;10000;\dfrac{ytop}{2}\right) \end{cases}$$

⊞— Stiffness matrix for a 1D finite element with shear deformation (Timoshenko)

⊞— Stiffness matrix for a 1D finite element with left internal hinge (Timoshenko)

⊞— Stiffness matrix for a 1D finite element with right internal hinge (Timoshenko)

⊟— Nodes - basic structure

$Nodes := \mathrm{matrix}(3 \cdot nPN; 5)$

for $\mathrm{i} \in [1..(nPN)]$

$$\left| \begin{array}{l} Nodes_{\mathrm{i}\,1} := (\mathrm{i}-1) \cdot d \\ Nodes_{\mathrm{i}\,3} := 3 \cdot \mathrm{i} - 2 \\ Nodes_{\mathrm{i}\,4} := 3 \cdot \mathrm{i} - 1 \\ Nodes_{\mathrm{i}\,5} := 3 \cdot \mathrm{i} \end{array} \right.$$

for $\mathrm{i} \in [(nPN+1)..(2 \cdot nPN)]$

$$\left| \begin{array}{l} Nodes_{\mathrm{i}\,1} := (\mathrm{i} - nPN - 1) \cdot d \\ Nodes_{\mathrm{i}\,2} := dtb \\ Nodes_{\mathrm{i}\,3} := 3 \cdot (\mathrm{i}) - 2 \\ Nodes_{\mathrm{i}\,4} := 3 \cdot (\mathrm{i}) - 1 \\ Nodes_{\mathrm{i}\,5} := 3 \cdot (\mathrm{i}) \end{array} \right.$$

for $\mathrm{i} \in [(2 \cdot nPN+1)..(3 \cdot nPN)]$

$$\left| \begin{array}{l} Nodes_{\mathrm{i}\,1} := (\mathrm{i} - 2 \cdot nPN - 1) \cdot d \\ Nodes_{\mathrm{i}\,2} := \dfrac{hbot}{2} + dl \\ Nodes_{\mathrm{i}\,3} := 3 \cdot (\mathrm{i}) - 2 \end{array} \right.$$

$Nodes_{i\,3} := 3\cdot(i)-2$

$Nodes_{i\,4} := 3\cdot(i)-1$

$Nodes_{i\,5} := 3\cdot(i)$

$nNodes := \mathrm{length}(\mathrm{col}(Nodes;1)) = 18$

⊞— Add Nodes - Connectors

⊟— Elements

$nEl := 2\cdot nPE + 2\cdot(nPE+1) = 22$

$$edof := \mathrm{matrix}(nEl;6) = \begin{bmatrix} 0&0&0&0&0&0\\ 0&0&0&0&0&0\\ 0&0&0&0&0&0\\ 0&0&0&0&0&0\\ 0&0&0&0&0&0\\ 0&0&0&0&0&0\\ 0&0&0&0&0&0\\ 0&0&0&0&0&0\\ 0&0&0&0&0&0\\ 0&0&0&0&0&0\\ 0&0&0&0&0&0\\ 0&0&0&0&0&0\\ 0&0&0&0&0&0\\ &&\vdots&&& \end{bmatrix}$$

$edofn := \mathrm{matrix}(nEl;2)$

for $i \in [1..nPE]$
- $edofn_{i\,1} := i$
- $edofn_{i\,2} := i+1$

for $i \in [(nPE+1)..(2\cdot nPE)]$
- $edofn_{i\,1} := i+1$
- $edofn_{i\,2} := i+2$

for $i \in [(2\cdot nPE+1)..(3\cdot nPE+1)]$
- $edofn_{i\,1} := (i-2\cdot nPE)$
- $edofn_{i\,2} := i+2$

for $i \in [(3\cdot nPE+2)..(4\cdot nPE+2)]$
- $edofn_{i\,1} := i-nPE+1$
- $edofn_{i\,2} := i-2\cdot nPE$

$$\begin{bmatrix} 1&2\\ 2&3\\ 3&4\\ 4&5\\ 5&6 \end{bmatrix}$$

$$edofn = \begin{bmatrix} 7 & 8 \\ 8 & 9 \\ 9 & 10 \\ 10 & 11 \\ 11 & 12 \\ 1 & 13 \\ 2 & 14 \\ 3 & 15 \\ 4 & 16 \\ 5 & 17 \\ 6 & 18 \\ 13 & 7 \\ 14 & 8 \\ 15 & 9 \\ 16 & 10 \\ 17 & 11 \\ 18 & 12 \end{bmatrix}$$

for $i \in [1..nEl]$

$$edof_{i\,1} := Nodes_{edofn_{i\,1}\,3}$$
$$edof_{i\,2} := Nodes_{edofn_{i\,1}\,4}$$
$$edof_{i\,3} := Nodes_{edofn_{i\,1}\,5}$$
$$edof_{i\,4} := Nodes_{edofn_{i\,2}\,3}$$
$$edof_{i\,5} := Nodes_{edofn_{i\,2}\,4}$$
$$edof_{i\,6} := Nodes_{edofn_{i\,2}\,5}$$

$$edof = \begin{bmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 4 & 5 & 6 & 7 & 8 & 9 \\ 7 & 8 & 9 & 10 & 11 & 12 \\ 10 & 11 & 12 & 13 & 14 & 15 \\ 13 & 14 & 15 & 16 & 17 & 18 \\ 19 & 20 & 21 & 22 & 23 & 24 \\ 22 & 23 & 24 & 25 & 26 & 27 \\ 25 & 26 & 27 & 28 & 29 & 30 \\ 28 & 29 & 30 & 31 & 32 & 33 \\ 31 & 32 & 33 & 34 & 35 & 36 \\ 1 & 2 & 3 & 37 & 38 & 39 \\ 4 & 5 & 6 & 40 & 41 & 42 \\ 7 & 8 & 9 & 43 & 44 & 45 \\ 10 & 11 & 12 & 46 & 47 & 48 \\ 13 & 14 & 15 & 49 & 50 & 51 \\ 16 & 17 & 18 & 52 & 53 & 54 \\ 37 & 38 & 39 & 19 & 20 & 21 \\ 40 & 41 & 42 & 22 & 23 & 24 \\ 43 & 44 & 45 & 25 & 26 & 27 \\ 46 & 47 & 48 & 28 & 29 & 30 \\ 49 & 50 & 51 & 31 & 32 & 33 \\ 52 & 53 & 54 & 34 & 35 & 36 \end{bmatrix}$$

$nDof := nNodes \cdot 3 = 54$

$Elsle := \mathrm{matrix}(nEl; 11)$

for $i \in [1..nPE]$

$Elsle := Nodes$

$$Elsle_{i\,1} := Nodes_{edofn_{i\,1},\,1}$$
$$Elsle_{i\,2} := Nodes_{edofn_{i\,1},\,2}$$
$$Elsle_{i\,3} := Nodes_{edofn_{i\,2},\,1}$$
$$Elsle_{i\,4} := Nodes_{edofn_{i\,2},\,2}$$
$$Elsle_{i\,5} := Abot$$
$$Elsle_{i\,6} := Ibot$$
$$Elsle_{i\,7} := Ebot$$
$$Elsle_{i\,8} := Gbot$$
$$Elsle_{i\,9} := \text{"nh"}$$
$$Elsle_{i\,10} := 0$$
$$Elsle_{i\,11} := 0$$

for $i \in \left[(nPE+1)..(2 \cdot nPE) \right]$

$$Elsle_{i\,1} := Nodes_{edofn_{i\,1},\,1}$$
$$Elsle_{i\,2} := Nodes_{edofn_{i\,1},\,2}$$
$$Elsle_{i\,3} := Nodes_{edofn_{i\,2},\,1}$$
$$Elsle_{i\,4} := Nodes_{edofn_{i\,2},\,2}$$
$$Elsle_{i\,5} := Atop$$
$$Elsle_{i\,6} := Itop$$
$$Elsle_{i\,7} := Etop$$
$$Elsle_{i\,8} := Gtop$$
$$Elsle_{i\,9} := \text{"nh"}$$
$$Elsle_{i\,10} := 0$$
$$Elsle_{i\,11} := qser$$

for $i \in \left[(2 \cdot nPE+1)..(3 \cdot nPE+1) \right]$

$$Elsle_{i\,1} := Nodes_{edofn_{i\,1},\,1}$$
$$Elsle_{i\,2} := Nodes_{edofn_{i\,1},\,2}$$
$$Elsle_{i\,3} := Nodes_{edofn_{i\,2},\,1}$$
$$Elsle_{i\,4} := Nodes_{edofn_{i\,2},\,2}$$
$$Elsle_{i\,5} := Aconser$$
$$Elsle_{i\,6} := Iconser$$
$$Elsle_{i\,7} := Econ$$
$$Elsle_{i\,8} := Gcon$$
$$Elsle_{i\,9} := \text{"lh"}$$
$$Elsle_{i\,10} := 0$$
$$Elsle_{i\,11} := 0$$

```
i 11
```

```
for i ∈ [(3·nPE+2)..(4·nPE+2)]
    Elsle[i 1 := Nodes[edofn[i 1] 1]
    Elsle[i 2 := Nodes[edofn[i 1] 2]
    Elsle[i 3 := Nodes[edofn[i 2] 1]
    Elsle[i 4 := Nodes[edofn[i 2] 2]
    Elsle[i 5 := Aconser
    Elsle[i 6 := Iconser
    Elsle[i 7 := Econ
    Elsle[i 8 := Gcon
    Elsle[i 9 := "rh"
    Elsle[i 10 := 0
    Elsle[i 11 := 0
```

Set connectors

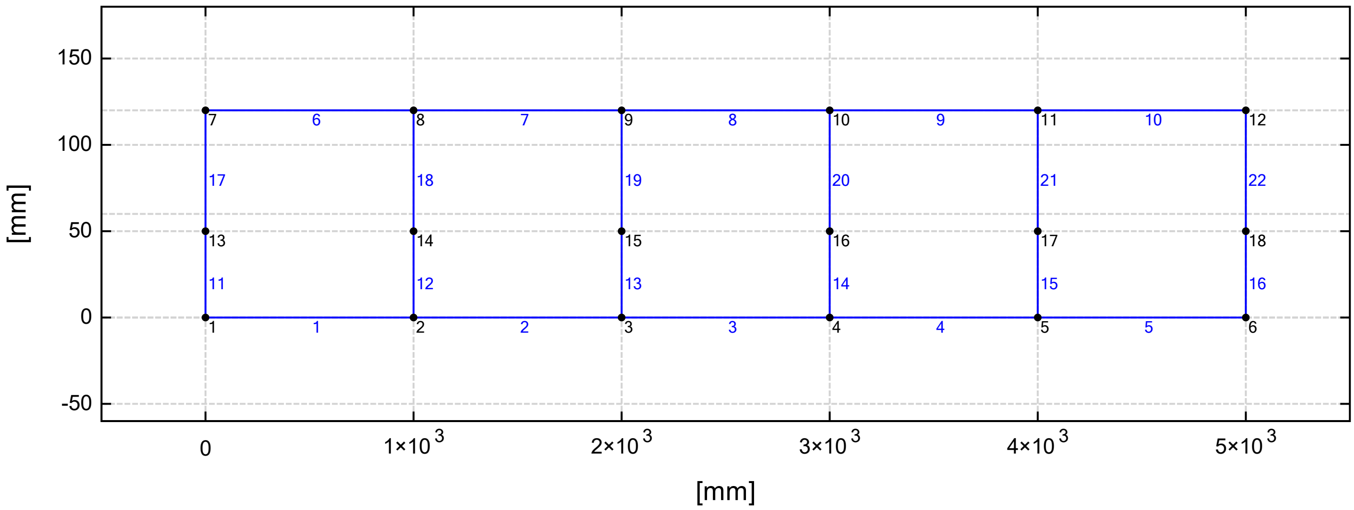
```
for i ∈ [1..(length(conns))]
    for j ∈ [(2·nPE+1)..(3·nPE+2)]
        if (Elsle[j 1 = Elsle[j 3) ∧ (Elsle[j 1 = conns[i)
            Elsle[j 9 := "rh"
    for j ∈ [(3·nPE+2)..(4·nPE+2)]
        if (Elsle[j 1 = Elsle[j 3) ∧ (Elsle[j 1 = conns[i)
            Elsle[j 9 := "nh"
```

Elsle =

0	0	1000	0	11800	$3,9333\cdot10^{5}$	11000	$6,9\cdot10^{8}$	"nh"	0	0
1000	0	2000	0	11800	$3,9333\cdot10^{5}$	11000	$6,9\cdot10^{8}$	"nh"	0	0
2000	0	3000	0	11800	$3,9333\cdot10^{5}$	11000	$6,9\cdot10^{8}$	"nh"	0	0
3000	0	4000	0	11800	$3,9333\cdot10^{5}$	11000	$6,9\cdot10^{8}$	"nh"	0	0
4000	0	5000	0	11800	$3,9333\cdot10^{5}$	11000	$6,9\cdot10^{8}$	"nh"	0	0
0	120	1000	120	82600	$1,3491\cdot10^{8}$	24900	$1,3\cdot10^{10}$	"nh"	0	−1
1000	120	2000	120	82600	$1,3491\cdot10^{8}$	24900	$1,3\cdot10^{10}$	"nh"	0	−1
2000	120	3000	120	82600	$1,3491\cdot10^{8}$	24900	$1,3\cdot10^{10}$	"nh"	0	−1
3000	120	4000	120	82600	$1,3491\cdot10^{8}$	24900	$1,3\cdot10^{10}$	"nh"	0	−1
4000	120	5000	120	82600	$1,3491\cdot10^{8}$	24900	$1,3\cdot10^{10}$	"nh"	0	−1
0	0	0	50	12027,2418	$1,2055\cdot10^{7}$	11000	$6,9\cdot10^{8}$	"lh"	0	0
1000	0	1000	50	12027,2418	$1,2055\cdot10^{7}$	11000	$6,9\cdot10^{8}$	"rh"	0	0
2000	0	2000	50	12027,2418	$1,2055\cdot10^{7}$	11000	$6,9\cdot10^{8}$	"rh"	0	0
3000	0	3000	50	12027,2418	$1,2055\cdot10^{7}$	11000	$6,9\cdot10^{8}$	"rh"	0	0

4000	0	4000	50	12027,2418	$1,2055\cdot10^{7}$	11000	$6,9\cdot10^{8}$	"rh"	0	0
5000	0	5000	50	12027,2418	$1,2055\cdot10^{7}$	11000	$6,9\cdot10^{8}$	"lh"	0	0
0	50	0	120	12027,2418	$1,2055\cdot10^{7}$	11000	$6,9\cdot10^{8}$	"rh"	0	0
1000	50	1000	120	12027,2418	$1,2055\cdot10^{7}$	11000	$6,9\cdot10^{8}$	"nh"	0	0
2000	50	2000	120	12027,2418	$1,2055\cdot10^{7}$	11000	$6,9\cdot10^{8}$	"nh"	0	0
3000	50	3000	120	12027,2418	$1,2055\cdot10^{7}$	11000	$6,9\cdot10^{8}$	"nh"	0	0
4000	50	4000	120	12027,2418	$1,2055\cdot10^{7}$	11000	$6,9\cdot10^{8}$	"nh"	0	0
5000	50	5000	120	12027,2418	$1,2055\cdot10^{7}$	11000	$6,9\cdot10^{8}$	"rh"	0	0

System



Stiffness matrix

```
assemk(KK; K; edofe) := | for i ∈ [1..nEdof]
                        |   for j ∈ [1..nEdof]
                        |     KK[edofe_i, edofe_j] := KK[edofe_i, edofe_j] + K[i j]
                        | KK

assemf(fl; fle; edofe) := | for i ∈ [1..nEdof]
                          |   fl[edofe_i] := fl[edofe_i] + fle_i
                          | fl
```

```
genKsle := | K := matrix(nDof; nDof)
           | for i ∈ [1..nEl]
           |   | if Elsle[i 9] = "nh"
           |   |   KKe := Ke(Elsle[i 1]; Elsle[i 2]; Elsle[i 3]; Elsle[i 4]; Elsle[i 5]; Elsle[i 6]; Elsle[i 7]; Elsle[i 8])
           |   | else
```

```
if Elsle[i 9] = "lh"
  KKe := Kel(Elsle[i 1]; Elsle[i 2]; Elsle[i 3]; Elsle[i 4]; Elsle[i 5]; Elsle[i 6]; Elsle[i 7]; Elsle
else
  KKe := Ker(Elsle[i 1]; Elsle[i 2]; Elsle[i 3]; Elsle[i 4]; Elsle[i 5]; Elsle[i 6]; Elsle[i 7]; Elsle
edofe := edof[[i..i][1..6]]
K := assemk(K; KKe; edofe)
K
```

Boundary conditions (penalty approach)

```
dia(Mat) := | " Diagonal elements "
            | for i ∈ [1..nDof]
            |   dia[i] := Mat[i i]
            | dia
```

```
km := dia(genKsle)
```

$c := \max(km) \cdot 1000000 = 3{,}4451 \cdot 10^{16}$

```
bc := matrix(nDof; 2)
```

```
for i ∈ [1..nDof]
  bc[i 1] := i
```

```
bc[1 2] := 1        bc[2 2] := 1        bc[edof[nPE 5] 2] := 1
```

```
curv0 := 0
```

```
curv1 := 1
```

```
curv := matrix(nPE; 1)
```

```
for i ∈ [1..nPE]
  curv[i 1] := 0,000000001
```

```
for i ∈ [(nPE + 1)..(2·nPE)]
  Elsle[i 1] := Nodes[edofn[i 1] 1]
  Elsle[i 2] := Nodes[edofn[i 1] 2]
  Elsle[i 3] := Nodes[edofn[i 2] 1]
  Elsle[i 4] := Nodes[edofn[i 2] 2]
  Elsle[i 5] := Atop
  Elsle[i 6] := Itop
```

```
Elsle[i 7] := E(curv[i - nPE 1]; 0; 0)
Elsle[i 8] := Gtop
Elsle[i 9] := "nh"
Elsle[i 10] := 0
Elsle[i 11] := - qser
```

```
Kbcsle := genKsle
```

```
for i ∈ [1..nDof]
  if bc[i 2] = 1
    Kbcsle[i i] := Kbcsle[i i] + c
  else
    continue
Kbc
```

⊟ — Loads

```
genFlsle := | fl := matrix(nDof; 1)
            | for i ∈ [1..nEl]
            |   | fle := fle(Elsle[i 1]; Elsle[i 2]; Elsle[i 3]; Elsle[i 4]; Elsle[i 10]; Elsle[i 11])
            |   | edofe := edof[[i..i][1..6]]
```

```
        fl := assemf(fl; fle; edofe)
    fl
```

```
fsle := genFlsle
```

Displacement (system solution)

```
usle := invert(Kbcsle)·fsle
```

Reactions

fsle

Internal forces

```
edsle := matrix(nEl; 6)
```

```
for i ∈ [1..nEl]
  for j ∈ [1..6]
    edsle[i j] := usle[edof[i j]]
```

$$
m(ed) := \left|\begin{array}{l}
b0 := \mathrm{matrix}(1; nEl) \\
b1 := \mathrm{matrix}(1; nEl) \\
\text{for } i \in [1..nEl] \\
\quad \left|\begin{array}{l}
L := \sqrt{\left(Elsle_{i\,3} - Elsle_{i\,1}\right)^2 + \left(Elsle_{i\,4} - Elsle_{i\,2}\right)^2} \\
n0_i := \dfrac{Elsle_{i\,3} - Elsle_{i\,1}}{L} \\
n1_i := \dfrac{Elsle_{i\,4} - Elsle_{i\,2}}{L}
\end{array}\right. \\
m := \mathrm{matrix}(1; nEl) \\
\text{for } i \in [1..nEl] \\
\quad \left|\; m_i := \begin{bmatrix} n0_i & -n1_i & 0 & 0 & 0 & 0 \\ n1_i & n0_i & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & n0_i & -n1_i & 0 \\ 0 & 0 & 0 & n1_i & n0_i & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \cdot \mathrm{submatrix}(ed; i; i; 1; 6)^{T} \right. \\
m
\end{array}\right.
$$

$msle := m(edsle)$

```
M1 := matrix(nEl; 1)
M2 := matrix(nEl; 1)
V1 := matrix(nEl; 1)
V2 := matrix(nEl; 1)
for i ∈ [1..nEl]
    x1 := Elsle_{i 1}
    y1 := Elsle_{i 2}
    x2 := Elsle_{i 3}
    y2 := Elsle_{i 4}
    L := √((x2 − x1)^2 + (y2 − y1)^2)
    A := Elsle_{i 5}
    I := Elsle_{i 6}
    E := Elsle_{i 7}
    G := Elsle_{i 8}
    qx := Elsle_{i 10}
    qy := Elsle_{i 11}
    co := 12/L^2 · (ks·E·I)/(G·A)
    u1 := msle_{1 i 1}
    u2 := msle_{1 i 4}
    v1 := msle_{1 i 2}
    t1 := msle_{1 i 3}
    v2 := msle_{1 i 5}
    t2 := msle_{1 i 6}
    fle := fle(x1; y1; x2; y2; qx; qy)
    if Elsle_{i 9} = "nh"
        M1sle_i := (−((1/(1+co))·(6·E·I/L^2)·v1 + (E/(1+co)·4·I/L·(1 + co/4))·t1 + (−E/(1+co))·6·I/L^2·v2 + ((E/(1+co))·2·I/L·(
        M2sle_i := (1/(1+co))·(6·E·I/L^2)·v1 + (E/(1+co)·2·I/L·(1 − co/2))·t1 + (−E/(1+co))·6·I/L^2·v2 + ((E/(1+co))·4·I/L·(1 + co/4
        V1sle_i := (1/(1+co))·(12·E·I/L^3)·v1 + (E/(1+co)·6·I/L^2)·t1 + (−E/(1+co))·12·I/L^3·v2 + ((E/(1+co))·6·I/L^2)·t2 − fle
        V2sle_i := −((−1/(1+co))·(12·E·I/L^3)·v1 + (−E/(1+co)·6·I/L^2)·t1 + (E/(1+co))·12·I/L^3·v2 + ((−E/(1+co))·6·I/L^2)·t2 − fle
    else
      if Elsle_{i 9} = "lh"
        M1sle_i := fle_2
        M2sle_i := (   6·E·I        +     6·E·I·(co − 2)   )·v1      6·E·I·(co − 2)      ·v2 + ( E·I·(co + 4)       E·I·(
```

$$M2sle_i := \left(\frac{\;}{L^2\cdot(co+1)}+\frac{\;}{L^2\cdot(co+4)\cdot(co+1)}\right)\cdot v1-\frac{\;}{L^2\cdot(co+4)\cdot(co+1)}\cdot v2+\left(\frac{\;}{L\cdot(co+1)}-\frac{\;}{L\cdot(co+\ldots}\right.$$

$$V1sle_i := \left(\frac{12\cdot E\cdot I}{L^3\cdot(co+1)}+\frac{(-36)\cdot E\cdot I}{L^3\cdot(co+4)\cdot(co+1)}\right)\cdot v1+\left(\frac{-12\cdot E\cdot I}{L^3\cdot(co+1)}+\frac{36\cdot E\cdot I}{L^3\cdot(co+4)\cdot(co+1)}\right)\cdot v2+\left(\frac{6\cdot E\ldots}{L^2\cdot(co\ldots}\right.$$

$$V2sle_i := -\left(\left(\frac{-12\cdot E\cdot I}{L^3\cdot(co+1)}+\frac{36\cdot E\cdot I}{L^3\cdot(co+4)\cdot(co+1)}\right)\cdot v1+\left(\frac{12\cdot E\cdot I}{L^3\cdot(co+1)}+\frac{(-36)\cdot E\cdot I}{L^3\cdot(co+4)\cdot(co+1)}\right)\cdot v2+\left(\frac{(-\ldots}{L^2\cdot\ldots}\right.\right.$$

else

$$M1sle_i := -\left(\left(\frac{6\cdot E\cdot I}{L^2\cdot(co+1)}+\frac{6\cdot E\cdot I\cdot(co-2)}{L^2\cdot(co+4)\cdot(co+1)}\right)\cdot v1-\frac{E\cdot I\cdot(co-2)^2}{L\cdot(co+4)\cdot(co+1)}\cdot t1-\left(\frac{6\cdot E\cdot I\cdot(co+4)}{L^2\cdot(co+1)}+\frac{6\ldots}{L^2\cdot(\ldots}\right.\right.$$

$$M2sle_i := fle_5$$

$$V1sle_i := \left(\frac{12\cdot E\cdot I}{L^3\cdot(co+1)}-\frac{36\cdot E\cdot I}{L^3\cdot(co+4)\cdot(co+1)}\right)\cdot v1+\left(\frac{6\cdot E\cdot I}{L^2\cdot(co+1)}+\frac{6\cdot E\cdot I\cdot(co-2)}{L^2\cdot(co+4)\cdot(co+1)}\right)\cdot t1+\left(\frac{-12\ldots}{L^3\cdot(co\ldots}\right.$$

$$V2sle_i := -\left(\left(\frac{-12\cdot E\cdot I}{L^3\cdot(co+1)}+\frac{36\cdot E\cdot I}{L^3\cdot(co+4)\cdot(co+1)}\right)\cdot v1+\left(\frac{12\cdot E\cdot I}{L^3\cdot(co+1)}+\frac{(-36)\cdot E\cdot I}{L^3\cdot(co+4)\cdot(co+1)}\right)\cdot v2+\left(\frac{(-\ldots}{L^2\cdot\ldots}\right.\right.$$

$$N1sle_i := \frac{E\cdot A}{L}\cdot(u1-u2)$$

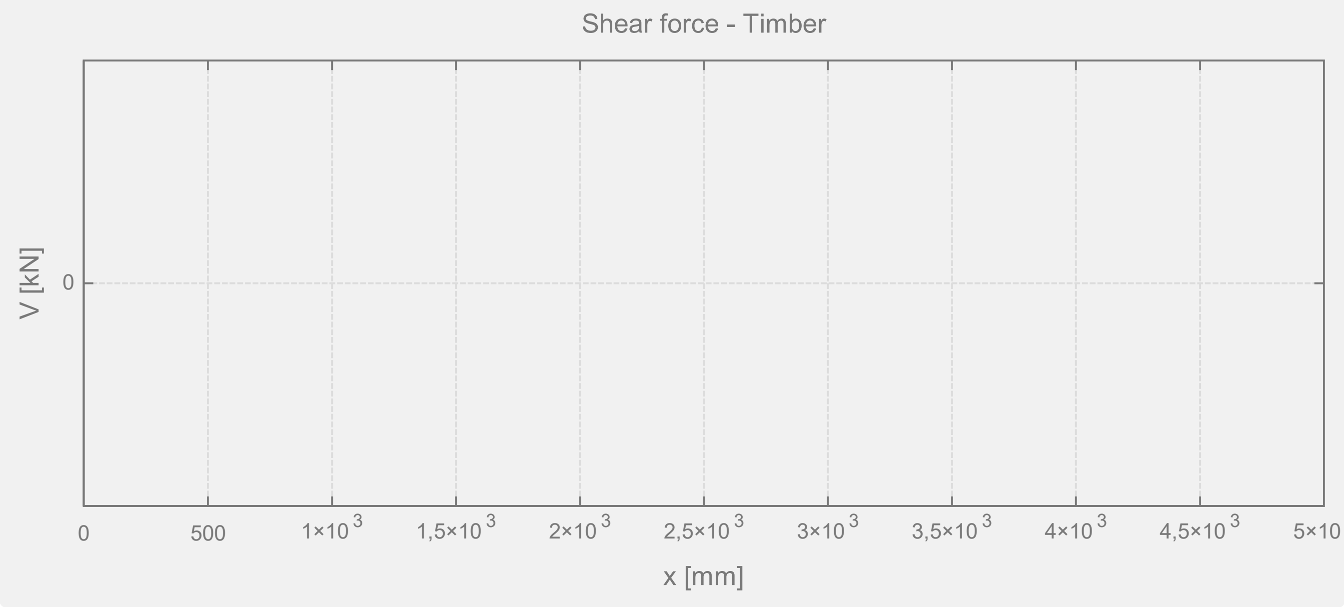
$$N2sle_i := \frac{E\cdot A}{L}\cdot(u1-u2)$$

$$M1sle=\begin{bmatrix}-1{,}3174\cdot10^{-10}\\43334{,}0974\\3265{,}1973\\-36934{,}9241\\-31945{,}4393\\-1{,}6667\cdot10^{5}\\-2{,}0293\cdot10^{6}\\-2{,}8928\cdot10^{6}\\-2{,}9491\cdot10^{6}\\-2{,}1347\cdot10^{6}\\0\\-6{,}5684\cdot10^{7}\\-1{,}1222\cdot10^{7}\\5{,}0355\cdot10^{7}\\1{,}0482\cdot10^{8}\\0\\1{,}1989\cdot10^{7}\\-6{,}9344\cdot10^{-8}\\-4{,}738\cdot10^{-8}\\4{,}7238\cdot10^{-8}\\1{,}2365\cdot10^{-7}\\7{,}9775\cdot10^{6}\end{bmatrix}$$

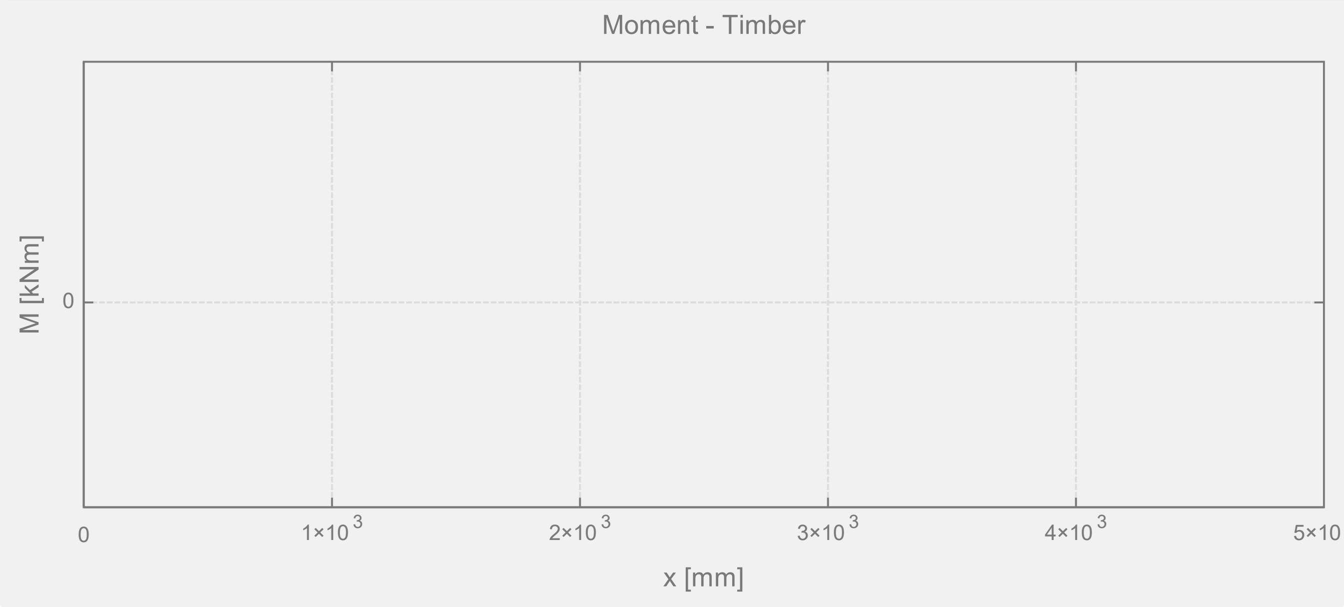
$$M2sle=\begin{bmatrix}-31945{,}4393\\-36934{,}9241\\3265{,}1973\\43334{,}0974\\-2{,}0478\cdot10^{-10}\\-1{,}9681\cdot10^{6}\\-2{,}7824\cdot10^{6}\\-2{,}7261\cdot10^{6}\\-1{,}8627\cdot10^{6}\\-9{,}1509\cdot10^{-8}\\2{,}889\cdot10^{6}\\0\\0\\0\\0\\1{,}0155\cdot10^{7}\\0\\1{,}0539\cdot10^{5}\\56280{,}1699\\-56280{,}1699\\-1{,}0539\cdot10^{5}\\0\end{bmatrix}$$

$$N1sle=\begin{bmatrix}-2{,}787\cdot10^{-9}\\-1505{,}5907\\-2309{,}5932\\-1505{,}5907\\2{,}9209\cdot10^{-10}\\-1{,}0015\cdot10^{-10}\\1505{,}5907\\2309{,}5932\\1505{,}5907\\1{,}4274\cdot10^{-10}\\2468{,}0546\\-48{,}3236\\80{,}269\\80{,}269\\-48{,}3236\\2468{,}0546\\2468{,}0546\\-48{,}3236\\80{,}269\\80{,}269\\-48{,}3236\end{bmatrix}$$

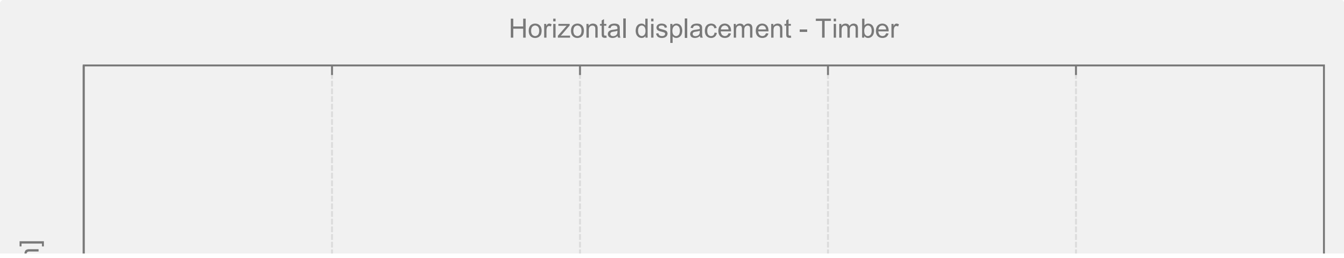
Shear force diagram - Timber

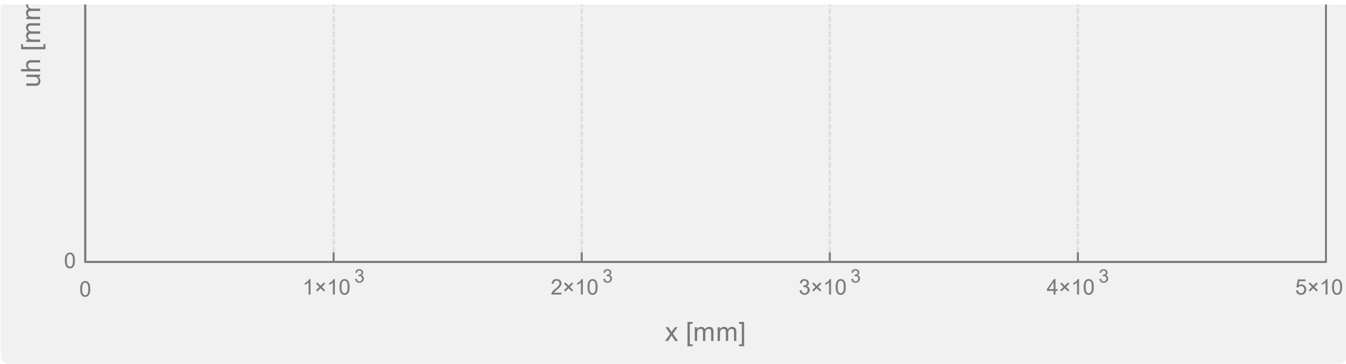


Moment diagram - Timber

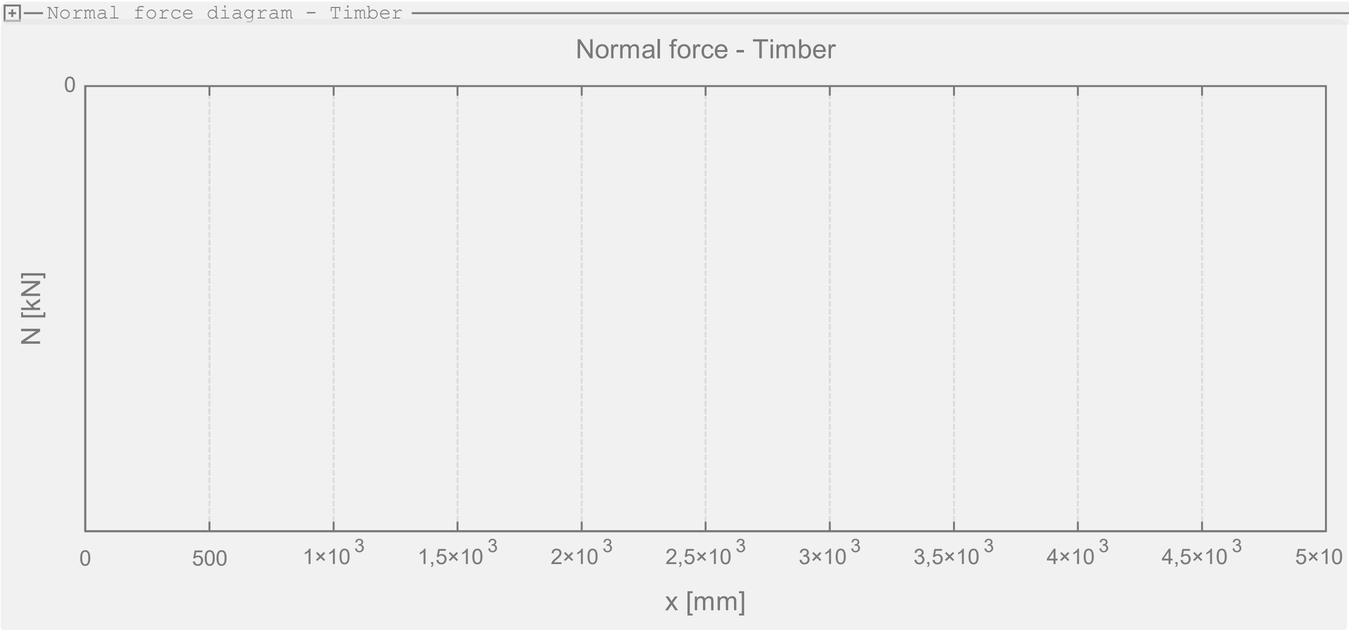


Horizontal displacement - Timber

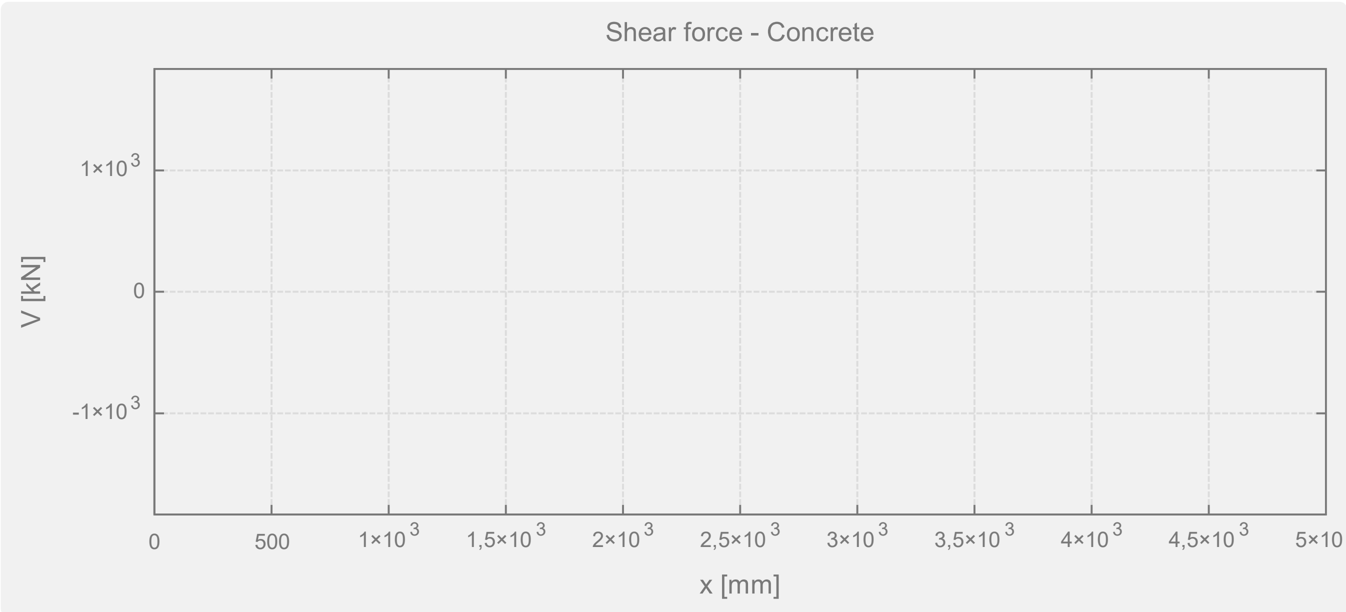




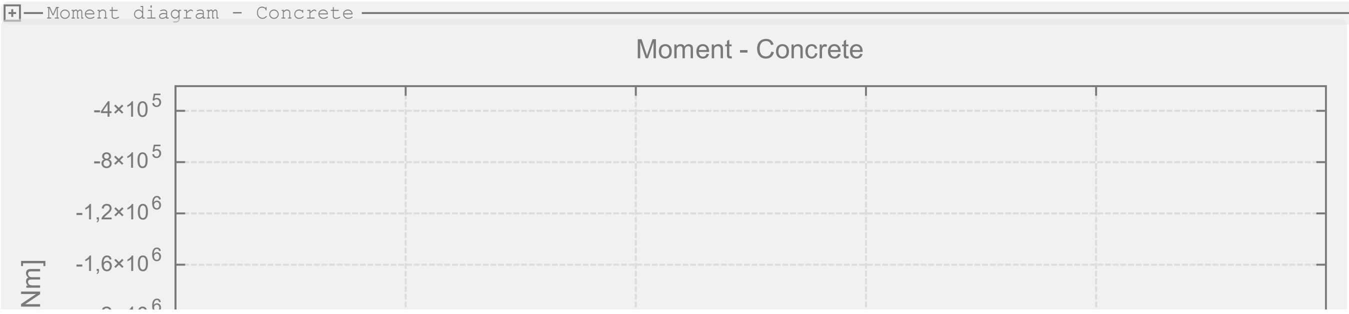
Normal force diagram - Timber

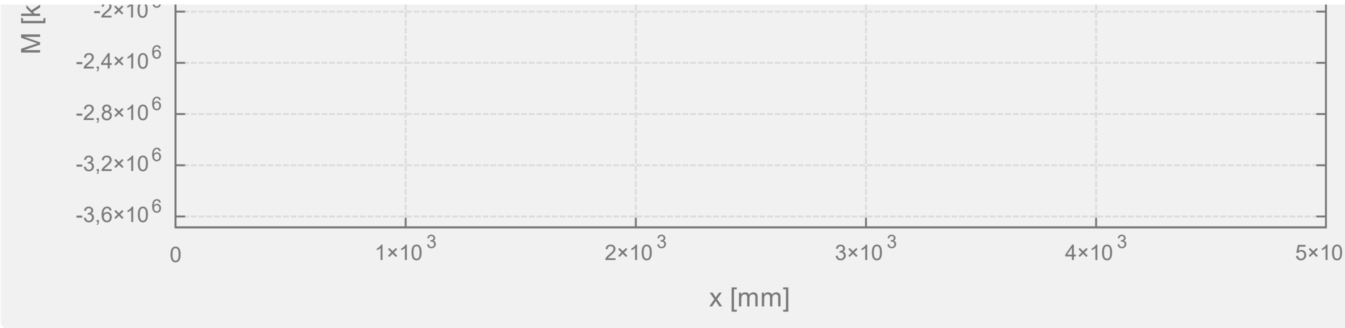


Shear force diagram - Concrete

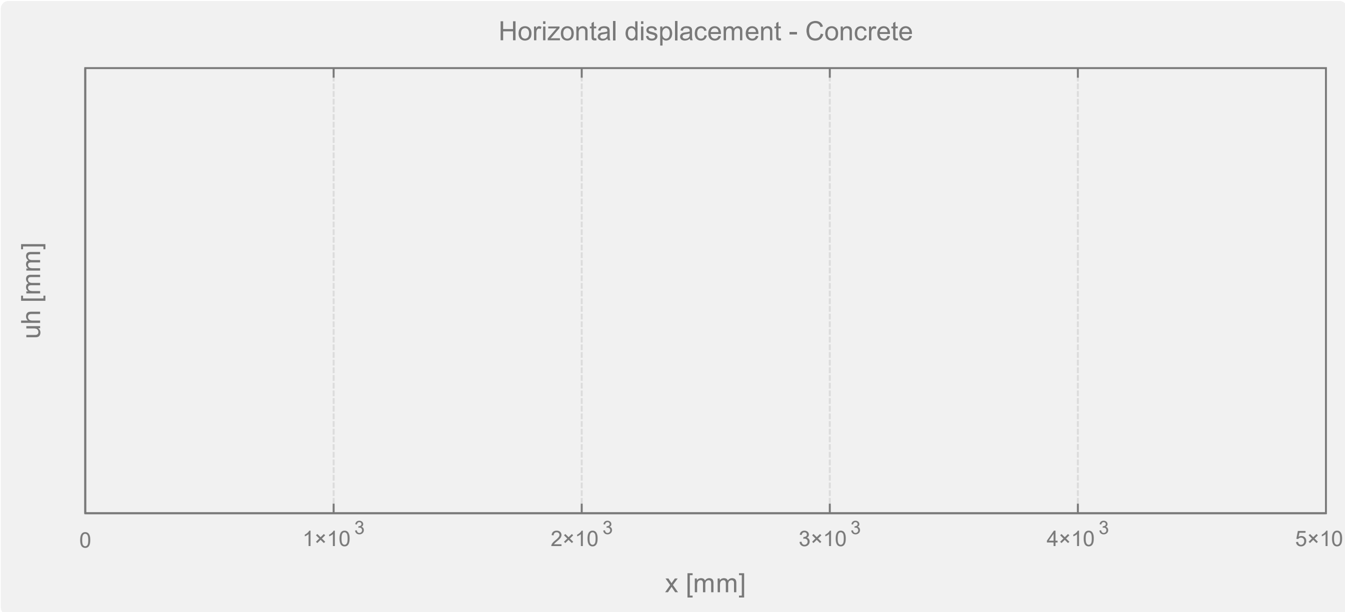


Moment diagram - Concrete

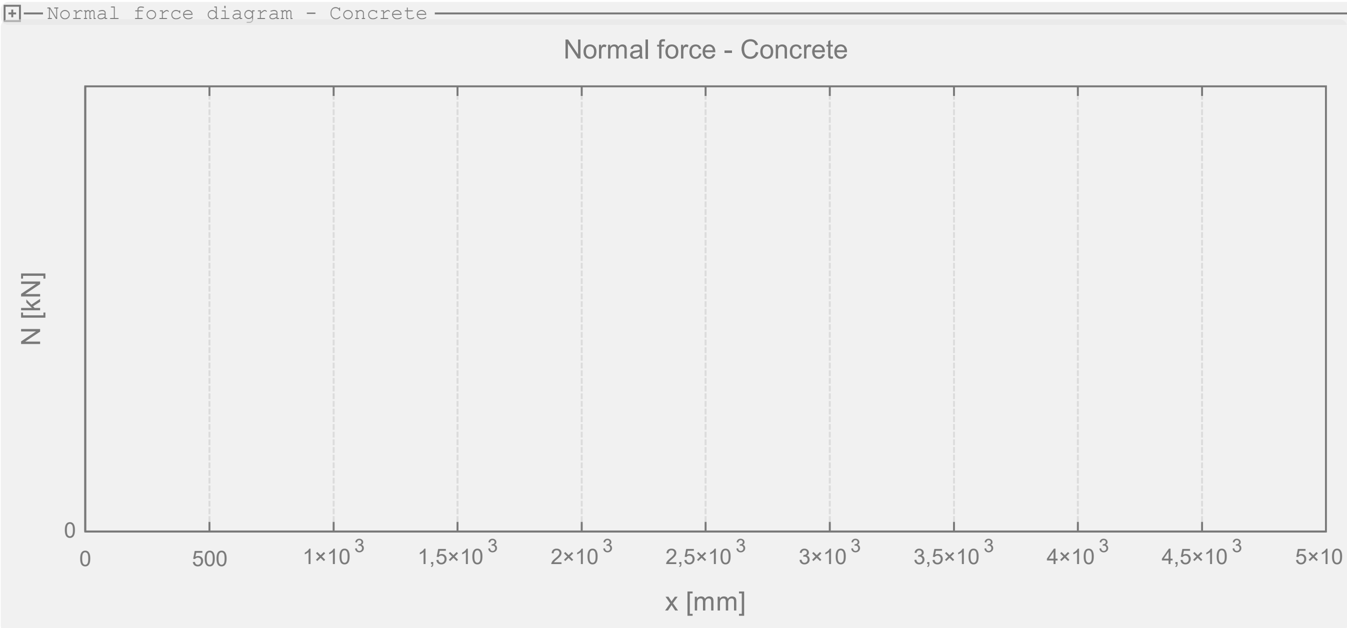




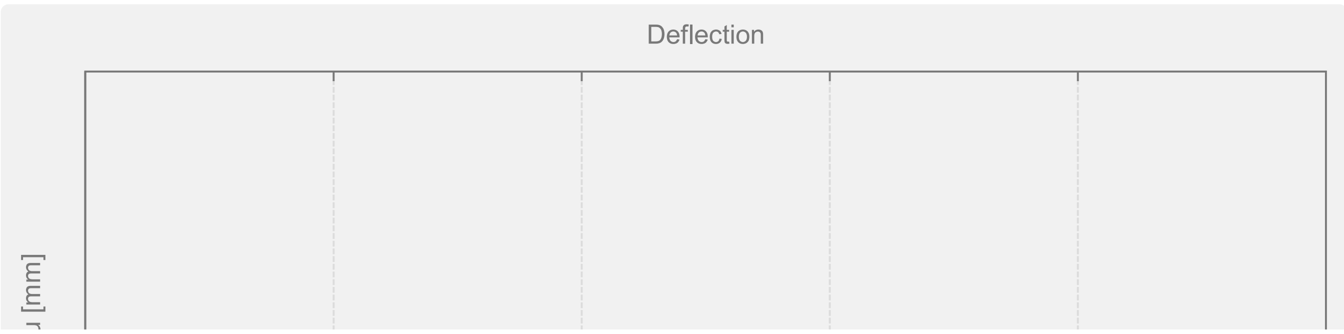
Horizontal displacement - Concrete

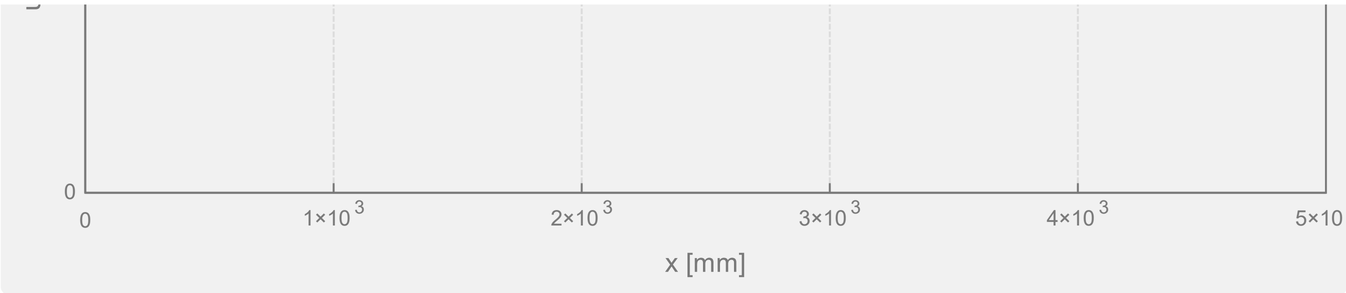


Normal force diagram - Concrete

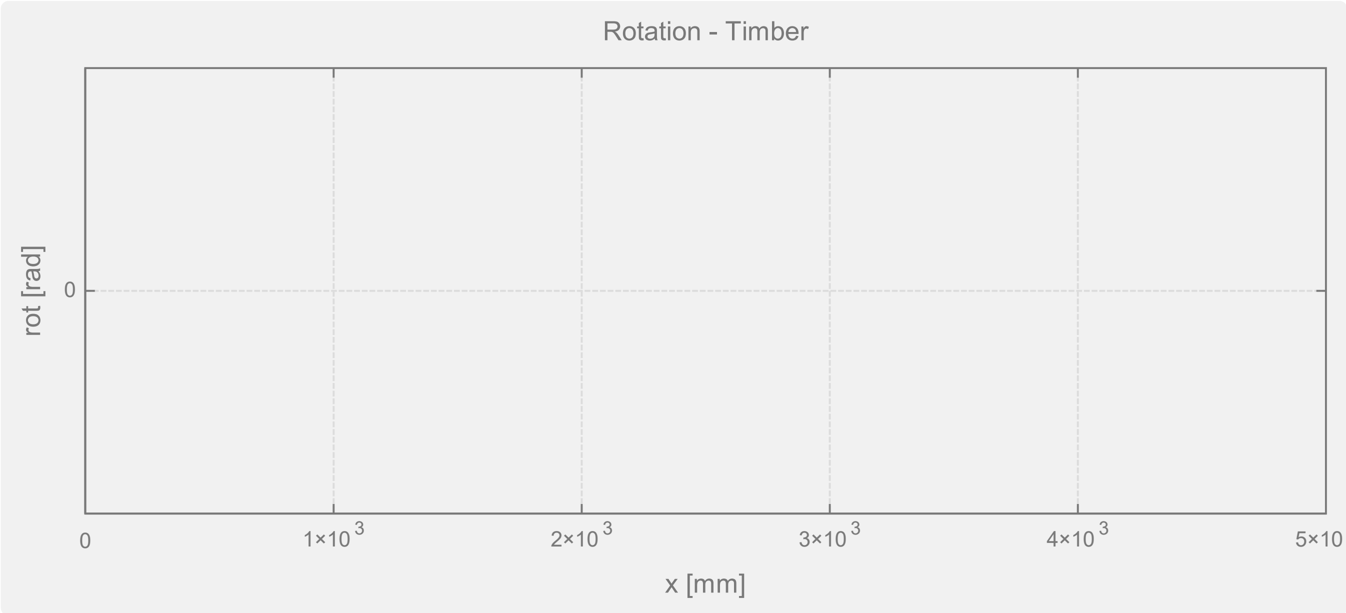


Deflection

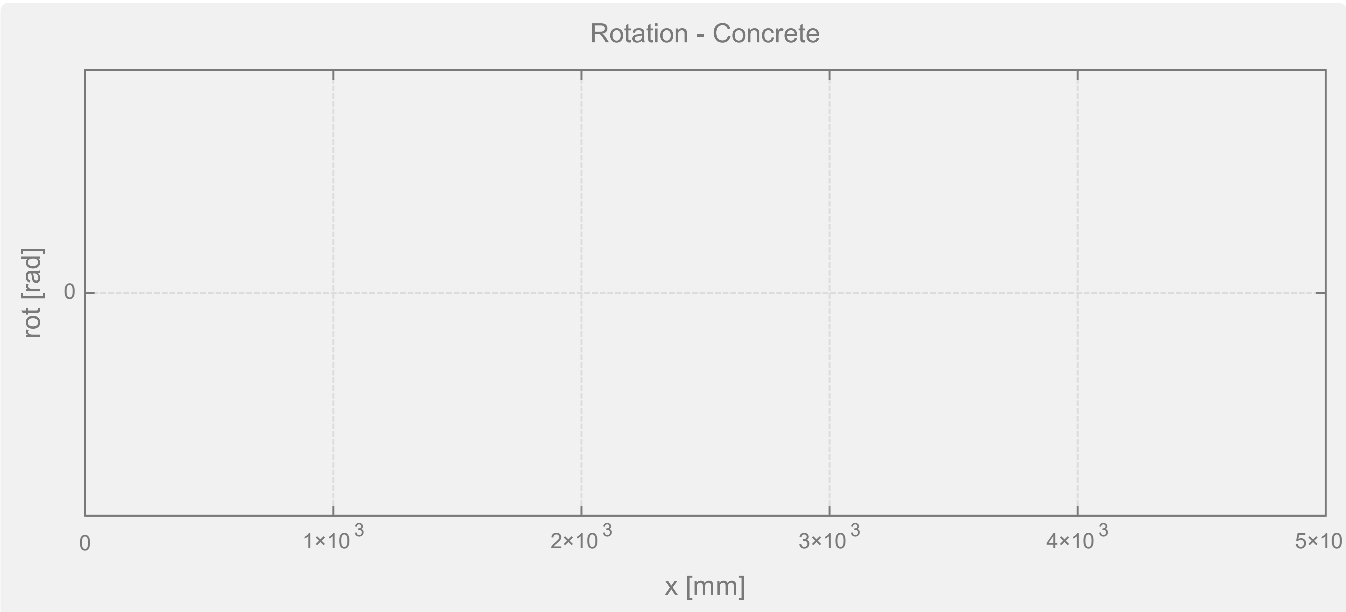




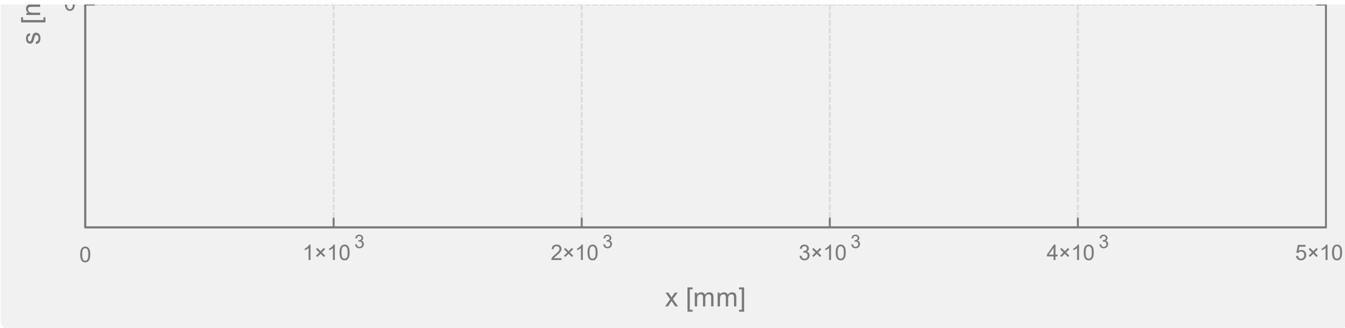
Rotation - Timber



Rotation - Concrete



Slip



for $i \in [(nPE+1)..(2 \cdot nPE)]$

$Elsle_{i,1} := Nodes_{edofn_{i,1},1}$

$Elsle_{i,2} := Nodes_{edofn_{i,1},2}$

$Elsle_{i,3} := Nodes_{edofn_{i,2},1}$

$Elsle_{i,4} := Nodes_{edofn_{i,2},2}$

$Elsle_{i,5} := Atop$

$Elsle_{i,6} := Itop$

$Elsle_{i,7} := E(curv_{i-nPE,1}; 0; ytop)$

$Elsle_{i\,8} := Gtop$

$Elsle_{i\,9} := \text{"nh"}$

$Elsle_{i\,10} := 0$

$Elsle_{i\,11} := -qser$

```
dia(Mat) := | " Diagonal elements "
            | for i ∈ [1..nDof]
            |    dia_i := Mat_{i i}
            | dia
```

$curv0 := 0$

$curv1 := 1$

$curv := \mathrm{matrix}(nPE; 1)$

```
for i ∈ [1..nPE]
  | curv_{i 1} := 0,000000000000000000001
```

$times := 0$

$NN := \mathrm{matrix}(nEl; 1)$

```
us(curv; Elsle; NN) := | while (|(curv_{1 1} - curv0) / curv_{1 1}| > 0,001) ∧ (times < 20)
                       |   | curv0 := curv_{1 1}
                       |   | times := times + 1
                       |   | for i ∈ [(nPE + 1)..(2·nPE)]
                       |   |   | Elsle_{i 7} := E(curv_{i - nPE 1}; NN_i; htop/2)
                       |   | genKsle := | K := matrix(nDof; nDof)
                       |   |            | for i ∈ [1..nEl]
                       |   |            |   | if Elsle_{i 9} = "nh"
                       |   |            |   |   KKe := Ke(Elsle_{i 1}; Elsle_{i 2}; Elsle_{i 3}; Elsle_{i 4}; Elsle_{i 5}; E
                       |   |            |   | else
                       |   |            |   |   if Elsle_{i 9} = "lh"
                       |   |            |   |     KKe := Kel(Elsle_{i 1}; Elsle_{i 2}; Elsle_{i 3}; Elsle_{i 4}; Elsle_{i 5
                       |   |            |   |   else
                       |   |            |   |     KKe := Ker(Elsle_{i 1}; Elsle_{i 2}; Elsle_{i 3}; Elsle_{i 4}; Elsle_{i 5
                       |   |            |   | edofe := edof
```

```
                    [i..i][1..6]
        K := assemk(K; KKe; edofe)
    K
km := dia(genKsle)
c := max(km)·1000000
bc := matrix(nDof; 2)
for i ∈ [1..nDof]
    bc[i 1] := i
bc[1 2] := 1
bc[2 2] := 1
bc[edof[nPE 5] 2] := 1
Kbcsle := genKsle
for i ∈ [1..nDof]
    if bc[i 2] = 1
        Kbcsle[i i] := Kbcsle[i i] + c
    else
        continue
genFlsle := | fl := matrix(nDof; 1)
            | for i ∈ [1..nEl]
            |     fle := fle(Elsle[i 1]; Elsle[i 2]; Elsle[i 3]; Elsle[i 4]; Elsle[i 10];
            |     edofe := edof[i..i][1..6]
            |     fl := assemf(fl; fle; edofe)
            | fl
fsle := genFlsle
usle := invert(Kbcsle)·fsle
edsle := matrix(nEl; 6)
for i ∈ [1..nEl]
    for j ∈ [1..6]
        edsle[i j] := usle[edof[i j]]
```

$m(ed) :=$

```
b0 := matrix(1; nEl)
b1 := matrix(1; nEl)
for i ∈ [1..nEl]
```

$$L := \sqrt{\left(Elsle_{i\,3} - Elsle_{i\,1}\right)^2 + \left(Elsle_{i\,4} - Elsle_{i\,2}\right)^2}$$

$$n0_{i} := \frac{Elsle_{i\,3} - Elsle_{i\,1}}{L}$$

$$n1_{i} := \frac{Elsle_{i\,4} - Elsle_{i\,2}}{L}$$

```
m := matrix(1; nEl)
for i ∈ [1..nEl]
```

$$m_{i} := \begin{bmatrix} n0_{i} & -n1_{i} & 0 & 0 & 0 & 0 \\ n1_{i} & n0_{i} & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & n0_{i} & -n1_{i} & 0 \\ 0 & 0 & 0 & n1_{i} & n0_{i} & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \cdot \mathrm{submatrix}\left(ed; i; i; 1; 6\right)^{T}$$

```
m
msle := m(edsle)
```

$M1 := \mathrm{matrix}(nEl; 1)$
$M2 := \mathrm{matrix}(nEl; 1)$
$V1 := \mathrm{matrix}(nEl; 1)$
$V2 := \mathrm{matrix}(nEl; 1)$
for $\mathrm{i} \in [1..nEl]$

$x1 := Elsle_{\mathrm{i}\,1}$

$y1 := Elsle_{\mathrm{i}\,2}$

$x2 := Elsle_{\mathrm{i}\,3}$

$y2 := Elsle_{\mathrm{i}\,4}$

$L := \sqrt{(x2 - x1)^2 + (y2 - y1)^2}$

$A := Elsle_{\mathrm{i}\,5}$

$I := Elsle_{\mathrm{i}\,6}$

$E := Elsle_{\mathrm{i}\,7}$

$G := Elsle_{\mathrm{i}\,8}$

$qx := Elsle_{\mathrm{i}\,10}$

$qy := Elsle_{\mathrm{i}\,11}$

$co := \frac{12}{L^2} \cdot \frac{ks \cdot E \cdot I}{G \cdot A}$

$u1 := msle_{1\,\mathrm{i}_1}$

$u2 := msle_{1\,\mathrm{i}_4}$

$v1 := msle_{1\,\mathrm{i}_2}$

$t1 := msle_{1\,\mathrm{i}_3}$

$v2 := msle_{1\,\mathrm{i}_5}$

$t2 := msle_{1\,\mathrm{i}_6}$

$fle := fle(x1; y1; x2; y2; qx; qy)$

if $Elsle_{\mathrm{i}\,9} = $ "nh"

$M1sle_{\mathrm{i}} := \left(-\left(\left(\frac{1}{1+co}\right) \cdot \left(\frac{6 \cdot E \cdot I}{L^2}\right) \cdot v1 + \left(\frac{E}{1+co} \cdot 4 \cdot \frac{I}{L} \cdot \left(1 + \frac{co}{4}\right)\right) \cdot t1 + \left(-\frac{E}{1+co}\right.\right.\right.$

$M2sle_{\mathrm{i}} := \left(\frac{1}{1+co}\right) \cdot \left(\frac{6 \cdot E \cdot I}{L^2}\right) \cdot v1 + \left(\frac{E}{1+co} \cdot 2 \cdot \frac{I}{L} \cdot \left(1 - \frac{co}{2}\right)\right) \cdot t1 + \left(\frac{-E}{1+co}\right) \cdot 6 \cdot$

$V1sle_{\mathrm{i}} := \left(\frac{1}{1+co}\right) \cdot \left(\frac{12 \cdot E \cdot I}{L^3}\right) \cdot v1 + \left(\frac{E}{1+co} \cdot 6 \cdot \frac{I}{L^2}\right) \cdot t1 + \left(-\frac{E}{1+co}\right) \cdot 12 \cdot \frac{I}{L^3} \cdot$

$V2sle_{\mathrm{i}} := -\left(\left(\frac{-1}{1+co}\right) \cdot \left(\frac{12 \cdot E \cdot I}{L^3}\right) \cdot v1 + \left(\frac{-E}{1+co} \cdot 6 \cdot \frac{I}{L^2}\right) \cdot t1 + \left(\frac{E}{1+co}\right) \cdot 12 \cdot \frac{I}{L^3}\right.$

else

if $Elsle_{\mathrm{i}\,9} = $ "lh"

$M1sle_{\mathrm{i}} := fle_2$

$M2sle_{\mathrm{i}} := \left(\frac{6 \cdot E \cdot I}{L^2 \cdot (co+1)} + \frac{6 \cdot E \cdot I \cdot (co-2)}{L^2 \cdot (co+4) \cdot (co+1)}\right) \cdot v1 - \frac{6 \cdot E \cdot I \cdot (co-2)}{L^2 \cdot (co+4) \cdot (co+1)}$

$V1sle_{\mathrm{i}} := \left(\frac{12 \cdot E \cdot I}{3 \ldots} + \frac{(-36) \cdot E \cdot I}{3 \ldots}\right) \cdot v1 + \left(\frac{-12 \cdot E \cdot I}{3 \ldots} + \ldots\right.$

$$V2sle_i := -\left(\left(\frac{-12\cdot E\cdot I}{L^3\cdot(co+1)} + \frac{36\cdot E\cdot I}{L^3\cdot(co+4)\cdot(co+1)}\right)\cdot v1 + \left(\frac{12\cdot E\cdot I}{L^3\cdot(co+1)} + \ldots\right.\right.$$

else

$$M1sle_i := -\left(\left(\frac{6\cdot E\cdot I}{L^2\cdot(co+1)} + \frac{6\cdot E\cdot I\cdot(co-2)}{L^2\cdot(co+4)\cdot(co+1)}\right)\cdot v1 - \frac{E\cdot I\cdot(co-2)^2}{L\cdot(co+4)\cdot(co+1)} \ldots\right.$$

$$M2sle_i := fle_5$$

$$V1sle_i := \left(\frac{12\cdot E\cdot I}{L^3\cdot(co+1)} - \frac{36\cdot E\cdot I}{L^3\cdot(co+4)\cdot(co+1)}\right)\cdot v1 + \left(\frac{6\cdot E\cdot I}{L^2\cdot(co+1)} + \frac{6\cdot \ldots}{L^2\cdot(\ldots}\right.$$

$$V2sle_i := -\left(\left(\frac{-12\cdot E\cdot I}{L^3\cdot(co+1)} + \frac{36\cdot E\cdot I}{L^3\cdot(co+4)\cdot(co+1)}\right)\cdot v1 + \left(\frac{12\cdot E\cdot I}{L^3\cdot(co+1)} + \ldots\right.\right.$$

$$N1sle_i := \frac{E\cdot A}{L}\cdot(u1-u2)$$

$$N2sle_i := \frac{E\cdot A}{L}\cdot(u1-u2)$$

$$NN_i := \frac{N1sle_i + N2sle_i}{2}$$

for $i \in [(nPE+1)..(2\cdot nPE)]$

$$curv_{i-nPE\,1} := \frac{\left|msle_{1\,i_6} - msle_{1\,i_3}\right|}{\left(Elsle_{i\,3} - Elsle_{i\,1}\right)}$$

usle

$$\begin{bmatrix} 1{,}9912\cdot 10^{-26} \\ -8{,}2564\cdot 10^{-14} \\ -0{,}0037 \\ 4{,}3754\cdot 10^{-15} \\ -1{,}9197 \\ 0{,}0017 \\ -0{,}0174 \\ -3{,}1621 \\ 0{,}0007 \\ -0{,}0447 \\ -3{,}1621 \\ -0{,}0007 \\ -0{,}0621 \\ -1{,}9197 \\ -0{,}0017 \\ -0{,}0621 \\ -8{,}2564\cdot 10^{-14} \\ 0{,}0037 \\ -0{,}0342 \\ -0{,}0022 \end{bmatrix}$$

$$us\left(curv;Elsle;NN\right)=\begin{bmatrix} -0,002 \\ -0,0342 \\ -1,9196 \\ -0,0017 \\ -0,0326 \\ -3,1622 \\ -0,0007 \\ -0,0295 \\ -3,1622 \\ 0,0007 \\ -0,0279 \\ -1,9196 \\ 0,0017 \\ -0,0279 \\ -0,0022 \\ 0,002 \\ -0,0142 \\ -0,0009 \\ -0,0003 \\ 0,0836 \\ -1,9196 \\ -0,0017 \\ 0,0161 \\ -3,1621 \\ -0,0007 \\ -0,0782 \\ -3,1621 \\ 0,0007 \\ -0,1457 \\ -1,9196 \\ 0,0017 \\ -0,0479 \\ -0,0009 \\ 0,0003 \end{bmatrix}$$

$$curv=\begin{bmatrix} 3,1557\cdot 10^{-7} \\ 9,9994\cdot 10^{-7} \\ 1,4223\cdot 10^{-6} \\ 9,9994\cdot 10^{-7} \\ 3,1557\cdot 10^{-7} \end{bmatrix}$$

$$NN=\begin{bmatrix} -5,6793\cdot 10^{-10} \\ 2262,5285 \\ 3538,4062 \\ 2262,5285 \\ 6,7931\cdot 10^{-10} \\ 1,9318\cdot 10^{-10} \\ -2262,5285 \\ -3538,4062 \\ -2262,5285 \\ -4,4112\cdot 10^{-10} \\ -2453,5577 \\ 78,3058 \\ -124,7481 \\ -124,7481 \\ 78,3058 \\ -2453,5577 \\ -2453,5577 \end{bmatrix}$$

$$\begin{bmatrix} 78,3058 \\ -124,7481 \\ -124,7481 \\ 78,3058 \\ \vdots \end{bmatrix}$$

$$Elsle = \begin{bmatrix}
0 & 0 & 1000 & 0 & 11800 & 3,9333 \cdot 10^{5} & 11000 & 6,9 \cdot 10^{8} & \text{"nh"} & 0 & 0 \\
1000 & 0 & 2000 & 0 & 11800 & 3,9333 \cdot 10^{5} & 11000 & 6,9 \cdot 10^{8} & \text{"nh"} & 0 & 0 \\
2000 & 0 & 3000 & 0 & 11800 & 3,9333 \cdot 10^{5} & 11000 & 6,9 \cdot 10^{8} & \text{"nh"} & 0 & 0 \\
3000 & 0 & 4000 & 0 & 11800 & 3,9333 \cdot 10^{5} & 11000 & 6,9 \cdot 10^{8} & \text{"nh"} & 0 & 0 \\
4000 & 0 & 5000 & 0 & 11800 & 3,9333 \cdot 10^{5} & 11000 & 6,9 \cdot 10^{8} & \text{"nh"} & 0 & 0 \\
0 & 120 & 1000 & 120 & 82600 & 1,3491 \cdot 10^{8} & 24900 & 1,3 \cdot 10^{10} & \text{"nh"} & 0 & -1 \\
1000 & 120 & 2000 & 120 & 82600 & 1,3491 \cdot 10^{8} & 17168,7007 & 1,3 \cdot 10^{10} & \text{"nh"} & 0 & -1 \\
2000 & 120 & 3000 & 120 & 82600 & 1,3491 \cdot 10^{8} & 13885,0578 & 1,3 \cdot 10^{10} & \text{"nh"} & 0 & -1 \\
3000 & 120 & 4000 & 120 & 82600 & 1,3491 \cdot 10^{8} & 17168,7007 & 1,3 \cdot 10^{10} & \text{"nh"} & 0 & -1 \\
4000 & 120 & 5000 & 120 & 82600 & 1,3491 \cdot 10^{8} & 24900 & 1,3 \cdot 10^{10} & \text{"nh"} & 0 & -1 \\
0 & 0 & 0 & 50 & 12027,2418 & 1,2055 \cdot 10^{7} & 11000 & 6,9 \cdot 10^{8} & \text{"lh"} & 0 & 0 \\
1000 & 0 & 1000 & 50 & 12027,2418 & 1,2055 \cdot 10^{7} & 11000 & 6,9 \cdot 10^{8} & \text{"rh"} & 0 & 0 \\
2000 & 0 & 2000 & 50 & 12027,2418 & 1,2055 \cdot 10^{7} & 11000 & 6,9 \cdot 10^{8} & \text{"rh"} & 0 & 0 \\
3000 & 0 & 3000 & 50 & 12027,2418 & 1,2055 \cdot 10^{7} & 11000 & 6,9 \cdot 10^{8} & \text{"rh"} & 0 & 0 \\
4000 & 0 & 4000 & 50 & 12027,2418 & 1,2055 \cdot 10^{7} & 11000 & 6,9 \cdot 10^{8} & \text{"rh"} & 0 & 0 \\
5000 & 0 & 5000 & 50 & 12027,2418 & 1,2055 \cdot 10^{7} & 11000 & 6,9 \cdot 10^{8} & \text{"lh"} & 0 & 0 \\
0 & 50 & 0 & 120 & 12027,2418 & 1,2055 \cdot 10^{7} & 11000 & 6,9 \cdot 10^{8} & \text{"rh"} & 0 & 0 \\
1000 & 50 & 1000 & 120 & 12027,2418 & 1,2055 \cdot 10^{7} & 11000 & 6,9 \cdot 10^{8} & \text{"nh"} & 0 & 0 \\
2000 & 50 & 2000 & 120 & 12027,2418 & 1,2055 \cdot 10^{7} & 11000 & 6,9 \cdot 10^{8} & \text{"nh"} & 0 & 0 \\
3000 & 50 & 3000 & 120 & 12027,2418 & 1,2055 \cdot 10^{7} & 11000 & 6,9 \cdot 10^{8} & \text{"nh"} & 0 & 0
\end{bmatrix}$$

$$NN = \begin{bmatrix}
-5,679 \\
2262 \\
3538 \\
2262 \\
6,793 \\
1,931 \\
-226 \\
-353 \\
-226 \\
-4,411 \\
-245 \\
78, \\
-12 \\
-12 \\
78, \\
-245 \\
-245 \\
78, \\
-12 \\
-12 \\
78, \\
-245
\end{bmatrix}$$

$$\begin{bmatrix} 4000 & 50 & 4000 & 120 & 12027{,}2418 & 1{,}2055\cdot 10^{7} & 11000 & 6{,}9\cdot 10^{8} & \text{"nh"} & 0 & 0 \\ 5000 & 50 & 5000 & 120 & 12027{,}2418 & 1{,}2055\cdot 10^{7} & 11000 & 6{,}9\cdot 10^{8} & \text{"rh"} & 0 & 0 \end{bmatrix}$$