已知荷载下的 "Z" 形单跨简支和连续檩条设计计算 ------ <GBJ 18 -- 87>:

包括以下计算内容:

1 檩条内力 ---- 弯矩, 剪力和扭矩

2 截面的力学特性

3. 在不考虑侧向失稳及扭转的情况 (屋面静, 活载作用) 下, 计算最大应力:

4 当檩条在负弯矩作用下, 验算整体稳定

5 当檩条在标准竖向荷载作用下的最大挠度(总是出现在端跨)

钢材强度设计值, 当: **Q345** 时:

$f := 315$ **N/mm^2**

$fy := 345$ **N/mm^2**

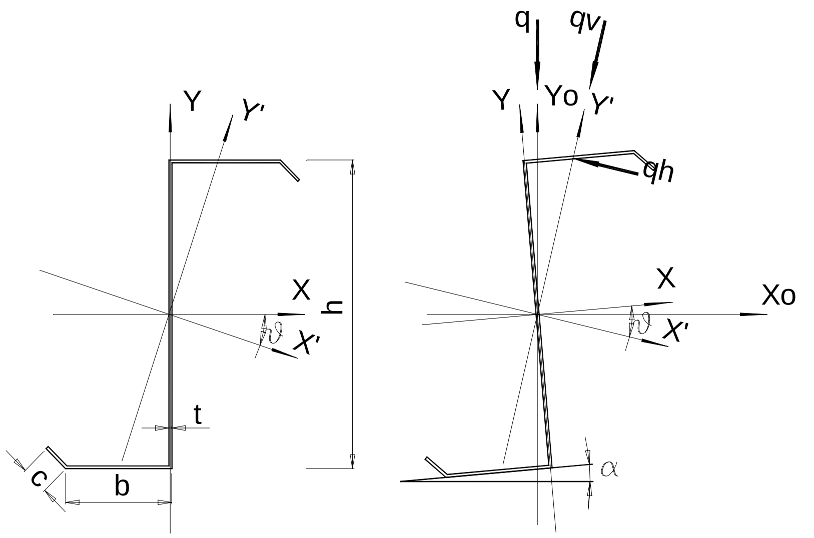
$fv := 185$ **N/mm^2**

钢材弹性模量:

$E := 2.06 \cdot 10^{5}$ **N/mm^2**

当屋面坡度为 1/12 时:

$\alpha := 2.286$ **Deg**



已知截面参数:

$h := 200$ **mm** $b := 70.0$ **mm** $c := 20.0$ **mm** $t := 2.5$ **mm** $\theta := -18.30$ **Deg**

1. 檩条内力 -- 弯矩, 剪力和扭矩:

屋面传来竖向线荷载值 (包括自重在内的设计值): $qo := 1.77$ **kN / m**

檩条跨度: $L := 6.0$ **m** $Pg := 0.075$ (檩条自重 kN / m), 已包簿在qo中.

檩条主轴方向的线荷载: $\alpha o := \frac{\pi \cdot \alpha}{180}$ $\theta o := \frac{\pi \cdot \theta}{180}$

$qv := qo \cdot \cos(\theta o + \alpha o)$ $qv = 1.70131394$ **kN / m**

$qh := qo \cdot \sin(\theta o + \alpha o)$ $qh = -0.48829384$ **kN / m**

檩条主轴方向的内力:

檩条的连续跨数 (最多 15 跨): $So := 1$ 檩条拉条数: $Tt := 1$

在弱轴方向, 由于设置拉条而形成的檩条跨数:

$$St(So) := \begin{array}{|l} T \leftarrow So \cdot (Tt + 1) \\ T \leftarrow 15 \quad \text{if} \quad T > 15 \\ T \end{array}$$

$To := St(So)$ $To = 2$

连续梁的支座弯矩系数 (表中数值已乘以**10^7**. 跨数自 **2** 至 **15**, 对称位置的支座弯矩系数值仅表为 **0**):

Mk :=

0.1250000	0	0	0	0	0	0
0.1000000	0	0	0	0	0	0
0.1071429	0.0714286	0	0	0	0	0
0.1052632	0.0789474	0	0	0	0	0
0.1057692	0.0769231	0.0865385	0	0	0	0
0.1056338	0.0774648	0.0845070	0	0	0	0
0.1056701	0.0773196	0.0850515	0.0824742	0	0	0
0.1056604	0.0773585	0.0849057	0.0830189	0	0	0
0.1056630	0.0773481	0.0849448	0.0828729	0.0835635	0	0
0.1056623	0.0773509	0.0849343	0.0829120	0.0834176	0	0
0.1056625	0.0773501	0.0849371	0.0829016	0.0834567	0.0832717	0
0.1056624	0.0773503	0.0849363	0.0829044	0.0834462	0.0833108	0
0.1056624	0.0773503	0.0849365	0.0829036	0.0834490	0.0833003	0.0833449
0.1056624	0.0773503	0.0849365	0.0829038	0.0834483	0.0833001	0.0833394

支座剪力系数 (跨数自 **2** 至 **11**, 自左至右每 2 列为一跨梁左, 右支座的值. 对称位置的值反号, 仅表为 **0**):

Qk :=

0.3750	–0.6250	0	0	0	0	0	0	0	0
0.40	–0.60	0.50	0	0	0	0	0	0	0
0.39286	–0.60714	0.53571	–0.46429	0	0	0	0	0	0
0.39474	–0.60526	0.52632	–0.47368	0.50	0	0	0	0	0
0.39423	–0.60577	0.52885	–0.47115	0.49039	–0.50962	0	0	0	0
0.39437	0.60563	0.52817	–0.47183	0.49296	–0.50704	0.50	0	0	0
0.39433	–0.60567	0.52835	–0.47165	0.49227	–0.50773	0.50257	–0.49742	0	0
0.39434	–0.60566	0.52830	–0.47170	0.49245	–0.50755	0.50189	–0.49811	0.50	0
0.39434	–0.60566	0.52832	–0.47169	0.49240	–0.50760	0.50207	–0.49793	0.49931	–0.50069
0.39434	–0.60566	0.52831	–0.47169	0.49242	–0.50758	0.50202	–0.49799	0.49949	–0.50051

跨间最大弯矩系数的计算: 需要计算的跨数: $Ss := \mathrm{floor}\left[\frac{(So+1)}{2}\right]$ $Ss = \mathbf{1}$

最大弯矩系数所在的位置: Xmm(So, ST, i, P) :=
```
Ml ← | Mk[So−2,i−1]  if  i > 0
     | 0  otherwise
Mr ← | if  So = 15
     |    | Ml  if  i = ST − 1
     |    | Mk[So−2,i]  otherwise
     | Mk[So−2,i]  if  So < 15  if  So > 1
     | Ml  if  i = ST − 1  if  mod(So, 2) ≠ 0
if  So = 1
    | Ml ← 0
    | Mr ← 0
Xmo ← 0.5 − (Mr − Ml)
Ml  if  P = 0
Mr  if  P = 1
Xmo  if  P = 2
```

沿强轴: $k := 0 .. Ss - 1$

$Ml_k := Xmm(So, Ss, k, 0)$ $Mr_k := Xmm(So, Ss, k, 1)$ $Xm_k := Xmm(So, Ss, k, 2)$

跨间最大弯矩系数的计算:

$k := 0 .. Ss - 1$ $Mkx_{0,k} := 0.5\cdot(1 - Xm_k)\cdot Xm_k - [Ml_k + Xm_k\cdot(Mr_k - Ml_k)]$

$Mkx = (\mathbf{0.125})$

对强轴的支座弯矩: $k := 0 .. Ss - 1$ $Mxm_{0,k} := -Mr_k\cdot qv\cdot L^2$

$Mxm = (\mathbf{0})$

对强轴的跨间最大弯矩: $k := 0 .. Ss - 1$ $Mxp_{0,k} := Mkx_{0,k}\cdot qv\cdot L^2$

$Mxp = (\mathbf{7.65591})$

对强轴的支座剪力 (当跨数超过 11 跨时, 按 11 跨计算. 11 跨的中间支座系数为 **0.5**):

```
Sqm(So) := | S ← So
           | S ← 10  if  S > 11
```
$Sq := Sqm(So)$ $Sq = \mathbf{1}$

$To := St(So)$ $To = \mathbf{2}$

$k := 0 .. Sq - 1$
```
Qym[0,k] := | 0.5  if  k ≥ 10
            | (Qk[Sq−2,k])  if  Sq > 1  if  k < 10
            | 0.5  if  Sq = 1
```
$Qym_{0,k} := Qym_{0,k}\cdot(qv\cdot L)$

$Qym = (\mathbf{5.104})$

沿弱轴: 沿弱轴的计算跨度: $Lt := \frac{L}{(Tt + 1)}$ $Lt = \mathbf{3}$ **m**

<u>跨间最大弯矩系数的计算:</u> 需要计算的跨数: $Ts := floor\left[\frac{(To+1)}{2}\right]$ $Ts = \mathbf{1}$

$k := 0 .. Ts-1$

$Ml_k := Xmm(To, Ts, k, 0)$ $Mr_k := Xmm(To, Ts, k, 1)$ $Ym_k := Xmm(To, Ts, k, 2)$

<u>跨间最大弯矩系数的计算:</u>

$k := 0 .. Ts-1$ $Mky_{0,k} := 0.5\cdot(1-Ym_k)\cdot Ym_k - \left[Ml_k + Ym_k\cdot(Mr_k - Ml_k)\right]$

$Mky = (\mathbf{0.0703125})$

<u>对**弱**轴的支座弯矩:</u> $k := 0 .. Ts-1$ $Mym_{0,k} := -Mr_k\cdot qh\cdot Lt^2$

$Mym = (\mathbf{0.5493})$

<u>对**弱**轴的跨间最大弯矩:</u> $k := 0 .. Ts-1$ $Myp_{0,k} := Mky_{0,k}\cdot qh\cdot Lt^2$

$Myp = (-\mathbf{0.30899845})$

<u>对**弱**轴的支座剪力 (当跨数超过 11 跨时, 按 11 跨计算. 11 跨的中间支座系数为 **0.5**):</u>

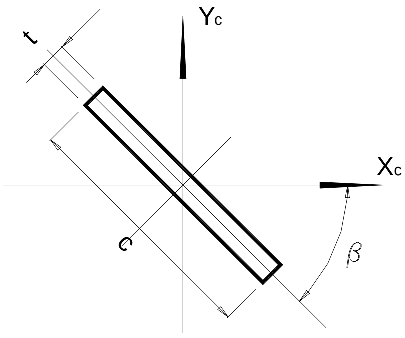
$k := 0 .. Sq-1$ $Qxm_{0,k} := \begin{cases} 0.5 & \text{if } k \geq 10 \\ (Qk_{Sq-2,k}) & \text{if } Sq > 1 \text{ if } k < 10 \\ 0.5 & \text{if } Sq = 1 \end{cases}$

$Qxm_{0,k} := Qxm_{0,k}\cdot qh\cdot L$

$Qxm = (-\mathbf{1.4649})$

<u>2. 截面的力学特性:</u>

2.1 <u>毛截面的截面特性</u>



<u>腹板高度:</u> $Wh := h - 2\cdot t$ $Wh = \mathbf{195}$ **mm**

<u>折边的折角:</u> $\beta o := 45$ **Deg** $\beta := \frac{\beta o\cdot\pi}{180}$ $\beta = \mathbf{0.7854}$ **Rad**

<u>折边的截面惯性矩 (对 **Xo** 轴):</u>

$Ac := c\cdot t$ $Ac = \mathbf{50}$ **mm^2**

$Icx := \frac{c\cdot t}{12}\cdot\left(t^2\cdot\cos(\beta)^2 + c^2\cdot\sin(\beta)^2\right)$ $Icx = \mathbf{846.3542}$ **mm^4**

<u>折边的截面惯性矩 (对 **Yo** 轴):</u>

$Icy := \frac{c\cdot t}{12}\cdot\left(c^2\cdot\cos(\beta)^2 + t^2\cdot\sin(\beta)^2\right)$ $Icy = \mathbf{846.3542}$ **mm^4**

<u>计算毛截面特性的过程:</u>

$$\mathrm{Sect}(b,t,\beta,Ac,Ic,hh,tt,P) := \left|\begin{array}{l}
Ab \leftarrow b\cdot t \\
Aw \leftarrow tt\cdot hh \\
Ai \leftarrow 2\cdot Ab + 2\cdot Ac + Aw \\
Ii \leftarrow \dfrac{2\cdot Ab\cdot t\cdot t + Aw\cdot hh\cdot hh}{12} + 2\cdot Ic \\
Ho \leftarrow \left|\begin{array}{ll} (hh + t + t) & \text{if } b > t \\ (hh + t + t + 2\cdot c\cdot \sin(\beta) - b) & \text{otherwise} \end{array}\right. \\
Hzo \leftarrow \dfrac{Ho}{2} \\
Ii \leftarrow \left|\begin{array}{ll} Ii + 2\cdot Ab\cdot\left(Hzo - \dfrac{t}{2}\right)^2 + 2\cdot Ac\cdot\left(Hzo - \dfrac{c\cdot\sin\left(\frac{\pi}{4}\right)}{2} - 1\right)^2 & \text{if } b > t \\ Ii + 2\cdot Ab\cdot\left(\dfrac{t}{2}\right)^2 + 2\cdot Ac\cdot\left(Hzo - \dfrac{c\cdot\sin(\beta)}{2} - 1\right)^2 & \text{otherwise} \end{array}\right. \\
Wo \leftarrow \dfrac{Ii}{Hzo} \\
Ho \ \text{ if } \ P = -1 \\
Hzo \ \text{ if } \ P = 0 \\
Ai \ \text{ if } \ P = 1 \\
Ii \ \text{ if } \ P = 2 \\
Wo \ \text{ if } \ P = 3
\end{array}\right.$$

$Ho := \mathrm{Sect}(b,t,0.0,Ac,Icx,Wh,t,-1)$	截面总高度	Ho = **200**	**mm**
$Hzox := \mathrm{Sect}(b,t,0.0,Ac,Icx,Wh,t,0)$	形心至下边缘距离:	Hzox = **100**	
$Hzoy := \mathrm{Sect}\left(t,b,\frac{\pi}{4},Ac,Icx,t,Wh,0\right)$	形心至侧边缘距离:	Hzoy = **84.1421**	**mm**
$Ax := \mathrm{Sect}(b,t,0.0,Ac,Icx,Wh,t,1)$	截面积:	Ax = **937.5**	**mm^2**
$Iix := \mathrm{Sect}(b,t,0.0,Ac,Icx,Wh,t,2)$	X 惯性矩:	Iix = **5804780.36**	**mm^4**
$Iiy := \mathrm{Sect}\left(t,b,\frac{\pi}{4},Ac,Icy,t,Wh,2\right)$	Y 惯性矩:	Iiy = **1152294.02**	**mm^4**
$Wx := \mathrm{Sect}(b,t,0.0,Ac,Icx,Wh,t,3)$	X 截面模量:	Wx = **58047.8**	**mm^3**
$Wy := \mathrm{Sect}(t,b,0.0,Ac,Icy,t,Wh,3)$	Y 截面模量:	Wy = **14995.9**	**mm^3**

形心主轴的惯性矩:

$Iixy := \dfrac{(Iiy - Iix)\cdot\tan(2\cdot\theta o)}{2}$	Iixy = **1727620.64**	**mm^4**
$Iixp := Iix\cdot\cos(\theta o)^2 + Iiy\cdot\sin(\theta o)^2 - Iixy\cdot\sin(2\cdot\theta o)$	Iixp = **6376136.26**	**mm^4**
$Iiyp := Iiy\cdot\cos(\theta o)^2 + Iix\cdot\sin(\theta o)^2 + Iixy\cdot\sin(2\cdot\theta o)$	Iiyp = **580938.12**	**mm^4**

计算腹板有效宽度的过程 $N := 0$

$$Wwe(N, M, P) := \left|\begin{array}{l} \sigma 2 \leftarrow \dfrac{N \cdot 10^3}{Ax} \\ Ho \leftarrow Sect(b, t, 0.0, Ac, Icx, Wh, t, -1) \\ Hzo \leftarrow Sect(b, t, 0.0, Ac, Icx, Wh, t, 0) \\ S1 \leftarrow -\dfrac{M \cdot 10^6}{Wx} \cdot \left(1 - \dfrac{t}{Ho - Hzo}\right) + \sigma 2 \\ S2 \leftarrow \dfrac{M \cdot 10^6}{Wx} \cdot \left(1 - \dfrac{t}{Hzo}\right) + \sigma 2 \\ \sigma 1 \leftarrow \left| \begin{array}{l} S1 \text{ if } M > 0 \\ S2 \text{ if } M \le 0 \end{array}\right. \\ \sigma 2 \leftarrow \left| \begin{array}{l} S2 \text{ if } M > 0 \\ S1 \text{ if } M \le 0 \end{array}\right. \\ \beta \leftarrow \dfrac{\sigma 2}{\sigma 1} \\ Fi \leftarrow 1 + \beta \\ K\sigma \leftarrow \dfrac{16}{\sqrt{Fi \cdot Fi + 0.112 \cdot (1 - \beta)^2} + Fi} \\ \lambda p \leftarrow \dfrac{Wh}{28.1 \cdot t \cdot \sqrt{K\sigma}} \cdot \sqrt{\dfrac{fy}{235}} \\ \rho \leftarrow \left| \begin{array}{l} 1 \text{ if } \lambda p \le 0.8 \\ 1 - 0.9 \cdot (\lambda p - 0.8) \text{ if } 0.8 < \lambda p \le 1.2 \\ [0.64 - 0.24 \cdot (\lambda p - 1.2)] \text{ otherwise} \end{array}\right. \\ hc \leftarrow \left| \begin{array}{l} Wh \text{ if } \beta > 0 \\ \dfrac{Wh}{1 - \beta} \text{ otherwise} \end{array}\right. \\ He \leftarrow \rho \cdot hc \\ He1 \leftarrow \left| \begin{array}{l} \dfrac{2 \cdot He}{(5 - \beta)} \text{ if } \beta > 0 \\ 0.4 \cdot He \text{ otherwise} \end{array}\right. \\ He2 \leftarrow \left| \begin{array}{l} He - He1 \text{ if } \beta > 0 \\ 0.6 \cdot He \text{ otherwise} \end{array}\right. \\ hc \text{ if } P = -1 \\ He \text{ if } P = 0 \\ He1 \text{ if } P = 1 \\ He2 \text{ if } P = 2 \end{array}\right.$$

-------- 式 (6.1.1-9)

-------- 式 (6.1.1-8)

-------- 式 (6.1.1-7)

-------- 式 (6.1.1-6)

-------- 式 (6.1.1-5)

-------- 式 (6.1.1-10)

-------- 式 (6.1.1-11)

-------- 式 (6.1.1-10)

-------- 式 (6.1.1-11)

有效截面特性的计算过程:

(**注**: 由于无轴向力, 且为中心对称, 故有: **S1 = S2**. 由 **"GBJ 18-87"**, 应取 α **= 2.0.** 如此**,** 截面全部有效)

$Ho := Sect(b, t, 0.0, Ac, Icx, Wh, t, -1)$ $Ho = \mathbf{200}$

$Hzo := Sect(b, t, 0.0, Ac, Icx, Wh, t, 0)$ $Hzo = \mathbf{100}$

$SectE(M, t, hc, Ho, He, He1, Hzo, Ai, Ii, He1, P) :=$

$$
\begin{array}{|l}
Hec \leftarrow hc - He \\
An \leftarrow t \cdot Hec \\
Hh \leftarrow He1 + \dfrac{Hec}{2} \\
Hh \leftarrow \begin{array}{|ll} Ho - Hh - t & \text{if } M \geq 0 \\ Hh + t & \text{otherwise} \end{array} \\
Hez \leftarrow \dfrac{Ai \cdot Hzo - An \cdot Hh}{Ai - An} \\
Hz \leftarrow He1 + \dfrac{Hec}{2} \\
Hz \leftarrow \begin{array}{|ll} Ho - t - Hz - Hez & \text{if } M \geq 0 \\ Hez - Hz - t & \text{otherwise} \end{array} \\
Ij \leftarrow An \cdot Hz^2 \\
Ij \leftarrow \dfrac{An \cdot Hec \cdot Hec}{12} + Ij \\
Ij \leftarrow Ii + Ai \cdot (Hzo - Hez)^2 - Ij \\
Weu \leftarrow \dfrac{Ij}{Ho - Hez - t} \\
Web \leftarrow \dfrac{Ij}{Hez - t} \\
An \ \text{ if } P = 0 \\
Hez \ \text{ if } P = 1 \\
Ij \ \text{ if } P = 2 \\
Weu \ \text{ if } P = 3 \\
Web \ \text{ if } P = 4
\end{array}
$$

<u>已知沿自然轴的内力设计值为:</u> $qx := qo \cdot \cos(\alpha o)$ $qx = \mathbf{1.768591}$ **kN / m**

在此, 应按不同跨上 (不考虑拉条时) 的最大弯矩值进行计算
(相应的剪力为零) !

$k := 0 .. Ss - 1$ $Mmp_{0,k} := Mkx_{0,k} \cdot qx \cdot L^2$

$Mmp = (\mathbf{7.9587})$

$$
\mathrm{EFectSect}(k,P) := \left|
\begin{array}{l}
He_k \leftarrow \mathrm{Wwe}\left(0, Mmp_{0k}, 0\right) \\
He1_k \leftarrow \mathrm{Wwe}\left(0, Mmp_{0k}, 1\right) \\
hc_k \leftarrow \mathrm{Wwe}\left(0, Mmp_{0k}, -1\right) \\
Hz_k \leftarrow \dfrac{Ho}{2} - Hzo \\
He2_k \leftarrow \mathrm{Wwe}\left(0, Mmp_{0k}, 2\right) \\
Hez_k \leftarrow \mathrm{SectE}\left(Mmp_{0k}, t, hc_k, Ho, He_k, He1_k, Hzo, Ax, Iix, He1_k, 1\right) \\
An_k \leftarrow \mathrm{SectE}\left(Mmp_{0k}, t, hc_k, Ho, He_k, He1_k, Hzo, Ax, Iix, He1_k, 0\right) \\
Ae_k \leftarrow Ax - An_k \\
Ijx_k \leftarrow \mathrm{SectE}\left(Mmp_{0k}, t, hc_k, Ho, He_k, He1_k, Hzo, Ax, Iix, He1_k, 2\right) \\
Ijy_k \leftarrow Iiy - \dfrac{\left(hc_k - He_k\right)\cdot t^3}{12} \\
Ijxy_k \leftarrow \dfrac{\left(Ijy_k - Ijx_k\right)\cdot \tan(2\cdot\theta o)}{2} \\
Ijx_k \quad \text{if} \quad P = 1 \\
Ijy_k \quad \text{if} \quad P = 2 \\
Ijxy_k \quad \text{if} \quad P = 3
\end{array}
\right.
$$

(形心位置)

无效截面积:

有效截面面积:

截面惯性矩:

惯性积

$k := 0 .. Ss - 1$ $\quad Iox_k := \mathrm{EFectSect}(k,1)$ $\quad Ioy_k := \mathrm{EFectSect}(k,2)$

$Ioxy_k := \mathrm{EFectSect}(k,3)$

关于形心主轴的截面力学特性:

形心主轴的惯性矩(有效截面):

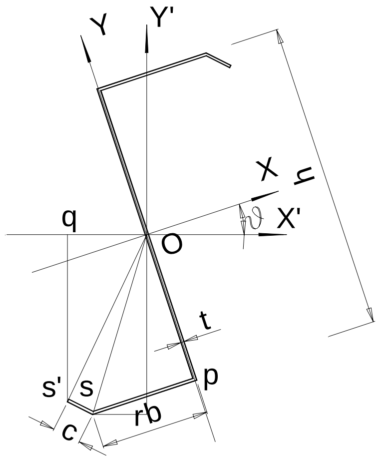
$$Ioxp_k := Iox_k\cdot\cos(\theta o)^2 + Ioy_k\cdot\sin(\theta o)^2 - Ioxy_k\cdot\sin(2\cdot\theta o)$$

$$Ioyp_k := Ioy_k\cdot\cos(\theta o)^2 + Iox_k\cdot\sin(\theta o)^2 + Ioxy_k\cdot\sin(2\cdot\theta o)$$

对形心主轴 **X'** 的截面模量:

距离形心主轴 X' 最远点 s (r) 的坐标: $Os := \sqrt{\left(b - \frac{t}{2}\right)^2 + \left(\frac{h}{2}\right)^2}$ $\quad Os = \mathbf{121.353}$

Os 与 Y 轴的夹角 γ: $\quad \gamma := \mathrm{asin}\left(\frac{b}{Os}\right)$ $\quad \gamma = \mathbf{0.6148}$



Os 与 Or 的夹角 δ: $\delta := \gamma - (-\theta o)$ $\delta = \mathbf{0.2954}$

Or 的长度: $Or := Os \cdot \cos(\delta)$

$Wxp_{0,k} := \dfrac{Ioxp_k}{Or}$ $Wx := \dfrac{Iixp}{Or}$

$Wxp_{0,0} = \mathbf{54921.67}$ **mm^3** $Wx = \mathbf{54921.67}$ **mm^3**

对形心主轴 **Y'** 的截面模量:

距离形心主轴 Y' 最远点 s' (q) 的坐标:

$Xsp := -b + \dfrac{t}{2} - c \cdot \cos\left(\dfrac{\pi}{4}\right)$ $Ysp := -\dfrac{h}{2} + c \cdot \sin\left(\dfrac{\pi}{4}\right)$

$Osp := \sqrt{Xsp^2 + Ysp^2}$

$Xsp = -\mathbf{82.8921}$ $Ysp = -\mathbf{85.8579}$ $Osp = \mathbf{119.3427}$ **mm**

Os' 与 Y 轴的夹角 ρ: $\rho := \operatorname{atan}\left(\dfrac{Xsp}{Ysp}\right)$ $\rho = \mathbf{0.7678}$

Os' 与 Y' 轴的夹角 (即 Os' 与 Oq 的夹角) ρ: $\rho := \rho - (-\theta o)$ $\rho = \mathbf{0.4484}$

于是, Oq 的长度: $Oq := Osp \cdot \sin(\rho)$ $Oq = \mathbf{51.7412}$ **mm**

$Wyp_{0,k} := \dfrac{Ioyp_k}{Oq}$ $Wy := \dfrac{Iiyp}{Oq}$

$Wyp_{0,0} = \mathbf{11227.77}$ **mm^3** $Wy = \mathbf{11227.77}$ **mm^3**

3. 在不考虑侧向失稳及扭转的情况 (屋面静, 活载作用) 下, 计算最大应力:

计算过程自中间向边跨逐跨进行. 在跨内, 侧向有无拉条时, 验算的截面位置不同.

计算各跨最不利截面的应力的涵数: $\omega := \dfrac{Wxp_0 \cdot qh}{Wyp_0 \cdot qv}$ $\omega = -\mathbf{1.40393506}$ (折算应力?
凳?

$$
\text{Fact}(e, Mx1, Mx2, My1, My2, \omega, D, P) := \left|
\begin{array}{l}
\text{if } Tt = 0 \\
\quad \left| \begin{array}{l} \xi x \leftarrow (0.5 - Mx2) + Mx1 \\ \xi y \leftarrow \xi x \end{array} \right. \\
\text{if } Tt = 1 \\
\quad \left| \begin{array}{l}
ko \leftarrow 1.0 \quad \text{if } e = 0 \\
ko \leftarrow 3 \quad \text{otherwise} \\
\xi x \leftarrow \left| \begin{array}{ll} \dfrac{0.5 - Mx2 + Mx1 + \omega \cdot [ko - 2 \cdot (My2 - My1)]}{(1 + 4.0 \cdot \omega)} & \text{if } \omega > 0 \\ 0.5 & \text{otherwise} \end{array} \right. \\
\xi y \leftarrow \xi x + \xi x - e \cdot 1.0
\end{array} \right. \\
\text{if } Tt = 2 \\
\quad \left| \begin{array}{l}
k1 \leftarrow 3.0 \\
ko \leftarrow 1.5 \quad \text{if } e = 0 \\
ko \leftarrow 4.5 \quad \text{if } e = 1 \\
ko \leftarrow 7.5 \quad \text{if } e = 2 \\
\xi x \leftarrow \left| \begin{array}{l} \dfrac{0.5 - Mx2 + Mx1 + \omega \cdot [ko - k1 \cdot (My2 - My1)]}{(1 + 3.0 \cdot k1 \cdot \omega)} \quad \text{if } qh > \\ \text{otherwise} \\ \quad \left| \begin{array}{ll} \dfrac{e + 1}{3} & \text{if } e < 2 \\ \dfrac{e}{3} & \text{otherwise} \end{array} \right. \end{array} \right. \\
\xi y \leftarrow 3.0 \cdot \xi x - e \cdot 1.0
\end{array} \right. \\
\zeta \leftarrow \left| \begin{array}{ll} 0.5 \cdot \xi x \cdot (1 - \xi x) - Mx1 - (Mx2 - Mx1) \cdot \xi x & \text{if } D = 0 \\ 0.5 \cdot \xi y \cdot (1 - \xi y) - My1 - (My2 - My1) \cdot \xi y & \text{otherwise} \end{array} \right. \\
\xi x \quad \text{if } P = 0 \\
\zeta \quad \text{if } P = 1
\end{array} \right.
$$

$k := 0 .. Ss - 1$ $\quad Mx1_k := \text{Xmm}(So, Ss, k, 0)$ $\quad Mx2_k := \text{Xmm}(So, Ss, k, 1)$

$k := 0 .. Ts - 1$ $\quad My1_k := \text{Xmm}(To, Ts, k, 0)$ $\quad My2_k := \text{Xmm}(To, Ts, k, 1)$

$$
Fs(k, \sigma) := \left| \begin{array}{ll} \textbf{"Ok"} & \text{if } \left|\sigma_{0,k}\right| \le f \\ \textbf{"No"} & \text{otherwise} \end{array} \right.
$$

(强度验算的判定条件)

计算折算最大弯矩所在的位置:

$$\xi(\omega,k) := \begin{array}{|l} \text{Fact}(0, Mx1_k, Mx2_k, My1_k, My2_k, \omega, 0, 0) \ \text{ if } Tt = 0 \\ \text{if } Tt = 1 \\ \quad \begin{array}{|l} d \leftarrow \text{floor}\left(\frac{k}{2}\right) \\ \text{Fact}(0, Mx1_d, Mx2_d, My1_k, My2_k, \omega, 0, 0) \ \text{ if } \operatorname{mod}(k,2) = 0 \\ \text{Fact}(1, Mx1_d, Mx2_d, My1_k, My2_k, \omega, 0, 0) \ \text{ otherwise} \end{array} \\ \text{if } Tt = 2 \\ \quad \begin{array}{|l} d \leftarrow \text{floor}\left(\frac{k}{3}\right) \\ \text{Fact}(0, Mx1_d, Mx2_d, My1_k, My2_k, \omega, 0, 0) \ \text{ if } \operatorname{mod}(k,3) = 0 \\ \text{Fact}(1, Mx1_d, Mx2_d, My1_k, My2_k, \omega, 0, 0) \ \text{ if } \operatorname{mod}(k,3) = 1 \\ \text{Fact}(2, Mx1_d, Mx2_d, My1_k, My2_k, \omega, 0, 0) \ \text{ otherwise} \end{array} \end{array}$$

计算折算最大弯矩:

$$\zeta(\omega,k,D) := \begin{array}{|l} \text{Fact}(0, Mx1_k, Mx2_k, My1_k, My2_k, \omega, 0, 1) \ \text{ if } Tt = 0 \\ \text{if } Tt = 1 \\ \quad \begin{array}{|l} d \leftarrow \text{floor}\left(\frac{k}{2}\right) \\ \text{Fact}(0, Mx1_d, Mx2_d, My1_k, My2_k, \omega, D, 1) \ \text{ if } \operatorname{mod}(k,2) = 0 \\ \text{Fact}(1, Mx1_d, Mx2_d, My1_k, My2_k, \omega, D, 1) \ \text{ otherwise} \end{array} \\ \text{if } Tt = 2 \\ \quad \begin{array}{|l} d \leftarrow \text{floor}\left(\frac{k}{3}\right) \\ \text{Fact}(0, Mx1_d, Mx2_d, My1_k, My2_k, \omega, D, 1) \ \text{ if } \operatorname{mod}(k,3) = 0 \\ \text{Fact}(1, Mx1_d, Mx2_d, My1_k, My2_k, \omega, D, 1) \ \text{ if } \operatorname{mod}(k,3) = 1 \\ \text{Fact}(2, Mx1_d, Mx2_d, My1_k, My2_k, \omega, D, 1) \ \text{ otherwise} \end{array} \end{array}$$

$k := 0 .. Ts - 1$

最大弯矩所在位置(**X/L**): $\xi x_{0,k} := \xi(\omega, k)$

$\xi x = (\mathbf{0.5})$

对强轴最大弯矩系数: $\zeta x_{0,k} := \zeta(\omega, k, 0)$

$\zeta x = (\mathbf{0.125})$

最大弯矩值: $Mx_{0,k} := \zeta x_{0,k} \cdot qv \cdot L \cdot L$

$Mx = (\mathbf{7.6559})$

对弱轴的最大弯矩系数: $\zeta y_{0,k} := \zeta(\omega, k, 1)$

$\zeta y = (\mathbf{-0.125})$

最大弯矩值: $My_{0,k} := \zeta y_{0,k} \cdot qh \cdot Lt \cdot Lt$

$My = (0.5493)$

最大应力: $\sigma x_{0,k} := \frac{Mx_{0,k} \cdot 10^6}{Wxp_{0,0}} + \frac{My_{0,k} \cdot 10^6}{Wyp_{0,0}}$ **"GBJ 18-87" 式 (4.5.1 -- 1)**

$\sigma x = (188.323)$

验算结果: $F := (0 \;\; 0)$ $F_{0,k} := Fs(k, \sigma x)$

$F = (\text{"Ok"} \;\; 0)$

4. 当檩条在负弯矩作用下, 验算整体稳定:

4.1 在静, 活荷载作用下的支座负弯矩 (无需考虑整体稳定):

需要计算的支座个数: $Sd := floor\left(\frac{So}{2}\right)$ $Sd = 0$ $Td := Tt + 1$ $Tk := 0$

$Km := (0 \;\; 0)$ $Mpx := (0 \;\; 0)$ $Mpy := (0 \;\; 0)$ $\sigma p := (0 \;\; 0)$ $D := (0 \;\; 0)$

$k := 0 .. Sd - 1$ $Tk := Tk + Td$

当为单跨简支时, 以下出现红字,
表明无支座负弯矩 !

$$Km_{0,k} := \begin{cases} -Mk_{To-2,k} & \text{if } So > 1 \\ 0 & \text{otherwise} \end{cases}$$

$Mpx_{0,k} := Km_{0,k} \cdot qv \cdot L \cdot L$

$Mpy_{0,k} := Km_{0,k} \cdot qh \cdot Lt \cdot Lt$

$\sigma p_{0,k} := \frac{Mpx_{0,k} \cdot 10^6}{Wxp_{0,0}} + \frac{Mpy_{0,k} \cdot 10^6}{Wyp_{0,0}}$

$\sigma p_{0,k} := 0.5 \cdot \sigma p_{0,k}$ (支座处 **2** 倍加强)

弯矩系数:

$Km = ▮$

对强轴的弯矩值:

$Mpx = ▮$

对弱轴的弯矩值:

$Mpy = ▮$

应力:

$\sigma p = ▮$

验算结果: $D_{0,k} := Fs(k, \sigma x)$ $D = ▮$

4.2 在风荷载吸力作用下的负弯矩 (需考虑整体稳定):

当檩条无拉条, 跨中一道拉条或等距离多道拉条时, 分别取其计算长度系数为 μ **= 1.0,** 0.5, 0.33.

取 $\mu := (1.0\ \ 0.5\ \ 0.33)$ 由此, 檩条计算长度: $Lo := \mu_{0,Tt} \cdot L$ $Lo = 3$ m

长细比: $\lambda y := Lo \cdot 10^3 \cdot \sqrt{\frac{Ax}{Iiy}}$ $\lambda y = 85.5707$

$$\zeta o := \begin{pmatrix} 0 & 1.13 & 0.46 & 0.53 \\ 0 & 1.35 & 0.14 & 0.83 \\ 0 & 1.37 & 0.06 & 0.88 \end{pmatrix}$$

系数. 由 **"GBJ 18-87"** 表 (附3.2-6) 查得. 第一个 "0" 意味着 ζ_0 不用

当静载与风载组合时的弯矩值: $qf := -0.77$ **kN / m** $qf := -0.75$ **kN / m** $qf := -0.75$

$qvf := qf \cdot \cos(\theta o + \alpha o)$ $qvf = -0.7209$ **kN / m**

$qhf := qf \cdot \sin(\theta o + \alpha o)$ $qhf = 0.2069$ **kN / m**

扭矩: $Mt := qh \cdot h \cdot 10^{-3}$ $Mt = -0.0977$ **kN--m**

现取: $\beta x := 0$ (按 **"GBJ 18-87"** 规定)

计算扇性惯性矩(为简单计, 折边部分略去):

$$I\omega := \frac{b^3 \cdot t \cdot (Wh + t)^2}{12} \cdot \frac{b + 2 \cdot (Wh + t)}{2 \cdot b + (Wh + t)}$$ $I\omega = 3.8403 \times 10^9$

计算抗扭惯性矩: $$It := \frac{(2 \cdot b + 2 \cdot c + Wh) \cdot t^3}{3}$$ $It = 1.9531 \times 10^3$

$$\zeta\omega := \frac{4 \cdot I\omega}{h^2 \cdot Iiy} + \frac{0.156 \cdot It}{Iiy} \cdot \left(\frac{Lo \cdot 10^3}{h}\right)^2$$ $\zeta\omega = 0.3928$

此处: $a := Os$ (见图), 则: $$\eta := \frac{\left(2 \cdot \zeta o_{Tt,2} \cdot a + \zeta o_{Tt,3} \cdot \beta x\right)}{h}$$ $\eta = 0.1699$

由此: $$\Phi bx := \frac{4320 \cdot Ax \cdot h}{\lambda y^2 \cdot Wx} \cdot \zeta o_{Tt,1} \cdot \left(\sqrt{\eta^2 + \zeta\omega} + \eta\right) \cdot \frac{235}{fy}$$ $\Phi bx = 1.5173$ **"GBJ 18-87" (附3.2 -- 1)**

$S := (0\ \ 0)$ $k := 0 .. Ts - 1$

最大弯矩所在位置(**X/L**): $\xi s_{0,k} := \xi(\omega, k)$

$\xi s = (0.5)$

对强轴最大弯矩系数: $\zeta sx_{0,k} := \zeta(\omega, k, 0)$

$\zeta sx = (0.125)$

对强轴的最大弯矩: $Msx_{0,k} := \zeta sx_{0,k} \cdot qv \cdot L \cdot L$

$Msx = (7.6559)$

对弱轴最大弯矩系数: $\zeta sy_{0,k} := \zeta(\omega, k, 1)$

$\zeta sy = (-0.125)$

对弱轴的最大弯矩: $Msy_{0,k} := \zeta sy_{0,k} \cdot qh \cdot Lt \cdot Lt$

$Msy = (0.5493)$

最大应力: $\sigma s_{0,k} := \frac{Msx_{0,k} \cdot 10^6}{\Phi bx \cdot Wx} + \frac{Msy_{0,k} \cdot 10^6}{Wy}$ **"GBJ 18-87" 式 (4.5.3 -- 2)**

$\sigma s = (140.7964)$

验算结果: $S_{0,k} := Fs(k, \sigma s)$

S = (**"Ok" 0**)

5. 当檩条在标准竖向荷载作用下的最大挠度(总是出现在端跨):

连续梁各跨间的最大挠读系数:

$Do1 := (0.520833 \quad 0.677083 \quad 0.63244 \quad 0.644189 \quad 0.641026 \quad 0.641872)$

$Do2 := (0.641645 \quad 0.641706 \quad 0.64169 \quad 0.641694 \quad 0.641693)$

竖向荷载的标准值(取组合系数 $c := 1.25$ 允许调整): $Ldb := \frac{qo \cdot \cos(\alpha o)}{c}$ $Ldb = 1.4149$

跨间最大挠度: $Def := \frac{10^5 \cdot Ldb \cdot L^4}{2.06 \cdot Iix}$ $Def := Do1_{0,0} \cdot Def$ $Def = 7.9867$ **mm**

跨挠比: $Rat := \frac{L}{Def} \cdot 10^3$ $Rat = 751.2479$ (1/) 注: 此处,
近似采用对自然轴的惯性矩, 偏安全 !