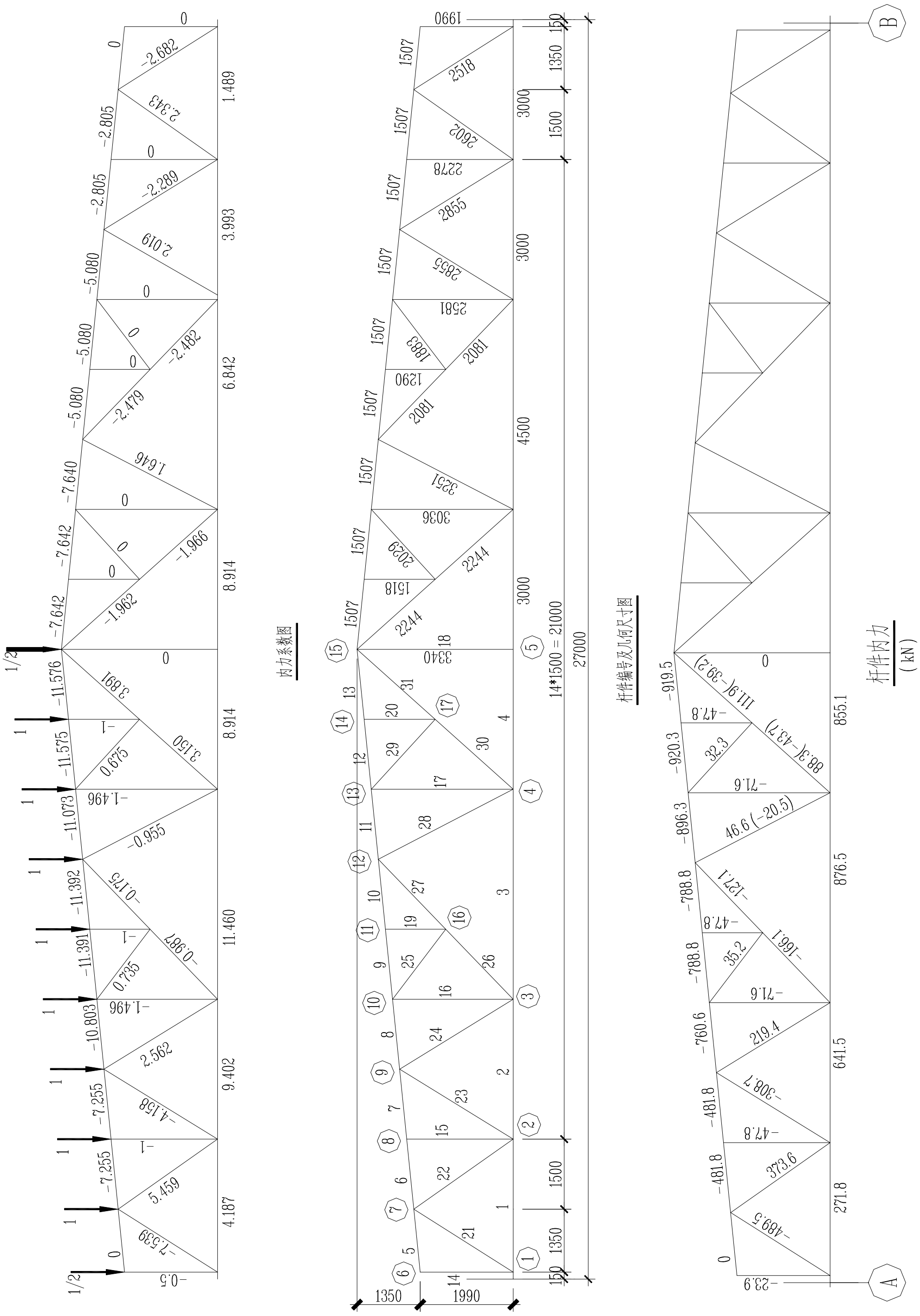
梯形钢屋架

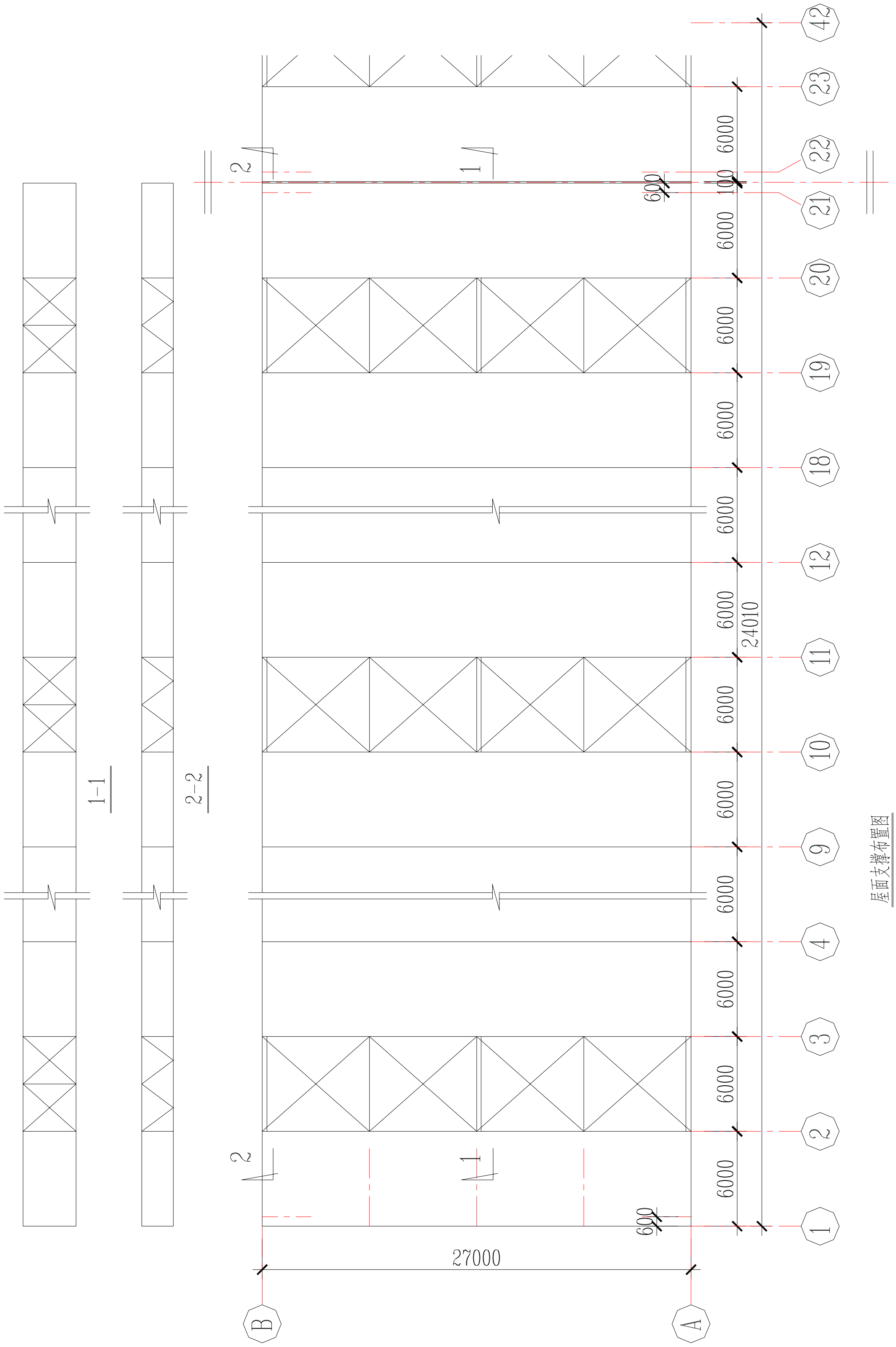
普通钢结构车间单跨27米, 柱距6米, 房屋长240米。采用梯形钢屋架, 屋面为大型屋面板(屋面板不考虑作支撑)。

钢材Q235B, 焊条E43xx手工焊。

梯形钢屋架尺寸见“杆件编号及几何尺寸图”。

屋面支撑布置见 “屋面支撑布置图”。




屋面支撑布置图
1-1
2-2
27000
24010
6000
600
100
A
B
1
2
3
4
9
10
11
12
18
19
20
21
22
23
42

1. 设计依据

1.1 《建筑结构荷载规范》GB 50009-2001

1.2 《建筑抗震设计规范》GB 50011-2001

1.3 《钢结构设计规范》GBJ 17-88

1.4 《混凝土结构设计规范》GB 50010-2002

2. 已知条件

2.1 材料

钢材Q235 $f_y := 235N \cdot mm^{-2}$ $f := 210N \cdot mm^{-2}$ $f_v := 125N \cdot mm^{-2}$

$E_s := 206 \cdot 10^3 N \cdot mm^{-2}$

焊条E43xx $f_{tw} := 160N \cdot mm^{-2}$

混凝土C20 $f_c := 9.6N \cdot mm^{-2}$

2.2 计算系数

2.2.1 荷载分项系数

永久荷载(可变荷载控制的组合) $\gamma_{G1} := 1.2$

永久荷载(永久荷载控制的组合) $\gamma_{G2} := 1.35$

活荷载 $\gamma_Q := 1.4$

2.2.1 活荷载组合值系数

屋面活荷载 $\psi_{q1} := 0.7$

屋面积灰荷载 $\psi_{q2} := 0.9$

2.2.3 轴心受压杆稳定系数

b类截面轴心受压杆稳定系数见《钢规》附录3

稳定系数是长细比的函数, 设长细比为λ, b类截面轴心受压杆稳定系数函数

$$\phi_b(\lambda) := \left| \begin{array}{l} \lambda_{Phi} \leftarrow \dfrac{\lambda}{\pi} \cdot \sqrt{\dfrac{f_y}{E_s}} \\ \alpha_4 \leftarrow 0.965 + 0.3 \cdot \lambda_{Phi} + \lambda_{Phi}^2 \\ 1 - 0.65 \cdot \lambda_{Phi}^2 \ \text{ if } \ \lambda_{Phi} \le 0.215 \\ \dfrac{1}{2 \cdot \lambda_{Phi}^2} \cdot \left(\alpha_4 - \sqrt{\alpha_4^2 - 4 \cdot \lambda_{Phi}^2} \right) \ \text{ otherwise} \end{array} \right.$$

校对 $\phi_b(60) = 0.807$ OK

2.2.4 计算长度系数

平面内：

弦杆 $\mu_{0x1} := 1$　　支座斜(竖)杆 $\mu_{0x2} := 1$　　其他腹杆 $\mu_{0x3} := 0.8$

平面外：

$\mu_{0y2} := 1$　　$\mu_{0y3} := 1$

2.2.5 允许长细比

受拉 $\lambda\_ := 350$　　受压 $\lambda\_1 := 150$

3. 荷载计算

屋架跨度 $L_k := 27m$　　柱距 $S_c := 6m$　　上弦杆节点距离 $S_s := 1500mm$

3.1 荷载汇集

梯形钢屋架 $g_{k1} := \left(120 + 11m^{-1} \cdot L_k\right) \cdot N \cdot m^{-2}$　　$g_{k1} = 417\,N \cdot m^{-2}$

支撑 $g_{k2} := 70N \cdot m^{-2}$

屋面板 $g_{k3} := 1400N \cdot m^{-2}$

二毡三油加绿豆砂 $g_{k4} := 400N \cdot m^{-2}$

找平层 $g_{k5} := 400N \cdot m^{-2}$

恒载合计 $g_k := g_{k1} + g_{k2} + g_{k3} + g_{k4} + g_{k5}$　　$g_k = 2.687\,kN \cdot m^{-2}$

活荷载

分布活荷载 $q_{k1} := 700N \cdot m^{-2}$　　$\psi_{q1} = 0.7$

积灰荷载 $q_{k2} := 800N \cdot m^{-2}$　　$\psi_{q2} = 0.9$

设计荷载取两种组合的最大值（详见新《荷载规范》第3.2.3条：

活荷载控制的组合

$\Sigma q_1 := \gamma_{G1} \cdot g_k + \gamma_Q \cdot q_{k2} + \gamma_Q \cdot \psi_{q1} \cdot q_{k1}$　　$\Sigma q_1 = 5.03\,kN \cdot m^{-2}$

恒荷载控制的组合

$\Sigma q_2 := \gamma_{G2} \cdot g_k + \gamma_Q \cdot \psi_{q1} \cdot q_{k1} + \gamma_Q \cdot \psi_{q2} \cdot q_{k2}$　　$\Sigma q_2 = 5.321\,kN \cdot m^{-2}$

显然, 屋架属于永久荷载效应控制的组合。荷载设计值为：

$g_a := \gamma_{G2} \cdot g_k \qquad q_a := \gamma_Q \cdot \left(\psi_{q1} \cdot q_{k1} + \psi_{q2} \cdot q_{k2}\right)$

$\Sigma q := \max\left(\left(\Sigma q_1 \;\; \Sigma q_2\right)\right)$

$g_a = 3.627\,kN \cdot m^{-2} \qquad q_a = 1.694\,kN \cdot m^{-2} \qquad \Sigma q = 5.321\,kN \cdot m^{-2}$

3.2 屋架节点荷载

3.2.1 全跨永久荷载＋全跨可变荷载

$F_1 := \Sigma q \cdot S_c \cdot S_s \qquad F_1 = 47.893\,kN$

3.2.2 全跨永久荷载＋半跨可变荷载

$F_{2L} := F_1 \qquad F_{2L} = 47.893\,kN$

$F_{2R} := g_a \cdot S_c \cdot S_s \qquad F_{2R} = 32.647\,kN$

3.2.3 全跨屋架包括支撑＋（半跨屋面板自重＋半跨屋面活荷载）

$F_{3L} := \left[\gamma_{G2} \cdot \left(g_{k1} + g_{k2} + g_{k3}\right) + \gamma_Q \cdot q_{k1}\right] \cdot S_c \cdot S_s \qquad F_{3L} = 31.747\,kN$

$F_{3R} := \gamma_{G2} \cdot \left(g_{k1} + g_{k2}\right) \cdot S_c \cdot S_s \qquad F_{3R} = 5.917\,kN$

4. 内力计算

钢屋架杆件编号见“杆件编号及几何尺寸图”。

内力系数见“内力系数图”

经蛳类工程比较, F2＊组合对设计不起控制作用。故未列入内力矩阵。

建立杆件内力矩阵

4.1 内力矩阵表头

杆件长度按顺序	内力系数 F=1			第一种组合 F1x①	第三种组合		杆件计算内力	
	全跨①	左半跨②	右半跨③		F3L *② + F3R *③	F3R *② + F3L *③	MAX	MIN
0	1	2	3	4	5	6	7	8

4.2 内力矩阵

内力计算转到Excel中进行。

Na :=

内力矩阵.xls

建立内力矩阵见下页

Na =

	0	1	2	3	4	5	6	7	8
0	0	1	2	3	4	5	6	7	8
1	2.85	5.676	4.187	1.489	271.841	141.735	72.046	271.841	72.046
2	3	13.395	9.402	3.993	641.527	322.112	182.397	641.527	182.397
3	4.5	18.302	11.46	6.842	876.538	404.305	285.022	876.538	285.022
4	3	17.855	8.914	8.941	855.13	335.897	336.594	855.13	335.897
5	1.357	0	0	0	0	0	0	0	0
6	1.507	-10.06	-7.255	-2.805	-481.804	-246.922	-131.978	-131.978	-481.804
7	1.507	-10.06	-7.255	-2.805	-481.804	-246.922	-131.978	-131.978	-481.804
8	1.507	-15.883	-10.803	-5.08	-760.685	-373.021	-225.196	-225.196	-760.685
9	1.507	-16.471	-11.391	-5.08	-788.846	-391.688	-228.675	-228.675	-788.846
10	1.507	-16.472	-11.392	-5.08	-788.893	-391.72	-228.681	-228.681	-788.893
11	1.507	-18.715	-11.075	-7.64	-896.317	-396.804	-308.078	-308.078	-896.317
12	1.507	-19.217	-11.575	-7.642	-920.36	-412.689	-311.1	-311.1	-920.36
13	1.507	-19.2	-11.576	-7.624	-919.546	-412.614	-310.534	-310.534	-919.546
14	1.99	-0.5	-0.5	0	-23.947	-15.873	-2.958	-2.958	-23.947
15	2.278	-1	-1	0	-47.893	-31.747	-5.917	-5.917	-47.893
16	2.581	-1.496	-1.496	0	-71.648	-47.494	-8.852	-8.852	-71.648
17	3.036	-1.496	-1.496	0	-71.648	-47.494	-8.852	-8.852	-71.648
18	3.34	0	0	0	0	0	0	0	0
19	1.29	-1	-1	0	-47.893	-31.747	-5.917	-5.917	-47.893
20	1.518	-1	-1	0	-47.893	-31.747	-5.917	-5.917	-47.893
21	2.518	-10.221	-7.539	-2.682	-489.514	-255.21	-129.754	-129.754	-489.514
22	2.602	7.802	5.459	2.343	373.661	187.17	106.684	373.661	106.684
23	2.855	-6.447	-4.158	-2.289	-308.766	-145.548	-97.272	-97.272	-308.766
24	2.855	4.581	2.562	2.019	219.398	93.282	79.257	219.398	79.257
25	1.883	0.735	0.735	0	35.201	23.334	4.349	35.201	4.349
26	2.081	-3.469	-0.987	-2.482	-166.141	-46.02	-84.636	-46.02	-166.141
27	2.081	-2.654	-0.175	-2.479	-127.108	-20.224	-79.736	-20.224	-127.108
28	3.251	0.691	-0.955	1.646	33.094	-20.579	46.605	46.605	-20.579
29	2.029	0.675	0.675	0	32.328	21.429	3.994	32.328	3.994
30	2.244	1.184	3.15	-1.966	56.705	88.37	-43.776	88.37	-43.776
31	2.244	1.929	3.891	-1.962	92.386	111.918	-39.265	111.918	-39.265

$Na := Na \cdot 1kN$

最大内力向量： $Nmax := Na^{\langle 7 \rangle}$

最小内力向量： $Nmin := Na^{\langle 8 \rangle}$

举例 ：

1 号杆最大内力 $Nmax_1 = 271.841\ kN$

21号杆最小内力 $Nmin_{21} = -489.514\ kN$

5. 杆件设计

5.1 建立计算模块

5.1.1 建立杆件长度向量

$La := Na^{\langle 0 \rangle} \cdot m \cdot kN^{-1}$

平面内计算长度

$L_{0x} := La$

$i := 15, 16 .. 20$ $\quad L_{0x_i} := 0.8 \cdot L_{0x_i}$

$i := 22, 23 .. 31$ $\quad L_{0x_i} := 0.8 \cdot L_{0x_i}$

平面外计算长度

$L_{0y} := La$

$i := 1, 2 .. 4$ $\quad L_{0y_i} := \dfrac{L_k}{2}$ （跨中有系杆）

$i := 5, 6 .. 13$ $\quad L_{0y_i} := 3 \cdot L_{0x_i}$

$$L_{0y_{26}} := \left| \begin{array}{l} N_1 \leftarrow (-1) \cdot \min\left(\left(Nmin_{26} \quad Nmin_{27}\right)\right) \\ N_2 \leftarrow (-1) \cdot \max\left(\left(Nmin_{26} \quad Nmin_{27}\right)\right) \\ l_1 \leftarrow La_{26} + La_{27} \\ l_0 \leftarrow l_1 \cdot \left(0.75 + 0.25 \cdot \dfrac{N_2}{N_1}\right) \\ \left(0.5 \cdot l_1\right) \ \text{ if } \ l_0 < 0.5 \cdot l_1 \\ l_0 \ \text{ otherwise} \end{array} \right.$$

$$L_{0y_{30}} := \left| \begin{array}{l} N_1 \leftarrow (-1) \cdot \min\left(\left(Nmin_{30} \quad Nmin_{31}\right)\right) \\ N_2 \leftarrow (-1) \cdot \max\left(\left(Nmin_{30} \quad Nmin_{31}\right)\right) \\ l_1 \leftarrow La_{30} + La_{31} \\ l_0 \leftarrow l_1 \cdot \left(0.75 + 0.25 \cdot \dfrac{N_2}{N_1}\right) \\ \left(0.5 \cdot l_1\right) \ \text{ if } \ l_0 < 0.5 \cdot l_1 \\ l_0 \ \text{ otherwise} \end{array} \right.$$

$L_{0y_{26}} = 3.918\,m$ $\quad L_{0y_{27}} := L_{0y_{26}}$

$L_{0y_{30}} = 4.372\,m$ $\quad L_{0y_{31}} := L_{0y_{30}}$

5.1.2 建立估算杆件截面积模块

$$Ag(Nmax,Nmin) := \begin{cases} \dfrac{Nmax}{f} & \text{if } Nmin \ge 0 \\ \left|\dfrac{Nmin}{\phi_b(60)\cdot f}\right| & \text{if } Nmax < 0 \\ \max\left(\left(\dfrac{Nmax}{f} \quad \left|\dfrac{Nmin}{\phi_b(60)\cdot f}\right|\right)\right) & \text{otherwise} \end{cases}$$

$$i_{g0x}(L_{0x}) := \frac{L_{0x}}{60} \qquad i_{g0y}(L_{0y}) := \frac{L_{0y}}{60}$$

5.1.3 建立强度及稳定性验算模块

设实际截面几何参数为 An、ixn、iyn

5.1.3.1 强度验算

$$\sigma_1(An,Nmax,Nmin) := \frac{\max((|Nmax| \quad |Nmin|))}{An}$$

$$R_{\sigma1}(\sigma_1) := \text{if}(\sigma_1 < f, \text{"OK"}, \text{"NO GOOD"})$$

5.1.3.2 稳定验算模块

$$\lambda_x(i_{xn},L_{0xn}) := \frac{L_{0xn}}{i_{xn}} \qquad \lambda_y(i_{yn},L_{0yn}) := \frac{L_{0yn}}{i_{yn}}$$

$$\lambda(\lambda_x,\lambda_y) := \max((\lambda_x \quad \lambda_y))$$

$$\sigma_2(\lambda,An,Nmin) := \begin{cases} \dfrac{Nmin}{\phi_b(\lambda)\cdot An} & \text{if } Nmin < 0 \\ 0 & \text{otherwise} \end{cases}$$

$$R_{\sigma2}(\sigma_2) := \text{if}(|\sigma_2| < f, \text{"OK"}, \text{"NO GOOD"})$$

5.2 估算截面

$i := 0, 1 .. 31$

$Nmax =$

	0
0	7
1	271.841
2	641.527
3	876.538
4	855.13
5	0
6	-131.978
7	-131.978
8	-225.196
9	-228.675
10	-228.681
11	-308.078
12	-311.1
13	-310.534
14	-2.958
15	-5.917
16	-8.852
17	-8.852
18	0
19	-5.917
20	-5.917
21	-129.754
22	373.661
23	-97.272
24	219.398
25	35.201
26	-46.02
27	-20.224
28	46.605
29	32.328
30	88.37
31	111.918

$Nmin =$

	0
0	8
1	72.046
2	182.397
3	285.022
4	335.897
5	0
6	-481.804
7	-481.804
8	-760.685
9	-788.846
10	-788.893
11	-896.317
12	-920.36
13	-919.546
14	-23.947
15	-47.893
16	-71.648
17	-71.648
18	0
19	-47.893
20	-47.893
21	-489.514
22	106.684
23	-308.766
24	79.257
25	4.349
26	-166.141
27	-127.108
28	-20.579
29	3.994
30	-43.776
31	-39.265

kN

$Ag(Nmax_i, Nmin_i)$ (cm²)	$i_{g0x}(L_{0x_i})$ (cm)	$i_{g0y}(L_{0y_i})$ (cm)
0.333	0	0
12.945	4.75	22.5
30.549	5	22.5
41.74	7.5	22.5
40.72	5	22.5
0	2.262	6.785
28.42	2.512	7.535
28.42	2.512	7.535
44.87	2.512	7.535
46.531	2.512	7.535
46.534	2.512	7.535
52.87	2.512	7.535
54.288	2.512	7.535
54.24	2.512	7.535
1.413	3.317	3.317
2.825	3.037	3.797
4.226	3.441	4.302
4.226	4.048	5.06
0	4.453	5.567
2.825	1.72	2.15
2.825	2.024	2.53
28.874	4.197	4.197
17.793	3.469	4.337
18.213	3.807	4.758
10.448	3.807	4.758
1.676	2.511	3.138
9.8	2.775	6.529
7.498	2.775	6.529
2.219	4.335	5.418
1.539	2.705	3.382
4.208	2.992	7.287
5.329	2.992	7.287

5.3 选择截面

最大腹杆内力绝对值 $\left|Nmin_{21}\right| = 489.514\ kN$

取节点板厚度 $t_a := 10mm$

支座节点板厚 $t_{a\_1} := 12mm$

5.3.1 下弦杆

采用用一截面, 为不等肢角钢短肢相拼。杆件编号 $i := 1, 2 .. 4$

当杆件编号 $j := 3$ 时最不利

选 2L140x90x10短肢相拼 $A_3 := 44.522cm^2$ $i_{x3} := 2.56cm$ $i_{y3} := 6.77cm$

$\sigma_{3\_1} := \sigma_1\left(A_3, Nmax_j, Nmin_j\right)$ $\sigma_{3\_1} = 196.877\ N\cdot mm^{-2}$

$R_{\sigma1}\left(\sigma_{3\_1}\right) = \text{"OK"}$

$\lambda_{x3} := \lambda_x\left(i_{x3}, L_{0x_j}\right)$ $\lambda_{y3} := \lambda_y\left(i_{y3}, L_{0y_j}\right)$ $\lambda_3 := \lambda\left(\lambda_{x3}, \lambda_{y3}\right)$

$\lambda_{x3} = 175.781$ $\lambda_{y3} = 199.409$ $\lambda_3 = 199.409$

$R_{\lambda3} := if\left(\lambda_3 < \lambda\_, \text{"OK"}, \text{"NO GOOD"}\right)$ $R_{\lambda3} = \text{"OK"}$

5.3.2 上弦杆

杆件编号范围 $i := 5, 6 .. 13$

可以看出, $j := 12$ 杆最不利

选 2L180x110x10短肢相拼 $A_{12} := 56.75cm^2$ $i_{x12} := 3.13cm$ $i_{y12} := 8.63cm$

$\lambda_{x12} := \lambda_x\left(i_{x12}, L_{0x_j}\right)$ $\lambda_{y12} := \lambda_y\left(i_{y12}, L_{0y_j}\right)$ $\lambda_{12} := \lambda\left(\lambda_{x12}, \lambda_{y12}\right)$

$\lambda_{x12} = 48.147$ $\lambda_{y12} = 52.387$ $\lambda_{12} = 52.387$

$R_{\lambda12} := if\left(\lambda_{12} < \lambda_{\_1}, \text{"OK"}, \text{"NO GOOD"}\right)$ $R_{\lambda12} = \text{"OK"}$

$\sigma_{2\_12} := \sigma_2\left(\lambda_{12}, A_{12}, Nmin_j\right)$ $\sigma_{2\_12} = -191.864\ N\cdot mm^{-2}$

$R_{\sigma2\_12} := R_{\sigma2}\left(\sigma_{2\_12}\right)$ $R_{\sigma2\_12} = \text{"OK"}$

5.3.3 支座斜杆

杆件编号 $j := 21$

采用 2L125x80x8 长肢相拼 $A_{21} := 31.978cm^2$ $i_{x21} := 4.01cm$ $i_{y21} := 3.27cm$

$\lambda_{x21} := \lambda_x(i_{x21}, L_{0x_j})$ $\lambda_{y21} := \lambda_y(i_{y21}, L_{0y_j})$ $\lambda_{21} := \lambda(\lambda_{x21}, \lambda_{y21})$

$\lambda_{x21} = 62.793$ $\lambda_{y21} = 77.003$ $\lambda_{21} = 77.003$

$R_{\lambda21} := if(\lambda_{21} < \lambda\_1, "OK", "NO GOOD")$ $R_{\lambda21} = "OK"$

$\sigma_{2\_21} := \sigma_2(\lambda_{21}, A_{21}, Nmin_j)$ $\sigma_{2\_21} = -216.458 N\cdot mm^{-2}$ $\sigma_{2\_21a} := 1.05^{-1}\cdot\sigma_{2\_21}$

$R_{\sigma2\_21} := R_{\sigma2}(\sigma_{2\_21a})$ $R_{\sigma2\_21} = "OK"$

5.3.4 竖腹杆计算

杆件编号 $i := 14, 15..17$ 显然 $j := 17$ 杆最不利

取 2L63x5 $A_{17} := 12.286cm^2$ $i_{x17} := 1.94cm$ $i_{y17} := 2.96cm$

$\lambda_{x17} := \lambda_x(i_{x17}, L_{0x_j})$ $\lambda_{y17} := \lambda_y(i_{y17}, L_{0y_j})$ $\lambda_{17} := \lambda(\lambda_{x17}, \lambda_{y17})$

$\lambda_{x17} = 125.196$ $\lambda_{y17} = 102.568$ $\lambda_{17} = 125.196$

$R_{\lambda17} := if(\lambda_{17} < \lambda\_1, "OK", "NO GOOD")$ $R_{\lambda17} = "OK"$

$\sigma_{2\_17} := \sigma_2(\lambda_{17}, A_{17}, Nmin_j)$ $\sigma_{2\_17} = -142.124 N\cdot mm^{-2}$

$R_{\sigma2\_17} := R_{\sigma2}(\sigma_{2\_17})$ $R_{\sigma2\_17} = "OK"$

5.3.5 斜腹杆

5.3.5.1 第 $j := 22$ 杆

受拉杆, 截面积按估算值取即可。选 2L90x6

$A_{22} := 21.174cm^2$ $i_{x22} := 2.79cm$ $i_{y22} := 4.05cm$

刚度验算

$\lambda_{x22} := \lambda_x(i_{x22}, L_{0x_j})$ $\lambda_{y22} := \lambda_y(i_{y22}, L_{0y_j})$ $\lambda_{22} := \lambda(\lambda_{x22}, \lambda_{y22})$

$\lambda_{x22} = 74.609$ $\lambda_{y22} = 64.247$ $\lambda_{22} = 74.609$

$R_{\lambda22} := if(\lambda_{22} < \lambda\_, "OK", "NO GOOD")$ $R_{\lambda22} = "OK"$

5.3.5.2 第 $j := 23$ 杆

取截面蚺22杆 $A_{23} := A_{22}$ $i_{x23} := i_{x22}$ $i_{y23} := i_{y22}$

$\lambda_{x23} := \lambda_x(i_{x23}, L_{0x_j})$ $\lambda_{y23} := \lambda_y(i_{y23}, L_{0y_j})$ $\lambda_{23} := \lambda(\lambda_{x23}, \lambda_{y23})$

$\lambda_{x23} = 81.864$ $\lambda_{y23} = 70.494$ $\lambda_{23} = 81.864$

$R_{\lambda23} := if(\lambda_{23} < \lambda\_1, "OK", "NO GOOD")$ $R_{\lambda23} = "OK"$

$\sigma_{2\_23} := \sigma_2(\lambda_{23}, A_{23}, Nmin_j)$ $\sigma_{2\_23} = -215.878\ N \cdot mm^{-2}$ $\sigma_{2\_23a} := \frac{\sigma_{2\_23}}{1.05}$

$R_{\sigma2\_23} := R_{\sigma2}(\sigma_{2\_23a})$ $R_{\sigma2\_23} = "OK"$

5.3.5.3 第 $i := 26, 27, 30, 31$杆

属于平面外计算长度大于平面内的腹杆, 选不等肢角钢短边相篯

$j := 26$最不利选 2L90x56x5 $A_{26} := 14.424cm^2$ $i_{x26} := 1.59cm$ $i_{y26} := 4.47cm$

$\lambda_{x26} := \lambda_x(i_{x26}, L_{0x_j})$ $\lambda_{y26} := \lambda_y(i_{y26}, L_{0y_j})$ $\lambda_{26} := \lambda(\lambda_{x26}, \lambda_{y26})$

$\lambda_{x26} = 104.704$ $\lambda_{y26} = 87.641$ $\lambda_{26} = 104.704$

$R_{\lambda26} := if(\lambda_{26} < \lambda\_1, "OK", "NO GOOD")$ $R_{\lambda26} = "OK"$

$\sigma_{2\_26} := \sigma_2(\lambda_{26}, A_{26}, Nmin_j)$ $\sigma_{2\_26} = -219.369\ N \cdot mm^{-2}$ $\sigma_{2\_26a} := \frac{\sigma_{2\_26}}{1.05}$

$R_{\sigma2\_26} := R_{\sigma2}(\sigma_{2\_26a})$ $R_{\sigma2\_26} = "OK"$

5.3.5.4 其他腹杆

选 2L63x5 即可。

5.4 确定填板间距

双角钢填板间距 (单位：mm)					
角钢规格	连接情况	受力情况	与填板平行的单肢回转半径(i)	受压40i	受拉80i
2L140x90x10	短肢相连	受拉	44.7		3576
2L180x110x10	短肢相连	受压	51.4	2056	
2L125x80x8	长肢相连	受压	22.9	916	
2L90x56x5	短肢相连	拉＆压	29.0	1160	
2L90x90x6		拉or压	27.9	1116	2232
2L63x63x5		拉or压	19.4	776	1552
2L63x63x5	十字相连	拉＆压	12.5	500	

6. 节点计算

6.0 建立双角钢与节点板搬接焊缝长度求解模块

输入：

结合方式 a_L 为 0、1 、2 分别表示等肢角钢、短肢相搬、长肢相搬。

轴力为 N_L

端焊缝长度 l_{w3} 焊缝高度蚺肢尖焊缝

肢背和肢尖焊缝高度 h_{f1} h_{f2}

输出肢背、肢尖和端焊缝长度： l_{w1} l_{w2} l_{w3}

（注意求出的是双角钢的焊缝长度）

$$l_{w\_2L}(a_L, N_L, l_{w3}, h_{f1}, h_{f2}) := \left| \begin{array}{l} K_L \leftarrow (0.7 \quad 0.3) \ \text{ if } \ a_L = 0 \\ K_L \leftarrow (0.75 \quad 0.25) \ \text{ if } \ a_L = 1 \\ K_L \leftarrow (0.65 \quad 0.35) \ \text{ if } \ a_L = 2 \\ K_L \leftarrow (-1 \quad -1) \ \text{ otherwise} \\ N_3 \leftarrow 1.22 \cdot (0.7 \cdot h_{f2}) \cdot (2 l_{w3}) \cdot f_{tw} \\ N_1 \leftarrow {K_L}_{0,0} \cdot N_L - 0.5 \cdot N_3 \\ N_2 \leftarrow {K_L}_{0,1} \cdot N_L - 0.5 \cdot N_3 \\ l_{w1} \leftarrow \dfrac{1}{2} \dfrac{N_1}{0.7 \cdot h_{f1} \cdot f_{tw}} \\ l_{w2} \leftarrow \dfrac{1}{2} \dfrac{N_2}{0.7 \cdot h_{f2} \cdot f_{tw}} \\ (l_{w1} \quad l_{w2} \quad l_{w3}) \end{array} \right.$$

计算结果为负值表示按构造设计。

6.0.1 支座腹杆焊缝计算

$i := 21$

$N_{max_i} := \max\left(\left|Nmax_i\right|, \left|Nmin_i\right|\right)$

$l_{w\_2L}\left(2, N_{max_i}, 125mm, 8mm, 6mm\right) = (120.371 \quad 51.228 \quad 125)\,mm$

6.0.2 竖腹杆焊缝计算

$i := 14, 15 .. 20$

$N_{max_i} := \max\left(\left|Nmax_i\right|, \left|Nmin_i\right|\right)$

肢背

$l_{w\_2L}\left(0, N_{max_i}, 63mm, 8mm, 5mm\right)_{0,0} =$

-14.665
-5.311
3.969
3.969
-24.019
-5.311
-5.311

mm

肢尖

$l_{w\_2L}\left(0, N_{max_i}, 63mm, 8mm, 5mm\right)_{0,1} =$

-32.016
-25.602
-19.239
-19.239
-38.43
-25.602
-25.602

mm

6.0.3 第22、23杆

$i := 22..23$

$N_{max_i} := \max\left(\left|Nmax_i\right|, \left|Nmin_i\right|\right)$

肢背

$l_{w\_2L}\left(0, N_{max_i}, 90mm, 8mm, 6mm\right)_{0,0} =$

104.786
79.437

mm

肢尖

$l_{w\_2L}\left(0, N_{max_i}, 63mm, 8mm, 5mm\right)_{0,1} =$

61.658
44.275

mm

6.0.4 第24、28杆

$i := 24, 28..28$

$N_{max_i} := \max\left(\left|Nmax_i\right|, \left|Nmin_i\right|\right)$

肢背

$l_{w\_2L}\left(0, N_{max_i}, 63mm, 8mm, 5mm\right)_{0,0} =$

61.684
-5.814

mm

肢尖

$l_{w\_2L}\left(0, N_{max_i}, 63mm, 8mm, 5mm\right)_{0,1} =$

20.337
-25.947

mm

6.0.5 第26、27、30、31杆

$i := 26..27$

$N_{max_i} := \max\left(\left|Nmax_i\right|, \left|Nmin_i\right|\right)$

肢背

$l_{w\_2L}\left(1, N_{max_i}, 56mm, 8mm, 5mm\right)_{0,0} =$

48.184
31.848

mm

肢尖

$l_{w\_2L}\left(1, N_{max_i}, 56mm, 8mm, 5mm\right)_{0,1} =$

2.925
-5.788

mm

$i := 30..31$

$N_{max_i} := \max\left(\left|Nmax_i\right|, \left|Nmin_i\right|\right)$

肢背

肢尖

$l_{w\_2L}\left(1, N_{max_i}, 56mm, 8mm, 5mm\right)_{0,0} =$

15.635
25.491

mm

$l_{w\_2L}\left(1, N_{max_i}, 56mm, 8mm, 5mm\right)_{0,1} =$

-14.435
-9.178

mm

6.0.6 第25、29杆

$i := 25, 29 .. 29$

$N_{max_i} := \max\left(\left|Nmax_i\right|, \left|Nmin_i\right|\right)$

肢背

$l_{w\_2L}\left(0, N_{max_i}, 63mm, 8mm, 5mm\right)_{0,0} =$

-10.268
-11.391

mm

肢尖

$l_{w\_2L}\left(0, N_{max_i}, 63mm, 8mm, 5mm\right)_{0,1} =$

-29.001
-29.771

mm

6.1 节点①计算

6.1.1 支座底板计算

支座反力 $F_v := 9 \cdot F_1$ $F_v = 431.037\,kN$

加劲肋下底板底面尺寸 $a_{d\_1} := 280mm$ $b_{d\_1} := 212mm$ $t_{d\_1} := 20mm$

验算柱顶承压强度

$$\sigma_c := \frac{F_v}{a_{d\_1} \cdot b_{d\_1}} \qquad \sigma_c = 7.261\,N \cdot mm^{-2}$$

$$R_{\sigma c} := \text{if}\left(\sigma_c \le f_c, \text{"OK"}, \text{"NO GOOD"}\right) \qquad R_{\sigma c} = \text{"OK"}$$

求底板厚度

为两相邻支撑板,

$$a_{dd1} := \sqrt{\left(0.5 \cdot a_{d\_1}\right)^2 + \left(0.5 \cdot b_{d\_1}\right)^2} \qquad b_{dd1} := \left(0.5 \cdot b_{d\_1}\right) \cdot \frac{0.5 \cdot a_{d\_1}}{a_{dd1}}$$

$$\nu_{ab1} := \frac{b_{dd1}}{a_{dd1}} \qquad \nu_{ab1} = 0.481$$

查表5—1得 $\beta_{ab1} := 0.0583$

$$M_{ab1} := \beta_{ab1} \cdot \sigma_c \cdot a_{dd1}^{\,2} \qquad M_{ab1} = 13.054\,kN \cdot \frac{m}{m}$$

$$t := \sqrt{\frac{6 \cdot M_{ab1}}{f}} \qquad t = 19.313\,mm$$

取 20mm

6.1.2 加劲肋与节点板掰接焊缝计算

$$V_d := \frac{1}{4} \cdot F_v \qquad V_d = 107.759\,kN$$

$M_d := V_d \cdot \left(\frac{1}{4} \cdot b_{d\_1}\right)$　　$M_d = 5.711\ kN \cdot m$

焊缝长度　$l_{wdw} := 480mm - 30mm$　　$l_{wdw} = 450\ mm$

焊缝高度　$h_f := 6mm$

$\sigma_{dw2} := \sqrt{\left(\frac{V_d}{2 \cdot 0.7 \cdot h_f \cdot l_{wdw}}\right)^2 + \left(\frac{M_d}{2 \cdot 0.7 \cdot h_f \cdot l_{wdw}^2 \cdot 1.22}\right)^2}$　　$\sigma_{dw2} = 28.64\ N \cdot mm^{-2}$

$R_{\sigma dw2} := if(\sigma_{dw2} > f_{tw}, "NO\ GOOD", "OK")$　　$R_{\sigma dw2} = "OK"$

6.1.3 节点板加劲肋与底板的鞢接焊缝计算

纵焊缝长度为：　$l_{wd} := 2(a_{d\_1} - 10mm) + 4 \cdot \left(\frac{b_{d\_1}}{2} - 36mm\right)$　　$l_{wd} = 820\ mm$

焊缝高度　$h_f := 6mm$

$\sigma_d := \frac{F_v}{0.7 \cdot h_f \cdot l_{wd} \cdot 1.22}$　　$\sigma_d = 102.587\ N \cdot mm^{-2}$

$R_{\sigma d} := if(\sigma_d > f_{tw}, "NO\ GOOD", "OK")$　　$R_{\sigma d} = "OK"$

6.2 节点②计算

腹杆与节点板鞢接见6.0节。

该点为节点板与下弦杆间的内力最大点, 节点板与弦杆鞢接：

焊缝受力为两弦杆的内力差　$\Delta N_2 := |Nmax_2 - Nmax_3|$　　$\Delta N_2 = 235.011\ kN$

需要的焊缝长度

$l_{w\_2L}(1, \Delta N_2, 0mm, 8mm, 8mm) = (98.358\quad 32.786\quad 0)\ mm$

6.3 节点⑦计算

腹杆与节点板翔接见6.0节。

该点为上弦杆中节点板与弦杆间的内力最大点, 节点板与弦杆翔接：

上弦与节点板间为槽焊缝, 等效角焊缝高度 $h_{f7\_up} := \frac{t_a}{2}$ $h_{f7\_up} = 5\,mm$

下弦与节点板翔接为角焊缝 $h_{f7\_dw} := 8mm$

节点力 $F_1 = 47.893\,kN$

弦杆的轴力差为 $\Delta N_7 := \left|Nmin_5 - Nmin_6\right|$ $\Delta N_7 = 481.804\,kN$

需要的焊缝长度 ：

肢背 $l_{w7\_up} := \frac{\sqrt{\left(0.75 \cdot \Delta N_7\right)^2 + \left(\frac{0.5 \cdot F_1}{1.22}\right)^2}}{2 \cdot 0.7 \cdot h_{f7\_up} \cdot \left(0.8 \cdot f_{tw}\right)}$ $l_{w7\_up} = 403.89\,mm$

肢尖 $l_{w7\_dw} := \frac{\sqrt{\left(0.25 \cdot \Delta N_7\right)^2 + \left(\frac{0.5 \cdot F_1}{1.22}\right)^2}}{2 \cdot 0.7 \cdot h_{f7\_dw} \cdot f_{tw}}$ $l_{w7\_dw} = 68.103\,mm$

6.4 节点⒂计算

6.4.1 屋脊拼接计算

屋脊采用蚌号角钢拼接, 由于有节点板强度不必计算。翔接焊缝计算如下

轴力为： $\left|Nmin_{13}\right| = 919.546\,kN$

焊缝高度： $h_{f15\_1} := 8mm$

需要的焊缝长度 ： $l_{w15\_1} := \frac{\left|Nmin_{13}\right|}{4 \cdot 0.7 \cdot h_{f15\_1} \cdot f_{tw}}$ $l_{w15\_1} = 256.57\,mm$

6.4.2 节点板受力计算

轴力 $N_{15\_2} := 0.15 \cdot \left|Nmin_{13}\right|$ $N_{15\_2} = 137.932\,kN$

集中力 $F_1 = 47.893\,kN$

肢尖焊缝高度 $h_{f15\_21} := 8mm$ 肢背 $h_{f15\_22} := 0.5 \cdot t_a$ $h_{f15\_22} = 5\,mm$

节点板宽为 $b_{15} := 500mm$ 焊缝计算长度 $l_{w15\_2} := \frac{b_{15}}{2} - 3cm$ $l_{w15\_2} = 220\,mm$

偏心 $e_{15} := 85mm$

6.4.2.1肢尖焊缝计算

假定承受轴力

假定承受轴力

$$\tau_{N15\_2} := \frac{N_{15\_2}}{2\cdot 0.7\cdot h_{f15\_21}\cdot l_{w15\_2}} \qquad \tau_{N15\_2} = 55.979\,N\cdot mm^{-2}$$

$$\sigma_{M15\_2} := \frac{N_{15\_2}\cdot e_{15}\cdot 6}{2\cdot 0.7\cdot h_{f15\_21}\cdot l_{w15\_2}^{2}} \qquad \sigma_{M15\_2} = 129.769\,N\cdot mm^{-2}$$

$$\sigma_{15\_2} := \sqrt{\tau_{N15\_2}^{2} + \left(\frac{\sigma_{M15\_2}}{1.22}\right)^{2}} \qquad \sigma_{15\_2} = 120.199\,N\cdot mm^{-2}$$

$$R_{\sigma15\_2} := if\left(\sigma_{15\_2} > f_{tw}, \text{"NO GOOD"}, \text{"OK"}\right) \qquad R_{\sigma15\_2} = \text{"OK"}$$

6.4.2.2 肢背焊缝计算

假定承受集中力 $F_v = 431.037\,kN$

$$\sigma_{t15\_2} := \frac{\frac{1}{1.22}\cdot\left(\frac{F_v}{2}\right)}{2\cdot 0.7\cdot h_{f15\_22}\cdot l_{w15\_2}} \qquad \sigma_{t15\_2} = 114.711\,N\cdot mm^{-2}$$

$$R_{\sigma t15\_2} := if\left(\sigma_{t15\_2} > 0.8f_{tw}, \text{"NO GOOD"}, \text{"OK"}\right) \qquad R_{\sigma t15\_2} = \text{"OK"}$$

6.5 节点⑤计算

6.5.1 拼接计算

采用与下弦构件相蜂的角钢拼接, 由于有节点板, 强度不用计算。

采用等强辫接, 角钢截面积 $A_4 := 22.26cm^2$ 计算拉力 $N_{5\_1} := A_4\cdot f$

焊缝高度 $h_{f5\_1} := 8mm$

需要的焊缝长度为

$$l_{w5\_1} := \frac{N_{5\_1}}{2\cdot 0.7\cdot h_{f5\_1}\cdot f_{tw}} \qquad l_{w5\_1} = 260.859\,mm$$

6.5.2 节点板计算

轴力 $N_{5\_2} := 0.15\,Nmax_4$ $N_{5\_2} = 128.269\,kN$

焊缝长度：

$$l_{w\_2L}\left(1, N_{5\_2}, 0mm, 8mm, 6mm\right) = (53.684 \quad 23.86 \quad 0)\,mm$$

（全部计算结束）