

Laced column Lacing elements

laced column bracing elements										
number	1	2	3	4	5	6	7	8	9	10 sum
length meter	1	2.3	1	2.3	1	2.3	1	2.3	1	2.3
K factor	1	1	1	1	1	1	1	1	1	1
effective length meter	1	2.3	1	2.3	1	2.3	1	2.3	1	2.3
compression tons	8	9	0.2	18.5	0.1	12	3.5	11.5	0.1	7.8
tension tons	6.7	16	1.3	7.5	0.1	9.2	0	4.2	0.3	2
box height mm	50	70	50	70	50	70	50	70	50	70
box thickness mm	4	5	4	5	4	5	4	5	5	5
box area mm2	736	1300	736	1300	736	1300	736	1300	900	1300
box volume mm3	736000	2990000	736000	2990000	736000	2990000	736000	2990000	900000	2990000
radius of gyration i	18.85028735	26.614532	18.8502874	26.614532	18.85028735	26.61453237	18.85028735	26.614532	18.4842275	26.6145324
λ max	53.04958918	86.418952	53.0495892	86.418952	53.04958918	86.41895217	53.04958918	86.418952	54.1001781	86.4189522
L/d	20	32.857143	20	32.857143	20	32.85714286	20	32.857143	20	32.8571429
applied compression stress	1.086956522	0.6923077	0.02717391	1.4230769	0.013586957	0.923076923	0.475543478	0.8846154	0.01111111	0.6
allowable compression stress	1.905073171	1.6025647	1.90507317	1.6025647	1.905073171	1.602564706	1.905073171	1.6025647	1.8977561	1.60256471
compression applied /allowable %	57.06	43.20	1.43	88.80	0.71	57.60	24.96	55.20	0.59	37.44
applied tension stress	0.910326087	1.2307692	0.17663043	0.5769231	0.013586957	0.707692308	0	0.3230769	0.03333333	0.15384615
Tension applied/allowable %	25.29	34.19	4.91	16.03	0.38	19.66	0.00	8.97	0.93	4.27
Weld calculations										
welding thickness mm	4	5	4	5	4	5	4	5	5	5
welding length cm	5.8	8.7	5.8	9.9	5.8	6.8	5.8	6.5	6.0	6.0

Roof wind Bracing

roof wind bracing			gusset plate weld calculation for max compression and tension				
type	cross members	straight members	Note: two members connected with one gusset plate are with same force with different direction , so there is no compression or tension force only shear force exists				
max compression tons	3.7	0.7					
max tension tons	3.5	0.7					
buckling length meter	5.7	6					
length meters	7.5	6					
HSS height mm	100	100	shear force =	$2 * 4 * \cos(56) =$	6.825761	tons	
HSS thickness mm	4	4	weld thickness = Sw	4		mm	
HSS area mm2	153600	153600	weld length =	shear force / $0.2 * F_u * S_w + 2 * S_w$	17.20808	cm	
HSS volume mm3	1152000000	921600000	Bolts required				
angle count	2	2	bolt diameter	10 mm			
angle height mm	100	100	bolt strength	10.9 ton/cm2			
angle thickness mm	10	10	bolts count	2 bolts			
angle area mm2	384000	384000	Rsh	2.054601595 tons			
angle volume mm3	2880000000	2304000000	R bearing	3.744 tons			
welding thickness mm	4	4	R total max	4.109203191 tons			
welding length cm	5.8	5.8					
saved weight percentage %	60%	60%					
decision	use HSS						

Truss connections

Connection T22 :

plate length	40	cm	gusset Plate design and its weld		
plate thickness	1	cm			
weld thickness	0.5	cm	moment due to tension	-231	ton.cm
tension	5.5	tons	Ix	5333.33	cm3
shear	15.5	tons	y	20	cm
normal eccentricity	20	cm	Area	40	cm2
shear eccentricity	22	cm	weld max +ve normal stress	0.72875	ton/cm
steel ultimate stress	5.2	ton/cm2	shear stress	0.3875	ton/cm2
steel yield stress	3.6	ton/cm2	combined stress	0.99073	ton/cm2
			weld safety	safe	
			gusset plate +ve normal stress	0.72875	ton/cm2
			gusset plate shear force	0.3875	ton/cm2
			combined stress	0.99073	ton/cm2
			plate safety	safe	

Gusset Plate Straining actions :

$$\text{Tension} = T = 5.5 * \cos(3) + 15.5 * \cos(45) = 16.5 \text{ tons}$$

$$\text{Shear} = Q = 5.5 * \sin(3) + 15.5 * \cos(45) = 11.3 \text{ tons}$$

use gusset plate = 20mm

Bolts Design :

Group A :

Normal force = 5.5 tons

Using 2 bolts , M16, grade 10.9

$$\text{Shear for bolt} = 5.5/2 = 2.8 \text{ tons}$$

Using gusset plate thickness for bolts = 10 mm

$$\text{Plate Bearing resistance } R_b = 1\text{cm} * 5.2 \text{ ton/cm}^2 * 1.6\text{cm} = 8.8 \text{ tons}$$

$$\text{Shear resistance } R_{sh} = \text{Bolt Area} * F_{sh} * \text{shear plans} = (3.14 * 1.6^2 * 0.25) * (0.2 * 10.9) * 1 = 4.4 \text{ t}$$

$$R_{\max} = 4.4 \text{ t}$$

Max Normal force = $4.4 * 2 = 8.8 \text{ tons}$ > applied Normal force safe

Group B :

Using 3 bolts , M20, grade 10.9

$$\text{Shear for bolt} = 15.5/3 = 5.2 \text{ tons}$$

Using gusset plate thickness for bolts = 10 mm

$$\text{Plate Bearing resistance } R_b = 1\text{cm} * 5.2 \text{ ton/cm}^2 * 2\text{cm} = 10.4 \text{ tons}$$

$$\text{Shear resistance } R_{sh} = \text{Bolt Area} * F_{sh} * \text{shear plans} = (3.14 * 2^2 * 0.25) * (0.2 * 10.9) * 1 = 6.8 \text{ t}$$

$$R_{\max} = 6.8 \text{ t}$$

Max Normal force = $6.8 * 3 = 20.4 \text{ tons}$ > applied Normal force safe

Connection T11 :

Gusset Plate Straining actions :

Tension = $T = 4$ tons

Compression = $C = 18$ tons

use gusset plate = 20mm

weld thickness = 1.2cm

$$L_{eff} = 18 / (2 * 1 * 0.2 * 5.2) = 7.2 \text{ cm}$$

$$L_{act} = L_{eff} + 2 S_w = 10 \text{ cm}$$

Gusset plate height = 10 cm

Gusset plate length = 20 cm

Gusset plate section Area = $10 * 2 = 20 \text{ cm}$

Gusset plate applied stress = $18 / 20 = 0.9 \text{ ton/cm}^2$

Gusset plate effective length = $20 * 2 = 40 \text{ cm}$ fixed free

Gusset plate smallest inertia = $2^3 * 10 / 12 = 6.67 \text{ cm}^4$

$$L_{eff}/i_{min} = 40 / (6.67 / 20)^{0.5} = 69.3 < 180 \text{ok}$$

$$F_{cr} = 0.58f_y - (KL/i)^2 (0.58f_y - 0.75) / 10000 = 1.6 \text{ ton/cm}^2 > f_{applied} \text{safe}$$

Bolts Design :

Normal force = 18 tons

Using 3 bolts , M20, grade 10.9

Shear for bolt = $18/3 = 6$ tons

Using gusset plate thickness for bolts = 10 mm

Plate Bearing resistance $R_b = 1 \text{ cm} * 5.2 \text{ ton/cm}^2 * 2 \text{ cm} = 10.4 \text{ tons}$

Shear resistance $R_{sh} = \text{Bolt Area} * F_{sh} * \text{shear plans} = (3.14 * 2^2 * 0.25) * (0.2 * 10.9) * 1 = 6.8 \text{ t}$

$R_{max} = 6.8 \text{ t}$

Max Normal force = $6.8 * 3 = 20.4$ tons > applied Normal force safe

Truss Elements

number	1	2	3	4	5	6	7	8	9	10
length meter	2.8	3	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7
K factor	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
effective length meter	3.36	3.6	3.6	3.72	3.84	3.96	4.08	4.2	4.32	4.44
compression tons	0	0	0	0	0	0	0.5	0.65	1	1.3
tension tons	16	13	11	9	7	5	4	2	0.8	0.8
box height mm	60	60	60	60	60	60	60	70	70	70
box thickness mm	4	4	4	4	4	4	4	5	5	5
box area mm2	896	896	896	896	896	896	896	1300	1300	1300
box volume mm3	2508800	2688000	2688000	2777600	2867200	2956800	3046400	4550000	4680000	4810000
radius of gyration i	22.920151	22.920151	22.920151	22.920151	22.920151	22.920151	22.920151	26.614532	26.6145324	26.6145324
λ max	146.59589	157.06703	157.06703	162.30259	167.53816	172.77373	178.0093	157.80852	162.317336	166.826151
L / d	46.666667	50	50	51.666667	53.333333	55	56.666667	50	51.4285714	52.8571429
applied compression stress	0	0	0	0	0	0	0.0558036	0.05	0.07692308	0.1
allowable compression stress	0.3489938	0.3040123	0.3040123	0.284715	0.2671984	0.2512499	0.2366878	0.3011621	0.28466328	0.26948401
compression applied /allowable %	0.00	0.00	0.00	0.00	0.00	0.00	23.58	16.60	27.02	37.11
applied tension stress	1.7857143	1.4508929	1.2276786	1.0044643	0.78125	0.5580357	0.4464286	0.1538462	0.06153846	0.06153846
Tension applied/allowable %	49.60	40.30	34.10	27.90	21.70	15.50	12.40	4.27	1.71	1.71
	Weld calculations									
welding thickness mm	4	4	4	4	4	4	4	5	5	5
welding length cm	10.4	8.6	7.4	6.2	5.8	5.8	5.8	6.0	6.0	6.0

lower elements										
number	1	2	3	4	5	6	7	8	9	10
length meter	2	2	2	2	2	2	2	2	2	2
K factor	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
effective length meter	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
compression tons	18	9	3	2	2	0	0	0	0	0
tension tons	4	4	5	12	17	21	24	26	27	27
box height mm	70	70	60	60	60	70	70	70	70	70
box thickness mm	5	5	4	4	4	5	5	5	5	5
box area mm2	1300	1300	896	896	896	1300	1300	1300	1300	1300
box volume mm3	2600000	2600000	1792000	1792000	1792000	2600000	2600000	2600000	2600000	2600000
radius of gyration i	26.614532	26.614532	22.920151	22.920151	22.920151	26.614532	26.614532	26.614532	26.6145324	26.6145324
λ max	90.176298	90.176298	104.71135	104.71135	104.71135	90.176298	90.176298	90.176298	90.1762979	90.1762979
L / d	28.571429	28.571429	33.333333	33.333333	33.333333	28.571429	28.571429	28.571429	28.5714286	28.5714286
applied compression stress	1.3846154	0.6923077	0.3348214	0.2232143	0.2232143	0	0	0	0	0
allowable compression stress	1.5594353	1.5594353	0.6840278	0.6840278	0.6840278	1.5594353	1.5594353	1.5594353	1.55943529	1.55943529
compression applied/allowable %	88.79	44.39	48.95	32.63	32.63	0.00	0.00	0.00	0.00	0.00
applied tension stress	0.3076923	0.3076923	0.5580357	1.3392857	1.8973214	1.6153846	1.8461538	2	2.07692308	2.07692308
Tension applied/allowable %	8.55	8.55	15.50	37.20	52.70	44.87	51.28	55.56	57.69	57.69
	Weld calculations									
welding thickness mm	5	5	4	4	4	5	5	5	5	5
welding length cm	9.7	6.0	5.8	8.0	11.0	11.1	12.5	13.5	14.0	14.0

