STEEL Arena Košice

Load Carrying Capacity Assessment for the Selected Parts of Supporting Structure for Purpose of Temporary Technology and Systems Installation

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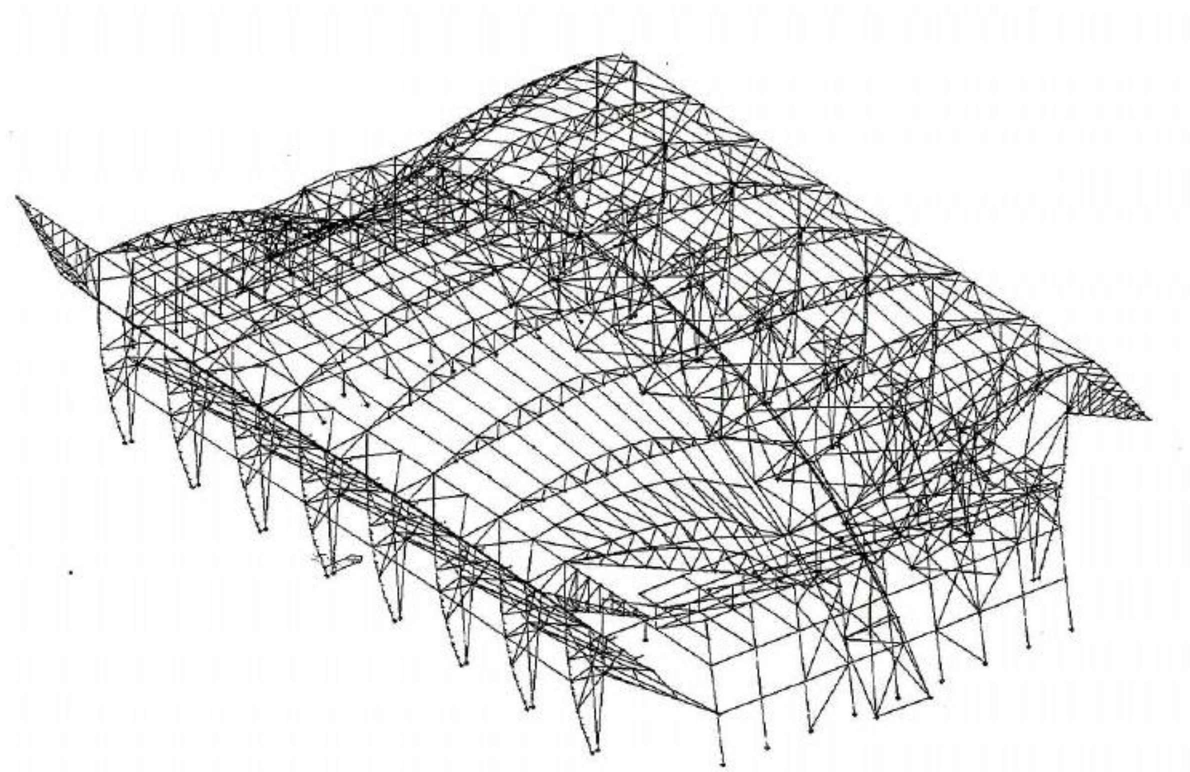
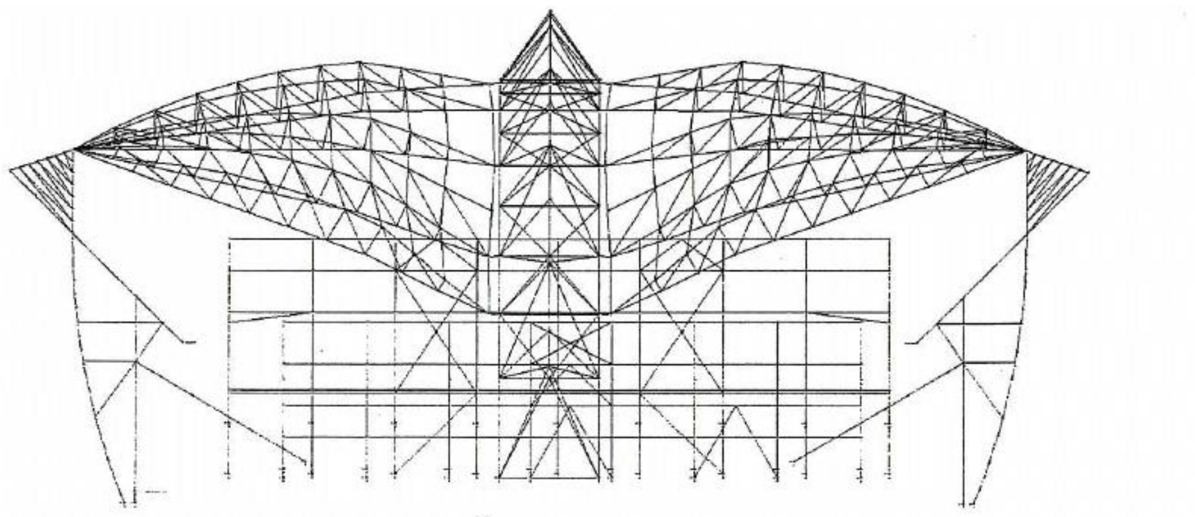
Additional Loading of Steel Arena Roof Structure

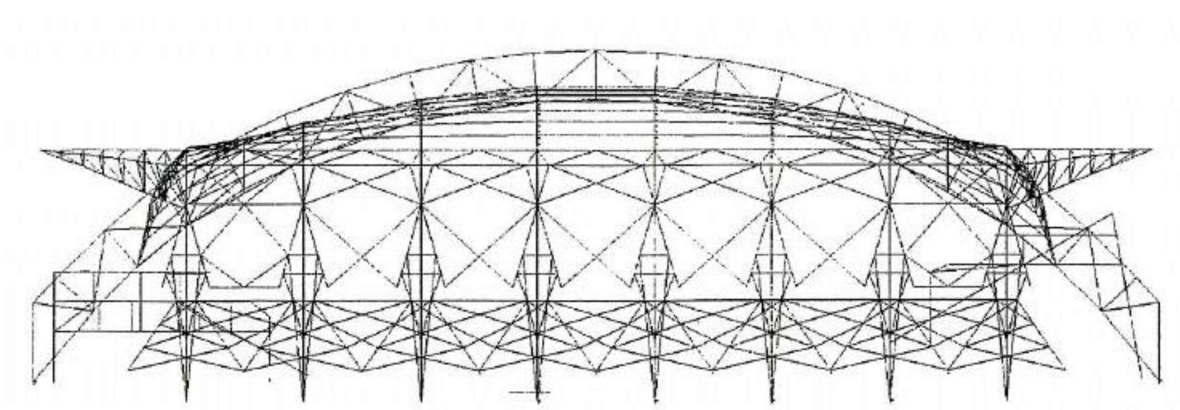
- **A snow load considered - 1.0 kN^{-2}.** So a limit value of snow load corresponds with approx. 1.0m of powder snow (with specific weight o 100kg.m^{-3}) and/or 0.25m of sleet (with specific weight o 400kg.m^{-3}). Such load complies with a water column height equivalent of 0.1m.



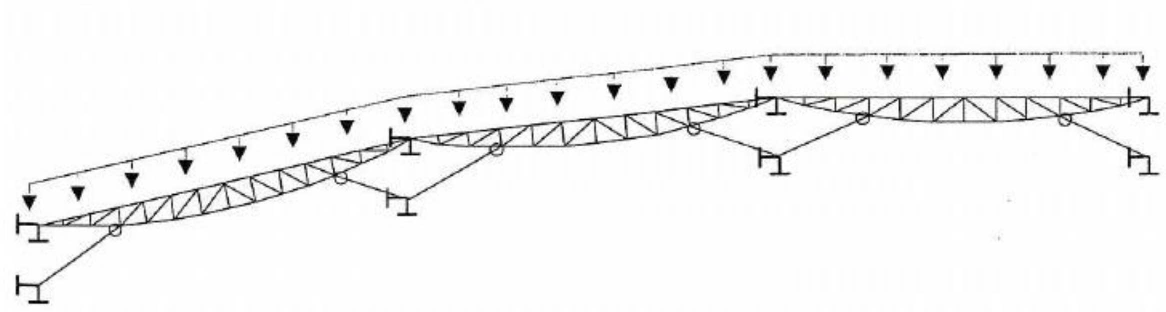
Axonometric view



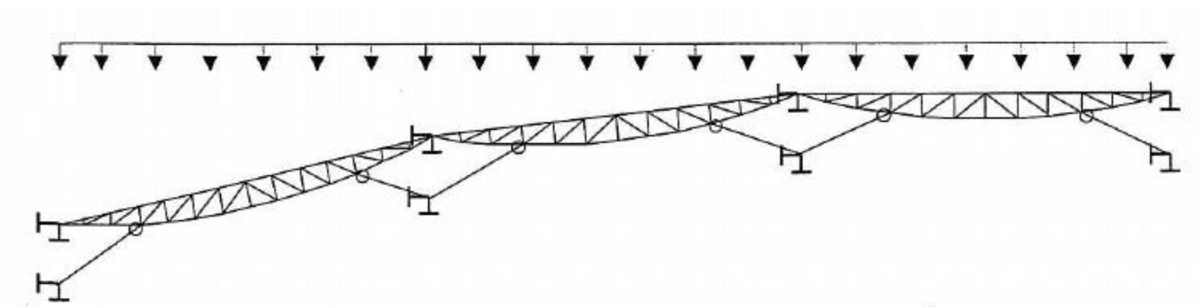
Front view


Side view

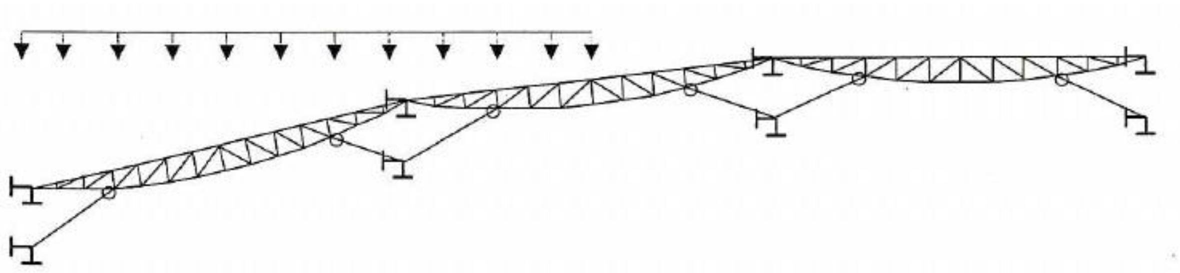
Girder Loading



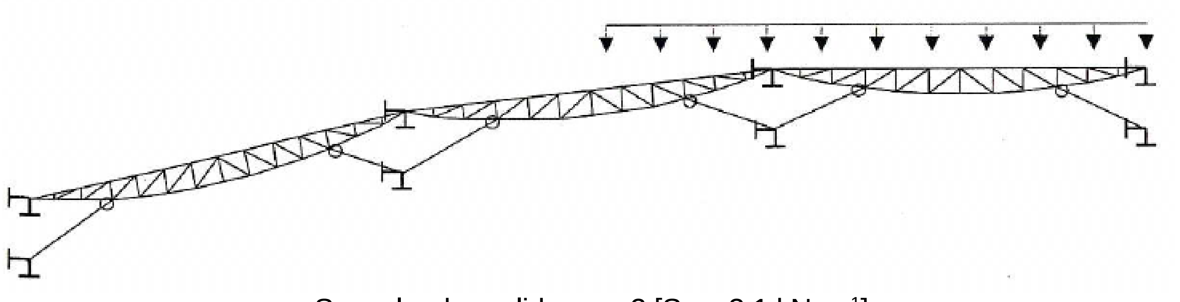
Fixed load [q_v = 1.0 kN.m^{-1}]



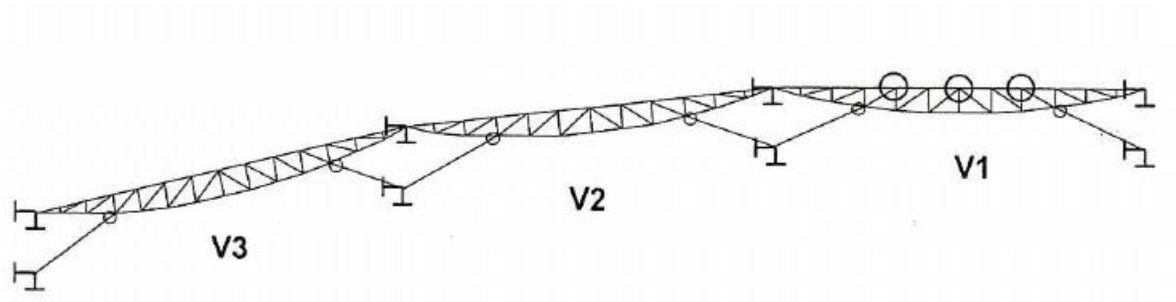
Snow load – full snow [S_v = 3.1 kN.m^{-1}]



Snow load – half snow 1 [S_v = 3.1 kN.m^{-1}]

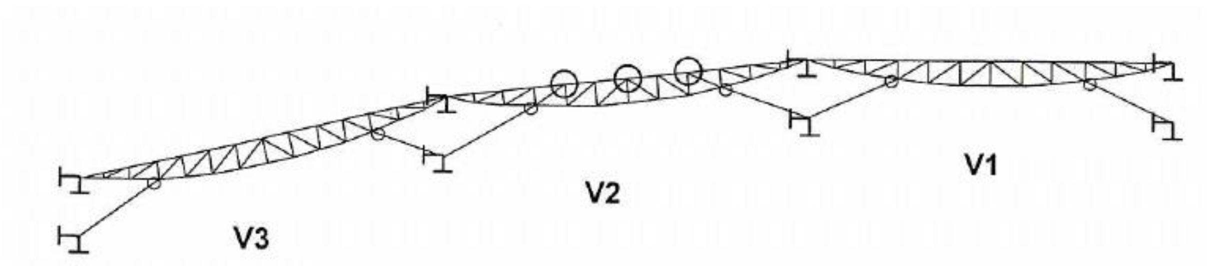


Snow load – solid snow 2 [S_v = 3.1 kN.m^{-1}]



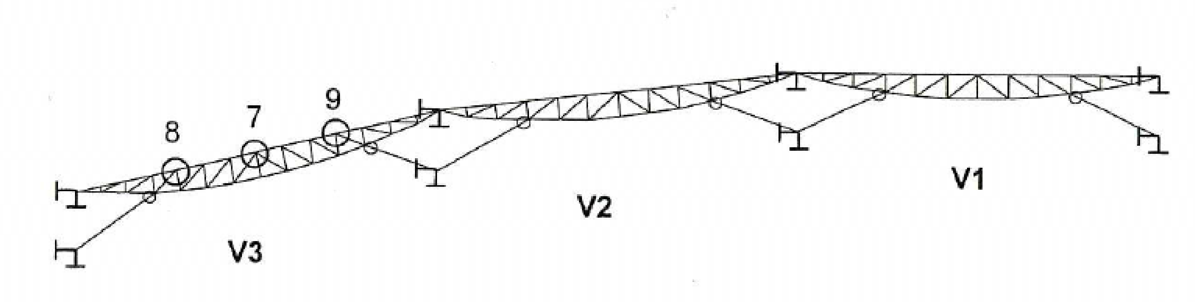
Girder V1. Forces that can act on girder

Junction	Angle	Without snow [kg]	Full snow [kg]	Half snow 1 [kg]	Half snow 2 [kg]
1	90°	750	0	0	0
	60°	850	0	0	0
	45°	1000	0	0	0
2	90°	500	0	0	0
	60°	600	0	0	0
	45°	700	0	0	0
1-2	90°	300	0	0	0
	60°	350	0	0	0
	45°	425	0	0	0
2-3	90°	400	0	0	0
	60°	460	0	0	0
	45°	560	0	0	0



Girder V2. Forces that can act on girder

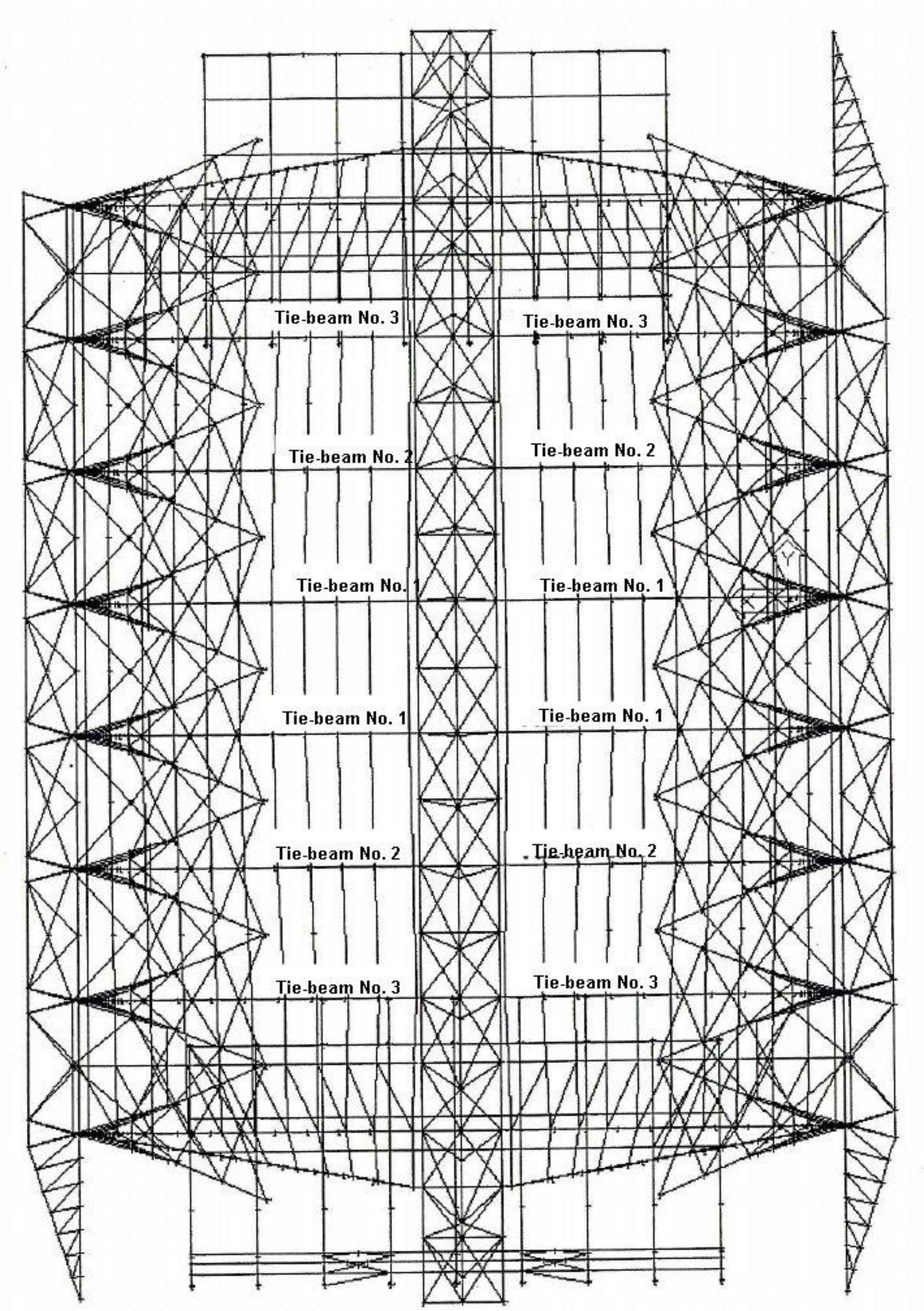
Junction	Angle	Without snow [kg]	Full snow [kg]	Half snow 1 [kg]	Half snow 2 [kg]
4	90°	750	0	0	0
	60°	780	0	0	0
	45°	850	0	0	0
5	90°	550	0	0	0
	60°	630	0	0	0
	45°	750	0	0	0
4-5	90°	330	0	0	0
	60°	370	0	0	0
	45°	440	0	0	0
5-6	90°	400	0	0	0
	60°	420	0	0	0
	45°	480	0	0	0



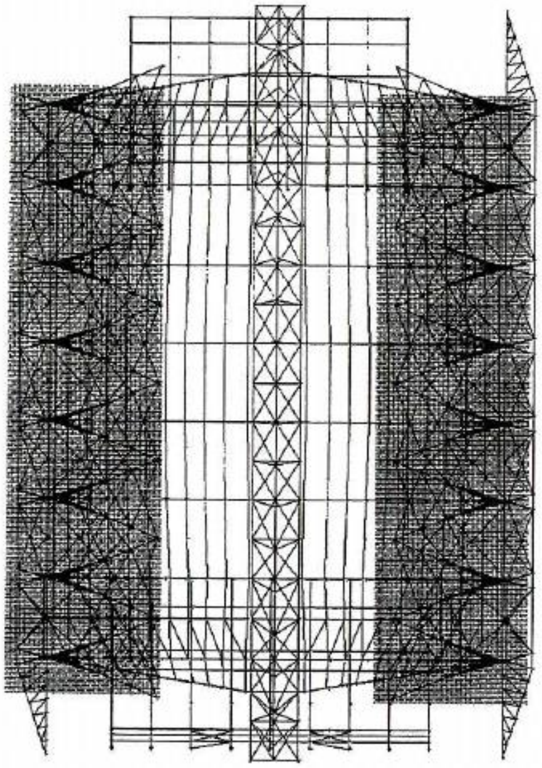
Girder V3. Forces that can act on girder

Junction	Angle	Without snow [kg]	Full snow [kg]	Half snow 1 [kg]	Half snow 2 [kg]
7	90°	950	0	0	0
	60°	960	0	0	0
	45°	1050	0	0	0
8	90°	750	0	0	0
	60°	770	0	0	0
	45°	900	0	0	0
7-8	90°	450	0	0	0
	60°	460	0	0	0
	45°	530	0	0	0
8-9	90°	550	0	0	0
	60°	550	0	0	0
	45°	600	0	0	0

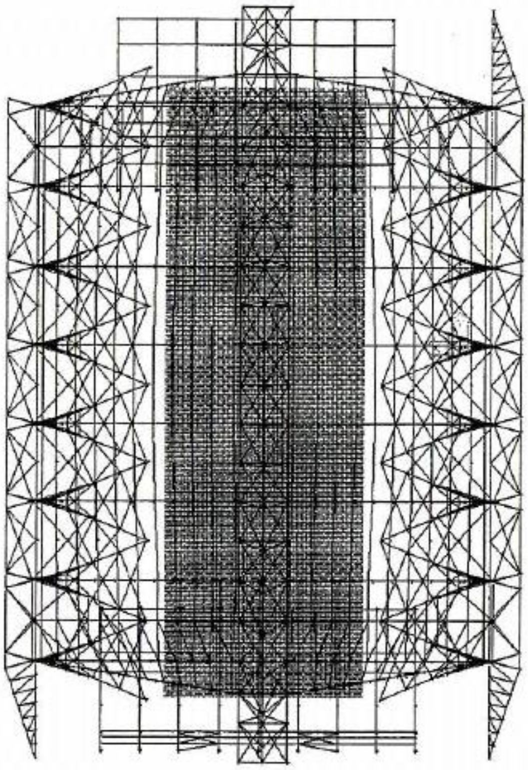
Tie-beam Loading



Ground-plan – tie-beam identification

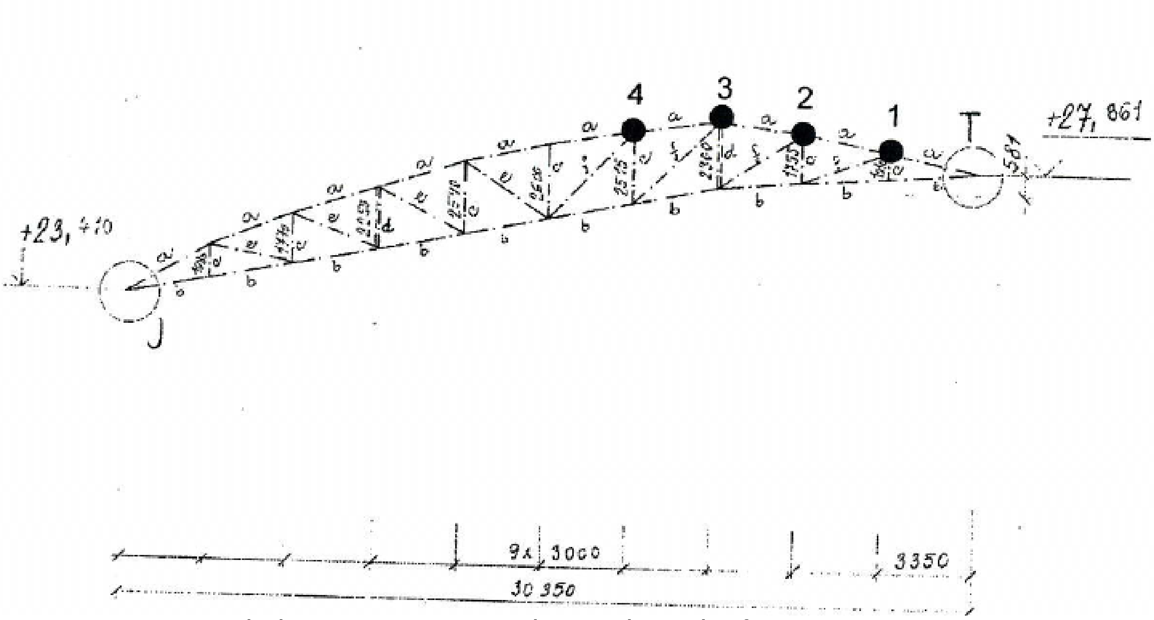


Half snow 1



Half snow 2

Half snow load



Tie-beam No. 1 – Junctions, where the forces can act

Tie-beam No. 1. Forces, acting independently (only a single force can act in time) 90 degrees.

Junction	Without snow [kg]	Full snow [kg]	Half snow 1 [kg]	Half snow 2 [kg]
1	3000	2000	2700	2500
2	3000	2000	2700	2500
3	3000	2000	2700	2500
4	3000	2000	2700	2500

Tie-beam No. 1. Forces, acting independently (only a single force can act in time) 60 degrees.

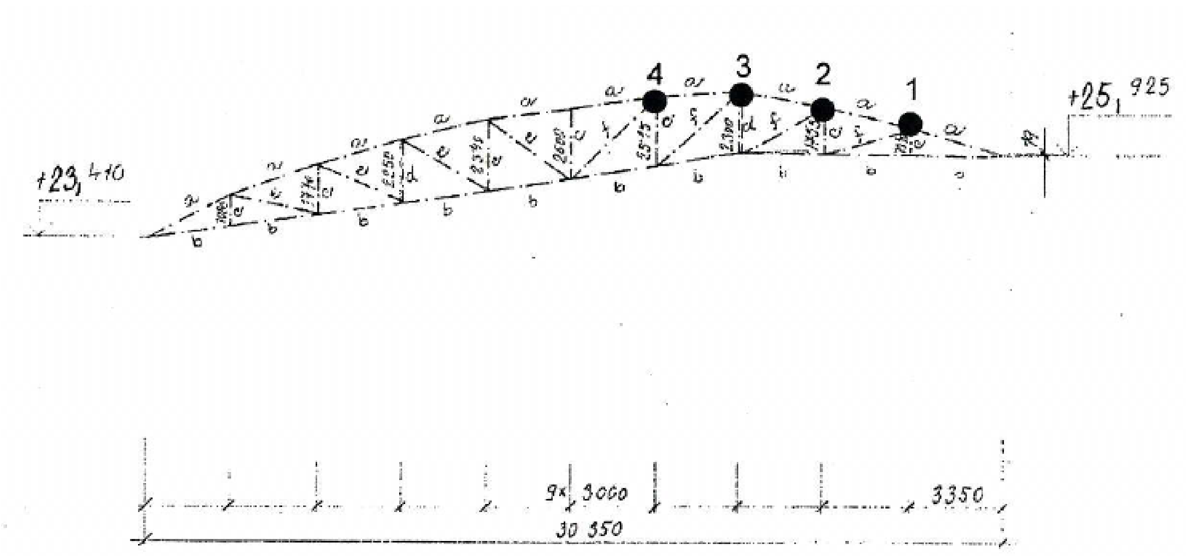
Junction	Without snow [kg]	Full snow [kg]	Half snow 1 [kg]	Half snow 2 [kg]
1	3200	2200	2800	2600
2	3200	2200	2800	2600
3	3200	2200	2800	2600
4	3200	2200	2800	2600

Tie-beam No. 1. Forces, acting independently (only a single force can act in time) 45 degrees.

Junction	Without snow [kg]	Full snow [kg]	Half snow 1 [kg]	Half snow 2 [kg]
1	3300	2300	2900	2700
2	3300	2300	2900	2700
3	3300	2300	2900	2700
4	3300	2300	2900	2700

Tie-beam No. 1. Forces, acting independently (only the two forces can act in time)

Junction	Without snow [kg]	Full snow [kg]	Half snow 1 [kg]	Half snow 2 [kg]
1-2	2000	1000	1700	1500
1-3	2000	1000	1700	1500
1-4	2000	1000	1700	1500
2-3	2000	1000	1700	1500
2-4	2000	1000	1700	1500



Tie-beam No. 2 – Junctions, where the forces can act

Tie-beam No. 2. Forces, acting independently (only a single force can act in time) 90 degrees.

Junction	Without snow [kg]	Full snow [kg]	Half snow 1 [kg]	Half snow 2 [kg]
1	2700	1900	2300	2100
2	2700	1900	2300	2100
3	2700	1900	2300	2100
4	2700	1900	2300	2100

Tie-beam No. 2. Forces, acting independently (only a single force can act in time) 60 degrees.

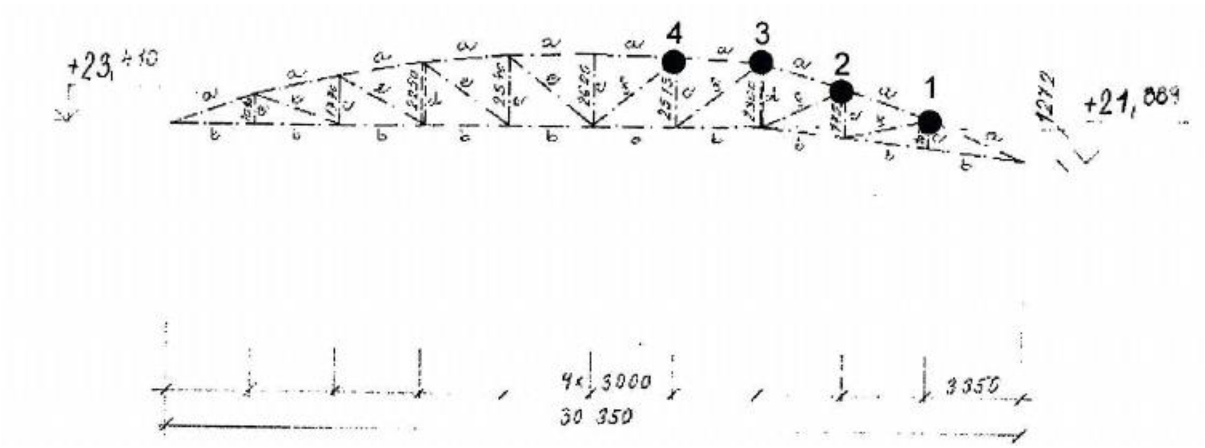
Junction	Without snow [kg]	Full snow [kg]	Half snow 1 [kg]	Half snow 2 [kg]
1	2900	2000	2400	2200
2	2900	2000	2400	2200
3	2900	2000	2400	2200
4	2900	2000	2400	2200

Tie-beam No. 2. Forces, acting independently (only a single force can act in time) 45 degrees.

Junction	Without snow [kg]	Full snow [kg]	Half snow 1 [kg]	Half snow 2 [kg]
1	3000	2100	2500	2300
2	3000	2100	2500	2300
3	3000	2100	2500	2300
4	3000	2100	2500	2300

Tie-beam No. 2. Forces, acting independently (only the two forces can act in time)

Junction	Without snow [kg]	Full snow [kg]	Half snow 1 [kg]	Half snow 2 [kg]
1-2	1350	950	1300	1100
1-3	1350	950	1300	1100
1-4	1350	950	1300	1100
2-3	1350	950	1300	1100
2-4	1350	950	1300	1100



Tie-beam No. 3 – Junctions, where the forces can act

Tie-beam No. 3. Forces, acting independently (only a single force can act in time) 90 degrees.

Junction	Without snow [kg]	Full snow [kg]	Half snow 1 [kg]	Half snow 2 [kg]
1	2500	1700	2100	1900
2	2500	1700	2100	1900
3	2500	1700	2100	1900
4	2500	1700	2100	1900

Tie-beam No. 3. Forces, acting independently (only a single force can act in time) 60 degrees.

Junction	Without snow [kg]	Full snow [kg]	Half snow 1 [kg]	Half snow 2 [kg]
1	2600	1800	2200	2000
2	2600	1800	2200	2000
3	2600	1800	2200	2000
4	2600	1800	2200	2000

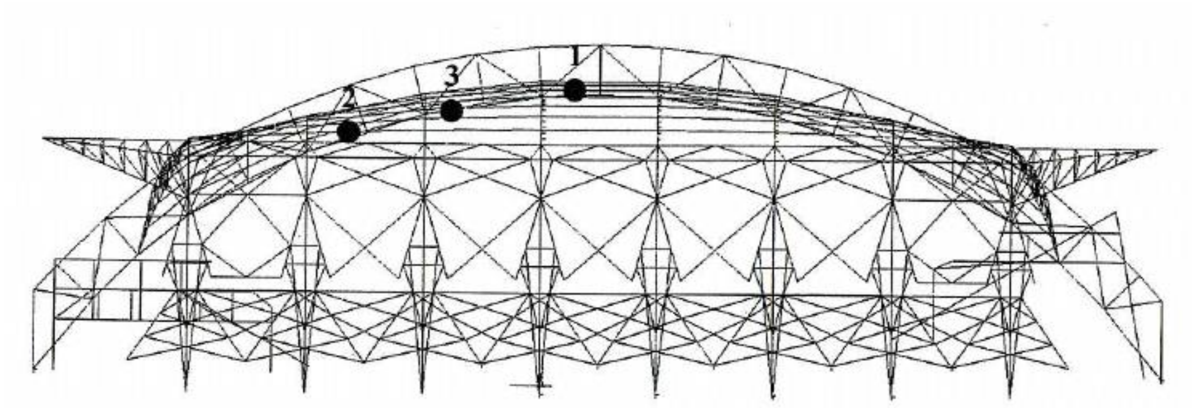
Tie-beam No. 3. Forces, acting independently (only a single force can act in time) 45 degrees.

Junction	Without snow [kg]	Full snow [kg]	Half snow 1 [kg]	Half snow 2 [kg]
1	2700	1900	2300	2100
2	2700	1900	2300	2100
3	2700	1900	2300	2100
4	2700	1900	2300	2100

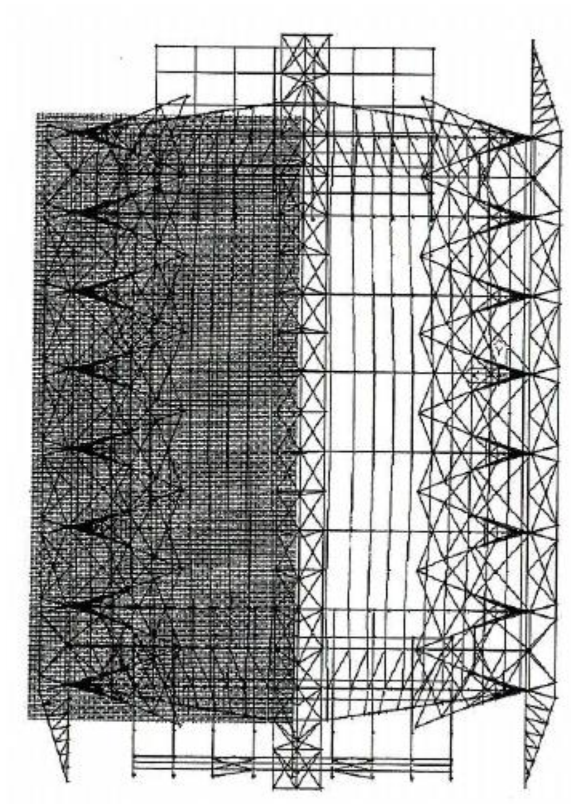
Tie-beam No. 3. Forces, acting independently (only the two forces can act in time)

Junction	Without snow [kg]	Full snow [kg]	Half snow 1 [kg]	Half snow 2 [kg]
1-2	1500	800	1200	1000
1-3	1500	800	1200	1000
1-4	1500	800	1200	1000
2-3	1500	800	1200	1000
2-4	1500	800	1200	1000

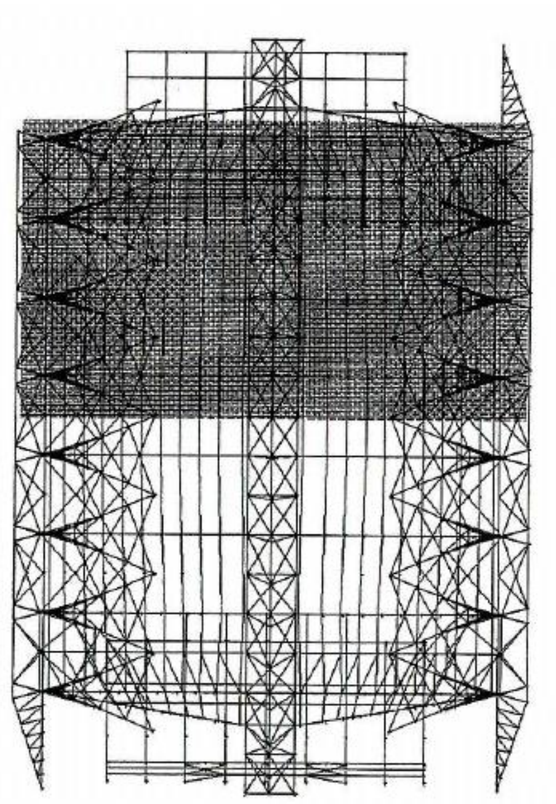
Load on Arc



Arc loading junction – bottom strip, independent forces



Half snow 1



Half snow 2

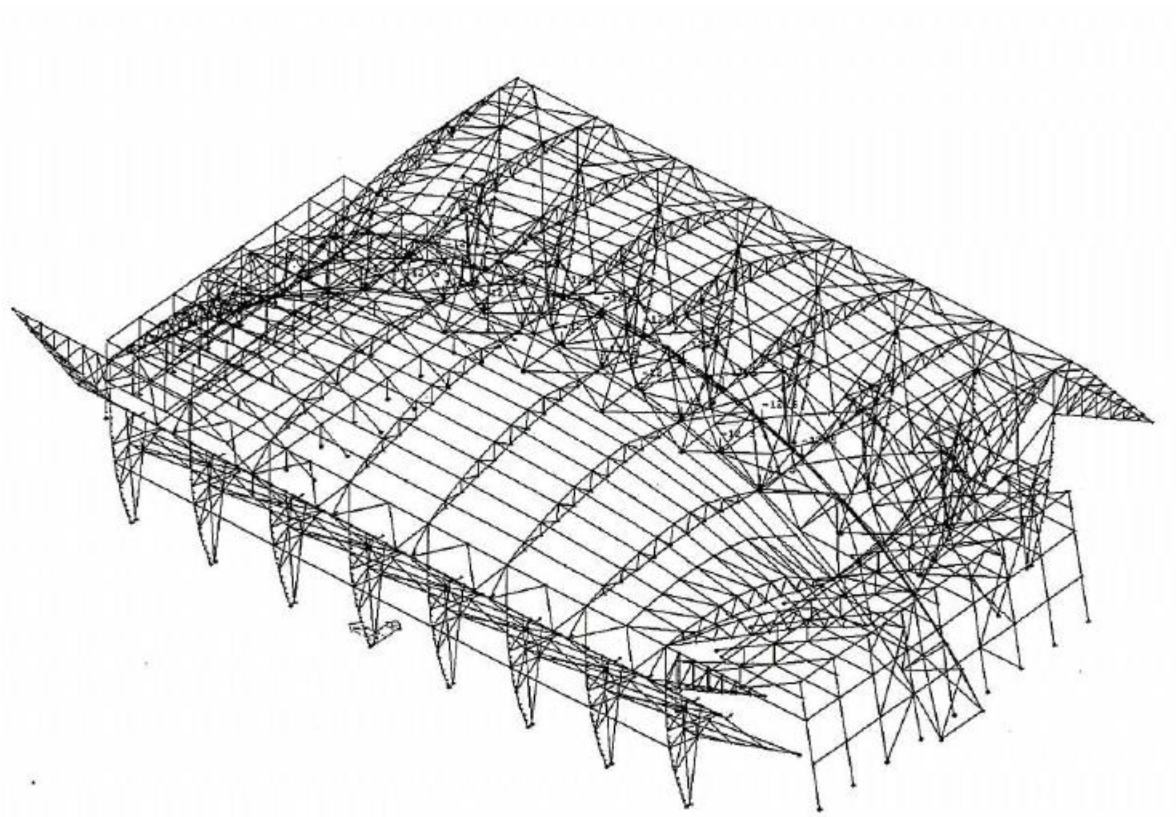
Half snow load

Independent forces, acting on bottom arc strip outside of node

Junction	Without snow [kg]	Full snow [kg]	Half snow 1 [kg]	Half snow 2 [kg]
1	2000	1700	1800	1900
2	2000	1700	1800	1900
3	2000	1700	1800	1900
1, 2, 3	2000	1700	1800	1900

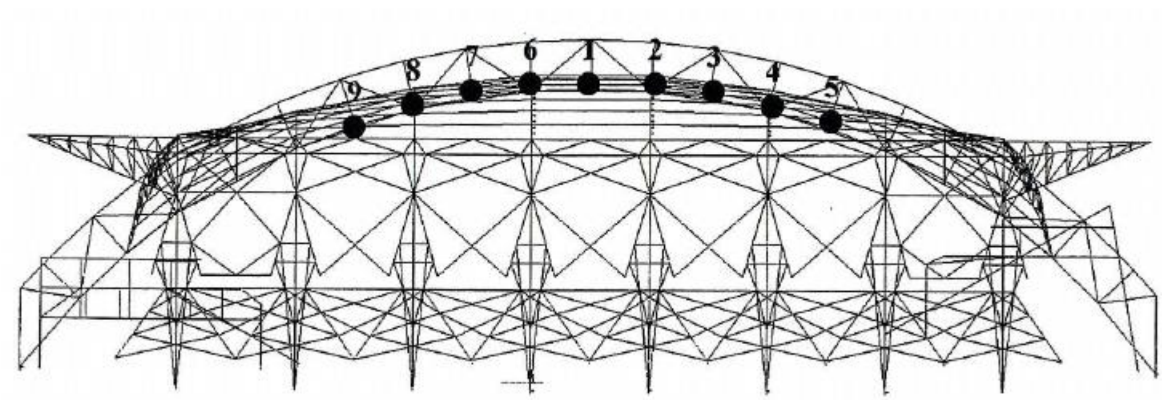
Load on Arc

Load – independent forces and load on girders and tie-beams



Load on arc
Load 25 tons – 25,000kg – auxiliary structure + snow load, steady load and self-weight. Efficiency 99%.

If a total load of suspended structure exceeds 12,000kg, a snow layer shall be removed from roof structure before a structure is suspended.



Nodes for arc loading – bottom strip on both sides

Nodes for arc loading – bottom strip on both sides (only a single force is acting on single strip but on both sides of bottom strip – however, it means that no other load is acting either on girders or tie-beams).

Junction	Without snow [kg]	Full snow [kg]	Half snow 1 [kg]	Half snow 2 [kg]
1	9000	7000	8000	7500
2	9000	7000	8000	7500
3	9000	7000	8000	7500
4	9000	7000	8000	7500
5	9000	7000	8000	7500
6	9000	7000	8000	7500
7	9000	7000	8000	7500
8	9000	7000	8000	7500
9	9000	7000	8000	7500

Note: I consider if so high values should be given to them – I'm afraid if they will understand correctly that nothing else can be suspended there and this solution is quite susceptible to the local damage and joints.

Assessment of welds of individual bars from the additional loading forces

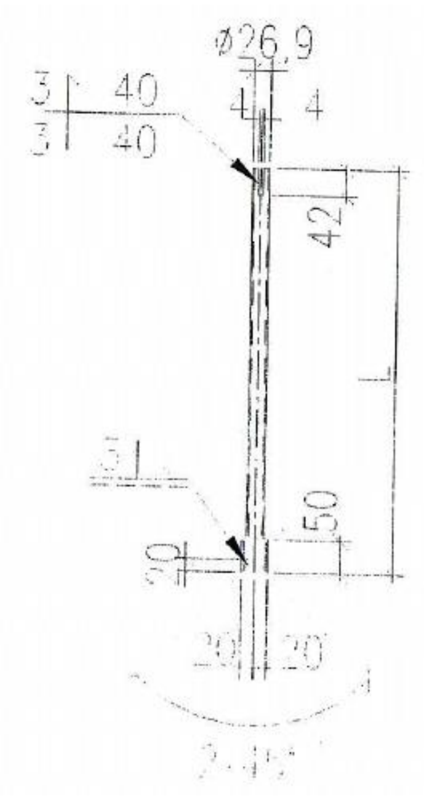
Original static calculation took a following roof load into account:
- Steady load, including a light soffit 0.68 kN/m^2
- Snow load 0.70 kN/m^2
  (half roof loading or full roof loading)
- Wind load 0.55 kN/m^2
- Loading with single load P = 1.0 kN
  (Load on top strip – as a mobile one and always in the most unfavorable position)

All above load values are the standard values. Individual load coefficients were taken from the load standard STN 73 0035.
This entire load was considered step-by-step for the supporting trapezoidal sheets, truss girders, truss tie-beams and supporting arc loading.

Dimensions for individual girder bars:
- Top strip………….……….……… welded T-shaped section – flange P10mm, web P6 mm – flange is broken acc. to roof slope.
- Bottom strip ……………………. Angle L 80x80x6
- Verticals ………………………... Tube TR ∅26.9x2.6
- Diagonals ………………………. Tube TR ∅26.9x2.6

The ends of verticals and diagonals are flattened and welded to the top and bottom strip.

VERTICALS



Max. force from original calculation:
Pmin = -7.3 kN ….. pressure.
Max. force from additional calculation of loading forces from jambs:
Pmin = -2.5 kN….. pressure
Pmax = 7.1 kN….. tension

Side fillet welds – **kut.3 –** near the top strip

$$\tau_{II} = \frac{P}{4.\beta.m.t.L} = \frac{7,1.10^3}{4.0,7.1,18.3.40} = 17,9MPa$$

$$\tau_{II} = 17,9MPa < 0,65.210 = 136,5MPa$$

Scarf fillet weld near the bottom strip – **kut.3**

L = 4x28 = 112mm
P ⊥ = P.sin45° = 7.1 x 0.707 = 5.02 kN
P_{II} = 5.02 kN

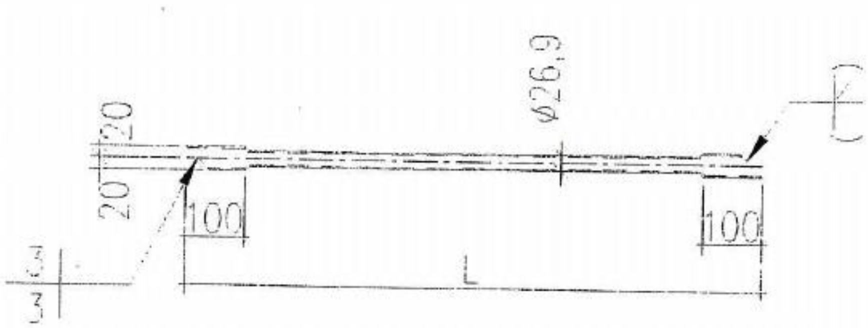
Tension in welds:

$$\tau_{\perp} = \tau_{II} = \frac{5,02.10^3}{112.0,7.3} = 21,34MPa$$

Strength precondition:

$$\sqrt{\left(\frac{21,34}{0,75}\right)^2 + \left(\frac{21,34}{0,65}\right)^2} = 43,44MPa < 210MPa$$

DIAGONALS



Loading force from original calculation: **Pmin = -7.3 kN** ….. pressure
Max. force from additional calculation of loading forces from jambs:
Pmin = -14.5 kN….. pressure
Pmax = 1.7 kN……. tension

Side fillet welds – **kut.3 –** near the top strip
α = 51.55°
P ⊥ = 14.5 x 51.55° = 7.1 x 0.707 = 10.5 kN
P_{II} = 14.5 x 51.55° = 7.1 x 0.707 = 10.0 kN

Weld length L = 2 x 58mm
Tension in welds:

$$\tau_{\perp} = \frac{10,5.10^3}{2.58.0,7.3} = 43,1MPa \qquad \tau_{II} = \frac{10,0.10^3}{2.58.0,7.3} = 41,0MPa$$

Strength precondition:

$$\sqrt{\left(\frac{43,1}{0,75}\right)^2 + \left(\frac{41,0}{0,65}\right)^2} = 85,3MPa < 210MPa$$

Dimensions for individual truss tie-beam bars:

- Top strip………………………… welded section of sheets – triangle shape – flange is broken acc. to roof slope.
- Bottom strip ……………………. Angle L 180x180x14 + sheet P14x300 - triangle
- Verticals ………………………... Tube TR ∅60.3x4 and TR ∅82.5x8
- Diagonals ………………………. Tube TR ∅70x3.6 and TR ∅82.5x5

The ends of verticals and diagonals are flattened and welded to the top and bottom strip along a contact perimeter using a fillet weld.

Max. forces in verticals:
Acc. to an additional calculation from jambs:

- Max. tension force P_{max} = 131.7 kN - TR ∅82.5x8
- Max. compression force P_{min} = -41.4 kN - TR ∅60.3x4

Acc. to original static calculation:

- Max. tension force P_{max} = 159.8 kN - TR ∅82.5x8
- Max. compression force P_{min} = -30.9 kN - TR ∅60.3x4

Max. forces in diagonals:
Acc. to an additional calculation from jambs:

- Max. tension force P_{max} = 70.9 kN - TR ∅82.5x5
- Max. compression force P_{min} = -33.9 kN - TR ∅82.5x5

Acc. to original static calculation:

- Max. tension force P_{max} = 57.9 kN - TR ∅82.5x5
- Max. compression force P_{min} = -46.4 kN - TR ∅82.5x5
- Max. tension force P_{max} = 92.8 kN - TR ∅70x3.6
- Max. tension force P_{min} = 29.3 kN - TR ∅70x3.6

The forces are comparable so the welds are acceptable so far.

All the top and bottom strips are contacted by fillet weld across the full section.

In spite of that all the welds are minimal acc. to project documentation. Therefore, I propose to check (measure) randomly a size and quality of welds when installing the suspension trusses. In case that any differences in regard to production documentation are found, the corrective measures shall be taken or a load from additional jambs shall be reduced. In spite of that I propose a reinforcement of welds in these nodes when installing the rods.

Consequently, if there isn't any snow on the roof an additional load can be added to replace the following values:

- For girders – loading width is approx. 3.0m
- Pmax = 0.7 x 1.152 x 1.4 x 3.0 x 12 = 40.8 kN – uniformly distributed in the particular nodes.
- For tie-beams – loading width is approx. 12.0m
- Pmax = 0.7 x 1.152 x 1.4 x 12.0 x 30.0 = 408.0 kN – uniformly distributed in the particular nodes.

When installing the particular rods it is necessary to attach a description label with individual possible loads to these roads so the max. values of additional load are not exceeded in future.

In Košice, May 2009 Ing. Mária Kolcunová