REPORT

Contact person RISE
Alastair Temple
Safety
+46 10 516 52 09
alastair.temple@ri.se

Date
2019-11-05

Reference
9P07588

Areco Profiles AB
Vinkelgatan 13
211 24 Malmö
Sverige

Calculation of under fire conditions capacity of roofing system Areco TP131

(3 appendices)

Introduction and Overview

This report details the results and the calculation method used to determine the capacity of the ARECO TP131 roof product under fire conditions. The approach taken was analytical, and comprised the following stages:

- determining the temperature of the steel using a finite difference approximation accounting for both radiation and convection and based on a standard fire
- calculating the tensile capacity of the deck based on the temperature dependent yield strength of steel
- calculating the maximum load which the deck is capable of supporting in a catenary

The approach taken is in line with EN 1991:2002 Actions on Structures - Part 1-2 Actions on Structures Exposed to Fire and on EN 1993:2005 Design of Steel Structures - Part 1-2 General Rules, Structural Fire Design. The calculation method used is described in Appendix 1. The scope of the study was limited to the spans and thicknesses reported in the Areco TP131 drawing sheet and information tables included in Appendix 2 and 3 (as provided by Areco on 15th October 2019), the study includes both unperforated and perforated options. Where perforations are included these are assumed to be of 3mm diameter with a centre to centre spacing of 6mm and accounting for not more than 50% of the cross-sectional area. The deck is shown schematically in Figure 1.

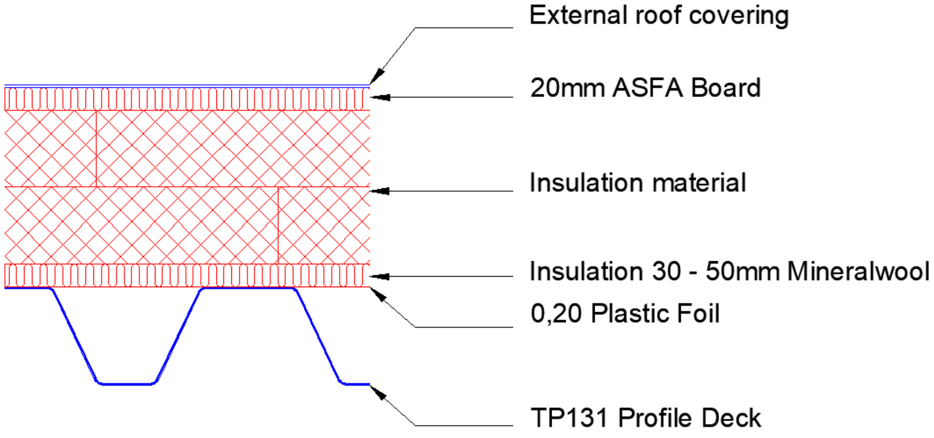


Figure 1 – Principle of insulation of TP131 roofing system

RISE Research Institutes of Sweden AB

Postal address
Ideon Science Park
Beta 5
SE-223 70 LUND
Sweden

Office location
Scheelevägen 17
Forskningsbyn Ideon
Beta 5 Vån 4

SE-223 70 LUND

Phone / Fax / E-mail
+46 10 516 50 00
+46 33 13 55 02
info@ri.se

The membrane effect used in the calculation is based upon the tensile resistance of the deck which is mobilized by large displacements which occur under fire – leading to the 'hanging cable effect', Figure 2. For the tensile forces to be available the connection at the vertical support needs to be protected so that it provides horizontal restraint. It is assumed in this study that adequate protection is provided to the connections.

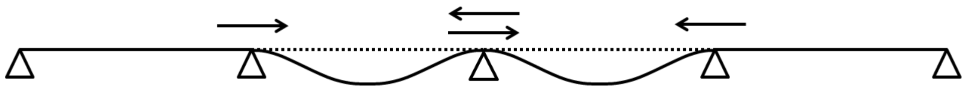


Figure 2 – Principle of the membrane action which supports the load on the roof

Due to the assumption that the load is carried only by tensile membrane action in the fire limit state, i.e. there is no bending resistance, the cross-section and thickness of deck is not considered. When considering the capacities calculated, the total loading (including any self-weight of the deck, weight of any insulation and covering above, and any applied mechanical live and dead loads) must be less than the capacity stated.

It is assumed in the calculation that the upper surface of the steel is adiabatic. This is a conservative assumption that has been made since the insulation material is not provided as part of the roof deck and therefore no information is available on the thermal properties of the materials. The limiting factor for insulation materials is therefore the self-weight rather than the thermal properties.

In order to make use of the bearing capacity in fire, the connections and roofing members should be protected internally and the underside of the deck should be protected a minimum of 500mm on either side of the connection detail, Figure 3. The end bays should be protected in their entirety since there are no adjacent bays to provide horizontal support to the membrane mechanism. The thickness and density of fire protection provided should be consistent with the fire resistance which the roof is being designed for. The supplier of the protection material should provide details of the thickness required and this will vary with the material used.

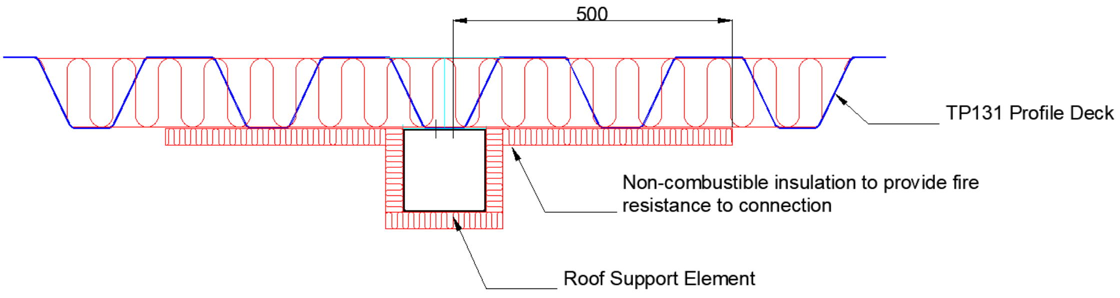


Figure 3 – Principal for protection of connection detail

The results of the study are presented in the following sections.

TP131 420 MPa no perforations

Table 1 shows the capacity for various spans and thicknesses at different fire exposure times of the TP131 roof deck. Table 2 shows the maximum deflection of the TP131 as a lower bound based on the thermal loading only and is therefore presented for various spans at different fire exposure times. Table 3 shows the horizontal loading of the TP131 at the supports for different thicknesses as a result of the membrane mechanism.

Table 1 – ARECO TP131 420 MPa Capacity under fire conditions

Thickness	Fire resistance	Capacity kN/m² – Span 4.2	4.5	4.8	5.1	5.4	5.7	6	6.3	6.6	6.9	7.2	7.5	8
0.7	R15	8.59	8.02	7.52	7.08	6.68	6.33	6.02	5.73	5.47	5.23	5.01	4.81	4.51
0.7	R30	4.33	4.05	3.79	3.57	3.37	3.19	3.03	2.89	2.76	2.64	2.53	2.43	2.28
0.7	R60	2.60	2.42	2.27	2.14	2.02	1.91	1.82	1.73	1.65	1.58	1.51	1.45	1.36
0.75	R15	9.24	8.62	8.08	7.61	7.18	6.81	6.47	6.16	5.88	5.62	5.39	5.17	4.85
0.75	R30	4.65	4.34	4.07	3.83	3.62	3.43	3.26	3.10	2.96	2.83	2.71	2.60	2.44
0.75	R60	2.78	2.60	2.44	2.29	2.16	2.05	1.95	1.86	1.77	1.69	1.62	1.56	1.46
0.8	R15	9.87	9.21	8.64	8.13	7.68	7.27	6.91	6.58	6.28	6.01	5.76	5.53	5.18
0.8	R30	4.96	4.63	4.34	4.09	3.86	3.66	3.47	3.31	3.16	3.02	2.89	2.78	2.60
0.8	R60	2.97	2.77	2.60	2.44	2.31	2.19	2.08	1.98	1.89	1.81	1.73	1.66	1.56
0.9	R15	11.31	10.55	9.89	9.31	8.80	8.33	7.92	7.54	7.20	6.88	6.60	6.33	5.94
0.9	R30	5.66	5.28	4.95	4.66	4.40	4.17	3.96	3.77	3.60	3.45	3.30	3.17	2.97
0.9	R60	3.38	3.16	2.96	2.79	2.63	2.49	2.37	2.25	2.15	2.06	1.97	1.89	1.78
1	R15	12.53	11.69	10.96	10.32	9.75	9.23	8.77	8.35	7.97	7.63	7.31	7.02	6.58
1	R30	6.25	5.84	5.47	5.15	4.86	4.61	4.38	4.17	3.98	3.81	3.65	3.50	3.28
1	R60	3.73	3.48	3.26	3.07	2.90	2.75	2.61	2.49	2.37	2.27	2.18	2.09	1.96
1.2	R15	15.17	14.16	13.27	12.49	11.80	11.18	10.62	10.11	9.65	9.23	8.85	8.49	7.96
1.2	R30	7.51	7.01	6.57	6.19	5.84	5.53	5.26	5.01	4.78	4.57	4.38	4.21	3.94
1.2	R60	4.47	4.17	3.91	3.68	3.48	3.30	3.13	2.98	2.85	2.72	2.61	2.50	2.35
1.5	R15	19.15	17.88	16.76	15.77	14.90	14.11	13.41	12.77	12.19	11.66	11.17	10.73	10.06
1.5	R30	9.36	8.74	8.19	7.71	7.28	6.90	6.56	6.24	5.96	5.70	5.46	5.24	4.92
1.5	R60	5.56	5.19	4.86	4.58	4.32	4.10	3.89	3.71	3.54	3.38	3.24	3.11	2.92

Table 2 – ARECO TP131 420 MPa deflection under fire conditions (lower bound based on thermal loading only)

Fire resistance	Deflection m – Span 4.2	4.5	4.8	5.1	5.4	5.7	6	6.3	6.6	6.9	7.2	7.5	8
R15	0.241	0.258	0.276	0.293	0.310	0.327	0.344	0.362	0.379	0.396	0.413	0.431	0.459
R30	0.258	0.277	0.295	0.313	0.332	0.350	0.369	0.387	0.406	0.424	0.443	0.461	0.492
R60	0.274	0.293	0.313	0.332	0.352	0.372	0.391	0.411	0.430	0.450	0.469	0.489	0.521

Table 3 – ARECO TP131 420 MPa horizontal reaction for different thickness of roof deck at different exposure times

Thickness	Fire resistance	Horizontal Reaction kN
		4.2
0.7	R15	78.57
0.7	R30	37.02
0.7	R60	20.90
0.75	R15	84.48
0.75	R30	39.73
0.75	R60	22.42
0.8	R15	90.29
0.8	R30	42.38
0.8	R60	23.90
0.9	R15	103.53
0.9	R30	48.38
0.9	R60	27.25
1	R15	114.78
1	R30	53.44
1	R60	30.06
1.2	R15	139.14
1.2	R30	64.22
1.2	R60	36.04
1.5	R15	176.08
1.5	R30	80.11
1.5	R60	44.79

TP131 420 MPa with perforations

Table 4 shows the capacity for various spans and thicknesses at different fire exposure times of the TP131 roof deck. Table 5 shows the maximum deflection of the TP131 as a lower bound based on the thermal loading only and is therefore presented for various spans at different fire exposure times. Table 6 shows the horizontal loading of the TP131 at the supports for different thicknesses as a result of the membrane mechanism.

Table 4 – ARECO TP131 420 MPa (Perforated) Capacity under fire conditions

Thickness	Fire resistance	Capacity kN/m²												
		Span												
		4.2	4.5	4.8	5.1	5.4	5.7	6	6.3	6.6	6.9	7.2	7.5	8
0.7	R15	4.30	4.01	3.76	3.54	3.34	3.17	3.01	2.86	2.73	2.62	2.51	2.41	2.26
0.7	R30	2.17	2.02	1.90	1.78	1.69	1.60	1.52	1.44	1.38	1.32	1.26	1.21	1.14
0.7	R60	1.30	1.21	1.14	1.07	1.01	0.96	0.91	0.87	0.83	0.79	0.76	0.73	0.68
0.75	R15	4.62	4.31	4.04	3.80	3.59	3.40	3.23	3.08	2.94	2.81	2.69	2.59	2.42
0.75	R30	2.33	2.17	2.03	1.91	1.81	1.71	1.63	1.55	1.48	1.42	1.36	1.30	1.22
0.75	R60	1.39	1.30	1.22	1.15	1.08	1.03	0.97	0.93	0.89	0.85	0.81	0.78	0.73
0.8	R15	4.93	4.61	4.32	4.06	3.84	3.64	3.45	3.29	3.14	3.00	2.88	2.76	2.59
0.8	R30	2.48	2.32	2.17	2.04	1.93	1.83	1.74	1.65	1.58	1.51	1.45	1.39	1.30
0.8	R60	1.48	1.38	1.30	1.22	1.15	1.09	1.04	0.99	0.94	0.90	0.87	0.83	0.78
0.9	R15	5.65	5.28	4.95	4.66	4.40	4.17	3.96	3.77	3.60	3.44	3.30	3.17	2.97
0.9	R30	2.83	2.64	2.48	2.33	2.20	2.09	1.98	1.89	1.80	1.72	1.65	1.59	1.49
0.9	R60	1.69	1.58	1.48	1.39	1.32	1.25	1.18	1.13	1.08	1.03	0.99	0.95	0.89
1	R15	6.26	5.85	5.48	5.16	4.87	4.62	4.39	4.18	3.99	3.81	3.65	3.51	3.29
1	R30	3.13	2.92	2.74	2.57	2.43	2.30	2.19	2.08	1.99	1.90	1.82	1.75	1.64
1	R60	1.87	1.74	1.63	1.54	1.45	1.37	1.31	1.24	1.19	1.14	1.09	1.04	0.98
1.2	R15	7.58	7.08	6.64	6.25	5.90	5.59	5.31	5.06	4.83	4.62	4.42	4.25	3.98
1.2	R30	3.76	3.51	3.29	3.09	2.92	2.77	2.63	2.50	2.39	2.29	2.19	2.10	1.97
1.2	R60	2.24	2.09	1.96	1.84	1.74	1.65	1.57	1.49	1.42	1.36	1.30	1.25	1.17
1.5	R15	9.58	8.94	8.38	7.89	7.45	7.06	6.70	6.38	6.09	5.83	5.59	5.36	5.03
1.5	R30	4.68	4.37	4.10	3.86	3.64	3.45	3.28	3.12	2.98	2.85	2.73	2.62	2.46
1.5	R60	2.78	2.59	2.43	2.29	2.16	2.05	1.95	1.85	1.77	1.69	1.62	1.56	1.46

Table 5 – ARECO TP131 420 MPa (Perforated) deflection under fire conditions (lower bound based on thermal loading only)

Fire resistance	Deflection m												
	Span												
	4.2	4.5	4.8	5.1	5.4	5.7	6	6.3	6.6	6.9	7.2	7.5	8
R15	0.241	0.258	0.276	0.293	0.310	0.327	0.344	0.362	0.379	0.396	0.413	0.431	0.459
R30	0.258	0.277	0.295	0.313	0.332	0.350	0.369	0.387	0.406	0.424	0.443	0.461	0.492
R60	0.274	0.293	0.313	0.332	0.352	0.372	0.391	0.411	0.430	0.450	0.469	0.489	0.521

Table 6 – ARECO TP131 420 MPa (Perforated) horizontal reaction for different thickness of roof deck at different exposure times

Thickness	Fire resistance	Horizontal Reaction kN
		4.2
0.7	R15	39.29
0.7	R30	18.51
0.7	R60	10.45
0.75	R15	42.24
0.75	R30	19.86
0.75	R60	11.21
0.8	R15	45.15
0.8	R30	21.19
0.8	R60	11.95
0.9	R15	51.77
0.9	R30	24.19
0.9	R60	13.62
1	R15	57.39
1	R30	26.72
1	R60	15.03
1.2	R15	69.57
1.2	R30	32.11
1.2	R60	18.02
1.5	R15	88.04
1.5	R30	40.05
1.5	R60	22.39

TP131 350 MPa no perforations

Table 7 shows the capacity for various spans and thicknesses at different fire exposure times of the TP131 roof deck. Table 8 shows the maximum deflection of the TP131 as a lower bound based on the thermal loading only and is therefore presented for various spans at different fire exposure times. Table 9 shows the horizontal loading of the TP131 at the supports for different thicknesses as a result of the membrane mechanism.

Table 7 – ARECO TP131 350 MPa Capacity under fire conditions

Thickness	Fire resistance	Capacity kN/m² Span 4.2	4.5	4.8	5.1	5.4	5.7	6	6.3	6.6	6.9	7.2	7.5	8
0.7	R15	7.16	6.68	6.27	5.90	5.57	5.28	5.01	4.77	4.56	4.36	4.18	4.01	3.76
0.7	R30	3.61	3.37	3.16	2.97	2.81	2.66	2.53	2.41	2.30	2.20	2.11	2.02	1.90
0.7	R60	2.16	2.02	1.89	1.78	1.68	1.59	1.51	1.44	1.38	1.32	1.26	1.21	1.14
0.75	R15	7.70	7.18	6.73	6.34	5.99	5.67	5.39	5.13	4.90	4.68	4.49	4.31	4.04
0.75	R30	3.88	3.62	3.39	3.19	3.01	2.86	2.71	2.58	2.47	2.36	2.26	2.17	2.03
0.75	R60	2.32	2.16	2.03	1.91	1.80	1.71	1.62	1.55	1.48	1.41	1.35	1.30	1.22
0.8	R15	8.22	7.68	7.20	6.77	6.40	6.06	5.76	5.48	5.23	5.01	4.80	4.61	4.32
0.8	R30	4.13	3.86	3.62	3.40	3.22	3.05	2.89	2.76	2.63	2.52	2.41	2.32	2.17
0.8	R60	2.47	2.31	2.16	2.04	1.92	1.82	1.73	1.65	1.57	1.51	1.44	1.38	1.30
0.9	R15	9.42	8.80	8.25	7.76	7.33	6.94	6.60	6.28	6.00	5.74	5.50	5.28	4.95
0.9	R30	4.72	4.40	4.13	3.89	3.67	3.48	3.30	3.15	3.00	2.87	2.75	2.64	2.48
0.9	R60	2.82	2.63	2.47	2.32	2.19	2.08	1.97	1.88	1.79	1.72	1.64	1.58	1.48
1	R15	10.44	9.75	9.14	8.60	8.12	7.69	7.31	6.96	6.64	6.36	6.09	5.85	5.48
1	R30	5.21	4.86	4.56	4.29	4.05	3.84	3.65	3.47	3.32	3.17	3.04	2.92	2.74
1	R60	3.11	2.90	2.72	2.56	2.42	2.29	2.18	2.07	1.98	1.89	1.81	1.74	1.63
1.2	R15	12.64	11.80	11.06	10.41	9.83	9.31	8.85	8.43	8.04	7.69	7.37	7.08	6.64
1.2	R30	6.26	5.84	5.48	5.16	4.87	4.61	4.38	4.17	3.98	3.81	3.65	3.51	3.29
1.2	R60	3.73	3.48	3.26	3.07	2.90	2.75	2.61	2.49	2.37	2.27	2.17	2.09	1.96
1.5	R15	15.96	14.90	13.97	13.14	12.41	11.76	11.17	10.64	10.16	9.72	9.31	8.94	8.38
1.5	R30	7.80	7.28	6.83	6.43	6.07	5.75	5.46	5.20	4.97	4.75	4.55	4.37	4.10
1.5	R60	4.63	4.32	4.05	3.81	3.60	3.41	3.24	3.09	2.95	2.82	2.70	2.59	2.43

Table 8 – ARECO TP131 350 MPa deflection under fire conditions (lower bound based on thermal loading only)

Fire resistance	Deflection m Span 4.2	4.5	4.8	5.1	5.4	5.7	6	6.3	6.6	6.9	7.2	7.5	8
R15	0.241	0.258	0.276	0.293	0.310	0.327	0.344	0.362	0.379	0.396	0.413	0.431	0.459
R30	0.258	0.277	0.295	0.313	0.332	0.350	0.369	0.387	0.406	0.424	0.443	0.461	0.492
R60	0.274	0.293	0.313	0.332	0.352	0.372	0.391	0.411	0.430	0.450	0.469	0.489	0.521

Table 9 – ARECO TP131 350 MPa horizontal reaction for different thickness of roof deck at different exposure times

Thickness	Fire resistance	Horizontal Reaction kN
		4.2
0.7	R15	65.48
0.7	R30	30.85
0.7	R60	17.42
0.75	R15	70.40
0.75	R30	33.11
0.75	R60	18.68
0.8	R15	75.24
0.8	R30	35.32
0.8	R60	19.92
0.9	R15	86.28
0.9	R30	40.32
0.9	R60	22.70
1	R15	95.65
1	R30	44.53
1	R60	25.05
1.2	R15	115.95
1.2	R30	53.52
1.2	R60	30.03
1.5	R15	146.73
1.5	R30	66.76
1.5	R60	37.32

TP131 350 MPa with perforations

Table 10 shows the capacity for various spans and thicknesses at different fire exposure times of the TP131 roof deck. Table 11 shows the maximum deflection of the TP131 as a lower bound based on the thermal loading only and is therefore presented for various spans at different fire exposure times. Table 12 shows the horizontal loading of the TP131 at the supports for different thicknesses as a result of the membrane mechanism.

Table 10 – ARECO TP131 350 MPa (Perforated) Capacity under fire conditions

Thickness	Fire resistance	Capacity kN/m²												
		Span												
		4.2	4.5	4.8	5.1	5.4	5.7	6	6.3	6.6	6.9	7.2	7.5	8
0.7	R15	3.58	3.34	3.13	2.95	2.78	2.64	2.51	2.39	2.28	2.18	2.09	2.01	1.88
0.7	R30	1.81	1.69	1.58	1.49	1.40	1.33	1.26	1.20	1.15	1.10	1.05	1.01	0.95
0.7	R60	1.08	1.01	0.95	0.89	0.84	0.80	0.76	0.72	0.69	0.66	0.63	0.61	0.57
0.75	R15	3.85	3.59	3.37	3.17	2.99	2.84	2.69	2.57	2.45	2.34	2.24	2.16	2.02
0.75	R30	1.94	1.81	1.70	1.60	1.51	1.43	1.36	1.29	1.23	1.18	1.13	1.09	1.02
0.75	R60	1.16	1.08	1.01	0.96	0.90	0.85	0.81	0.77	0.74	0.71	0.68	0.65	0.61
0.8	R15	4.11	3.84	3.60	3.39	3.20	3.03	2.88	2.74	2.62	2.50	2.40	2.30	2.16
0.8	R30	2.07	1.93	1.81	1.70	1.61	1.52	1.45	1.38	1.32	1.26	1.21	1.16	1.09
0.8	R60	1.24	1.15	1.08	1.02	0.96	0.91	0.87	0.82	0.79	0.75	0.72	0.69	0.65
0.9	R15	4.71	4.40	4.12	3.88	3.66	3.47	3.30	3.14	3.00	2.87	2.75	2.64	2.47
0.9	R30	2.36	2.20	2.06	1.94	1.83	1.74	1.65	1.57	1.50	1.44	1.38	1.32	1.24
0.9	R60	1.41	1.32	1.23	1.16	1.10	1.04	0.99	0.94	0.90	0.86	0.82	0.79	0.74
1	R15	5.22	4.87	4.57	4.30	4.06	3.85	3.65	3.48	3.32	3.18	3.05	2.92	2.74
1	R30	2.61	2.43	2.28	2.15	2.03	1.92	1.82	1.74	1.66	1.59	1.52	1.46	1.37
1	R60	1.55	1.45	1.36	1.28	1.21	1.15	1.09	1.04	0.99	0.95	0.91	0.87	0.82
1.2	R15	6.32	5.90	5.53	5.20	4.92	4.66	4.42	4.21	4.02	3.85	3.69	3.54	3.32
1.2	R30	3.13	2.92	2.74	2.58	2.43	2.31	2.19	2.09	1.99	1.91	1.83	1.75	1.64
1.2	R60	1.86	1.74	1.63	1.53	1.45	1.37	1.30	1.24	1.19	1.13	1.09	1.04	0.98
1.5	R15	7.98	7.45	6.98	6.57	6.21	5.88	5.59	5.32	5.08	4.86	4.66	4.47	4.19
1.5	R30	3.90	3.64	3.41	3.21	3.03	2.88	2.73	2.60	2.48	2.38	2.28	2.19	2.05
1.5	R60	2.32	2.16	2.03	1.91	1.80	1.71	1.62	1.54	1.47	1.41	1.35	1.30	1.22

Table 11 – ARECO TP131 350 MPa (Perforated) deflection under fire conditions (lower bound based on thermal loading only)

Fire resistance	Deflection m												
	Span												
	4.2	4.5	4.8	5.1	5.4	5.7	6	6.3	6.6	6.9	7.2	7.5	8
R15	0.241	0.258	0.276	0.293	0.310	0.327	0.344	0.362	0.379	0.396	0.413	0.431	0.459
R30	0.258	0.277	0.295	0.313	0.332	0.350	0.369	0.387	0.406	0.424	0.443	0.461	0.492
R60	0.274	0.293	0.313	0.332	0.352	0.372	0.391	0.411	0.430	0.450	0.469	0.489	0.521

Table 12 – ARECO TP131 350 MPa (Perforated) horizontal reaction for different thickness of roof deck at different exposure times

Thickness	Fire resistance	Horizontal Reaction kN
		4.2
0.7	R15	32.74
0.7	R30	15.43
0.7	R60	8.71
0.75	R15	35.20
0.75	R30	16.55
0.75	R60	9.34
0.8	R15	37.62
0.8	R30	17.66
0.8	R60	9.96
0.9	R15	43.14
0.9	R30	20.16
0.9	R60	11.35
1	R15	47.83
1	R30	22.27
1	R60	12.52
1.2	R15	57.97
1.2	R30	26.76
1.2	R60	15.02
1.5	R15	73.37
1.5	R30	33.38
1.5	R60	18.66

RISE Research Institutes of Sweden AB
Safety - Fire Research Resistance

Performed by | Examined by

Signed by: Petra Andersson
Reason: I have reviewed this document
Date & Time: 2019-11-14 13:46:32 +01:00

Alastair Temple | Petra Andersson

Appendices
Appendix 1 Calculation method
Appendix 2 Drawings
Appendix 3 Profile Data

Appendix 1

Calculation method

A.1 Thermal response

The thermal response is calculated based on EN 1991-1-2:2002. The temperature time curve used is that for a standard fire, EN 1363-1:1999. Because of the insulation on the steel deck, heat losses to ambient are ignored. The total heat flux to the surface is given by:

$$\dot{q}_{net} = \dot{q}_c + \dot{q}_{rad}$$

The convective heat flux is given by:

$$\dot{q}_c = h_c(\theta_f - \theta_s)$$

Where h_c is the convective heat transfer coefficient, 25W/m^{2}K according to Eurocode 1, θ_s is the steel temperature and θ_f is the fire temperature.

The radiative heat flux is given by:

$$\dot{q}_r = h_{rad}(\theta_f - \theta_s)$$

Where h_{rad} is the radiative heat transfer coefficient, $h_{rad} = \varepsilon\sigma({\theta_f}^2 + {\theta_s}^2)(\theta_f + \theta_s)$, ε is the emissivity of the steel (in this case assumed to be 0.8) and σ is the Stefan Boltzman constant.

The temperature in the steel, θ_s, may then be obtained from the forward difference approach:

$$\theta_s(t + \Delta t) = \frac{\dot{q}_{net}\Delta t}{\rho_s c_{ps} d_s} + \theta_s(t) \qquad [1]$$

ρ_s, c_{ps} and d_s are the density, the specific heat and the thickness of steel respectively.

A.2 Tensile Capacity

The membrane capacity is based upon the tensile resistance of the roof deck. This means that all bending, or flexural capacity, is ignored in the calculation and the determination of the capacity is based upon the ability of the roof to 'hang' in tension. This means that there are large horizontal 'pull-in' forces generated at the supports. These forces are restrained by adjacent roof deck panels which generate equivalent forces in adjacent bays.

From Eurocode 3, the resistance of a tension member in fire conditions is given by:

$$T(\theta) = k_{y,\theta} T_{amb} \qquad [2]$$

where T_{amb} is the tensile resistance of the member at ambient, and $k_{y,\theta}$ is the reduction factor of the yield stress at temperature θ.

A.3 Mechanical Response

The roof deck deflected shape and boundary conditions is shown in Figure A1. The deflection is labelled δ and varies with position (x) along the span. The maximum deflection, δ_{max}, occurs at the mid span. Based on the temperature alone, the total length, L_T, is given by:

$$L_T = L(1 + \alpha\Delta\theta_s)$$

Where L is the original length or the length between the supports, α is the coefficient of thermal expansion and $\Delta\theta_s$ is the change in temperature from ambient. Approximating the deflected shape as a quadratic, the maximum deflection is therefore given by:

Appendix 1

$$\delta = L\sqrt{\frac{3}{8}\alpha\Delta\theta_s}$$ [3]

At the supports, there is a horizontal reaction component as a result of the tension in the deck at midspan, there is also a vertical shear reaction as well as the resultant tension in the roof deck. The load applied, q, is constant across the deck.

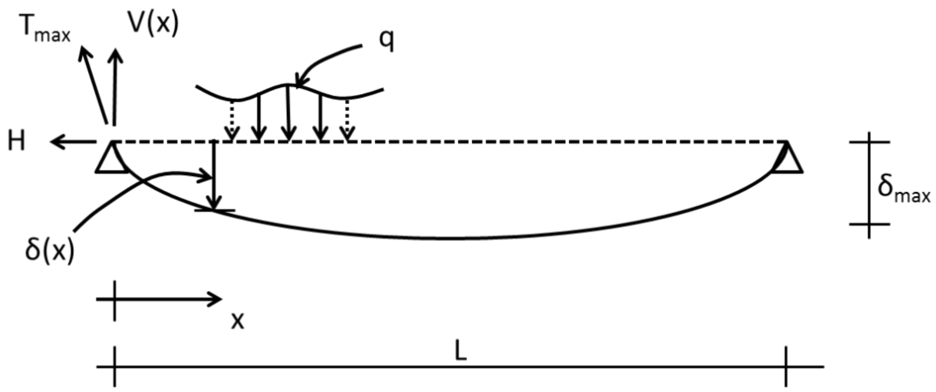


Figure A1 – The boundary conditions and deflected shape of the deck

Taking account of symmetry, and taking moments about one of the supports, the horizontal reaction in the deck can be determined to be:

$$H = \frac{qL^2}{8\delta}$$ [4]

Considering the variation in shear and tension across the span, the tension in the roof system is equal to the resultant of these two forces, Figure A2. From equilibrium, the horizontal force is constant across the span of the deck. The shear force at any point, x, is given by:

$$V(x) = \frac{q(L-x)}{2}$$

The membrane force at x is given by:

$$T(x) = \sqrt{V(x)^2 + H(x)^2}$$

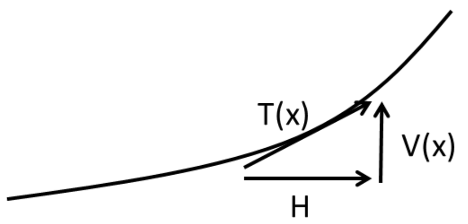


Figure A2 – Components of the force in the deck

At the supports of the floor, the shear force is at its highest, and therefore the membrane reaction in the roof deck is also highest, and is given by:

$$T_{max} = \sqrt{\left(\frac{qL}{2}\right)^2 + H^2}$$ [5]

By combining equations 4 and 5, the following expression is obtained for the maximum tension in the roof deck:

$$T_{max} = \sqrt{\frac{q^2L^2}{4} + \frac{q^2L^4}{64\delta^2}}$$

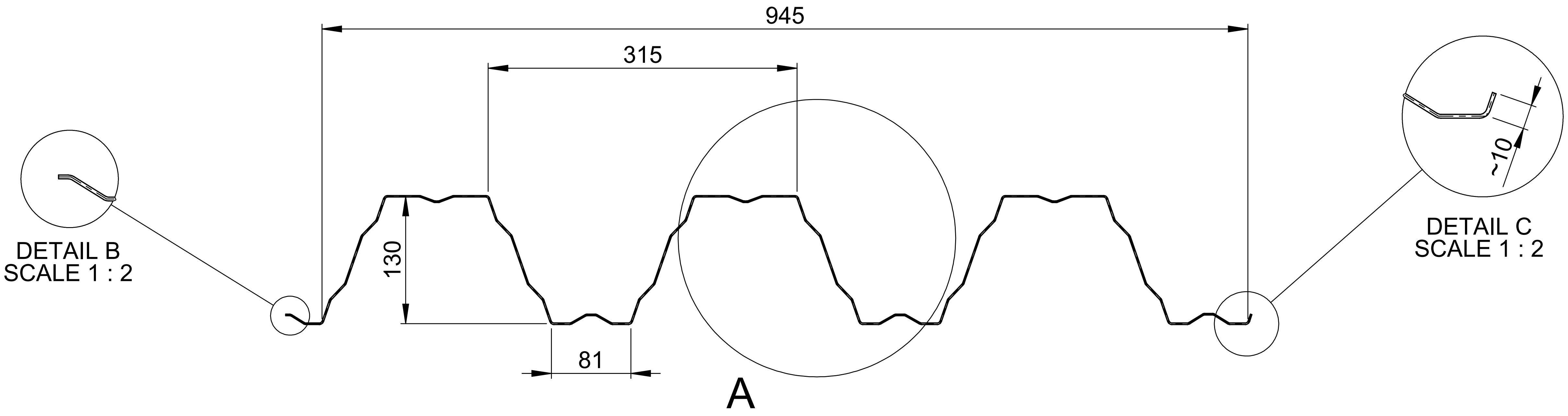
Rearranging this, the following expression for q is obtained:

$$q = \sqrt{\frac{{T_{max}}^2}{\left(\frac{L^2}{4} + \frac{L^4}{64\delta^2}\right)}}$$ [6]

Inserting into Equation 6 the maximum deflection and the maximum resistance of the deck calculated as a tension member, as shown above, we obtain the ultimate capacity of the deck, q_{ult}.

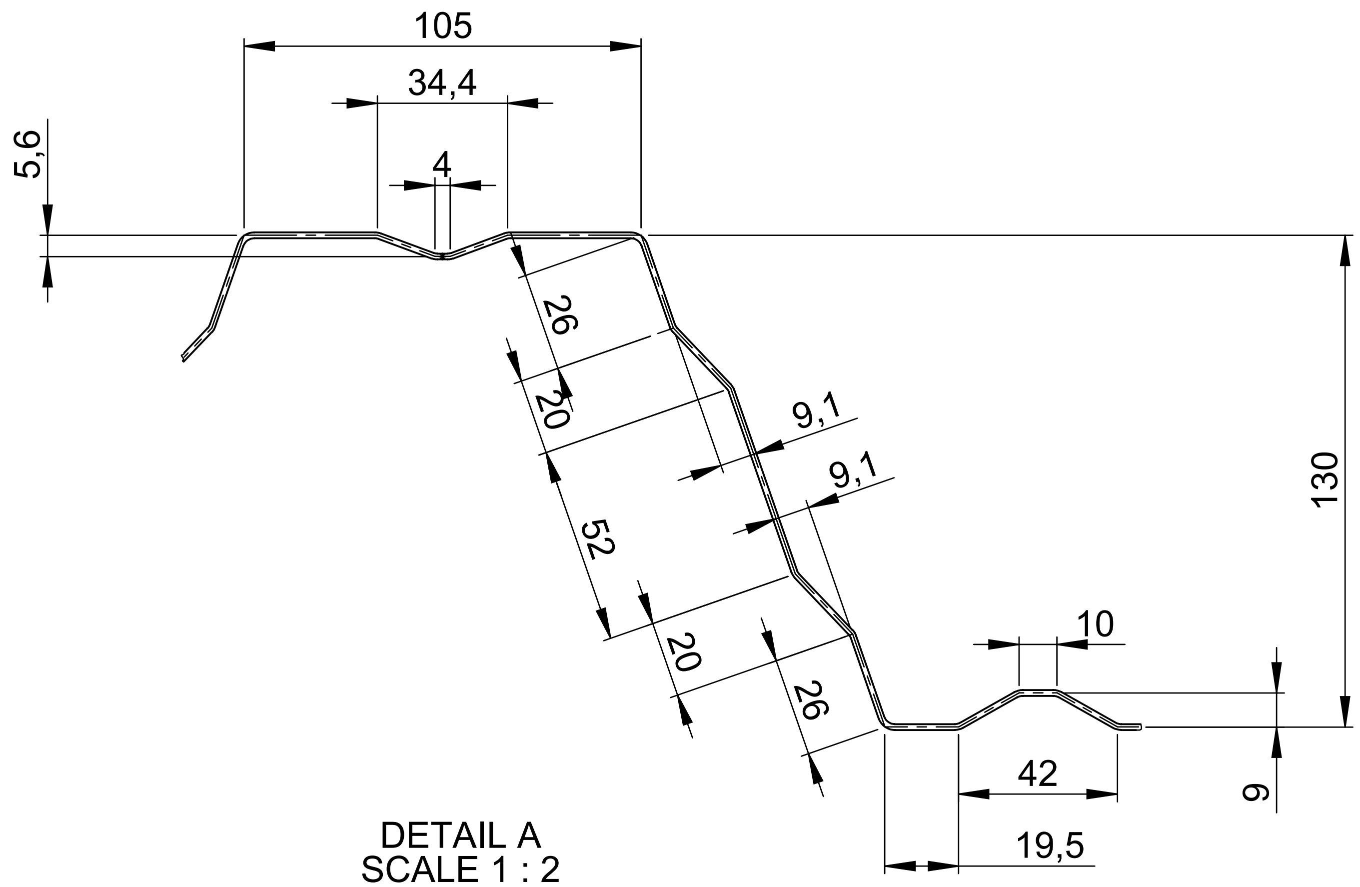
A.4 References

1. Areco TP131 Profile Drawing (Drawing number 35244)
2. Areco TP131 Information Data Sheet
3. EN 1991:2002 Actions on Structures - Part 1-2 Actions on Structures Exposed to Fire
4. EN 1993:2005 Design of Steel Structures - Part 1-2 General Rules, Structural Fire Design
5. EN 1363-1:1999 Fire resistance tests – Part 1: General requirements

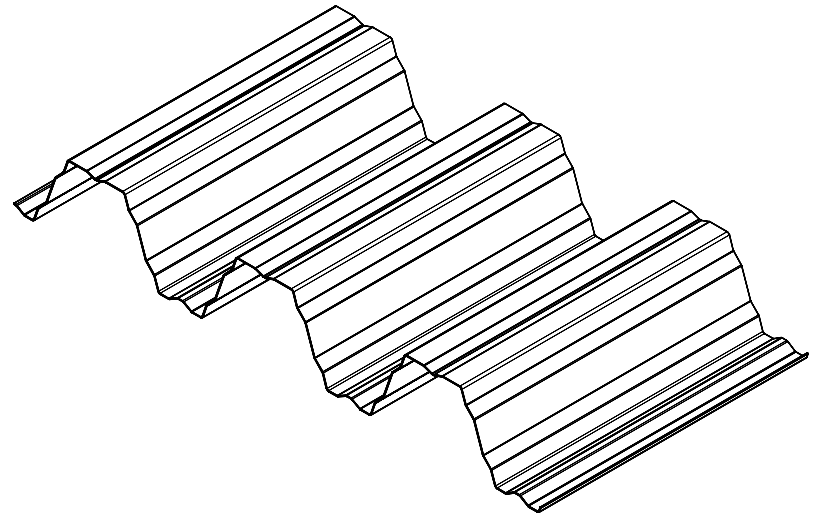


DETAIL B
SCALE 1 : 2

DETAIL C
SCALE 1 : 2



DETAIL A
SCALE 1 : 2



REF:	9P07588
APP:	2 (page 1)

Weight	Classification	Designer	Date	
9.10 kg		ReH	08.11.2018	
Surface treating	Project number	Approver	Date	
	Description	Drawing number		Sheets
AJV MACHINE	Profile TP131	35244		2/3
				Rev A

Rev	Muutos / Change	Pvm / Date	Suun. / Des´d
-	See Sheet1	-	-

Tvärsnittsdata Areco TP131-350

Plåttjocklek	nominell	mm	0.7	0.8	0.9	1.0	1.2	1.5
	vid beräkning	mm	0.665	0.760	0.866	0.955	1.144	1.42
Sträckgräns	f_{ty}	N/mm²	350	350	350	350	350	350
Innerstöd smal	Upplagsreaktion ls=100mm	kN/m	22.2	28.7	36.8	44.2	61.9	91.9
Smal fläns	Moment M_D	kNm/m	11.93	14.04	16.42	18.85	25.08	34.27
tryckpåverkad	Tröghetsmoment I_{def}	mm4/mm	2478	2832	3227	3558	4262	5291
Innerstöd bred	Upplagsreaktion ls=100mm	kN/m	20.6	27.2	36.1	44.2	61.9	91.9
Bred fläns	Moment M_D	kNm/m	9.68	11.85	14.38	16.58	21.39	26.88
tryckpåverkad	Tröghetsmoment I_{def}	mm4/mm	2456	2832	3227	3558	4262	5291

Tvärsnittsdata Areco TP131-420

Plåttjocklek	nominell	mm	0.7	0.8	0.9	1.0	1.2	1.5
	vid beräkning	mm	0.665	0.760	0.866	0.955	1.144	1.42
Sträckgräns	f_{ty}	N/mm²	420	420	420	420	420	420
Innerstöd smal	Upplagsreaktion ls=100mm	kN/m	24.3	31.5	40.3	48.5	67.8	100.7
Smal fläns	Moment M_D	kNm/m	13.75	16.32	19.16	21.56	27.85	38.9
tryckpåverkad	Tröghetsmoment I_{def}	mm4/mm	2478	2832	3227	3558	4262	5291
Innerstöd bred	Upplagsreaktion ls=100mm	kN/m	22.6	29.8	39.6	48.5	67.8	100.7
Bred fläns	Moment M_D	kNm/m	10.75	13.24	16.15	18.7	24.33	32.07
tryckpåverkad	Tröghetsmoment I_{def}	mm4/mm	2419	2827	3227	3558	4262	5291