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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.

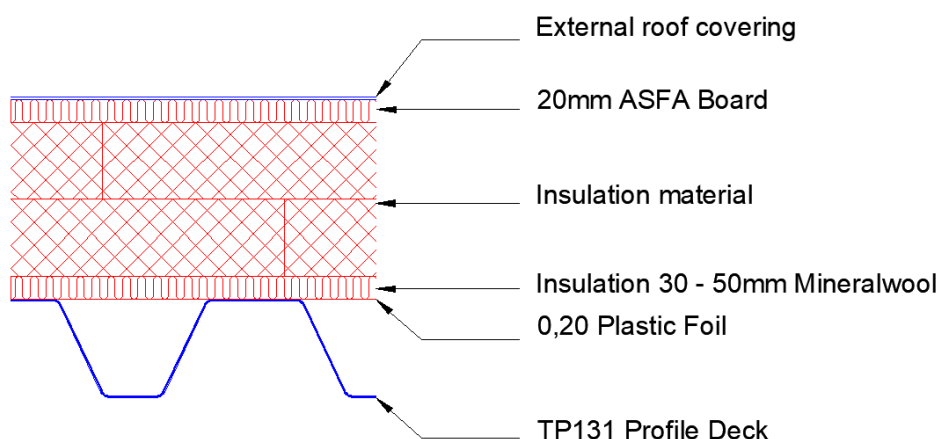


Figure 1 – Principle of insulation of TP131 roofing system

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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.

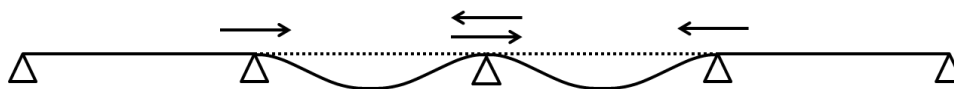


Figure 2 – Principle of the membrane action which supports the load on the roof

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.

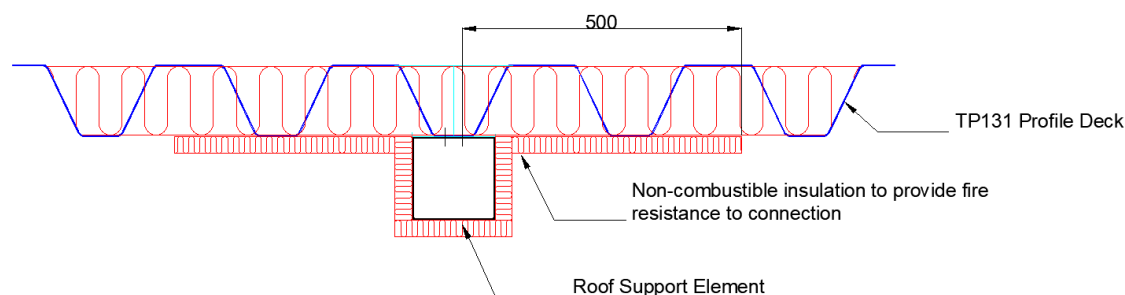


Figure 3 – Principal for protection of connection detail

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/m ²														
		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/m ²														
		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/m ²													
		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/m ²													
		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

Alastair Temple

Petra Andersson



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Appendices

Appendix 1 Calculation method

Appendix 2 Drawings

Appendix 3 Profile Data