Stevenage Arts and Leisure Centre

Roof Assessment

Background

This document has been prepared for the sole benefit, use and information of Flying FX and for the purposes set out in the following pages.

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Issue History

Rev.	Date	Comments
-	30.08.2013	First Draft

Contents

1.0 Introduction

The existing roof of Arts and Leisure centre in Stevenage is a space truss - space deck system, built in 1975.

The truss is 1.2 metres deep, on 1.2 metre module on plan. The upper chord cassettes are made of 40x40x6.0 angles, the bottom chord rods are 20.5mm dia solid bars. The diagonals are 26mm dia, assumed hollow sections. The grade of steelwork is unknown. The steelwork is supported by concrete frame of the building.

The main hall roof covers space 36m by 33.6m.
The roof of Gordon Craig theatre covers approximately 25.2m by 22.8m.

Momentum visited the site on 30 April 2012 and on 25 July 2013.

2.0 Methodology

It was impossible to ascertain with any degree of certainty the exact roof build-up, during Momentum's visits. The grade of existing steelwork is also unknown. These two reasons preclude a traditional structural analysis of the roof giving the ultimate stresses acting on the structure.

The presented analysis instead relies on assumption that the roof was originally designed to the requirements of British Standard Code of Practice: CP3 : Chapter V: Part 1: 1967 ('Code of basic data for the design of buildings, Loading'), valid at the time of construction. The minimum imposed loading, to this code, on flat roofs with no access is 0.75kN/m² (including snow load).
To allow for water runoff during periods of heavy rain in summer months, this figure was reduced in the analysis to 0.5kN/m². This represents total design live load on the roof in summer months.
To allow for snow buildup in winter months, the minimum imposed loading was reduced in the analysis to 0.35kN/m² (see section 3.0). This represents total design live load on the roof in winter months.

The effects of unit point loads for different rigging patterns on each element of primary structure were compared to the effects of total design live load (for summer and winter conditions). The results were linearly prorated to obtain maximum rigging point loads that achieve the same effect as the original design loads.

Given the uncertainties of the original design assumptions, and unknown quality control during construction, the results from the above approach were further reduced by a factor of 2.

Two sets of rigging allowances are given, one for summer condition , one for winter condition.

The above approach assumes that no maintenance work will by carried out on the roof during events when rigging is suspended from the roof.

Any modification of the roof structure or the roof itself (changes to build-up etc.) will invalidate the given results.

3.0 Loadings

3.1 Rain runoff
allow 0.25kN/m²

3.2 Snow load
to BS6399 part 3

basic snow load $s_b = 0.5$kN/m²
altitude $A = 100$m above sea level   ($s_b = s_o$)
shape coefficient $\eta_1 = 0.8$
snow load $S_d = 0.8 * 0.5 = 0.4$kN/m²

4.0 Factors of safety

The imposed design load of the roof and rigging loads have identical load safety factors (to BS).
The calculations therefore do not contain extra allowance for safety factors, and the rigging allowances given in summary chapters 5.3 and 6.3 below represent static rigging weight that may be safely suspended from highlighted nodal positions.

The rigging allowances given in this document apply to static load rigging only, acting in vertical direction.
Any activities that may require dynamic load rigging will have to be assessed separately on individual basis.
The given rigging allowances will reduce if load is bridled and shared between nodes.
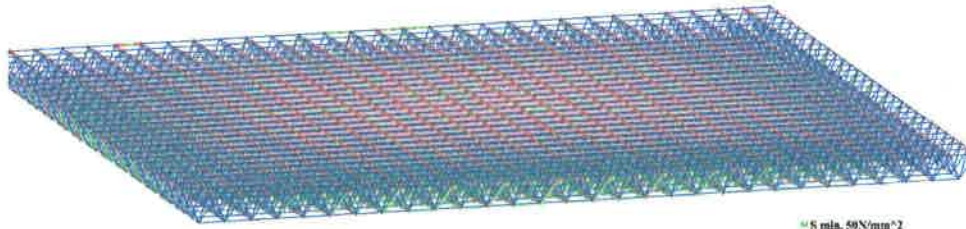
5.0 Main Hall Roof

5.1 Analytical model
The space deck of main hall was modelled in its entirety. The results are from analytical model '1708 Model3D 004 130814dc.rtd'.
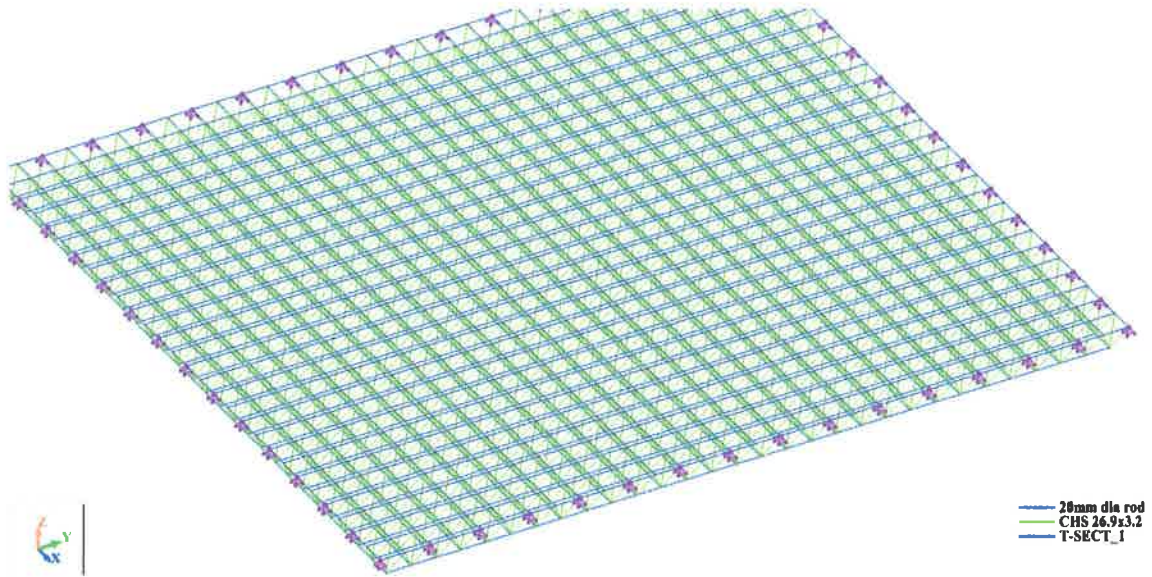
5.2 Stress comparison analysis

maximum stresses under 0.5kPa imposed load (example)

S min. 50N/mm^2
Max=58.03
Min=-155.79
S max. 50N/mm^2
Max=65.35
Min=-152.15

Cases: 5 (0.5kPa roof imposed)

Summer Condition:

element normal stresses (Smax, Smin)

load condition	point load on nodes [kN]	total model load on roof [kN]	top chords [N/mm2]	node load equivalent [kN]	[kg]	bottom chords [N/mm2]	node load equivalent [kN]	[kg]	diagonals [N/mm2]	node load equivalent [kN]	[kg]	deflection [mm]	node load equivalent [kN]	[kg]	maximum node load [kg]	total rigging load on roof [tonnes]
roof imposed (0.5kPa)	0.72	469	65.35	0.720	73.4	3.25	0.720	73.4	25.01	0.720	73.4	107.9	0.720	73.4	36.7	23.9
	0.72		-26.51	0.720	73.4	-155.79	0.720	73.4	-18.15	0.720	73.4					
pattern A	1.000	728	90.23	0.724	73.9	5.22	0.623	63.5	33.20	0.752	76.7	148.5	0.727	74.1	31.7	23.1
	1.000		-36.41	0.728	74.2	-214.35	0.727	74.1	-53.54	0.713	72.7					
pattern B	1.000	182	22.64	2.886	294.3	1.38	2.355	240.1	8.63	2.898	295.5	37.1	2.908	296.6	120.1	21.9
	1.000		9.2	2.882	293.8	-53.68	2.902	295.9	-14.03	2.719	277.3					
pattern C	1.000	80	10.05	6.502	663.0	0.64	5.078	517.8	4.04	6.191	631.2	16.4	6.579	670.9	258.9	20.7
	1.000		4.03	6.578	670.8	-23.74	6.562	669.1	-5.82	6.555	668.4					
pattern D	1.000	49	5.9	11.076	1129.4	0.37	8.784	895.7	2.59	9.656	984.6	9.5	11.358	1158.1	447.8	21.9
	1.000		-2.39	11.092	1131.0	-13.87	11.232	1145.3	-3.98	9.585	977.4					
pattern E	1.000	36	3.78	17.288	1762.9	0.15	21.667	2209.3	1.83	13.667	1393.6	6.1	17.689	1803.7	696.8	25.1
	1.000		-1.56	16.994	1732.8	-8.73	17.845	1819.7	-2.65	14.396	1468.0					
pattern F	1.000	224	53.93	1.212	123.6	3.09	1.052	107.2	19.37	1.291	131.7	81.4	1.326	135.2	53.6	12.0
	1.000		-17.52	1.513	154.3	-127.86	1.218	124.2	-18.59	2.052	209.3					
pattern G	1.000	55	13.6	4.805	490.0	0.81	4.012	409.1	5.07	4.933	503.0	20.4	5.289	539.3	204.6	11.5
	2.000		-4.51	5.878	599.4	-32.04	4.862	495.8	-4.95	7.707	785.9					
pattern H	1.000	36	7.47	8.748	892.0	0.46	7.065	720.4	3.1	8.068	822.7	11.7	9.222	940.4	360.2	13.0
	1.000		2.61	10.157	1035.7	-17.54	8.882	905.7	3.08	12.386	1263.0					
pattern J	1.000	120	35.5	1.841	187.7	1.82	1.786	182.1	12.72	1.966	200.5	49.5	2.180	222.3	91.0	10.9
	1.000		-10.23	2.591	264.2	84.01	1.854	189.1	-10.22	3.733	380.6					

Winter Condition

element normal stresses (Smax, Smin)

| load condition	point load on nodes [kN]	total model load on roof [kN]	top chords [N/mm2]	node load equivalent [kN]	[kg]	bottom chords [N/mm2]	node load equivalent [kN]	[kg]	diagonals [N/mm2]	node load equivalent [kN]	[kg]	deflection [mm]	node load equivalent [kN]	[kg]	maximum node load [kg]	total rigging load on roof [tonnes]
roof imposed (0.35kPa)	0.504	329	45.745	0.504	51.4	2.275	0.504	51.4	17.507	0.504	51.4	75.5	0.504	51.4	25.7	16.8
	0.504		-18.557	0.504	51.4	-109.053	0.504	51.4	-26.705	0.504	51.4					
pattern A	1.000	728	90.23	0.507	51.7	5.22	0.436	44.4	33.26	0.526	53.7	148.5	0.509	51.9	22.2	16.2
	1.000		-36.41	0.510	52.0	-214.35	0.509	51.9	-53.54	0.499	50.9					
pattern B	1.000	182	22.64	2.021	206.0	1.38	1.649	168.1	8.63	2.029	206.9	37.1	2.036	207.6	84.0	15.3
	1.000		9.2	2.017	205.7	-53.68	2.032	207.2	-14.03	1.903	194.1					
pattern C	1.000	80	10.05	4.552	464.1	0.64	3.555	362.5	4.04	4.333	441.9	16.4	4.605	469.6	181.2	14.5
	1.000		-4.03	4.605	469.5	23.74	4.594	468.4	-5.82	4.588	467.9					
pattern D	1.000	49	5.9	7.753	790.6	0.37	6.149	627.0	2.59	6.759	689.2	9.5	7.951	810.7	313.5	15.4
	1.000		-2.39	7.764	791.7	-13.87	7.863	801.7	-3.98	6.710	684.2					
pattern E	1.000	36	3.78	12.102	1234.0	0.15	15.167	1546.5	1.83	9.567	975.5	6.1	12.382	1262.6	487.7	17.6
	1.000		-1.56	11.896	1213.0	-8.73	12.492	1273.8	-2.65	10.077	1027.6					
pattern F	1.000	224	53.93	0.848	86.5	3.09	0.736	75.1	19.37	0.904	92.2	81.4	0.928	94.6	37.5	8.4
	1.000		-17.52	1.059	108.0	-127.86	0.853	87.0	-18.59	1.437	146.5					
pattern G	1.000	56	13.6	3.364	343.0	0.81	2.809	286.4	5.07	3.453	352.1	20.4	3.702	377.5	143.3	8.0
	1.000		-4.51	4.115	419.6	-32.04	3.404	347.1	-4.95	5.395	550.1					
pattern H	1.000	36	7.47	6.124	624.4	0.46	4.946	504.3	3.1	5.647	575.9	11.7	6.458	658.3	252.1	9.1
	1.000		2.61	7.110	725.0	-17.54	6.217	634.0	3.08	8.670	884.1					
pattern J	1.000	120	35.5	1.289	131.4	1.82	1.250	127.5	12.72	1.376	140.3	49.5	1.526	155.6	63.7	7.6
	1.000		-10.23	1.814	185.0	84.01	1.298	132.4	10.22	2.613	266.4					

5.3 Results Summary

Load pattern A

North

South
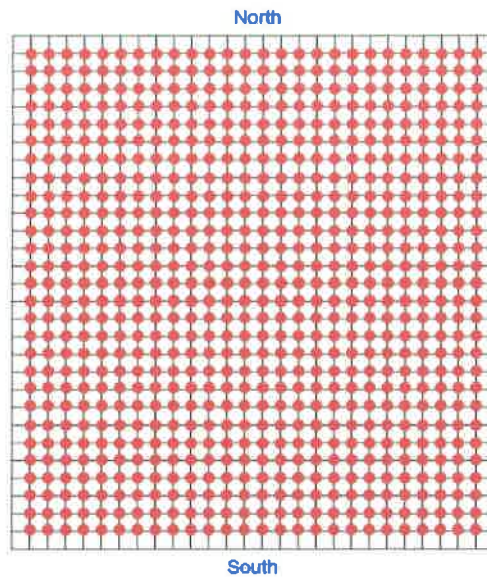
maximum rigging point load on highlighted nodes - summer   = 31kg
maximum rigging point load on highlighted nodes - winter   = 22kg

Load pattern B

North

South
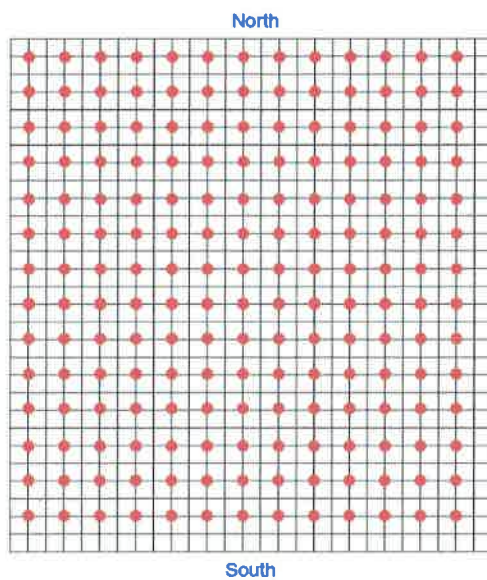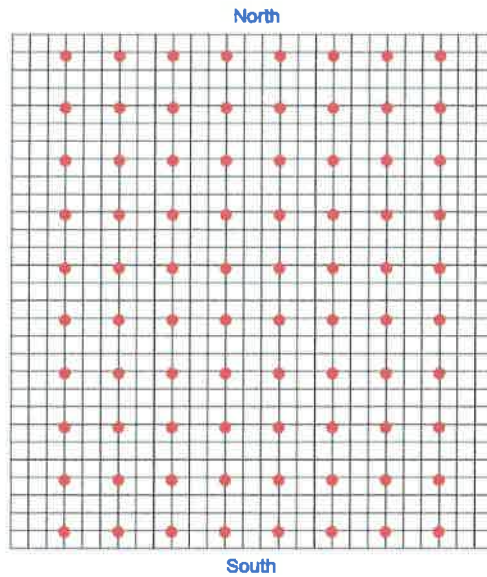
maximum rigging point load on highlighted nodes - summer   = 120kg
maximum rigging point load on highlighted nodes - winter   = 84kg

Load pattern C
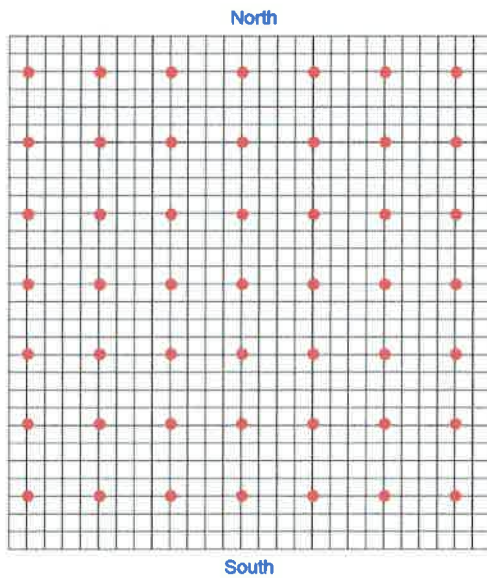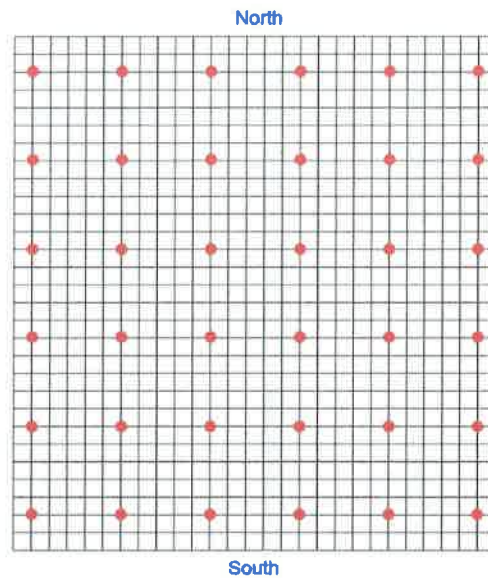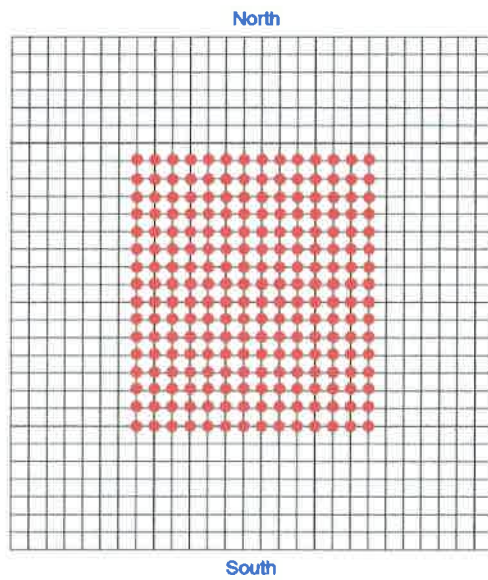
North

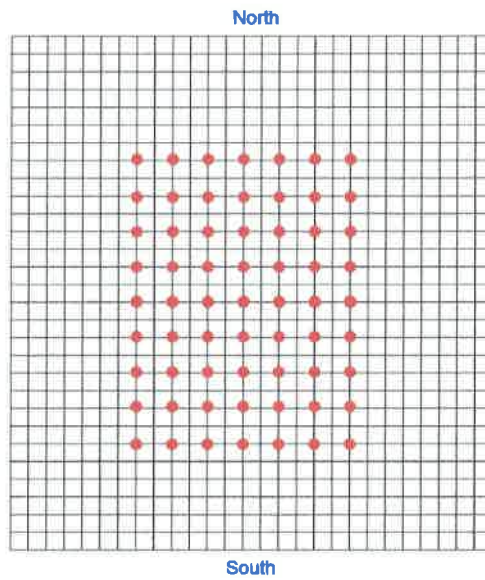South

maximum rigging point load on highlighted nodes - summer   = 258kg
maximum rigging point load on highlighted nodes - winter   = 181kg

Load pattern D

North

South

maximum rigging point load on highlighted nodes - summer   = 447kg
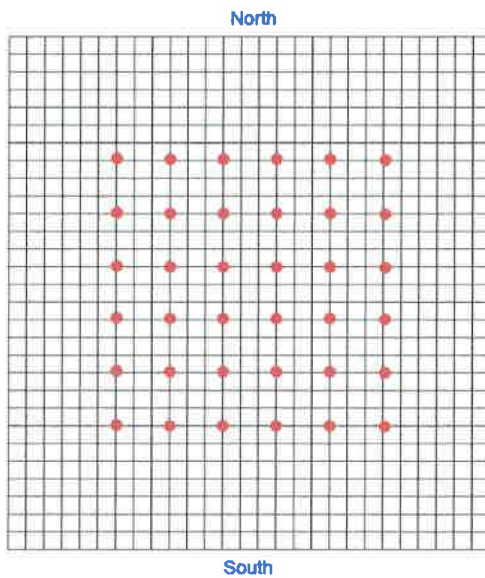maximum rigging point load on highlighted nodes - winter   = 313kg

Load pattern E

maximum rigging point load on highlighted nodes - summer   = 696kg
maximum rigging point load on highlighted nodes - winter   = 487kg

Load pattern F

North

South

maximum rigging point load on highlighted nodes - summer   = 53kg
maximum rigging point load on highlighted nodes - winter   = 37kg

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Load pattern G

maximum rigging point load on highlighted nodes - summer   = 204kg
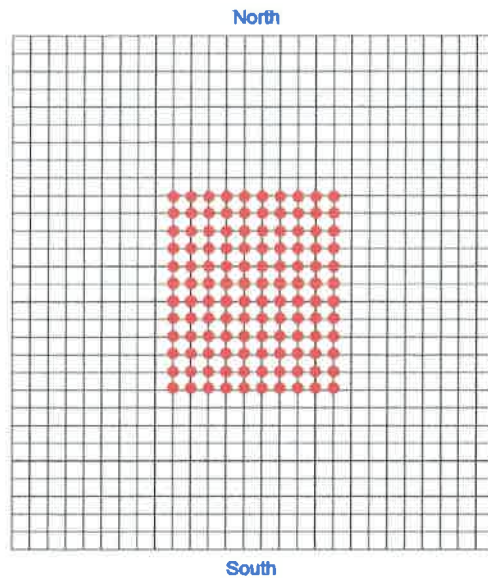maximum rigging point load on highlighted nodes - winter   = 143kg

Load pattern H

North

South

maximum rigging point load on highlighted nodes - summer   = 360kg
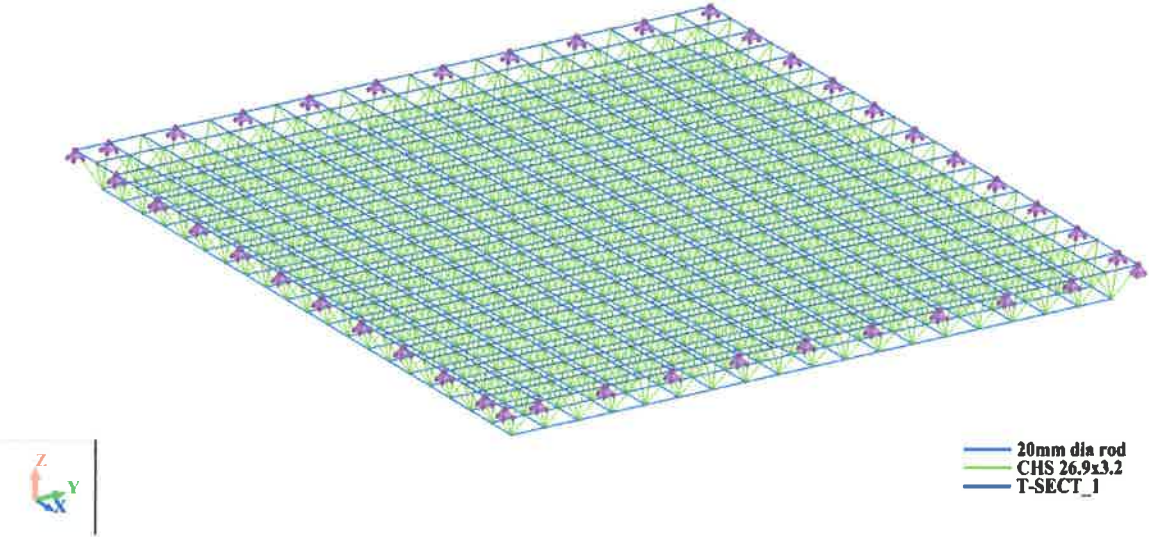maximum rigging point load on highlighted nodes - winter   = 252kg

Load pattern J

North

South

maximum rigging point load on highlighted nodes - summer = 91kg
maximum rigging point load on highlighted nodes - winter   = 63kg

6.0   Theatre Roof

6.1   Analytical model

The space deck of theatre roof was modelled in its assumed entirety (our visual survey could not identify the exact extent of the roof, or the exact arrangement of boundary conditions). The results are from analytical model '1708 Model3D Theatre 001 130829dc.rtd'.

——	20mm dia rod
——	CHS 26.9x3.2
——	T-SECT_1

6.2 Stress comparison analysis

Summer Condition:

element normal stresses (Smax, Smin)

| load condition	point load on nodes [kN]	total model load on roof [kN]	top chords [N/mm2]	node load equivalent		bottom chords [N/mm2]	node load equivalent		diagonals [N/mm2]	node load equivalent		deflection [mm]	node load equivalent		maximum node load [kg]	total rigging load on roof [tonnes]
				[kN]	[kg]		[kN]	[kg]		[kN]	[kg]		[kN]	[kg]		
roof imposed (0.5kPa)	0.72	259	31.59	0.720	73.4	2.14	0.720	73.4	16.47	0.720	73.4	24.7	0.720	73.4	36.7	11.2
	0.72		-11.93	0.720	73.4	-75.27	0.720	73.4	-27.71	0.720	73.4					
pattern K	1.000	323	43.32	0.729	74.4	3.12	0.686	69.9	21.31	0.773	78.8	33.7	0.733	74.7	35.0	11.3
	1.000		-15.93	0.749	76.4	-102.49	0.734	74.9	-35.62	0.778	79.3					
pattern L	1.000	90	11.14	2.836	289.2	0.75	2.853	290.9	5.73	2.874	293.1	8.6	2.872	292.9	144.6	13.0
	1.000		-4.17	2.861	291.7	-26.16	2.877	293.4	-9.62	2.880	293.7					
pattern M	1.000	42	5.06	6.243	636.6	0.37	5.784	589.8	2.71	6.077	619.7	3.9	6.333	645.8	294.9	12.4
	1.000		-1.92	6.214	633.6	-11.89	6.331	645.5	-4.58	6.050	616.9					
pattern N	1.000	25	3.01	10.495	1070.2	0.23	9.304	948.7	1.83	9.000	917.7	2.2	11.227	1144.8	458.9	11.5
	1.000		-1.13	10.558	1076.5	-6.95	10.830	1104.3	-2.84	9.757	994.9					
pattern O	1.000	12	1.83	17.262	1760.2	0.15	14.267	1454.7	1.32	12.477	1272.3	1.3	19.000	1937.4	636.1	7.6
	1.000		-0.71	16.803	1713.3	4.19	17.964	1831.8	-2.03	13.650	1391.9					
pattern P	1.000	81	20.33	1.554	158.4	1.47	1.456	148.4	12.32	1.337	136.3	13.5	1.830	186.6	68.2	5.5
	1.000		-7.42	1.608	162.9	-47.86	1.573	160.4	-17.75	1.561	159.2					
pattern Q	1.000	25	5.9	5.354	546.0	0.44	4.864	495.9	3.65	4.512	460.1	4.0	6.175	629.7	230.1	5.8
	1.000		-2.25	5.302	540.7	-13.85	5.435	554.2	-5.45	5.084	518.4					
pattern R	1.000	9	2.44	12.947	1320.2	0.17	12.588	1283.6	1.65	9.982	1017.8	1.5	16.467	1679.1	508.9	4.6
	1.000		-0.83	14.373	1465.6	-5.62	13.393	1365.7	-2.09	13.258	1351.9					
pattern S	1.000	25	8.79	3.594	366.5	0.51	4.196	427.9	5.45	3.022	308.1	4.9	5.041	514.0	154.1	3.9
	1.000		-2.37	5.034	513.3	20.45	3.681	375.3	5.62	4.931	502.8					

Winter Condition

element normal stresses (Smax, Smin)

load condition	point load on nodes [kN]	total model load on roof [kN]	top chords [N/mm2]	node load equivalent		bottom chords [N/mm2]	node load equivalent		diagonals [N/mm2]	node load equivalent		deflection [mm]	node load equivalent		maximum node load [kg]	total rigging load on roof [tonnes]
				[kN]	[kg]		[kN]	[kg]		[kN]	[kg]		[kN]	[kg]		
roof imposed (0.35kPa)	0.504	181	-22.113	0.504	51.4	1.498	0.504	51.4	11.529	0.504	51.4	17.3	0.504	51.4	25.7	9.3
	0.504		-8.351	0.504	51.4	-52.689	0.504	51.4	-19.397	0.504	51.4					
pattern K	1.000	323	43.32	0.510	52.1	3.12	0.480	49.0	21.31	0.541	55.2	33.7	0.513	52.3	24.5	7.9
	1.000		-15.93	0.524	53.5	-102.49	0.514	52.4	-35.62	0.545	55.5					
pattern L	1.000	90	11.14	1.985	202.4	0.75	1.997	203.7	5.73	2.012	205.2	8.6	2.010	205.0	101.2	9.1
	1.000		-4.17	2.003	204.2	-26.16	2.014	205.4	-9.62	2.016	205.6					
pattern M	1.000	42	5.06	4.370	445.6	0.37	4.049	412.8	2.71	4.254	433.8	3.9	4.433	452.1	206.4	8.7
	1.000		-1.92	4.349	443.5	-11.89	4.431	451.9	-4.58	4.235	431.8					
pattern N	1.000	25	3.01	7.347	749.1	0.23	6.513	664.1	1.83	6.300	642.4	2.2	7.859	801.4	321.2	8.0
	1.000		-1.13	7.390	753.6	-6.95	7.581	773.0	-2.84	6.830	696.4					
pattern O	1.000	12	1.83	12.084	1232.1	0.15	9.987	1018.3	1.32	8.734	890.6	1.3	13.300	1356.2	445.3	5.3
	1.000		-0.71	11.762	1199.3	-4.19	12.575	1282.2	-2.03	9.555	974.3					
pattern P	1.000	81	20.33	1.088	110.9	1.47	1.019	103.9	12.32	0.936	95.4	13.5	1.281	130.6	47.7	3.9
	1.000		-7.42	1.125	114.8	-47.86	1.101	112.3	-17.75	1.093	111.4					
pattern Q	1.000	25	5.9	3.748	382.2	0.44	3.405	347.2	3.65	3.159	322.1	4.0	4.323	440.8	161.0	4.0
	1.000		-2.25	3.712	378.5	-13.85	3.804	387.9	-5.45	3.559	362.9					
pattern R	1.000	9	2.44	9.063	924.1	0.17	8.812	898.5	1.65	6.987	712.5	1.5	11.527	1175.4	356.2	3.2
	1.000		-0.83	10.061	1025.9	-5.62	9.375	956.0	-2.09	9.281	946.4					
pattern S	1.000	25	8.79	2.516	256.5	0.51	2.937	299.5	5.45	2.115	215.7	4.9	3.529	359.8	107.9	2.7
	1.000		-2.37	3.524	359.3	-20.45	2.576	262.7	-5.62	3.451	351.9					

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6.3   Results Summary
Load pattern K

North

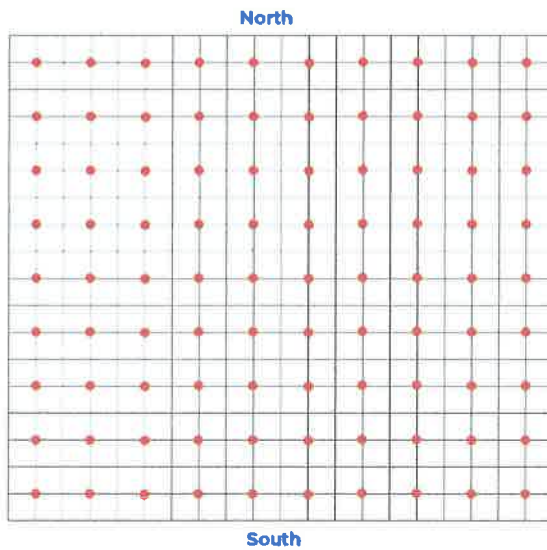**South**
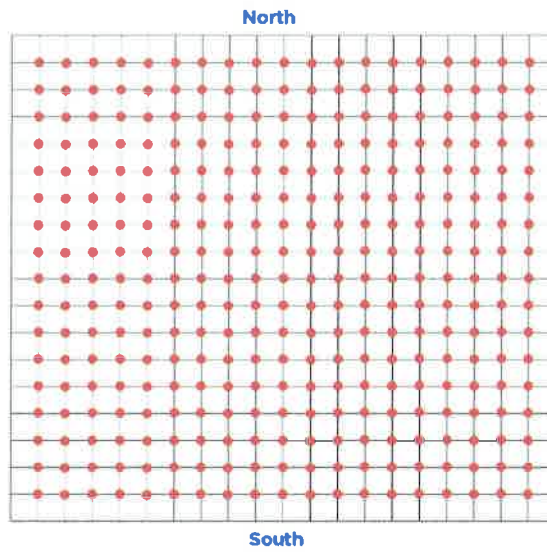
maximum rigging point load on highlighted nodes - summer   = 35kg
maximum rigging point load on highlighted nodes - winter   = 24kg

Load pattern L

North

South
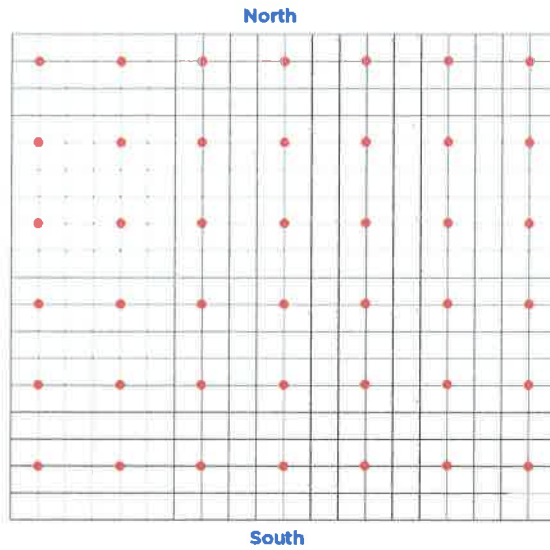
maximum rigging point load on highlighted nodes - summer   = 144kg
maximum rigging point load on highlighted nodes - winter   = 101kg

Load pattern M
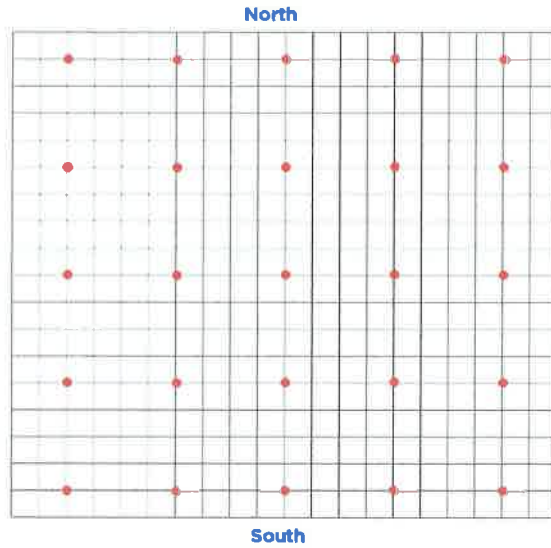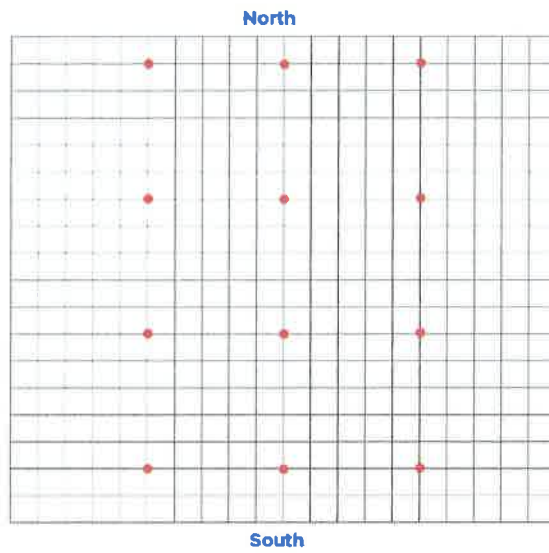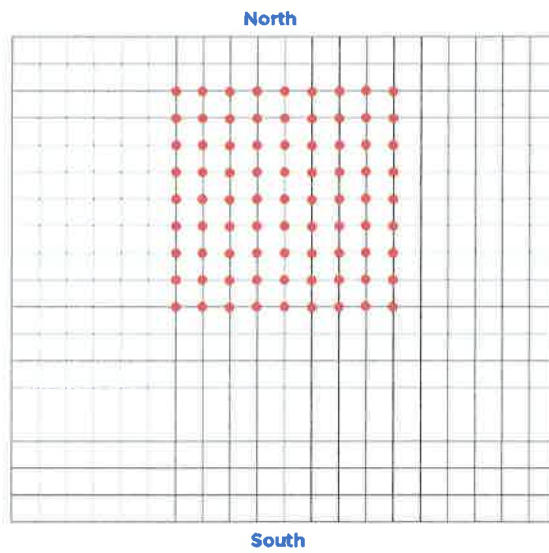
North

South

maximum rigging point load on highlighted nodes - summer   = 294kg
maximum rigging point load on highlighted nodes - winter   = 206kg

Load pattern N

North

South

maximum rigging point load on highlighted nodes - summer   = 458kg
maximum rigging point load on highlighted nodes - winter   = 321kg

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Load pattern O

North

South

maximum rigging point load on highlighted nodes - summer   = 636kg
maximum rigging point load on highlighted nodes - winter   = 445kg
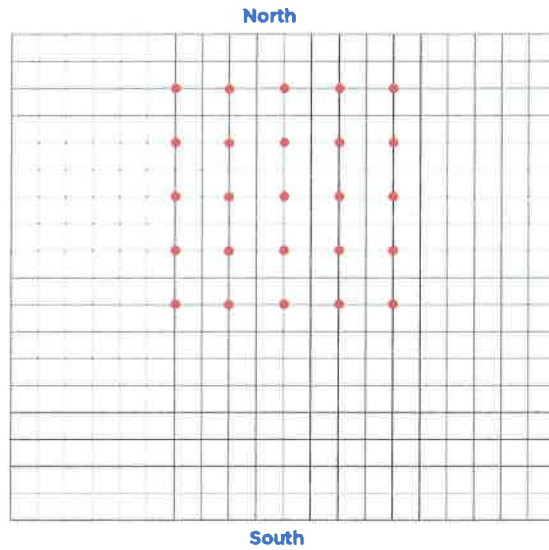
Load pattern P

North

South

maximum rigging point load on highlighted nodes - summer   = 68kg
maximum rigging point load on highlighted nodes - winter   = 47kg
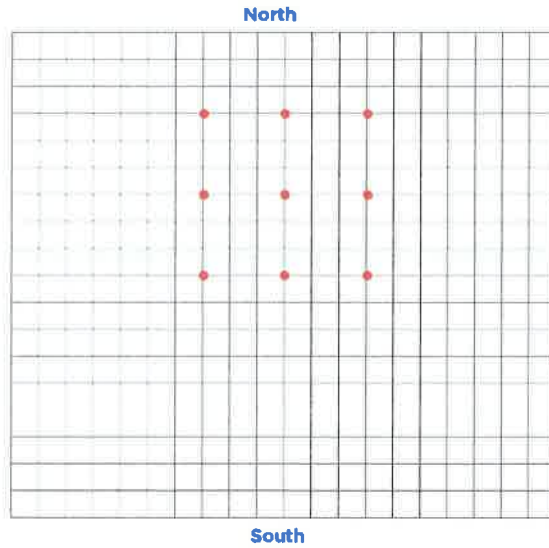
Load pattern Q

North

South

maximum rigging point load on highlighted nodes - summer   = 230kg
maximum rigging point load on highlighted nodes - winter   = 161kg

Load pattern R

North

South

maximum rigging point load on highlighted nodes - summer   = 508kg
maximum rigging point load on highlighted nodes - winter   = 356kg

Load pattern S

maximum rigging point load on highlighted nodes - summer   = 154kg
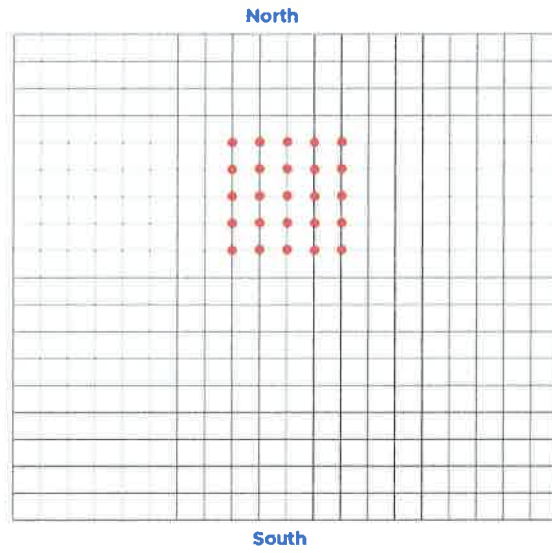maximum rigging point load on highlighted nodes - winter   = 107kg