RAWLINGS
LIMITED
structural design

CONSIDERATION OF THE CAPACITY

Of the

ROOF TRUSSES

At

89 1/2 WORSHIP STREET, LONDON EC2A 2BF

91 Leighton Road
Wing
LEIGHTON BUZZARD
LU7 0NN
T: 01296 681876
E: keith@rawlings.uk.net

August 2012

1. INTRODUCTION

Rawlings Structural Design Ltd were appointed to consider the load capacity of the roof trusses over multiple use space at $89^{1}/_{2}$ Worship Street. The intention is to suspend various banners and equipment from the rafters and the capacity of the load is required.

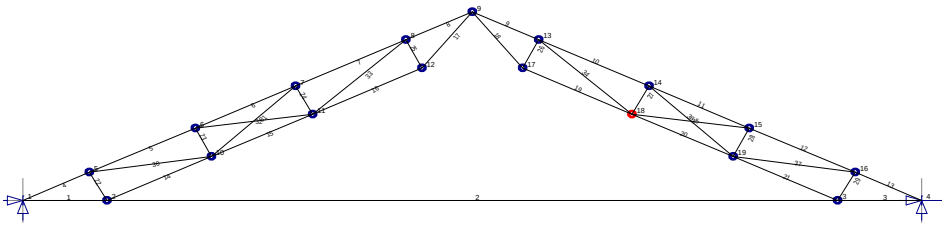
2. THE BUILDING

The property consists of an office block in a mews off Worship Street, with a large former industrial unit attached. It is intended that the unit be used for fashion and other shows, and to this end the capacity of the roof structure is required.

3. THE STRUCTURE

The roof structure is most unusual. It consists of a series of duopitched frames at 3.5m centres, with rafters manufactured as girders from circular hollow sections. There are parallel chords along the slope with ties and cross braces between them. The feet of the frame are tied together using a circular hollow section with anti-sag rods at the quarter points.

Most roof frames are particular types of frame; fink or warren truss, king post and queen post trusses for instance. This form of structure is atypical and arguably unique, therefore it was necessary to analyse the frame from first principles. All of the loads are deemed to act at the nodes – the junctions at which the structural elements meet.



For the purposes of this report the elements are defined as follows:

Main tie	Members 1 to 3	48.3 CHS 4.0 thk
Outer rafter	Members 4 to 13	76.1 CHS 4.0 thk
Inner rafter	Members 14 to 21	26.9 CHS 3.0 thk
Rafter ties	Members 22 to 29	26.9 CHS 3.0 thk
Cross ties	Members 30 to 37	26.9 CHS 3.0 thk

4. LOADS

Detailed calculations are attached as an appendix, but in summary, there are three sets of loads required for the analysis of the roof; dead load, live load and wind load. The dead load is the self-weight of the structure; the wind load is self-explanatory and the live load is the weight of people walking on the roof as well as equipment suspended from the roof.

Roof dead load is defined as 0.6 kN/m^2. The wind load is calculated as either 0.41 kN/m^2 uplift or 0.42 kN/m^2 pressure. This means that there is no net uplift and the total pressure is 1.02 kN/m^2. The pressure translates into the following node pressures:

5. Section capacities

Main tie	Members 1 to 3	48.3 CHS 4.0 thk	Tension capacity	= 187 kN
			Moment capacity	= 2.6 kNm
Outer rafter	Members 4 to 13	76.1 CHS 4.0 thk	Compression capacity	= 214.7 kN
			Moment capacity	= 5.7 kNm
Inner rafter	Members 14 to 21	26.9 CHS 3.0 thk	Compression capacity	= 12.8 kN
			Moment capacity	= 0.5 kNm
Rafter ties	Members 22 to 29	26.9 CHS 3.0 thk	Compression capacity	= 12.8 kN
			Moment capacity	= 0.5 kNm
Cross ties	Members 30 to 37	26.9 CHS 3.0 thk	Compression capacity	= 12.8 kN

Moment capacity = 0.5 kNm

6. LOAD CASES

a. Symmetrical

The number of load cases is legion. Initially they can be divided into two categories; symmetrical and asymmetrical.

The symmetrical loads are simply the same load applied to nodes that are symmetrical about the centre line. This could be single loads, pairs, three loads or all nodes loaded. There are thirteen load cases as noted in the following table.

Case/Node	2	10	11	12	17	18	19	3
1	X							X
2		X					X	
3			X			X		
4				X	X			
5	X	X					X	X
6	X		X			X		X
7	X			X	X			X
8		X	X			X	X	
9		X		X	X		X	
10			X	X	X	X		
11	X	X	X			X	X	X
12	X	X		X	X		X	X
13	X		X	X	X	X		X
14		X	X	X	X	X	X	
15	X	X	X	X	X	X	X	X

b. Asymmetrical

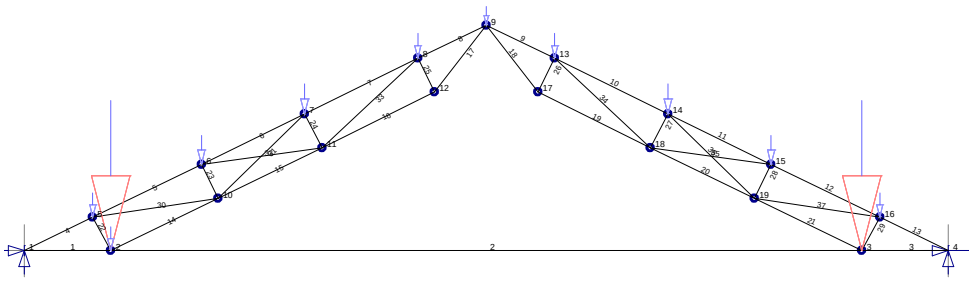
The asymmetrical load cases are even more numerous. Not only can a load be applied to different nodes either side of the centre line, but loads of different values can be applied to symmetrical nodes. The possible variation in loads is infinite and always has an effect on the value of the load on the other side of the centre line. There could be hundreds of asymmetrical load cases. The brief does not run to this level of detail and it would be an expensive, and ultimately pointless exercise.

Instead the load cases were limited to those that are likely to occur as part of the use of the building. It is extremely likely that the any equipment or banners are going to be suspended from the roof symmetrically. Therefore the load cases are confined to loads applied symmetrically on the four outer nodes plus a fifth load where the same load is applied to all of the nodes.

The allowable load is therefore defined as the smallest node load that does not overstress the members.

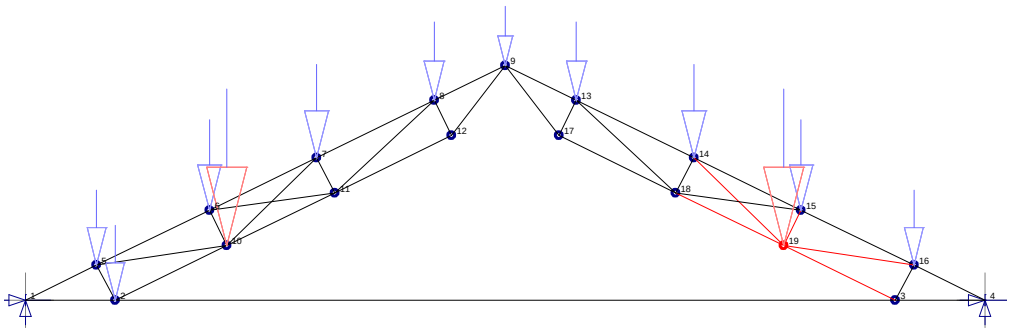
7. RESULTS

a. Case i) Nodes 2 and 3 loaded



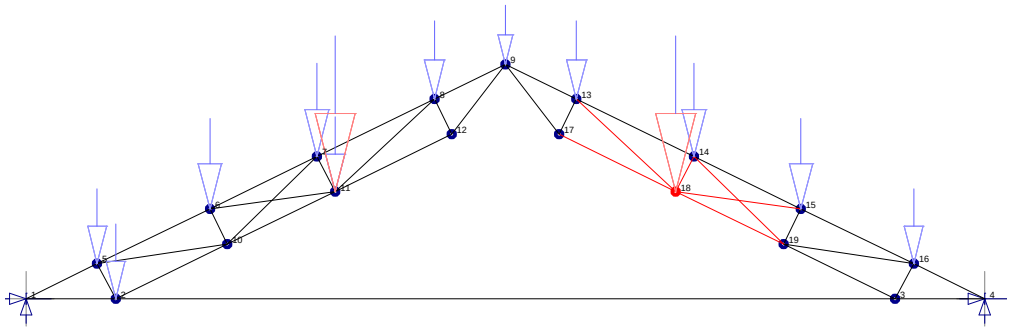
Element	Members	Applied Load kN	Tension kN	Compression kN	Moment kNm	Usage %
Tie	1 to 3	35	87.7		0.209	55
Tie	1 to 3	35		19.5	0.115	15
Outer Rafter	4 to 13	15		95.4	0.376	93
Inner Rafter	14 to 21	15	63.4		0.031	102
Rafter Ties	22 to 29	15		9.8	0.114	108
Cross Ties	30 to 37	15	28.2		0.013	46

b. Case ii) Nodes 10 and 19 loaded



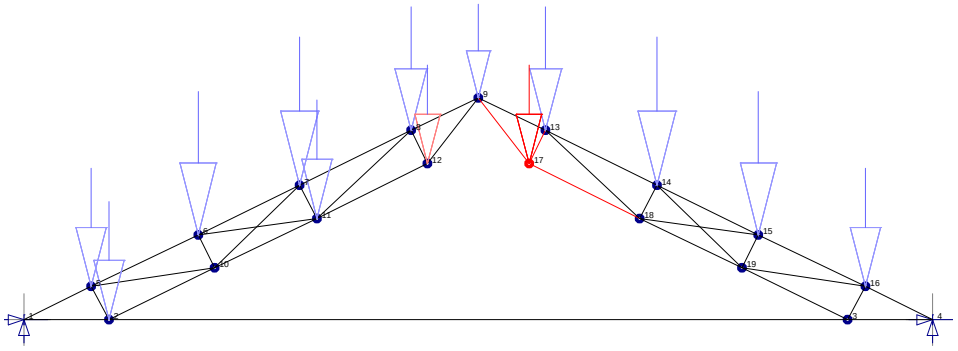
Element	Members	Applied Load kN	Tension kN	Compression kN	Moment kNm	Usage %
Tie	1 to 3	50	89.9		0.269	59
Tie	1 to 3	50		20.0	0.195	87
Outer Rafter	4 to 13	5		81.6	0.300	82
Inner Rafter	14 to 21	5	43.5		0.017	70
Rafter Ties	22 to 29	5		10.5	0.049	96
Cross Ties	30 to 37	5	25.0		0.022	43

c. Case iii) Nodes 11 and 18 loaded



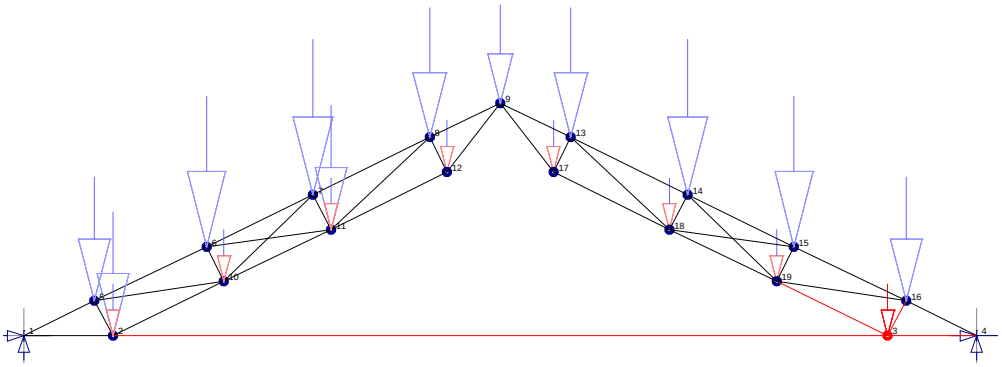
Element	Members	Applied Load kN	Tension kN	Compression kN	Moment kNm	Usage %
Tie	1 to 3	75	83.9		0.364	59
Tie	1 to 3	75		18.4	0.28	85
Outer Rafter	4 to 13	5		91.1	0.260	89
Inner Rafter	14 to 21	5	47.4		0.019	76
Rafter Ties	22 to 29	2		9.8	0.102	105
Cross Ties	30 to 37	2	27.4		0.015	45

d. Case iv) Nodes 12 and 17 loaded



Element	Members	Applied Load kN	Tension kN	Compression kN	Moment kNm	Usage %
Tie	1 to 3	200	65.2		0.678	61
Tie	1 to 3	200		14.1	0.431	75
Outer Rafter	4 to 13	2		69	0.165	65
Inner Rafter	14 to 21	2	34.6		0.012	55
Rafter Ties	22 to 29	2		7.6	0.095	84
Cross Ties	30 to 37	2	20.3		0.014	34

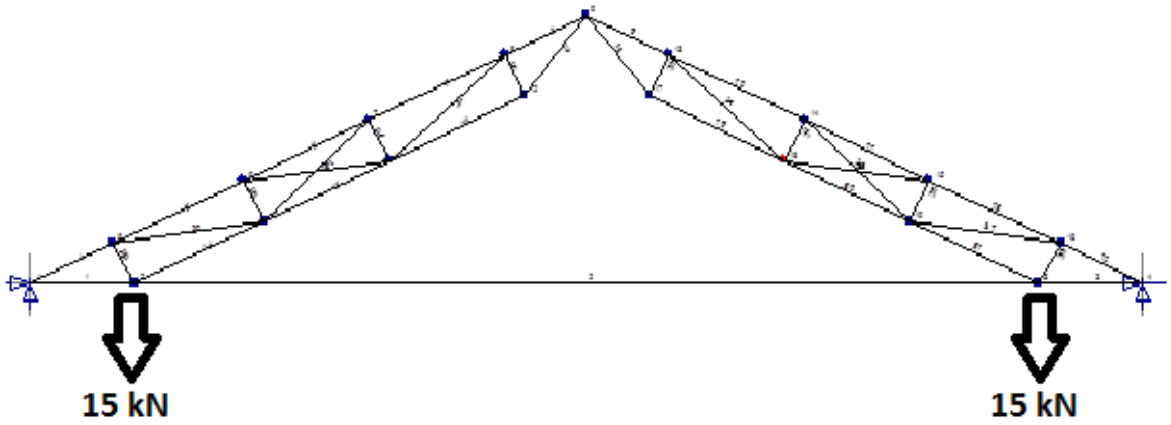
e. Case v) All nodes loaded

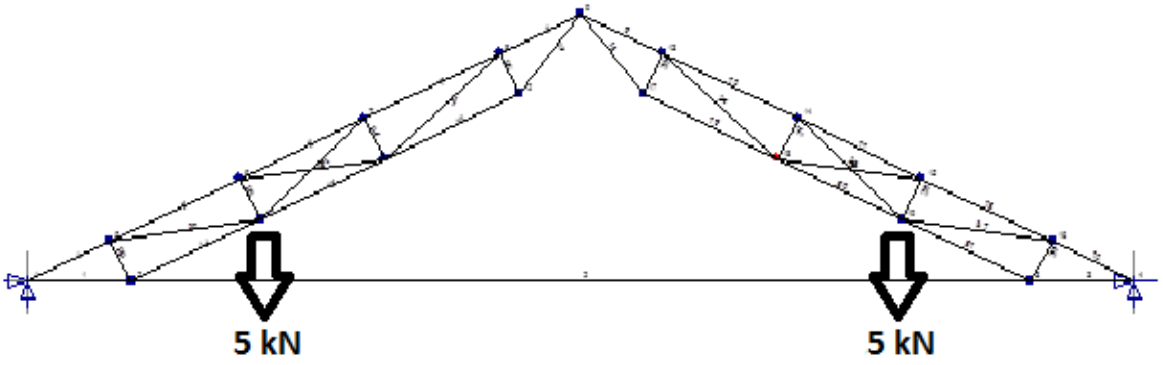


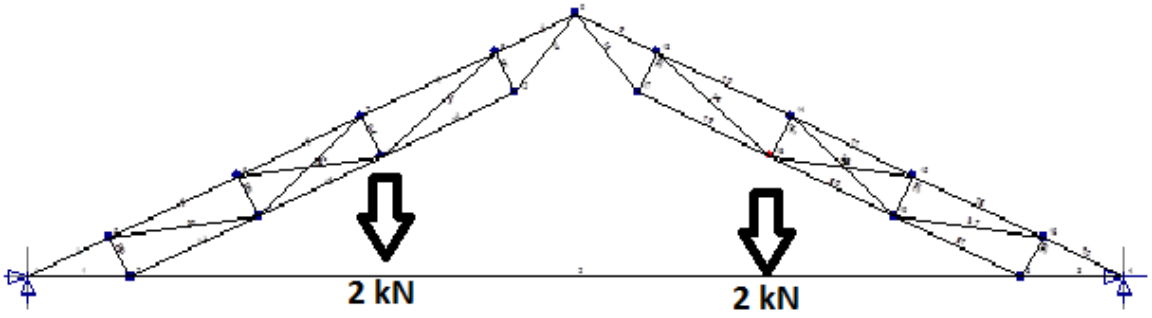
Element	Members	Applied Load kN	Tension kN	Compression kN	Moment kNm	Usage %
Tie	1 to 3	1	23.2		0.078	15
Tie	1 to 3	1		4.4	0.056	19
Outer Rafter	4 to 13	1		79.2	0.192	75
Inner Rafter	14 to 21	1	41.5		0.013	66
Rafter Ties	22 to 29	1		9.4	0.109	103
Cross Ties	30 to 37	1	26.8		0.013	44

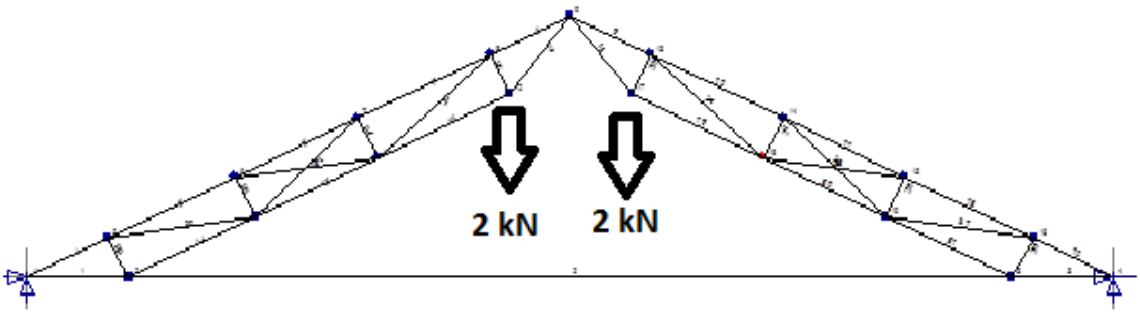
8. CONCLUSION

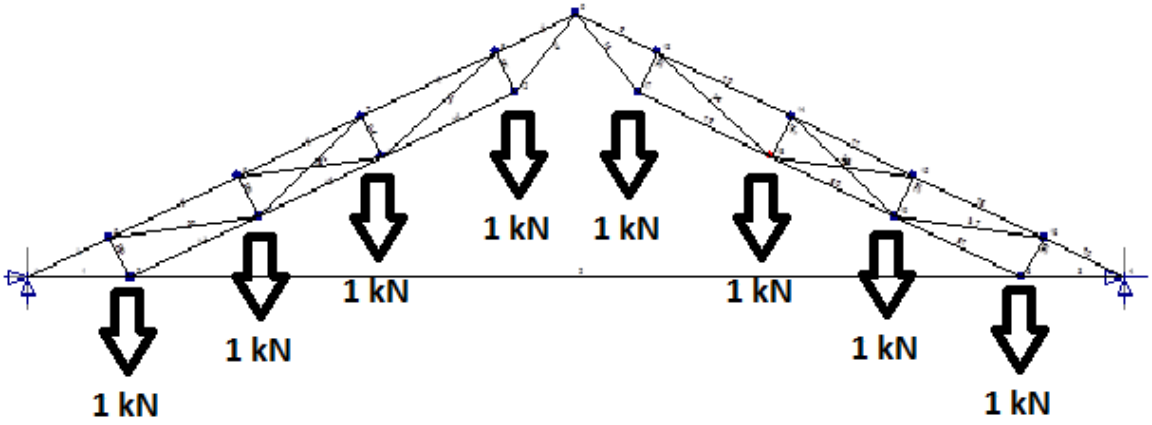
The following load combinations are permissible.











NB 1kN = 100kgs force

Alternative loading patterns are available but are too complex to be assessed in this method. Detailed structural analysis is required and is available from Rawlings Structural Design Ltd.

KEITH RAWLINGS
RAWLINGS STRUCTURAL DESIGN LTD
August 2012