Mobile arena: a tensioned fabric multi-hall

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Mobile Arena: a Tensioned Fabric Multi-Hall

Arène mobile: une structure en tension

"Mobile Arena":eine membranüberdachte Mehrzweckhalle

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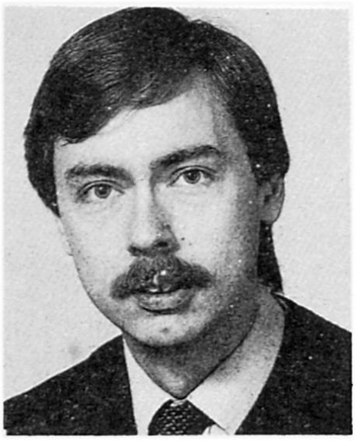

Michael Cook, born 1955, obtained his engineering degree from Cambridge University and his second degree from Bath University. He has worked with Engineering Consultants Buro Happold since 1982 and has been particularly involved in the design and construction of wide span and flexible structures in the UK, USA, Saudi Arabia and Hong Kong.

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SUMMARY
This paper describes the recent design and construction of a mobile tension structure in the UK. The Arena provides a column-free area 79m by 54m with internal heights to 19m and a very high roof loading capacity. Rapid erection, dismantling and easy transport were important features of the design.

RÉSUMÉ
L'auteur décrit la conception et la construction récentes d'une structure de tension mobile au Royaume-Uni. Cette arène offre une surface sans colonnes de 79m sur 54 avec des hauteurs intérieures de 19m et une portance du toit très élevée. Elle se caractérise par un montage et démontage rapides et est aussi facile à transporter.

ZUSAMMENFASSUNG
Dieser Beitrag beschreibt die jüngste Konstruktion und Montage eines mobilen Zugspannungstragwerks in Großbritannien. Die Arena besteht aus einer frei überspannten Fläche von 79m mal 54 m einer Innenhöhe von 19m und einer sehr hohen Dachbelastungskapazität.Schneller Auf- und Abbau und problemloser Transport wurden bei der Konstruktion besonders berücksichtigt.

1 INTRODUCTION

The clients for the Arena, 'Mobile Entertainment Centres Ltd', commissioned Buro Happold as structural engineers in 1989. They required the development of a building system which would provide the entertainment industry with a multi-purpose venue which could travel to its own audience. Prime considerations for the design were:

(1) An extendable structural system to seat up to 10,000 people
(2) Ease of transport, construction and dismantling (erection time up to five days)
(3) Interior ceiling height of 19m to allow overhead lighting and sound equipment over central area
(4) Roof capacity to carry up to 30T on every frame for performance equipment
(5) Completely column-free interior
(6) A pyramid form to be expressed externally
(7) Structure to be capable of use throughout the UK, Europe and USA - design wind and snow loadings to comply with current building requirements
(8) Reusable anchorage system for wide range of ground conditions.

A prototype structure was fabricated and erected in the UK in 1990. This comprises a 'two pyramid' configuration, internal length 79m, internal width 54m with a seating capacity of about 5,000. Overall footprint of the structure is 90m by 70m. Internal volume 40,000m^2. Configurations of up to four pyramids are envisaged to seat 10,000.

2 PRIMARY STRUCTURE

The primary load carrying system comprises five tubular steel portal frames with legs splayed at 45^o set at 12.5m centres. These have a clear span of 63m. These portal frames are linked by tubular steel trusses of similar cross section to form a 12.5m square structural grillage 19m above the ground. The ends of the structure are closed by raking trusses which provide longitudinal stability to the linked portal frames. The frames stand on steel base plates anchored to the ground with screw anchors.

The trusses all break down into 6m lengths weighing 800kg for transportation. In addition there are special sections for the joints. The cross section is trapezoidal, 1168 mm deep by 928 mm at the top and 548 mm at the bottom. This enables eighteen sections to fit within the truck loading section and allows space for maintenance access within the trusses. The sections are joined by four vertical plates and single large pins. These joints fit within the cross section of the 168 mm diameter tubes and can take the full tensile capacity of the tubes.

3 ALUMINIUM PYRAMID LEGS

Standing astride the Arena there are two pyramid frames 36m high towards which the roof fabric is tensioned to create two conical peaks. This adds greatly to the dramatic effect of the building. Each pyramid has four legs 50m long formed from aluminium trusses with a triangular cross section. These trusses break down into 6m lengths for transportation and the cross section has been designed to be very compact so that 25 elements can fit into the standard truck section. Each section weighs 150 kg and can be handled by two men. The jointing system is similar to the steel trusses.

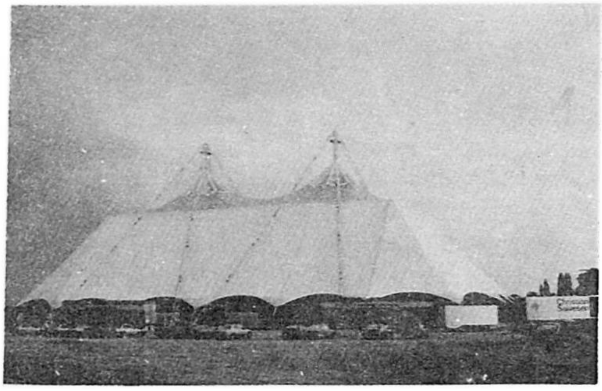

Figure 1 - The Prototype Arena

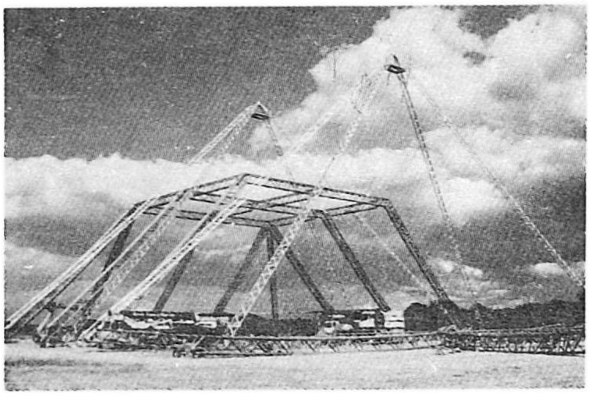

Figure 2 - Framework during erection

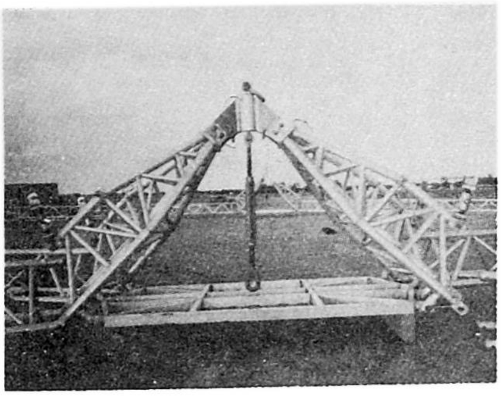

Figure 3 - Apex of pyramid legs

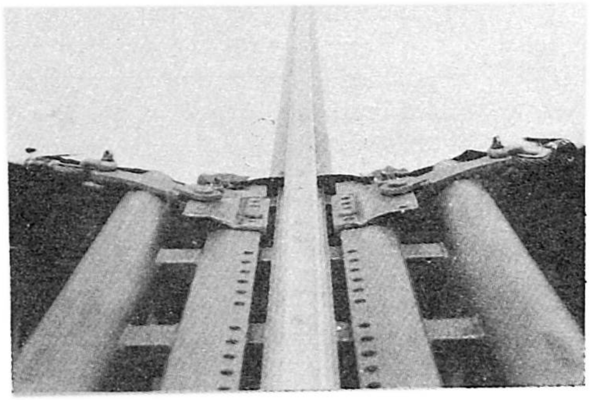

Figure 4 - Membrane panel perimeter detail

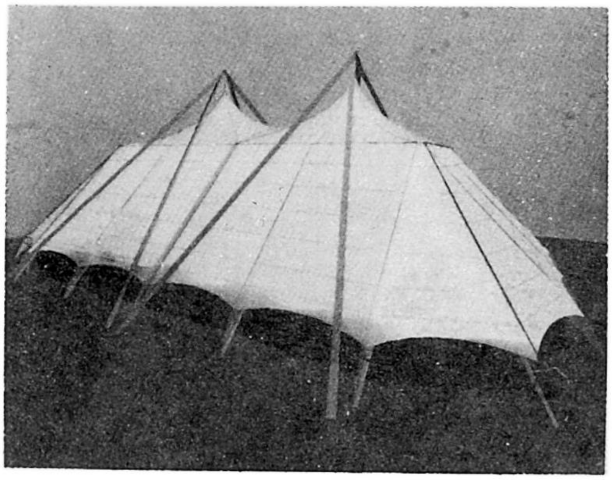

Figure 5 - Analysis model

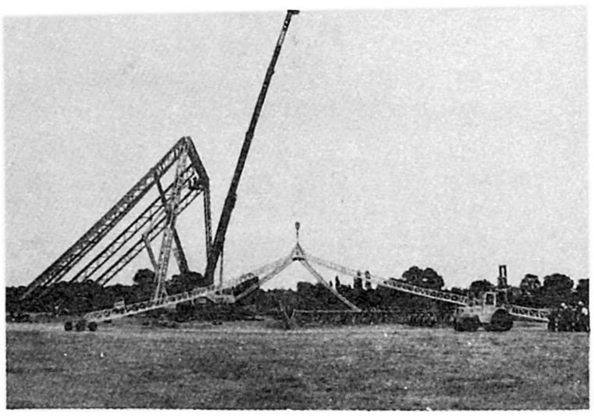

Figure 6 - Erection: raising pyramid

4 FABRIC CLADDING

4.1 Side Panels

The tensioned fabric cladding was the key to the design of the Arena structure. The sloping sides are infilled with flat panels of fabric 12.5m wide by 25m long. The fabric was Type 3 PVC-coated polyester, 1050 gms/m^2 with a strip tensile strength of 100 kN/m. the long edges are finished with a 'Keder' roped edge which fits into an aluminium luff groove extrusion bolted to the trusses. The top edge is connected at points to the truss while the bottom edge has a catenary cable boundary. For installation the panel was made 40 mm over size. This reduced the fabric tensions sufficient to allow the specially treated Keder edge to slide into the luff groove. The edge of the cloth was hauled up with a wire rope halyard running over a fixed sheave.

The warp direction of the cloth runs horizontally. When installed the fabric is tensioned in the fill direction by hauling down on the catenary cable to induce a tension of 5 kN/m. The fabric stretches in the fill direction and the crimp interchange effect causes the warp to shrink, pulling out the 40 mm slackness and inducing some tension.

Under wind loading the flat fabric deflects and the radius of curvature of the cloth decreases until the tension equilibrates with the applied pressures. These fabric panels have performed excellently in practice. They do not flap or wrinkle and the deflections are not alarming. If such panels were fixed horizontally there would be a danger of ponding, the question is how much slope is required to prevent this.

4.2 Top Cones

Each roof cone covers a plan area of 25m x 25m. The edges are fixed to the outer trusses at 1.5m spacing using webbing belts and ratchet buckles. The cones are made of Type 4 fabric, patterned to shape and tensioned by pulling the peaks up to the apices of the aluminium pyramids and holding them with rigging screws.

Each cone is patterned into four fields with belts running out to the corners. Flaps are used to seal the joints with the side panels which are closed with PVC zips. The fabric is installed by hoisting it up as a bundle and pulling out the corners. Ventilation is provided by a large area of plissé fabric around each peak. This consists of folded strips of PVC fabric welded on to a mesh. It keeps the rain out and is flexible.

The form finding load analysis and patterning of the fabric cones were carried out using the TENSYL analysis suite, as described in the accompanying article by Dalland/Gill. [Ref 1] Wind loads were taken from the results of wind tunnel tests at Bristol University.

5 WALLING SYSTEM

The 5m high vertical perimeter wall consists of aluminium posts at 2.5m spacing fixed to the ground and to a horizontal truss spanning between frames . For a frequently moved structure the posts are infilled with PVC panels slotted into luff grooves. For a semi-permanent installation rigid panels could be substituted. The clearance is such that articulated trucks can be driven into the building through roller shutter doors and temporary buildings can be 'plugged in' to the walling system.

6 INSTALLATION

The procedure involved laying out the trusses on the ground and lifting them by crane. An end portal frame was erected first and propped by the raking end trusses. The erection then proceeded frame by frame along the axis of the hall, each frame being stabilised by the infill members. The aluminium pyramids were lifted before the steelwork when the crane was in the appropriate place. The main steel being completed, the walling trusses were installed and then the side panels could be hauled up the luff grooves. The top cones were the final part of the cladding to be

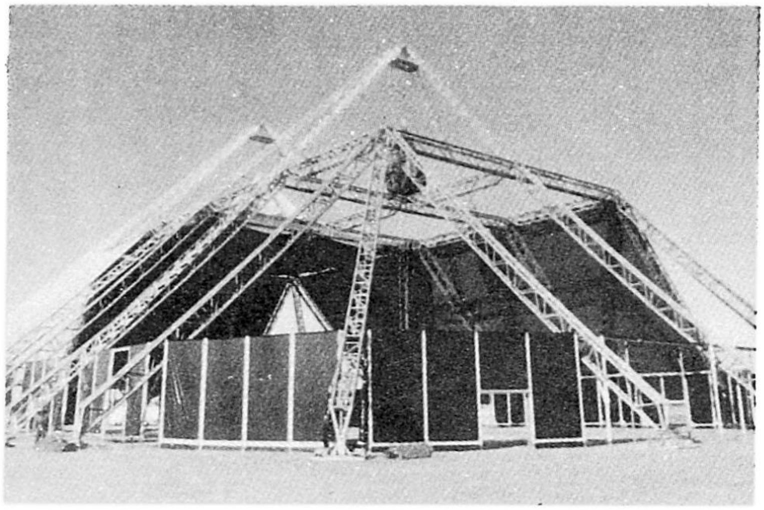

Figure 7 - Erection: installing fabric

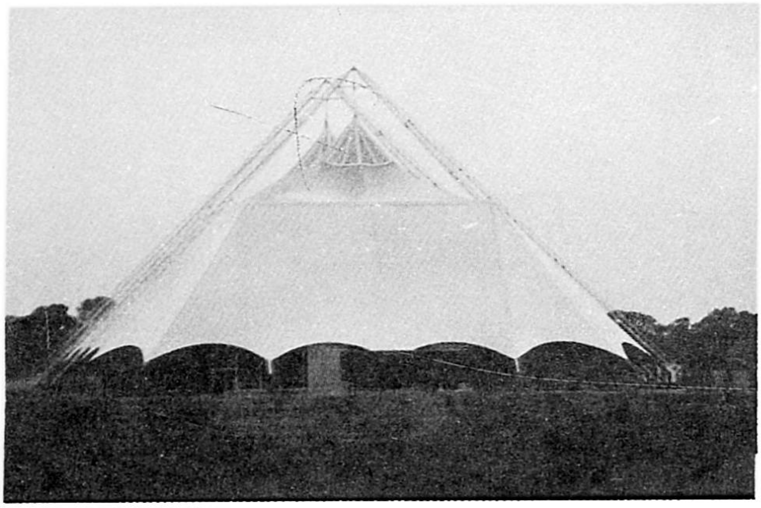

Figure 8 - Completed structure

installed. On the second installation the time was less than the required period of five days.

ACKNOWLEDGEMENTS

The Client:
Mobile Entertainment Centres Ltd, 201 Coventry Road, Birmingham B10 0RA
Steelwork Fabricators:
Tubeworkers Ltd, Claverdon, Warwicks CV35 8PR
Membrane Fabricators:
Landrell Fabric Engineering, Station Road, Chepstow, Gwent NP6 5PF

REFERENCE

[1] DALLAND, T and GILL C 'Interactive graphic CAD for tension structures as used for the design of the new concert pavilion, Pier 6, Baltimore'

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