

MSAA/LSAA Conf Proceedings

COSTS AND ECONOMY OF FABRIC STRUCTURES

B T DAVIS
McWilliam Consulting Engineers

COSTS AND ECONOMY OF FABRIC STRUCTURES

B T DAVIS

1. SYNOPSIS

An introduction to some of the basic cost elements in Fabric Structures is presented, together with relativities of other roofing systems. Factors influencing both increases and controls of final cost are outlined.

Finally, summary costings of two practical structures are included to illustrate the most significant elements contributing to overall cost.

2. WHAT IS 'COST'

Almost everyone associated with a project has a different interest in and measure of 'Cost' as it relates to his involvement in the project.

The Developer, Financier, Sub-Contractor, Engineer, Inspector see different horizons and include different elements in their cost equations.

However, central to anyone's assessment of a project cost is that figure which the Contractor/Builder charges for producing the physical part of the project. This is what we will concentrate on in this paper.

Costing can be a fairly complicated procedure, or it can be kept simple. Experience shows that the overwhelming majority of successful contractors, while they may price set items in significant detail as a routine, place greatest reliance on relatively simple summary costs and general overall area rates.

This approach has come about for two reasons, one is the usual tight time limits on pricing, while the other recognises the old axiom that simplified procedures give rise to fewer major mistakes and can be relied upon to give a much more comfortable 'feeling' due to the ease with which results from comparative projects can be compared.

So, in what follows, the 'costs' referred to will include material and labour plus oncosts for preliminaries, etc. as would normally form part of a Contract 'Price' at today's rates.

3. FABRIC STRUCTURES

Commonly, two broad classes of structure type are often described viz. tension structures and pneumatic structures. Clearly there are a host of intermediate or mixed possibilities, however, all could be seen to comprise basic cost elements as follows:

- ▶ fabric
- ▶ support structures
- ▶ cables
- ▶ anchorages (foundations)
- ▶ doors, windows or other features
- ▶ mechanical items
- ▶ delivery and installation
- ▶ design and documentation
- ▶ contractor costs and miscellaneous

Table 1 sets out an extension of this list indicating various sub-items which need to be considered in a project.

4. INDICATIVE UNIT RATES

As noted, above, the depth to which a costing exercise is taken is purely at the choice of the estimator. However, within the Industry estimates are prepared and checked at two general levels, viz:

- (a) by application of real quoted costs or known (or anticipated) unit rates to individual item list such as might be derived from Table 1 to arrive at a final 'cost'; and
- (b) by applying a general overall unit rate to the structure covered area, such a rate being derived from experience and past records of similar structures. Refer to 5 below.

This system is, of course, no different from that used in other sectors of construction.

In Table II some indicative costs at today's rates are set out. These are fair average rates which need to be used with the Factors noted in 6 below given due consideration.

5. OVERALL AREA RATES

Surprisingly accurate all up final cost figures can be achieved by experienced estimators in applying a general all-inclusive unit rate to the 'covered area' under the fabric structure.

Such figures are invaluable at the early stages of project development when decisions are being made on the type or extent of a fabric structure because such figures are directly comparable with other construction systems.

For this reason Table III provides some realistic guideline rates for both fabric and other roof structure systems.

6. FACTORS AFFECTING COSTS

As with any construction system various factors, often specific to a project, will provide reason to reduce or increase standard unit rates quite significantly. At the same time the effect on the overall final cost has to be considered.

For example, selecting a very low curvature (flattish) fabric structure form will decrease the area of fabric needed and make the conversion and fabric element design a little faster. However, it will result in higher cable and anchorage forces with heavier members. This can be an effective procedure with PTFE/glass fabrics because of their relatively high cost on the roll and noting that they are usually a little more highly prestressed than PVC/Polyester fabrics anyhow.

Some of the factors which can increase the normal area cost of a fabric structure are:

- ▶ high wind or snow loads
- ▶ very low fabric curvatures
- ▶ high peaked structures
- ▶ lots of steel framing
- ▶ 'cable net' type support systems
- ▶ long 'life' guarantees
- ▶ poor foundations
- ▶ asymmetry
- ▶ seam type and size
- ▶ demountable or moveable structures
- ▶ difficult access
- ▶ short contract times

Factors which can be of value in keeping costs to a reasonable minimum include:

- ▶ moderate fabric curvature
- ▶ make the fabric do all the work by reducing support structures
- ▶ symmetry
- ▶ repetition
- ▶ select fabric type and strength for 'realistic' project life cycles

- ▶ select metalwork and cables/fittings just sufficient for the environment
- ▶ ensure client and approval authority are informed and have realistic expectations
- ▶ soft tolerances

7. **EXAMPLES OF PROJECT COSTING**

Set out in Table IV are typical cost estimate summaries for two fabric structures.

The first is a freeform open tension structure, the second a conventional air-supported roof intended to be removed and re-erected at 6 monthly intervals. Both are PVC/Polyester with an acrylic top coating.

It can be informative to compare the relative contributions of the various portions of the work to see where significant economics should be targeted if needed.

8. **COMPARATIVE ECONOMY**

In all of the above we have referred to what might be termed 'first cost'.

The second example in Table IV introduces a recurring cost for demounting, storing and re-erecting the structure, while at the same time requiring a 6 monthly power cost.

While there is much talk about selecting a structure form/material system which will give best life cycle economy, it is a sad fact that very few Clients want to see other than the first cost.

Reference 1 gives a good background to and practical procedures for working through life cycle costs of both fabric and other structures.

9. **CONCLUSION**

Well designed fabric structures with their myriad of vibrant geometric forms will find continued use where their economy and pleasant ambience via their light translucence is appreciated, and where the ease with which they can provide openable roofs provides an essential feature in modern architecture.

TABLE 1**GUIDELINE COST ITEMS****DESIGN AND DOCUMENTATION**

- Influence on existing buildings
- Wind Tunnel tests (Code Data)
- Shape studies/stress analysis
- Architectural and engineering details
- Workshop details and patterns
- Approvals
- Inspections and monitoring performance
- Preliminary cost analyses
- Authority standards/codes
- Fixed/retractable or demountable design

FABRIC

- Watertight or shade type
- Structural 'Type'/test data
- PVC/P; PTFE/glass/other
- Top coatings/colour
- Seam Type and size
- Translucent/UV control
- Cleansability
- A n t i c i p a t e d life/guarantees
- Spares and samples

CABLES AND FITTINGS

- Membrane plates and clamps/field joints
- Galv., coated or SS cables. Special cables or ropes
- Static or running rigging
- Bolts/pins
- Terminations/swages, eyes, thimble, turnbuckles
- Tensioning procedure
- Corrosion protection

DOORS, WINDOWS, ETC.

- Glazed/solid
- Framed/Hung/Pivoted
- Removable/demountable
- Cleaning
- Escape Regulations
- Flaps clips and zipper system

SUPPORT STRUCTURE

- Free-stand or guyed masts
- A-frames/post and guys
- Cantilever post
- Arch/portal
- Air support or air inflate
- Space frame/cable net system
- Catenary or framed edge.

MECHANICAL

- Heating/ventilation/services
- Lighting
- Maintenance
- First Cost/life cycle cost
- Retractable mechanisms
- Plant and storage rooms
- Flexible interfaces
- Controls/PLC

ANCHORAGE

- Site Surveys
- Foundation investigation
- Ground water and services
- Compression footings/piers
- Tension piers/soil or rock anchors
- Capacity for fixing to existing structures
- Footing subject to overturning moment

TABLE 1

GUIDELINE COST ITEM

DELIVERY AND INSTALLATION

- Import/export costs
- Prevention of damage
- Check surveys
- Handling volumes and weights
- Crane requirements - reach and load
- Scaffolding and access/safety
- Weather and wind influences
- Working time/noise restraints

CONTRACTOR COSTS AND MISCELLANEOUS

- Patent rights
- Profit
- Supervision and project management
- Accomodation & communication
- Overheads
- Defects liability
- Insurances
- Labour on-costs
- Escalation
- Project record
- Timetables

MANUFACTURER

- Fabric acceptance inspections
- Timetable
- Marking out
- Cutting operations
- Clean operations
- Seaming and doublers/pockets
- Folding and packing
- Round edges on metal elements
- Local or remote production facilities
- production testing

TABLE 2

INDICATIVE UNIT RATES

FABRIC (in store, on roll)

PVC / POLYESTER / ACRYLIC

TELDAR OR SIMILAR

Type 1	\$ 18 / m ²	\$ 24 / m ²
2	\$ 22 / m ²	\$ 30 / m ²
3	\$ 28 / m ²	\$ 36 / m ²

PTFE / GLASS

Lightweight	\$ 70 / m ²
Heavyweight	\$ 90 / m ²

SHADE FABRIC

Knitted or open woven	\$ 2-3 / m ²
Woven coated	\$ 2-4 / m ²

SUPPORT STRUCTURES (on site/erected)

Steel	\$ 4,000 / tonne
Aluminium	\$ 10,000 / tonne
S/Steel	\$ 12,000 / tonne

Timber frames

- small	\$ 20 / lin. m
- large	\$ 60 / lin. m

Concrete (reinforced)	\$ 400 / lin. m
-----------------------	-----------------

Cables and terminations

- small	\$ 120 each
- large	\$ 600 each

Membrane plates

- small	\$ 125 each
- large	\$ 400 each

TABLE 3

**GUIDELINE COVERED AREA RATES FOR
FABRIC AND OTHER ROOF STRUCTURE SYSTEMS**

A. OPEN TENSION STRUCTURES

▶	Small / medium span Hypars (incl. poles / cables / anchors)		
	PVC / P	-	\$ 200 / m ²
	PTFE / G	-	\$ 350 / m ²
	Shade	-	\$ 60 / m ²
▶	Large Hypars and free-form tent structure		
	PVC / P	-	\$ 300 / m ²
	PTFE / G	-	\$ 550 / m ²
	Shade	-	\$ 120 / m ²
▶	Arch, truss or cable net / space frame supported tent forms		
	PVC / P	-	\$ 600 / m ²
	PTFE / G	-	\$ 900 / m ²

B. AIR STRUCTURES

▶	Simple Geometric form air supports include plant, doors, windows		
	PVC / P	-	\$ 250 - 320 / m ²
▶	Complex geometric form		
	PVC / P	-	\$ 350 - 450 / m ²
▶	Air-inflated structures		
	PVC / P	-	\$ 600 - 1000 / m ²

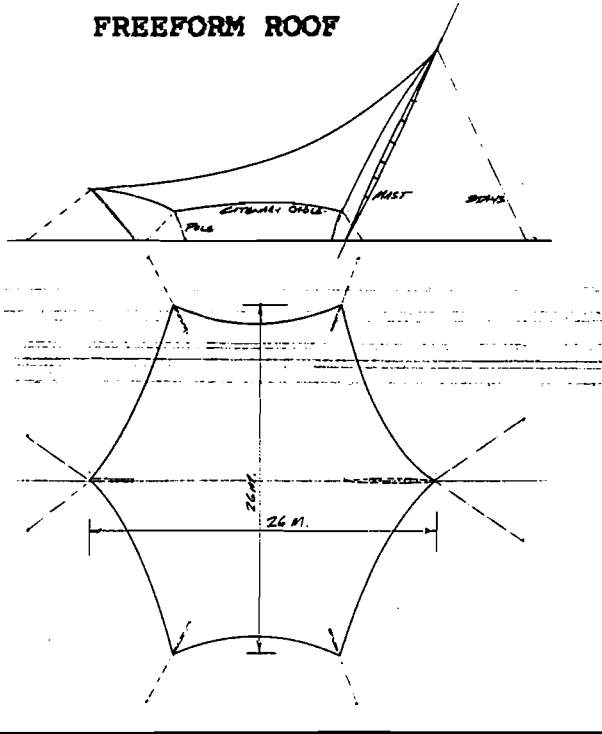
C. CONVENTIONAL ROOF SYSTEMS

▶	Metal deck/purlins/portals/footings	\$ 120 - 140 /m ²
▶	Translucent sheet/purlin/glued laminated beams/posts	\$ 200 - 250 /m ²
▶	Polycarbonate barrel vaults/steel framing	\$ 600 - 850 /m ²

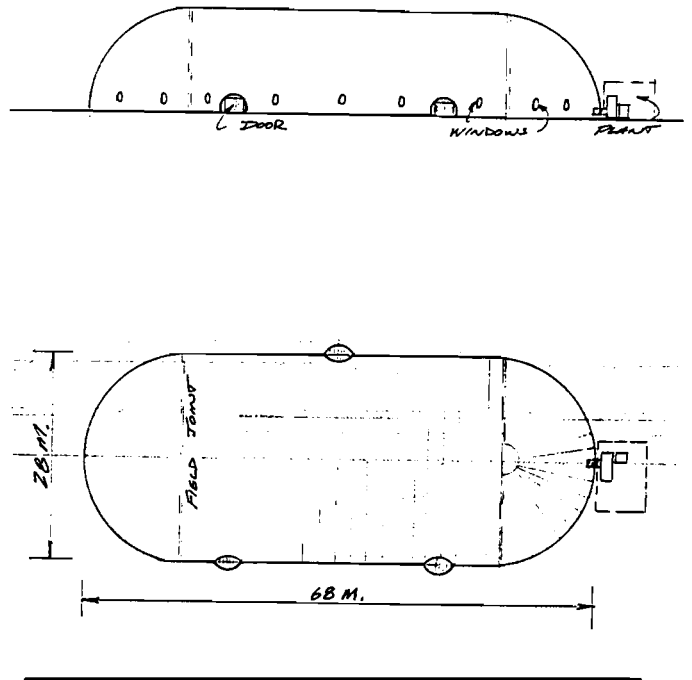
TABLE 4

TYPICAL PROJECT COSTING SUMMARIES

FREEFORM ROOF



AIR-HOUSE



(AUD, 000)

Contractors Preliminaries	8.0
Fabric (ex Shop)	27.6
Cables (ex Shop)	8.7
Steelwork (ex Shop)	12.7
Metalwork (ex Shop)	2.1
Footings and Anchors	17.1
Delivery and Erect	<u>10.1</u>
Nett Works	86.2

Design, Documentation & Workshop Drawings	<u>16.0</u>
	102.2

+ Contractors 15%	<u>15.3</u>
TOTAL	<u>\$117,500.00</u>

Nett Covered Area = 418m²
Unit Area Rate = \$281/m²

(AUD, 000)

Contractors Preliminaries	13.0
Fabric (ex Shop)	162.0
Anchor Footing and Fixings	20.0
Doors and Windows	111.0
Cables	8.0
Plant and Enclosure	57.0
Deliver, Erect & Commission	14.0
Contingencies	<u>5.0</u>
Nett Works	390.3

Design, Documentation & Workshop Drawings	<u>52.0</u>
	442.3

+ Contractors 15%	<u>66.1</u>
TOTAL	<u>\$508,400.00</u>

Nett Covered Area = 1,640m²
Unit Area Rate = \$310/m²