Fabric Structures in Australia

Growing our Industry through Technology

Structureflex

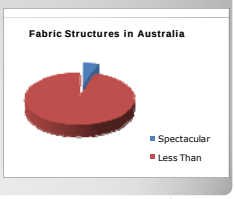
Growing our Industry through Technology

- Shade industry in Australia
- Technical challenges it faces
- Focus on Engineering
- What Engineering Choices are available
- Characteristics and risks associated with choices

Demonstrate that the use of simple fabric software can help improve quality and outcomes for the whole industry

Outline

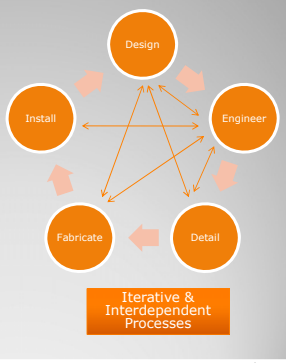
- **Australia has many spectacular fabric structures**
  - World class
  - Demonstrate ingenuity and professionalism
- **Unfortunately**
  there are many more "less than spectacular"
- **Typically these are Shade Structures**
  - Reflect poorly on the whole industry
  - Adversely affecting industry potential.



Introduction

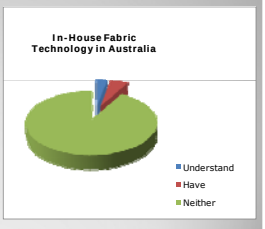
Fabric Technology

- Design
  - Form Finding
  - Shadow Analysis
- Engineering
  - Design Loads
  - Determine Reactions
  - Design Structure
- Detailing
  - Seams/Edges
  - Connections/Tensioning
- Fabrication
  - Computer Patterning
  - Computer Plotting



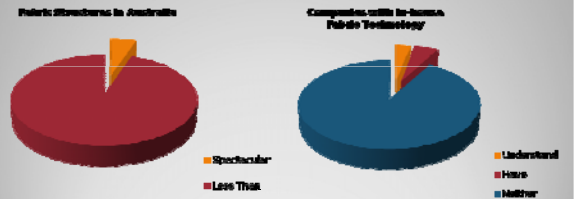
Introduction

- Companies in Australia with in-house fabric technology is estimated to be less that 5%.
  - More have basic Design/Fabrication
  - Few have Form Finding/Patterning/FEA/Structural Engineering
- Companies with comprehensive understanding of all elements of the technology and their interactions is even less



Introduction

Clear correlation



Introduction

The majority of companies we talk to who do not have in-house technology have a genuine desire to develop a better understanding of the technology and to improve their quality

Objective of presentation is to suggest ways

- Shade companies can improve their knowledge of 'how fabric technology works'
- The industry can work together to address the growing consumer concerns regarding the quality and safety of these products

Introduction

Background of the Shade Industry

- Lack of Empirical References
  - There has been little in the way of 'exact' engineering as there is for conventional prismatic solid-clad structures
- Lack of Formal Training
  - The industry has by and large been left to its own devices to trial-and-error what works with little in the way of formal testing
  - Nothing in the way of design or installation of these type of LW structures are covered in any TAFE or building courses
- Copying
  - Industry began with a few entrepreneurs whose methods were either copied or passed on to others over the years with little variation or improvement

Background

The Shade Market Today

- Competitive
  - An over-supply of low-tech shade solutions, with little regulation result in shade companies competing on price alone – typically driving down quality.
  - Cheap 'D.I.Y.' shade from hardware chains.
  - Shift away from the use of fabric by schools due to vandalism and competitive marketing efforts of metal roof suppliers
- Cottage Industry
  - Installers need little more than a 'ute and a shovel'
  - Fabricators can get away with the minimum of a sewing machine and a garage floor
  - Sales only businesses that subcontract everything require nothing more than a phone, a car and a business card
- Rapid growth
  - The combination of mandated provision of sun shade, low barriers to entry and with Governments injecting millions into school facilities, it's natural that we've seen an massive influx of new shade providers in the industry

Background

The Shade Market Today

- Little Regulation
  - Unlike most other forms of manufacturing, fabrication, production and construction, there is little in the way of regulation or certification of approved providers in the shade industry. Only recently has there been the need even to provide engineering certification for these structures
  - Most industries require suitable licenses to operate equipment which can cause harm. Today the shade industry has unlicensed and unqualified individuals and companies welding together steel frames which have the potential to cause serious harm.
- Copying
  - Tendency to copy the simpler low-tech examples resulting in devolution
- Consumer Perception
  - The proliferation of less than attractive low-tech shade structures, has resulted in fabric structures being perceived by many as a 'cheap-and-nasty' and undesirable.

Background

The Shade Market Today

- Recent Accidents
  - Recent failures of fabric structures within schools, resulted in Education Departments in several states reacting unfavorably for the industry.
- Reactions
  - While we welcome a degree of regulation and the need for providing proper engineering, S.A. has effectively outlawed fabric structures in schools, and N.S.W. are considering following suite.
  - As an industry, we need to respond positively and quickly to restore confidence and counter this trend.
- As an Industry – we MUST improve
  - We're at a stage where we must improve the quality of all industry participants or we could face further negative reaction and possible contraction.

Background

Correct design and implementation are more complex processes, with many more stages and interactions than most shade companies appreciate

"There's a lot more to it than meets the eye"

Design	Engineering	Fabrication
• Form Finding • Permissible Forms • Inherent Stiffness	• Determine Loads • Determine Reactions • Design Structure	• Seam Design • Patterning • Plotting/Cutting • Fabric Choice

Technical Challenges

Proper engineering is paramount and fundamental to:

- ensuring a safe and structurally sound product
- ensuring that the fabric is able to perform to its optimum design
  - maintain tension and rigidity under load
  - maintain shape and form in service.

A quote often seen in engineering publications is especially relevant in our industry:

"Structural engineering is the art of applying loads we cannot estimate, to structures we cannot analyse, which are made from materials we do not understand, in such a way that the public at large has no idea of the extent of our ignorance."

(unknown source)

Technical Challenges

Engineering choices available to shade companies

1. Copy another structure/Pre-Engineered Structures
2. Engage a specialist fabric engineering firm
3. Engage a general engineering firm
4. Engage Specialist Fabric Service Providers
5. Do it yourself
6. Do Nothing

Regardless of the chosen approach

Having an understanding of fabric structure technology WILL result in better outcomes

Technical Challenges

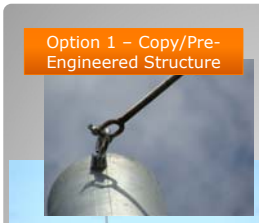
Widely Held Beliefs

- Members of the Shade Industry are often heard criticising engineers for "over-engineering" (i.e. make sizes too big):
  - to cover their a - s either because they are uncertain or are (understandably) afraid of litigation if they're wrong.
  - The more they have to guess, the bigger their risk will be.
- Shade suppliers who do use engineers believe:
  - they are doing the right thing.
  - that their 'engineered' product is bullet-proof/right/better.

This, unfortunately, is NOT always the case

Technical Challenges

Option 1 – Copy/Pre-Engineered Structure



Characteristics/Risks

- Engineering costs amortised over many structures and therefore appear to be low
- High probability that site conditions/shape will not/are not identical
- Low cost if nothing goes wrong but higher risk that it will

Technical Challenges

Option 1 – Copy/Pre-Engineered Structure

- Examples of pre-engineered structures installed in a locations where it appears local wind conditions exceed original design parameters

Technical Challenges

Technical Challenges

Option 2 – Specialist Engineering Firms

Characteristics
- Higher Initial Cost
- Complete Service
- Complete suite of fabric software
- Significant resources
- Significant capacity
- Rarely Fail

Technical Challenges

Option 3 – General Engineering Firms

Characteristics
- Low initial cost
- Limited service
- Tendency toward "Over-Engineering"

Risks
- Limited if any understanding of fabric technology
- Design as if normal building materials
- Prone to Failure

Technical Challenges

The ability and resources required to undertake proper engineering and achieve "Spectacular Structures" is not at the fingertips of every engineer

Many fabric structure failures are testament to this or evidence that no engineering was undertaken at all

It's engineered, therefore its right.
is NOT always true

Technical Challenges

More Examples

Technical Challenges

Option 4 – Specialist Fabric Services Providers

Characteristics
- Low Initial Cost
- Practical Advice
- Not "Over-Engineered"

Technical Challenges

Option 4 – Specialist Fabric Services Providers

Can work well

Technical Challenges

Days later

Risks

- •High Real Cost
- •Typically unqualified
- •Capacity/ability/skill of individual

Technical Challenges

Revised structure 5yrs later

Technical Challenges

Option 5 – DIY

Characteristics

- Learning Curve
- Satisfaction
- Reduced Risk
- Increased Responsibility

Technical Challenges

- Design Standards & Codes:
  - Obsolete Codes.
    - The citing of wind data using terms such as W41 etc. is misleading, and the Building Code of Australia does not permit the use of the obsolete code with the new AS4100 steel structures code etc.
    - Fabric structures must be designed for the site specific Ultimate Strength Limit State design wind speed and for the pressure coefficient applicable to the fabric surface.
  - Irrelevant Codes.
    - In addition to this, the publication of AS 4055 – Wind Loads for Housing in 1992 has frequently been used by design engineers when designing fabric structures, and surprisingly, accepted by some building surveyors. This code is specific to housing and is NOT relevant to shade structures.
  - Limited design Criteria.
    - Given the correct wind speed, there are limited wind pressure coefficients that engineers can access that may apply to a structure. AS/NZS 1170.2 has included the wind pressure coefficients for a typical hypar shade sail, but even this is limited to specific geometries, and does NOT include allowances for porosity.

Technical Challenges

Fabric structure engineering is specialised however, it need not be exclusive.

By providing general engineers and shade designers with the right tools and resources, we can empower the industry to develop a new generation of successful fabric structures.

- Making the systems and processes available and accessible to the moderate sized fabric structure supplier, will enable them to confidently work in partnership with their consulting engineer to produce good designs.
- The process of learning to use these products positively impacts the business and the quality of products it produces
- MPanel fabric modeling and FEA analysis products are good examples of simple yet powerful products which will help to achieve this goal.

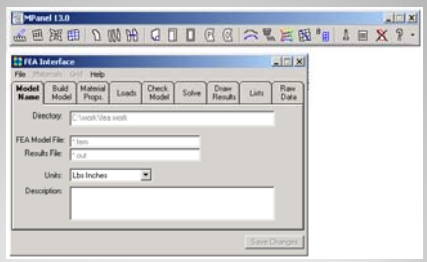
Where do go from here?

- **Fabric Engineering Software**
- **Form finding** to determine the natural saddle shape for a membrane surface. The shape is drawn out as a model in CAD
- **FEA** takes the CAD model and determines the stress distributions, and how the model shape and stresses change with applied loads such as wind and snow.
- **MPanel FEA** is specially developed for analyzing tensile structures, which can involve large displacements, wrinkled fabric, and partially slack fabric.

Where do go from here?

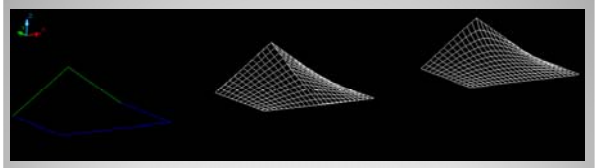
Floating Toolbar

- MPanel Patterning – operates in AutoCAD or Rhino
- Mpanel FEA – operates in AutoCAD



Where do go from here?

MPanel models can have fixed edges, or cable edges.

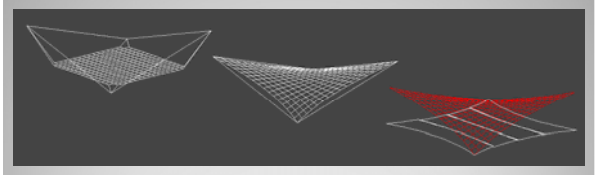


Here we show a fixed edge boundary that is a simple awning on a shop front.

MPanel finds the smooth form within the boundaries.

MPanel Modelling

A common cable edge shape is a hypar sail.

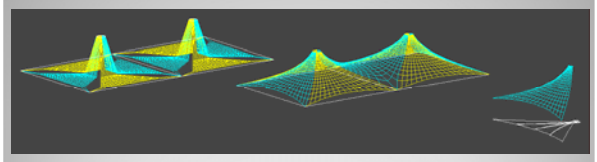


MPanel relaxes this with cable edges all around to make the saddle shape shown

Then convert the 3D form into flat fabric panels

MPanel Modelling

MPanel models can also consist of several meshes smoothly joined together.

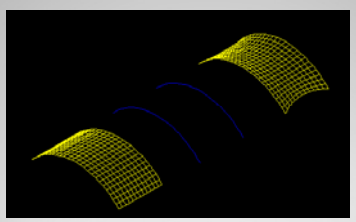


MPanel relaxes the multiple meshes to form a smooth conic shape

Then convert the 3D form into flat fabric panels

MPanel Modelling

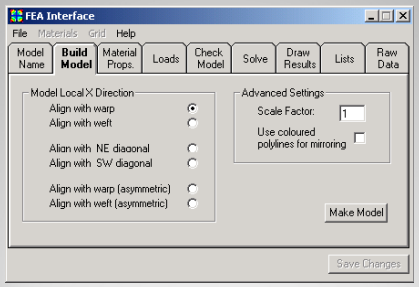
To look at the FEA, it is best to start with a simple model.



The fixed points are shown in Blue, the fabric surface in Yellow, and the relaxed model on the right.

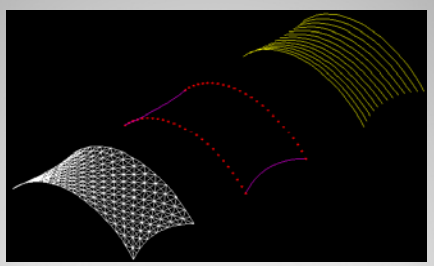
MPanel FEA

Transferring the Model to FEA



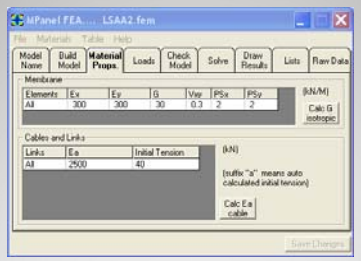
MPanel FEA

- Cables, Fixed points
- Local X direction



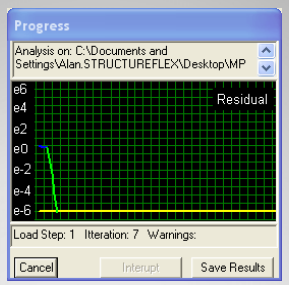
Check the model

- Material values
- Default values are suitable for the unit system chosen
- Pre-stress values are most important-Here we chose a pre-stress of 2kN/m
- For a simple model, cable initial tension is auto calculated



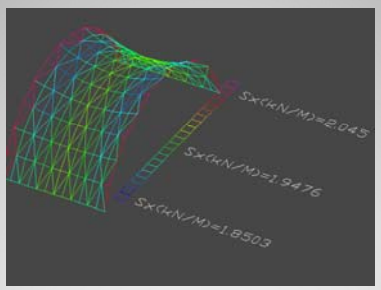
Setting the Initial Conditions.

Run the Solver:



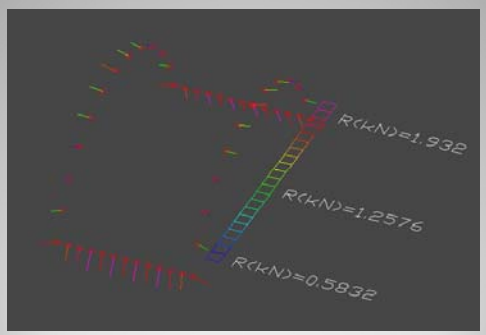
Static Stress

- Skin stress close to initial value.
- Nominally 2kN/m, varies slightly over the membrane.



Membrane Stress Plots

Vector Reactions and Scale Values:



Reactions

- Companies can improve their product quality by using software
- BUT
- Software alone is not a panacea
  - Its purchase will not make us instant experts
  - Its purchase does not preclude the need to understand fabric technology in fact it is essential to the proper operation of the software.
  - Its correct use tends to reduce poor design practices
  - Finally, it is no substitute for specialist engineering – if you get an order for a Millennium Dome – proceed directly to your friendly specialist engineer.

Summary


As an industry association we can help improve the quality of the products produced by all participants in several ways:
Provide or fund more research for its members:
Testing to develop a database of more applicable pressure coefficients for a broader range of surface shapes
Lobby the Standards Association of Australia to extend their work in these areas.
Assist by publicizing the industry as a sound and confident to turn back the tide of 'banning' the use of L.W. shade structures
Provide leadership in developing minimum standards.
Summary