FABRICATING FORM

Shade Sail Manufacturing

TOPICS

Why is 3D form important

How to make 3D sails

Catenary - what size is right?

Reactions - value and direction

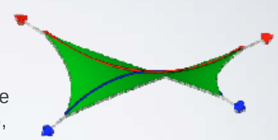
3D FORM ESSENTIALS

3D SAILS

- Shape formed by applying tension to the fabric along opposing radii.
  - gain strength through this double curved shape.
  - gain stiffness to withstand loads.

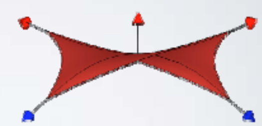
3D SAILS

- In the example of the simple 4 sided “Hypar” sail think of it as two curves - one between the 2 low points (blue curve), and one between the 2 high points (red curve).



3D SAILS

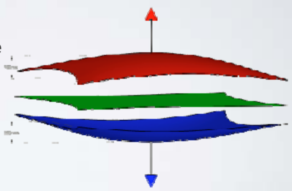
- A load will cause the sail to change shape until it finds a new “Force Balance” shape.
- A Hypar subjected to uplift, increases tension in the low arc while decreasing tension in the high arc allowing the fabric to change shape.



5m sail with 0.3kPa applied – deflection 350mm

FLAT SAILS

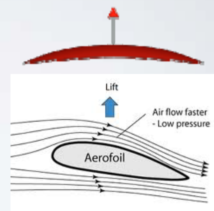
- In contrast, a flat sail subjected to the same load deflects in only one direction.
- Total deflection is larger leading to:
  - stretching
  - the "saggy-baggy" look
  - early failure



5m sail with 0.3kPa applied – deflection 500mm

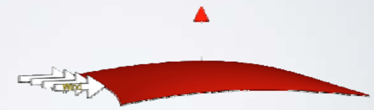
FLAT SAILS

- Shape formed under load similar to aerofoil leading to increased uplift further compounding stresses



FLAT SAILS

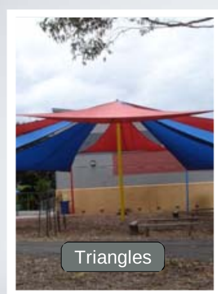
Increased cross-sectional area leads to increased drag which increases stress on leading edge

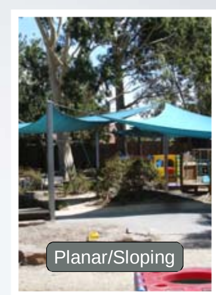


FLAT SAILS

Large deflections and increased drag stresses result in edge cables working like hacksaws on the fabric edges

FLAT SAILS





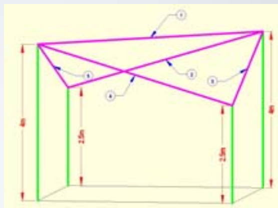
MAKING 3D SAILS

OLD PROCESS

(1) Site measured - often only 5 dimensions

(2) No checks for measurement errors

(3) Sail patterns "worked out" by averaging diagonals



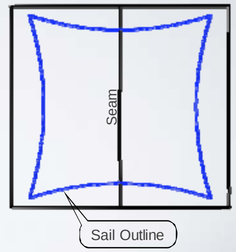
OLD PROCESS

(4) Flat fabric joined to form a large flat panel

(5) Sail pattern marked onto flat fabric

(6) Fabric cut and hemmed

(7) Sail forced into 3D form by "Shear" force during installation



THE OUTCOME

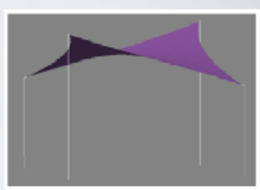
- Forcing flat fabric into 3D forms result in uneven stress and zones of:
  - (a) low tension = wrinkles
  - (b) high stress and stretching = shorter product life
- Consequently sails tend to be made too flat to avoid these problems

MODERN PROCESS

(1) Site measure - 10 dimensions for Hypar enabling a check of accuracy

(2) Model sail as 3D mesh

(3) Pattern by splitting mesh into multiple "shaped" panels



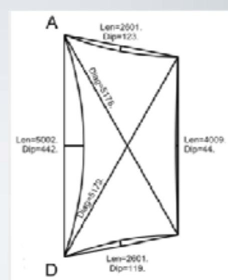
MODERN PROCESS

(4) Join shaped panels

(5) Hem

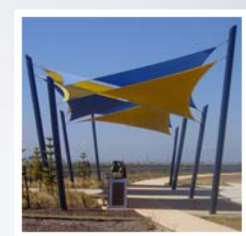
(6) Sail formed into 3D shape

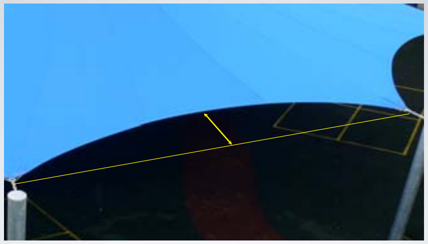
(7) Low shearing stress during installation



OUTCOME

- Correctly formed sails result in even stresses:
  - (a) less wrinkles
  - (b) longer product life
  - (c) better looking product
  - (d) increased inherent stiffness

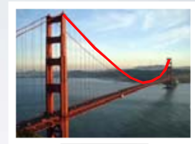


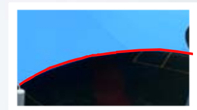


CATENARY DEPTH

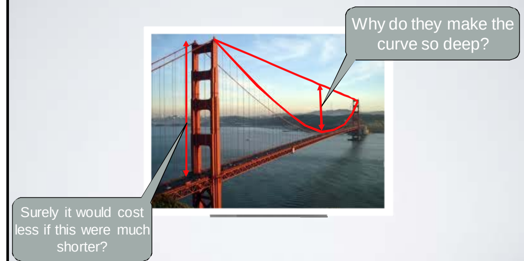
WHAT IS A CATENARY?

- The curved edge of the sail like the suspension bridge, is often referred to as a catenary
- For the sake of simplicity we assume this shape is a simple arc of radius "R"

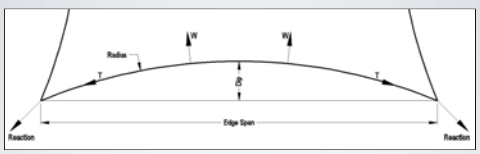




WHAT DEPTH?



THE MATH



T - Edge Tension
W - Load/m (pre-stress)
R - Radius

T = W x R

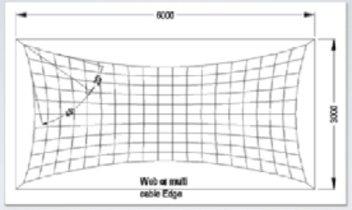
REACTIONS

10M SAIL EXAMPLE

Fabric Pre-Stress W		0.25	kN/m	
Sail Edge Span		10.0	m	
Corner Angle		90.00	degrees	

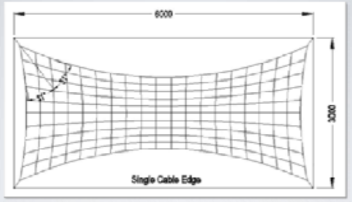
Cable T (kN)	Radius (m)	Dip (m)	Dip (%)	Pre-Stress Reaction kN
2.5	10.0	1.3	13%	4.83
2.8	11.0	1.2	12%	5.24
3.0	11.9	1.1	11%	5.59
3.3	13.0	1.0	10%	6.01
3.6	14.3	0.9	9%	6.52
4.0	16.0	0.8	8%	7.15
4.6	18.2	0.7	7%	7.96
6.3	25.3	0.5	5%	10.52
7.9	31.5	0.4	4%	12.75
10.5	41.8	0.3	3%	16.45
15.7	62.6	0.2	2%	23.83
31.3	125.1	0.1	1%	45.94

REACTIONS



- We know different radii give different edge tensions which is only possible if we fix edges with web or individual cables
- Reaction does not bisect corner angle which is commonly held misconception

REACTIONS



- For single cable with corner rings – all edge tensions must be the same
- Reaction will only bisect corner angle if edge radii are same (as above)
- % of span method to determine dip will mean fabric is subjected to uneven stresses

SUMMARY

- Low cost software now allows all fabricators to pattern shade sails in the same way as the previously out of reach systems used by the big professional players
- Properly patterned shade sails will last longer, and look better and your best advertising are ecstatic customers and your installed base of great looking work
- Understanding the basic maths of tensile architecture will help inform your decisions about how to make a sail, communicate better with your clients, and head off problems before they occur

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Thank You

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