Lightweight Façade Systems

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LSAA 2013 Conference Touching the Earth Lightly
14th – 15th November 2013

Aglient Façade, Melbourne

LSAA LIGHTWEIGHT STRUCTURES ASSOCIATION OF AUSTRALASIA

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Introduction

- What are lightweight façade systems?
- Why look at planar tensioned cable supported facades?
- How do we deal the difficulties of these? (lessons to learn)
- When should they be used?

Wintergarden Artwork Facade, Brisbane – Studio505

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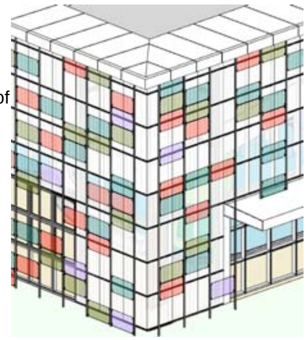
Introduction

What are lightweight façade systems?

- Minimal materials – lightweight and economical
- Large spans – relative to structural sizes
- Transparency – minimum visual impact of structure

Planar Tensioned Cable supported systems

- Have to deflect to resist wind loads
- use pretension to control deflections
- deflection limits can be higher for screen type applications than those for the weatherproof façade elements
- lower prestress = less structure which make this cost competitive option compared to conventional framing
- can be fitted to new buildings or existing
- Present a number of engineering challenges



MARC Facade, Perth – DovanPayne

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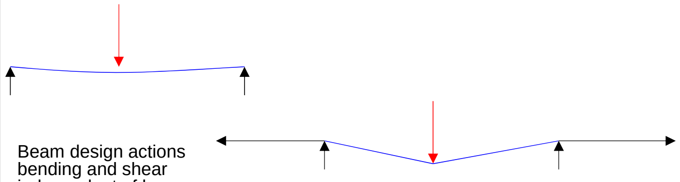
Planar Tensioned Cable support systems

Beam compared to Cable supports



Beam design actions bending and shear independent of beam properties

AS4100 design code

Cable design action tension is a function of cable prestress, material and area

Large displacement Non linear analysis needs to be used

ASCE 19-10 or EC3 1-11 design codes

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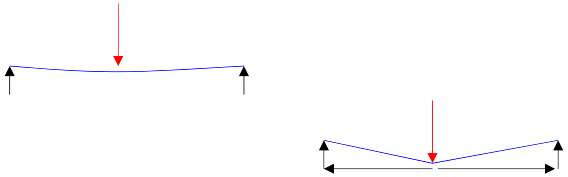
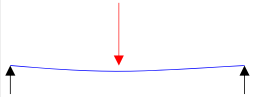
Beam compared to Cable supports



Proportions of in plane force to out of plane force can be found from cable geometry

Beam compared to Cable supports



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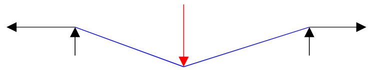
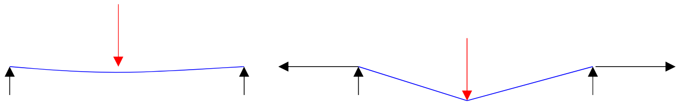


Cable design action tension is a function of cable prestress, material and area

Lower these and the design force reduces

Beam compared to Cable supports



Beam deflection a function of

E material
I section geometry (depth cubed)
L^3 span length cubed

Typical deflection limit span/250 to 150

Cable deflection a function of;

E material
A section geometry (area)
L span length
P cable pretension

Typical deflection limit span/50 to 20
i.e. 5 to 6 times more than beam
3 to 7 degrees rotation 10 to 4 times applied force

Planar Tensioned Cable supported systems design challenges

- Determination of design loads
- large displacements
  - acceptance limit
  - rotations at end terminations
  - dynamic implications
- large in-plane loads
- mid cable connections (saddles/deflectors and clamps)
- creep
- installing and maintaining desired prestress levels

Taronga Zoo Chimp Enclosure, Sydney

Determination of design loads

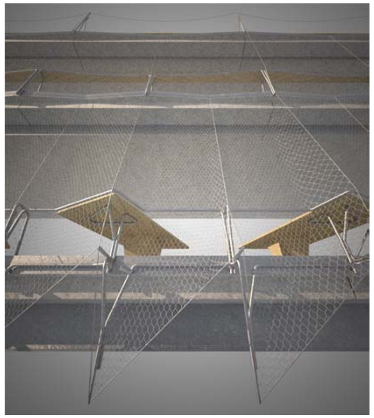
- AS1170 covers imposed loads on barriers and wind loads on buildings

- barriers (balustrade in-fills) have different design loads depending on what the space is being used for

- wind loads on porous screens near face of building not covered by code, wind tunnel testing required but this is too expensive for many projects

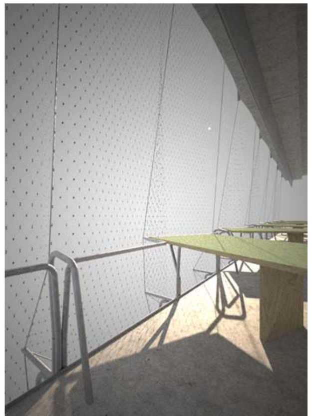
Large displacements – acceptance limit

- Tensioned SS cable net with additional cables
- Provides edge protection
- Designed to barrier loads from AS1170 and BCA requirements for balustrade infills



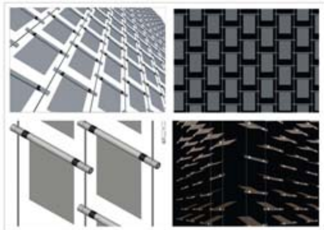
Uni of Melbourne New Architecture Building – NADAA / Wardle

Large displacements - user acceptance



Large displacements - user acceptance

Displacement can be desirable

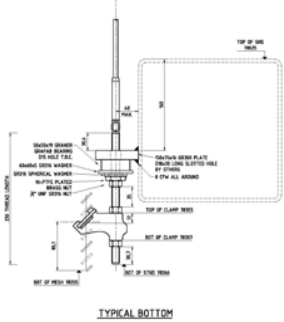


Ned Khan Wind Veil, MASDAR, UAE – Foster and Partners

Large displacements - user acceptance

Wind Veil, prototype – UAP

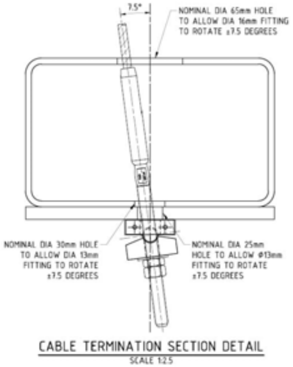
Large Displacements - Rotations at End Terminations



Aglient Façade, Melbourne – Locker/Ronstan

Large displacements - Rotations at end terminations

Walga Façade, Perth – Hassell



Dynamic Implications

A number of wind induced dynamic responses possible
- Vortex shedding
- Galloping
- Divergence and Flutter

Difficult to get correct results even from up to software
- dampening hard to predict
- correct modeling of large displacement cables

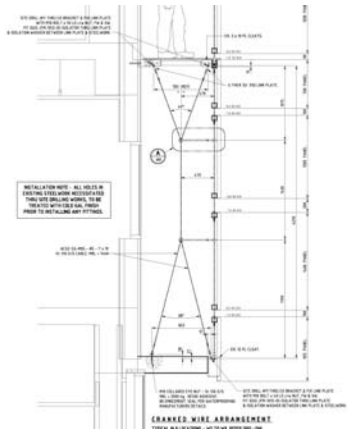
Fatigue
- Function of number of cycles and change in stress level

Park Beach Plaza Carpark Screen, Coffs Harbour – Hassell

Dynamic Implications

Michie Facade, QUT, Brisbane – Wilson Architects

Dynamic implications



Michie Facade, QUT, Brisbane – Ronstan

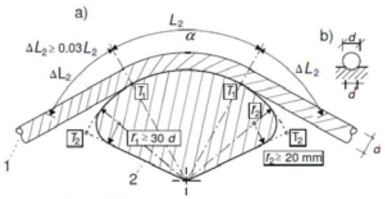
Large In-plane Loads

YVW Screen, Melbourne – Arup

Agilent Facade, Melbourne – Bonacci

Mid Cable Connections

BS EN 1993-1-11: 2006
EN 1993-1-11: 2006 (E)



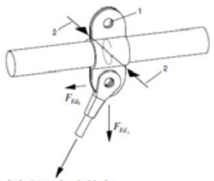
1 strand/rope
2 saddle
L_2 length of strand/rope between the two theoretical tangent points T_1 under the most unfavourable characteristic combination of loads and the catenary effects
ΔL_2 additional length of wrap

Figure 6.1: Bedding of a strand/rope over a saddle

NOTE: Compliance with the requirements in (1) above will result in the breaking resistance of the strand and rope being reduced by not more than 3 %.

Mid Cable Connections

BS EN 1993-1-11: 2006
EN 1993-1-11: 2006 (E)



1 *hole for preloaded bolts*
2 *preload F, from preloaded bolts*

Figure 6.2: Clamp

NOTE: F_k is not directly related to ULS. By the use of F_k capacity design (see EN 1993-1-1, 1.5.8) is applied.

Mid Cable Connections

Table C-1 Clamp Groove Diameter Tolerances

Wire Ropes			Strands		
	Tolerance (in.)			Tolerance (in.)	
Wire Rope Diameter (in.)	Min.	Max.	Strand Diameter (in.)	Min.	Max.
3/8 to 1-1/8	+1/32	+3/32	1/2 to 1-1/2	+1/32	+3/32
1-3/16 to 1-1/2	+1/16	+1/8	1-9/16 to 2-1/2	+1/16	+1/8
1-9/16 to 2-1/8	+3/32	+5/32	Over 2-1/2	+1/8	+3/16
2-3/16 to 3	+1/8	+3/16			
Over 3	+5/32	+1/4			

Note: 1 in. = 25.4 mm.

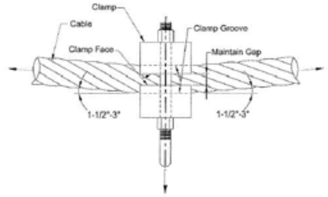
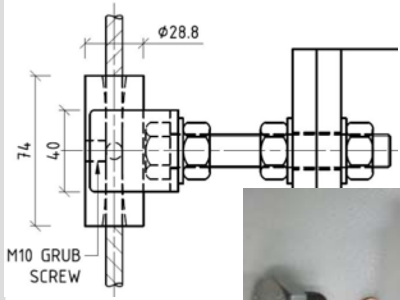


FIGURE C-1. Cable Clamp Fitting.

Mid Cable Connections

Mid Cable Connections



Planar Tensioned Cable support systems

Creep

Inelastic cable elongation over time due to long term stress level

Occurs to concrete support structure and foundations also.

Typically between 0.01% and 0.06% after prestretching

- pre-stretching
- install at higher prestress
- inspect, measure and re-tension

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Planar Tensioned Cable support systems

Installing and Maintaining Desired Prestress Levels

Adjustment required for support structure
- misalignment
- deflection due to prestress

Inspection and monitoring

Re-tension capability

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Concluding comments

Conclusions

Tensioned planar cable supported façade systems
- Real potential to 'touch the earth lightly'
- Minimal visual impact
- Minimal space
- Minimal materials
- Economic

for appropriate use

Getting the Design Right
- Understanding the movement
- Resisting the in place forces efficiently
- Appropriate connections
- Design for long term performance

Where next – doubly curved cable nets, cable trusses

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