Tensile Guide

Many clients approach us to build their designs, sometimes from detailed drawings, usually from a rough outline.

Others ask us to design and build something they have in their heads from scratch.

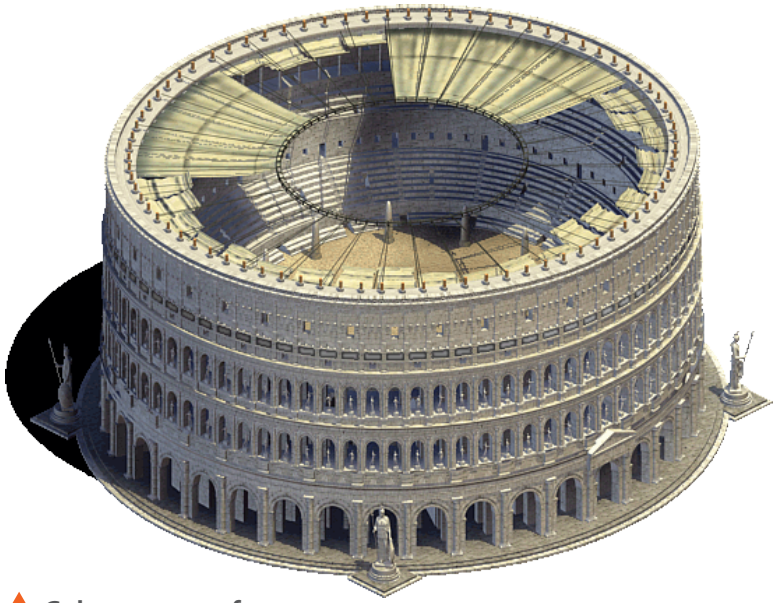
But everyone is now recognising the massive potential that this technology offers… not just to enhance their designs but to have unique benefits in terms of cost and environmental performance.

For that to happen, more people need to know what's possible and how it works.

So here is our stress free guide to tensile structures

BASE

Frei Otto Olympic Stadium



Colosseum roof

The briefest of histories

Tensile fabric structures have been with us since the Mongolians swept down from the plains, with their yurts as their transportable overnight accommodation. The Bedouins have done the same for untold years. And there's evidence that the Romans even covered the Colosseum with massive canopies, hoisted by an intricate system of pulleys, to protect the audience from the elements.

But they really came into their own in the last half of the 20th century, when designs like this by Germany's Frei Otto opened everyone's eyes to what could be created with a little imagination… and a deeper understanding of fabric and cable engineering.

The ability of fabric to form double curvature surfaces and its inherent translucency has always been attractive for designers. But with the advent of computer form finding and the development of reliable structural fabrics the world of tensile structures took a giant leap forward.

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Why tensiles are the shape they are

Large flat pieces of fabric are very poor at resisting loads*. Imagine four of you each pulling on the strings laced through a tennis ball. Fig 1. A fifth person pushing down on the ball can deflect it easily. Imagine a flappy marquee roof. Try lifting two opposite strings and lowering the other two. Fig 2. The ball is now locked in space. Apply this principle to fabric and you have created 'anticlastic' double curvature**. Sounds grand but actually is simply derived from one of three fabric shapes; the hypar, the cone and the barrel.

The fabric can now not only cope with snow loads but also wind uplift.

Those footnotes -

*Flat fabric panels can be used to create larger structures – The O2 dome in Greenwich is a cable net with lots of flat panels inbetween.

**Inflatables have synclastic curvature where the fabric is curved the same way in two axis.

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Barrel Vault

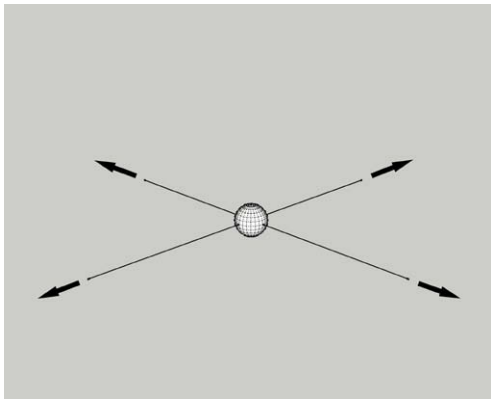

Fig. 1

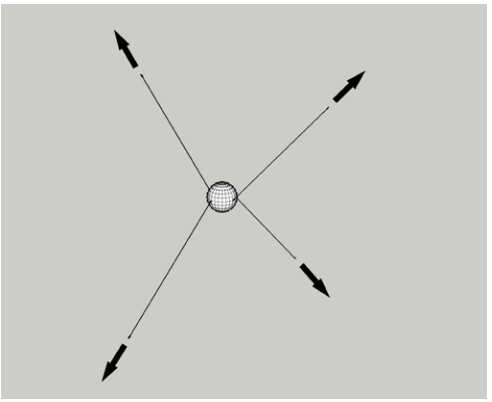

Fig. 2

Cone

Hypar

Where do the loads go?

Good question.

In the image below you can see that all the tensile loads are contained within the steel frame. This solution is particularly appealing where you don't want to apply 'pull out' loads to an existing building.

With the classic tensile fabric structure there is no frame and the tensile loads are transferred directly into the surrounding building or foundations via masts and tie rods. So while the structure itself will look lighter and

airier, it will probably require larger foundations – not unlike a suspension bridge.

There are some complex maths involved in deriving loads, all of it meat and drink to a computer, and we can advise on this.

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Knowing your boundaries

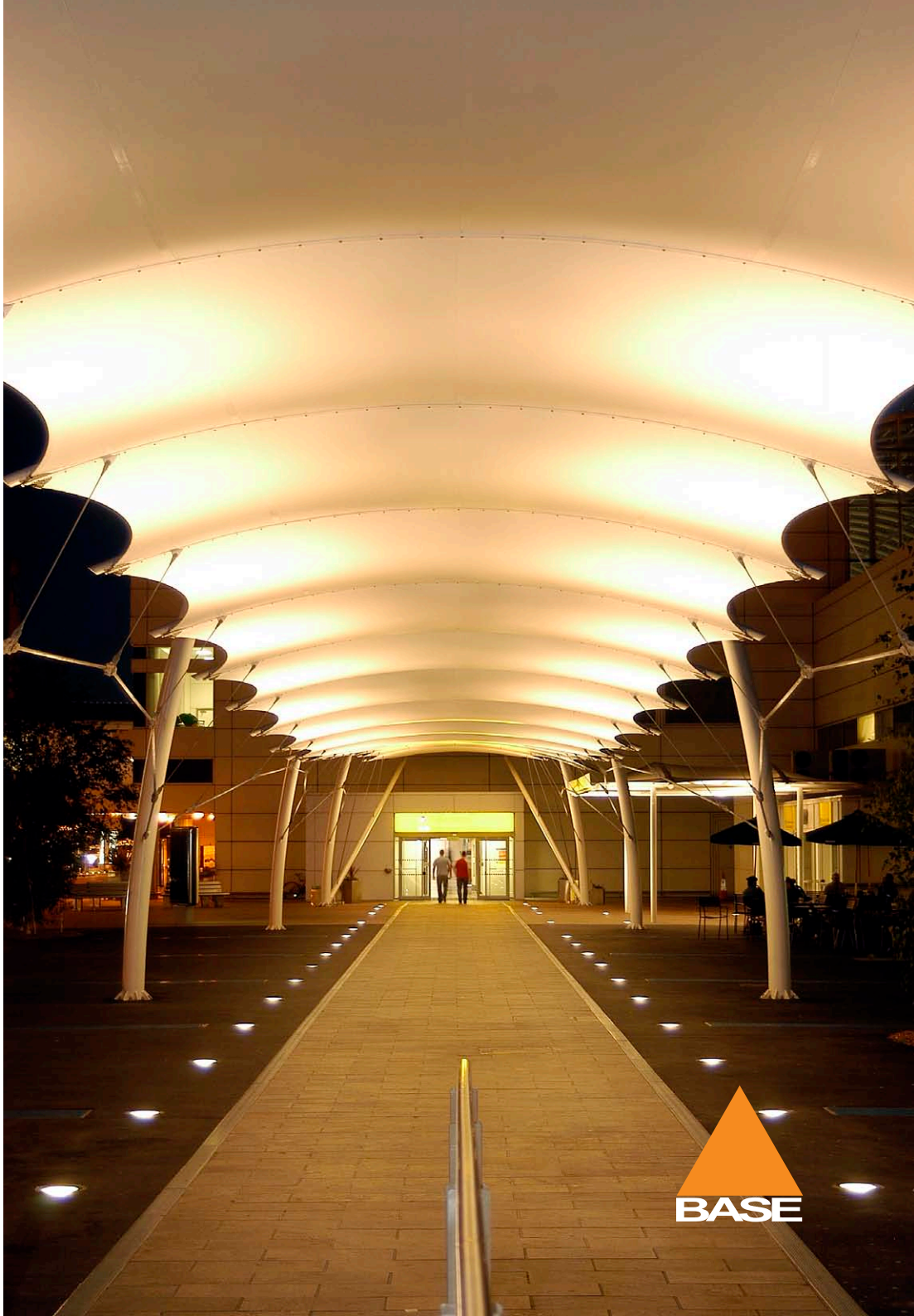
The fabric membrane obviously needs to be attached to the supporting structure somehow. There are two principal approaches: A continuous fixed edge or a scalloped edge with attachment points just at the corners.

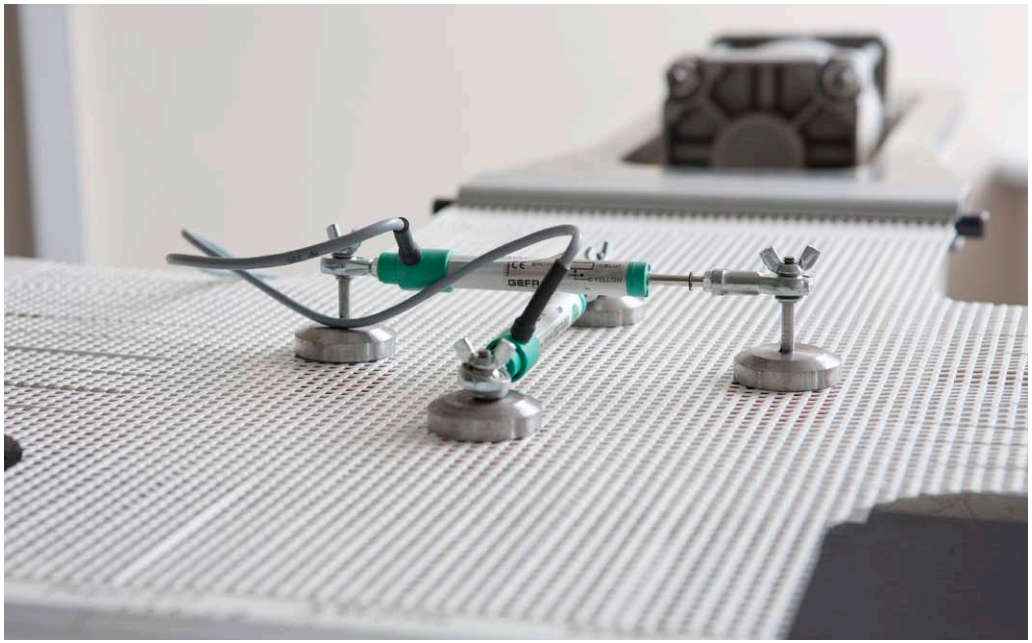
With the former, the fabric slides into an aluminium extrusion (just like a yacht mast), which is easily bolted to the steel frame.

The scalloped edge incorporates a fabric pocket or "cuff" through which a cable is run. The cables terminate on a membrane plate which is connected to the primary frame often with an adjustable link. An optional extra with this design is a rainwater diverter upstand that allows you to collect rainwater.

▼ Aluminium luff track edge

▼ Scalloped edge detail





▲ Biaxial Rig

Pre-tensioning: cutting the slack

Every fabric used in tensile structures has different stretch characteristics but critically they will not creep overtime.

At Base Structures, each roll of fabric is tested in our biaxial rig to the same design loads that the actual canopy will need to be tensioned out to. The amount the fabric stretches is fed back into how much the fabric pattern is 'compensated ' in the patterning software; ie 'shrunk' in size so that it fits perfectly when tensioned out to datum.

This pre-tension ensures that even under snow load there is no ponding once the snow begins to melt.

The safety factor used for choosing the fabric weight is around 1:6 based on the maximum design loads.

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The fabric of (long) life

How do you choose the optimum fabric for each project? Major criteria include strength, translucency, colour range and most important of all longevity. External tensile structures are asked to keep on performing for anything between 5 and 35 years, in wind, rain and sun.

Inevitably, cost comes into it too as, off the roll, they can vary by a factor of 20. That said, the fabric purchase accounts for about 10% of the total project cost. Increasingly, the recyclability of the material is a factor for clients.

Fortunately, there is a quick way to check out all these options: a click here takes you to our fabric matrix. And an even quicker way is to call us for advice.

A model life

One common complaint is that tensiles are difficult to draw and harder still for the client to visualize.

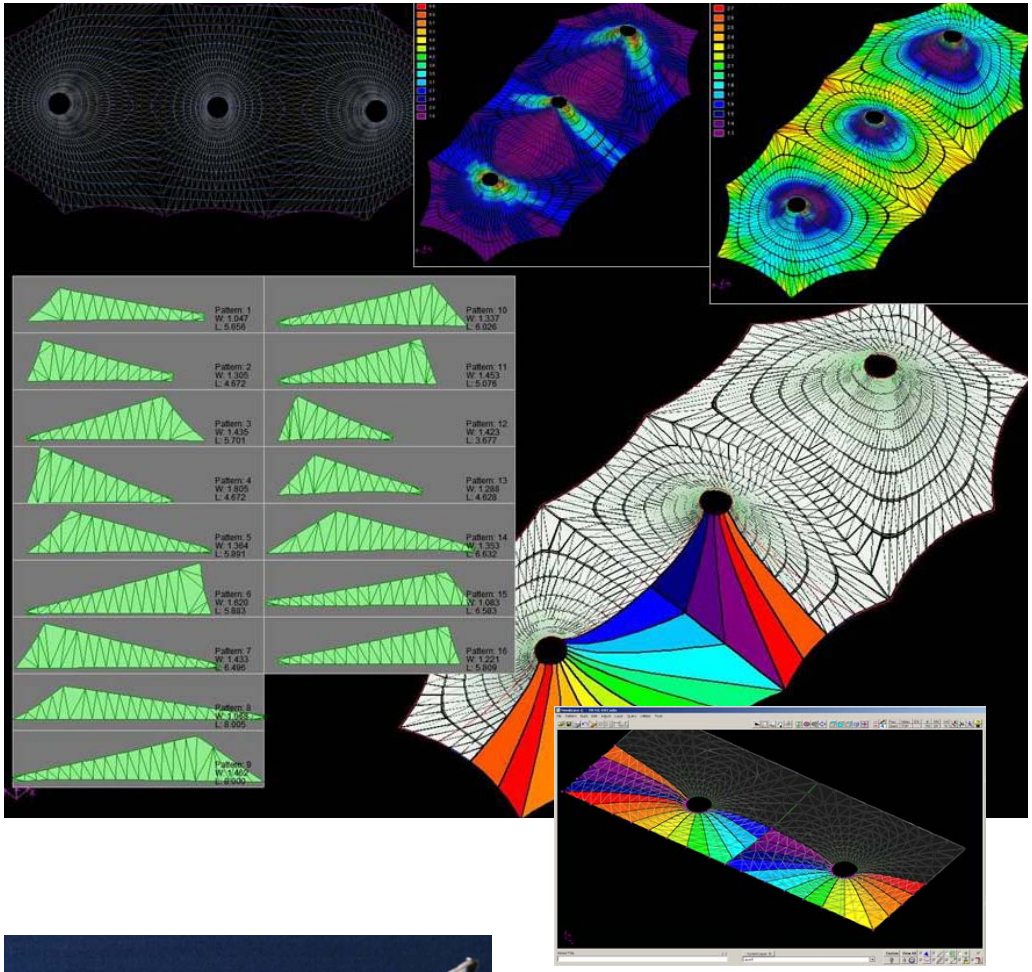
The traditional way round this was to create a physical model (using a curious combination of foamboard, timber dowels and ladies' tights).

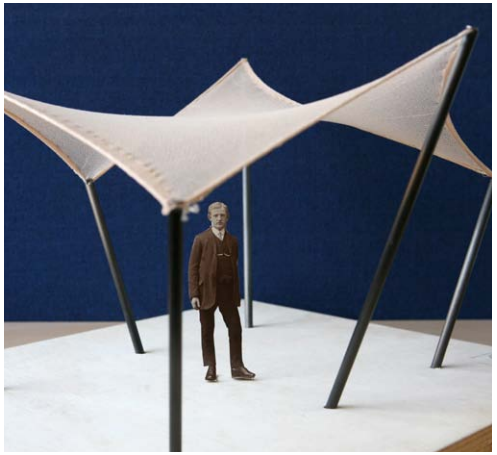
Now we have a whole range of CAD programmes such as 'Rhino Membrane'* that can give designers the tools for the job.

More specialist software incorporating 'dynamic relaxation' allows us specialists to find the exact form the fabric will take and also is clever enough to spit out a loading analysis.

But don't knock the tights.

*Try these links
http://www.ixcube.com/dettagli.asp?n=20
http://www.youtube.com/watch?v=nDowdjdrqHA





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Things you should know

Insulation: Although fabric structures are generally used to cover unheated spaces it is possible to have a multi layer construction consisting of an inner and outer fabric skin with an interlayer of insulation. One disadvantage is the loss of translucency, although there are now translucent products such as Nanogel that could be used if the budget permits. A double skin construction can be used to reduce the risk of condensation if this cannot be designed out by other means.

Fire safety: All structural fabrics are fire rated although some behave differently than others in a fire. Pvc coated polyesters will melt back from a heat source which is useful for venting the flames & smoke. Coated glass fibre based fabrics will tend to produce less smoke and stay intact longer until the seams fail at very high temperatures. Any fabric producing burning droplets is totally unsuitable. The European fire coding system measures flammability, smoke production and burning droplets. A typical PVC coated polyester Euro Class fire rating would be B-s2,d0.

Acoustics: To achieve an effective sound absorption you need plenty of mass, which is not one of fabric's strong points. What fabric is useful for is reducing reverberation times in interiors with a lot of hard surfaces. The best combination is a mesh fabric with an acoustic quilt behind. One technical fabric by Mermet has been engineered to reduce mid to high frequency sound whilst still being translucent to light.

Environmental: Many (but not all) of the fabrics now in popular use can be recycled. If this is a major concern for you or your client, the fabric matrix gives an indication of this and we can give more detailed advice. The amount of embodied carbon can also be calculated for your project.

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Appearance is all

Lighting: Some spectacular effects can be achieved by incorporating low energy LED lighting into the design. Any project where lighting has not been considered is a missed opportunity. Backlighting shows off the fabric's translucency and up lighting highlights the canopy's form as well as providing soft indirect illumination. Imagine your canopy as a projection screen and you can start to see the possibilities.

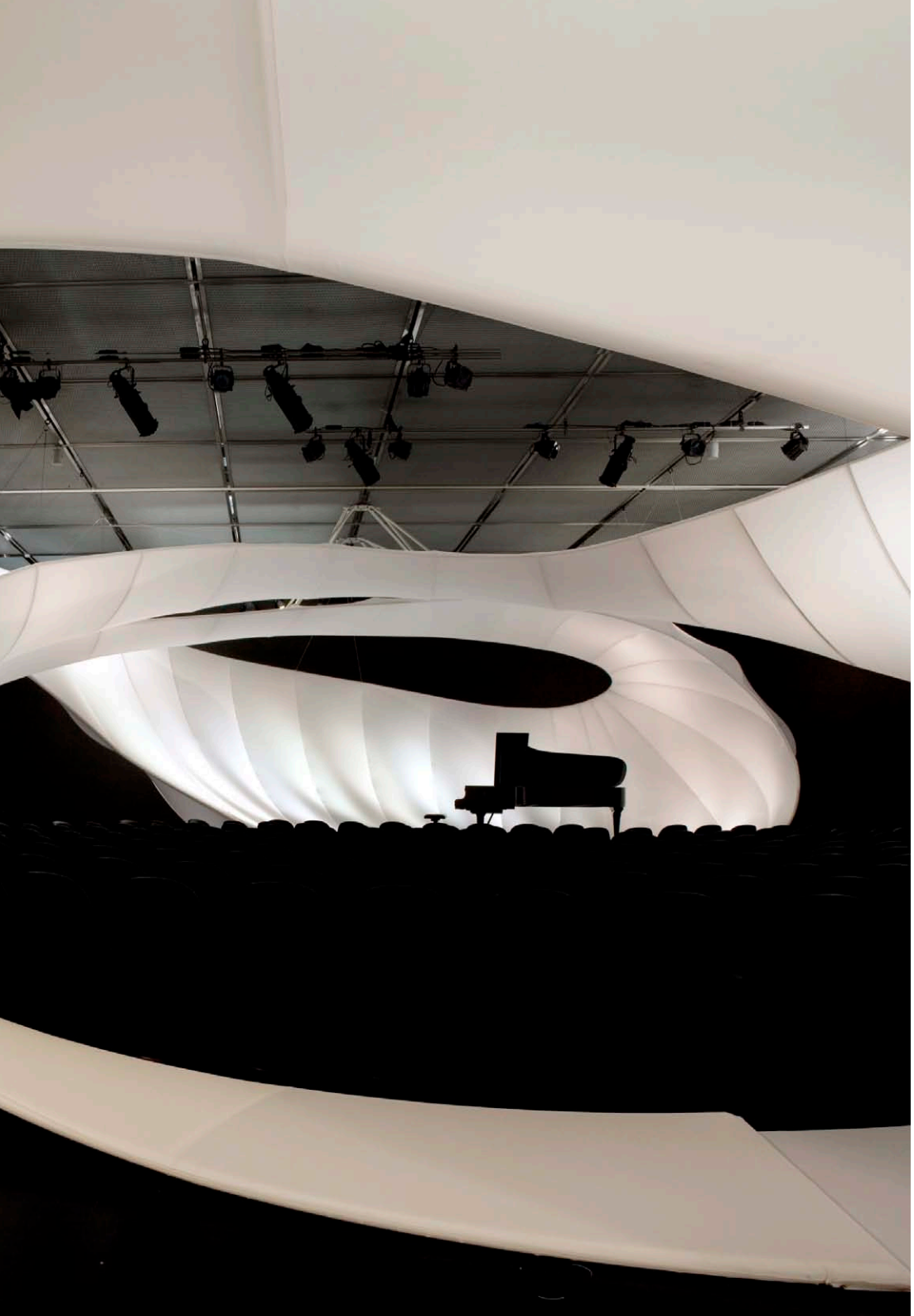
Cleaning and maintenance: Depending upon the local environment and climate, canopies should ideally be cleaned annually to maintain their appearance and translucency. The modern PVDF and TiO2 (titanium dioxide) laquers used on pvc coated polyesters are now almost as good as a PTFE (Teflon) coated glass fabric at throwing off the dirt , but any canopy will be hard to clean if not maintained at regular intervals.
Each structure is accompanied with a maintenance manual showing how the structure can be safely maintained either by the client or a specialist cleaning company.

101 uses...

Stadiums, stages, covered malls, transport interchanges, walkways, play areas, entrances, atriums, sports arenas….

Tensile fabric structures have come a long way in the last 50 years, and that pace of development and adaptability is still quickening as architects let their imagination flow and new materials come to the fore.

And for sheer architectural variety within one project, look no further than the astonishing array of different designs at the 2012 Olympics – where many of the structures will be relocated or the parts recycled for new projects.



Going indoors

This array of different projects demonstrates the greater design flexibility possible with interior structures: the obvious difference is that material choice is wider and the support structures can be much lighter.

Uses include sun shading, ceilings, screens or just inspiring sculpture such as Zaha Hadid's design for the Manchester International Festival.

◀ Manchester International Festival

A whole new (greener) world

Tensile fabric technology has developed fast – far from being just a front of house teaser, tensile fabric is increasingly providing some real green solutions.

Overcladding

New uses include covering old or unlovely buildings with a modular fabric cladding panel (see TEXO presentation) which acts as a new 'skin': a low carbon solution that will give a building another 10, 20 or even 30 years more life as well as reducing electricity bills. Mesh fabrics allow views out – but also prevent solar gain, significantly reducing the need for air conditioning in warmer climates.

Fabric panels can also incorporate flexible PV collectors, meaning your fabric façade can make it's contribution to running costs.

Natural Ventilation Towers

As demonstrated in the Middle East model city of MASDAR the concept of wind scoops can make living in cities in hot climates all the more bearable. Fabric mesh could make an ideal cladding material.

Environmental Products

One of our latest applications for tensiles is in the storage of biogas – triple skin methane gas storage domes for anaerobic digester plants. A cost-effective and versatile alternative to traditional storage products that is also quick to install. Further information is available at our sister website

▲ Biogas

▲ Texo

▲ Texo

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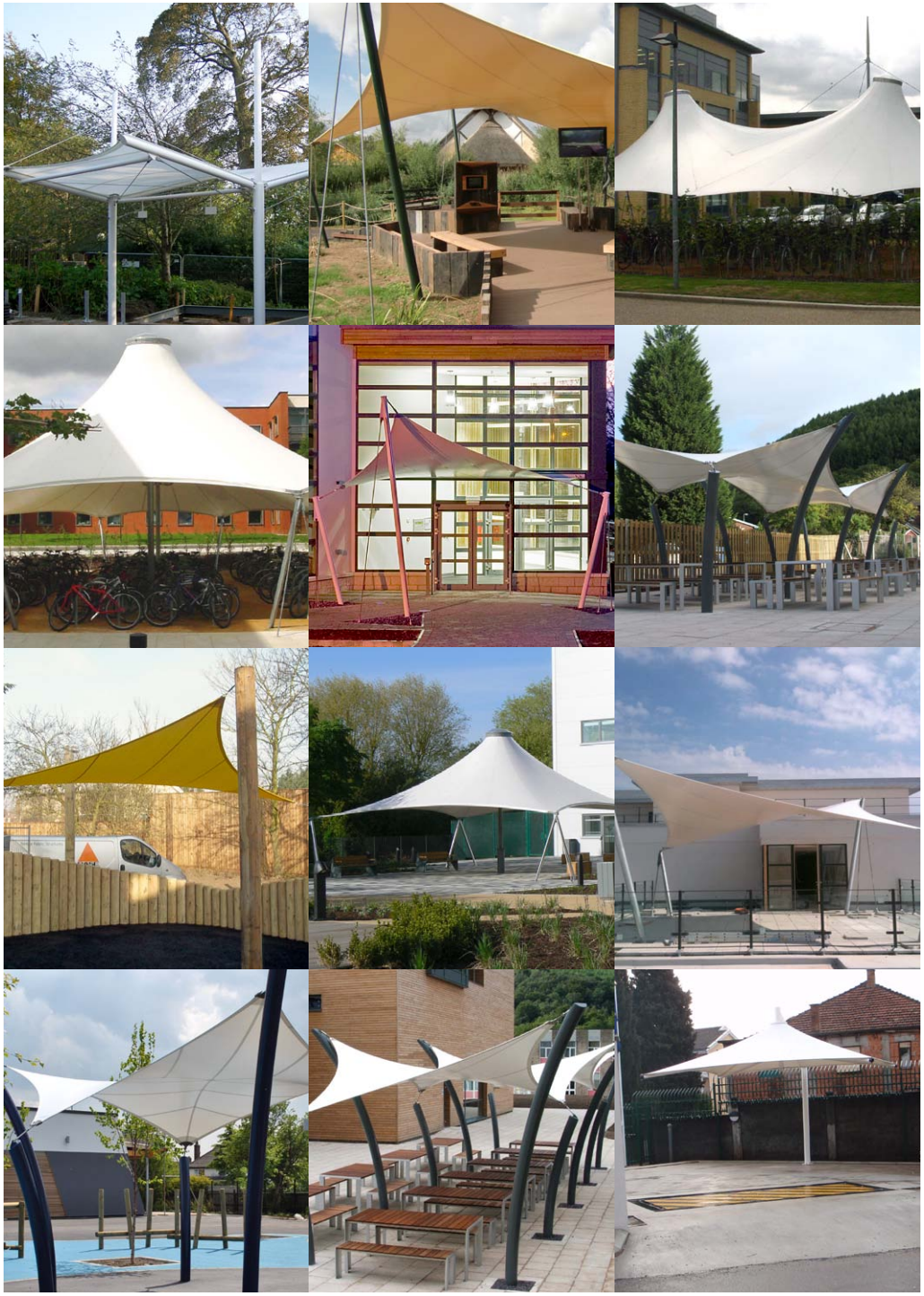

Off the peg to suit you

Inevitably budgets are often tight. If you are after a free standing external canopy it sometimes pays to look into pre-designed alternatives.

Significant cost and time savings can be achieved using an 'off-the-peg' design – and Base Structures can offer a wide choice.

Every pre-designed product is engineered to current British Standards, making them suitable for year-round use, even in wind and snow. They also come with maintenance guidelines and a 5 year warranty, so whichever fabric structure you choose, you can be certain it's engineered to last.

These are just a few examples of some of our most popular designs. See the full range here

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Let there be light

Tensile structures don't necessarily have to keep out all the elements.

A wide range of mesh fabrics are available that are perfect for solar protection, used either as a sunshade or on a façade.

A variation on this theme is the use of very open mesh materials – as here at the Newhaven energy recovery facility in Sussex. The incorporation of metal in the material weave allows it to be open AND strong - so it allows in air, and provides an aesthetically pleasing exterior to a very large piece of equipment in an environmentally sensitive area.

Equally, cable supported mesh structures are ideal for animal and aviary enclosures with a variety of material specifications to suit budgets and requirements.

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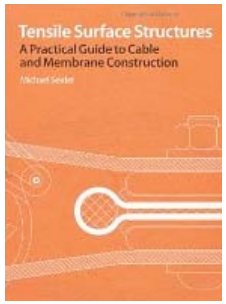
www.basestructures.com

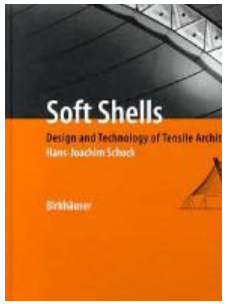
Over to you...

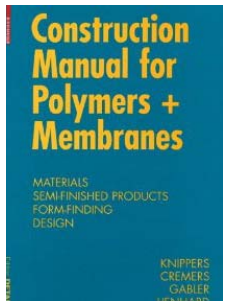
And there you have it. We hope this introductory guide has been useful to you. If you have some more specific queries, we're more than happy to help out – see overleaf for more details.

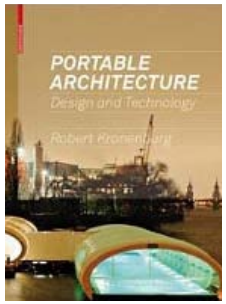
In the meantime, thanks for reading. Here's some more resources to help you on your way.

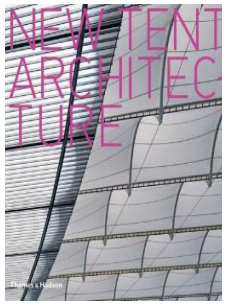
Books











Projects & Case studies

- 1,001 projects at a glance
- Breaking new ground – a single skin ETFE roof case study
- Creating an architectural masterpiece with Zaha Hadid - case study
- Nottingham University Samworth Academy Case Study
- MSCP Cardiff Case Study
- Heathrow Terminal 5 Case Study
- Slimbridge WWT Case Study

Scribbles & musings

- A little inspiration

Otherwise, we'd be grateful if you could take a moment to let us have your feedback and if you've found it useful, perhaps you'd like to tweet it, share it or like it so that your friends, colleagues & countrymen can enjoy it too.

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About Base Structures

Base Structures is one of the UK's most respected and experienced specialist in tensile fabric structures – working directly with clients as well as architects to realise their visions and maximise their budgets.

With over 1400 projects delivered across the globe, we know a thing or two about getting tensiles right.

Hopefully this guide will help steer you on the right path but if you would like some support, we are always happy to work on the conceptual stages of a project on a speculative basis – providing advice, samples, budget estimates and hand sketch or rendered images. So please don't hesitate to get in touch.

We appoint a single Project Manager to each project so that it receives the individual attention of a specialist through from start to finish. Base Structures also offers an after sales service with a fully staffed maintenance department offering a 24 hour response.

To find out more, you can get in touch on +44 (0)117 971 2229, email mail@basestructures.com or visit our website www.basestructures.com - where you will find a wealth of helpful information as well as some inspirational ideas in our portfolio.