



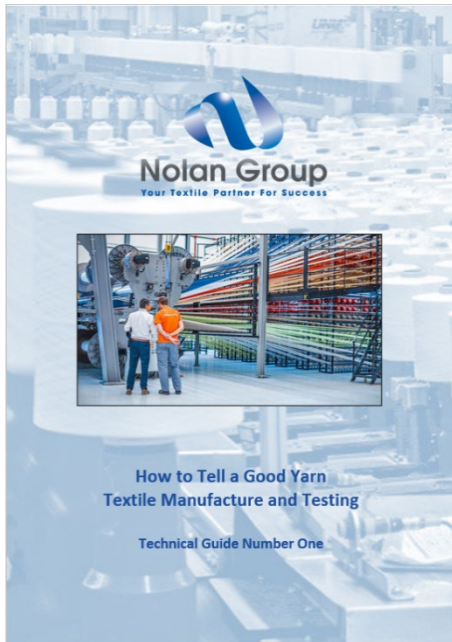
Nolan Group

Industrial Fabrics Division



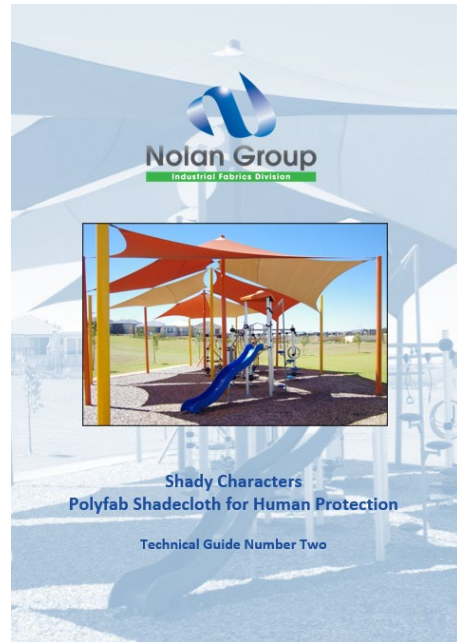
Shady Characters Polyfab Shadecloth for Human Protection

Technical Guide Number Two



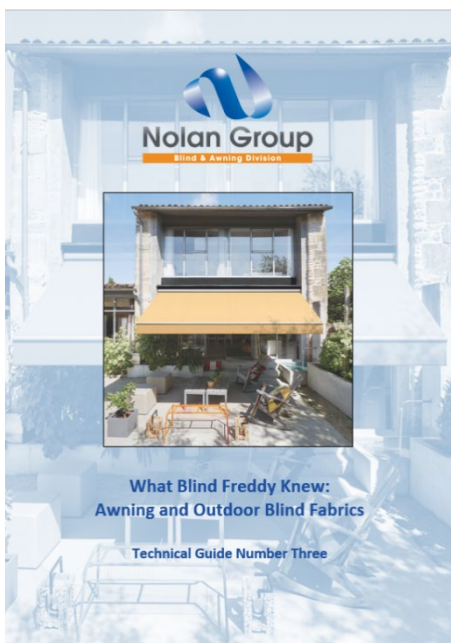
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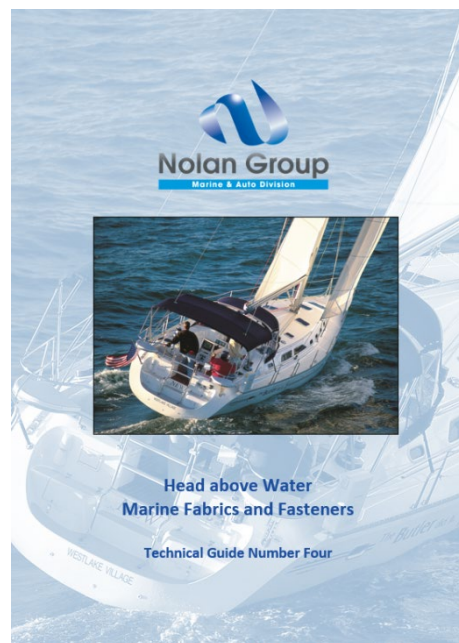
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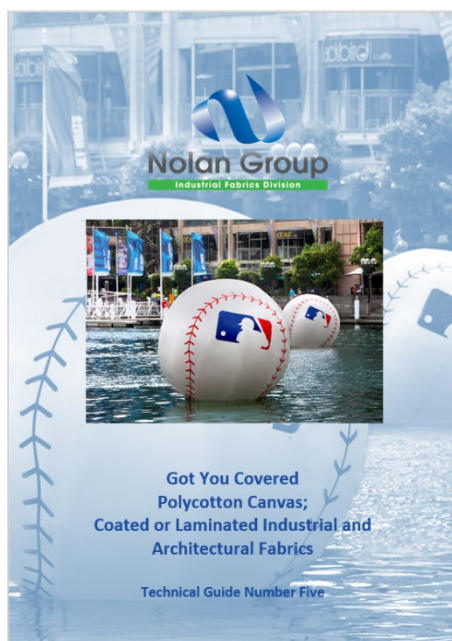
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Shady Characters

Polyfab Shadecloth for Human Protection

Technical Guide Number Two

Third Edition, First Printing May 2020

About the Nolan Group

Nolan.UDA Pty Ltd, now trading as the Nolan Group, was officially incorporated in 2009. It originally comprised the merger of the trading operations of Nolan O'Rourke and Co. Pty Ltd (trading as Nolan Warehouses) and Upholstering Distributors Australia Pty Ltd as a 50-50 joint venture, and hence the company name.

In 2016, the Business of Radins Australia Pty Ltd was formally integrated into the company. Despite its hybrid nature and relatively short history, the Nolan Group has a proud legacy inherited from its constituent partners.

Nolan O'Rourke was established in 1920 by William Bernard Nolan, and is still third generation family owned. The company had its beginnings importing Motor Body Parts and Accessories, but over the years, it diversified first into wholesaling upholstery and furnishing supplies; and then related products in Marine and Motor Trim, Industrial Textiles and Commercial Flooring markets.



A delivery vehicle at Circular Quay, Sydney circa 1930

Upholstering Distributors Australia Pty Ltd (UDA) is itself a subsidiary of a fourth generation family company, Thomas Peacock and Sons, established in 1881. The principal operations of that group are the manufacture of Bedding, expanded foam and lofted polyester.

These two businesses were well suited to merger. They were of similar size, operated in a like fashion, sold comparable (some identical) products to the same market segments in overlapping geographic areas. They complemented each other well, especially in terms of relative market penetration by both product type and geographic location.

Importantly, the partnering businesses were well established, had an excellent reputation and a high level of mutual respect, mainly because of similarities in their cultures and business approach.

The success of the original merger led to the Radins' acquisition. Radins had its origins in the nineteenth century as a sailmaker, and the morphing into a wholesale distributor occurred gradually, with the fabrication arm sold off in the early nineties. The company's specialty was fabric supply to the awning and blind sector, complemented by a significant presence in Marine and Industrial Fabrics.

The business of Polyfab Australia was acquired in 2017. Originally founded in 1995, the company had developed a number of innovative knitted shade and horticultural products in conjunction with its Indonesian manufacturing partner P.T. Carillon Sdn Bhd, which were sold internationally, including in the USA, New Zealand and the Middle East. The Nolan Group had been distributing these products in Australia for many years.



The Sydney Warehouse in the mid-sixties. Captured in the picture (bottom right) is William Marden Nolan, son of Nolan O'Rourke's founder William Bernard Nolan.



Thomas Peacock and Sons factory at Maylands, Perth circa 1946.

The original merger and subsequent acquisitions have allowed the company to realise its ambition to become a complete wholesaler of outdoor textiles and related products to the automotive, marine, awning and blind, industrial fabrics and commercial market sectors. The business trades from six branches throughout Australia, located concentrically with its customer base and the country's population; and has contract arrangements with Polyfab operations in the USA and the Middle East.

Our Company's philosophy is building and strengthening partnerships with our Customers and Suppliers. Our team of account managers and customer service staff undertake extensive product and sales training to ensure they provide the highest level of support and advice possible.

TECHNICAL GUIDE NUMBER TWO
Shady Characters
Polyfab Shadecloth for Human Protection

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Disclaimer

This guide is designed to provide appropriate technical information to specifiers, fabricators, installers and consumers. The information contained herein or otherwise supplied is based on our own general knowledge, research, and advice obtained from consultants and experienced fabricators in the industry. The information is provided in good faith, but no warranty is given or is to be implied with respect to its accuracy or applicability to a particular circumstance.



Polyfab Shadecloth – protecting people just like you.



INTRODUCTION

Polyfab is the masthead brand for a range of knitted shade cloth and other similar fabrics marketed by the Nolan Group. The brand itself is underpinned by a rigorous product development process, based on three basic principles:-

1. Selection of an appropriate standard, preferably Australian, but where this does not exist, the most applicable European, American or Japanese.
2. Rigorous and exhaustive testing, both in the laboratory and the field, with particular emphasis on the resistance to the deleterious effects of ultra-violet light.
3. Provision of a warranty that states the product meets the chosen specification and is fit for purpose for a reasonably expected field life; provided it is selected, fabricated, installed and maintained, in accordance with the advice provided in the 'Technical Guides'.

The principal objective of this Technical Guide is therefore to fully document the above product development process for the Polyfab ranges of knitted shade cloth and provide the relevant information necessary to satisfy the conditions of our warranty.

The adopted standard for material performance is Australian Standard AS 4174 – 2018 “Knitted and Woven Shade Fabrics”, which in turn specifies Australian Standard AS 2001 “Method of Test for Textiles” for physical properties and light fastness. Testing has been independently undertaken to the relevant standards by either AWTa Textile Testing, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), or the Commonwealth Research and Industrial Research Organisation (CSIRO).

The Speciality Textiles Association has produced a publication “Minimum Specifications for Fabric Structures”, (refer www.specialisedtextiles.com.au), which is an excellent guide to the design process required for a shade structure. A key recommendation is that professional advice be sought to ensure that the structure has the appropriate engineering integrity. Further detail on the requirements in this latter respect is given in the “Guidelines for Design, Fabrication, and Installation of Tension Membrane and Shade Structures” published by the Lightweight Structures Association of Australia (refer www.lsa.org). The necessary Biaxial testing data required by structural engineers to carry out this analysis is available on request, and an explanation of the procedure for calculating Elastic Parameters is provided in **Appendix C1**.

The costs of engineering design can be a relatively high proportion of the costs of smaller structures, and possibly a deterrent for the fabricator or the consumer. Consequently, the ‘Design Centre’ portal on the Polyfab website www.polyfab.com.au provides a series of standard details and specifications for typical tensioned shade structures of surface area less than fifty square metres, utilising the budget Parasol brand. These have been prepared by Izzat Consulting Engineers Pty Ltd; and for a modest fee, the consultants can verify these to be suited for a specific site, by checking local terrain (for wind loading risk) and ground conditions (for foundation design criteria), then issue an engineering certificate for that particular location. The procedure for obtaining certification is outlined on the website.

The National Construction Code (NCC) has prescriptive requirements for the fire hazard properties of materials, linings and surface finishes in buildings. Although subject to interpretation, shade cloth structures fall within the ambit of these regulations, and in this context a conservative approach has been adopted in this guide.

FIT FOR PURPOSE STATEMENT

Under the Australian Consumer Law (which was enacted January 2011), a shadesail fabricator, being 'a supplier and manufacturer of goods', must guarantee that his goods are of 'acceptable quality'. The test for 'acceptable quality' is whether a reasonable consumer would find them fit for purpose, acceptable in appearance and finish, free from defects, and durable, that is, function for a reasonable period of time after purchase.

A "consumer" can be a corporation. For example, a building body corporate, which commissions a fabricator to undertake work up to \$40,000 in value, is considered a 'consumer' under the Act, and has considerable rights of remedy if the goods are found not to be of acceptable quality, including full replacement or refund.

To assist fabricators in managing this risk, the Nolan Group has developed a formal 'Fit for Purpose' statement which is designed to clarify the meaning of the frequently used terms of the Consumer Act, in the context of products used in an outdoor environment. This refers to the basic product technical specifications published in our "Fabricator Product Catalogue" and Technical Guides and is incorporated into all our formal warranties.



The Nolan Group 'Fit for Purpose' Statement

The Nolan Group's products are specifically designed to be used for the recommended purpose and are guaranteed to be supplied free of defects.

'Free of Defects' means that the product meets its published description and technical specification and is homogeneous in appearance after allowance for minor variance that is inherently the result of the manufacturing process.

The Nolan Group further warrants that the product will perform satisfactorily when used in its design context in the temperate climatic conditions experienced throughout Australia.

'Satisfactorily' means with continued but gradually diminished utility over its expected life, due to the unavoidable effects of Ultra-Violet Radiation and weathering, such as colour variation, strength loss, and dimensional change. Extreme climatic conditions, particularly high temperature and humidity may accelerate the inevitable product degradation.

'Expected Life' is at least the period covered by warranty, provided the product is installed properly, and cleaned and maintained as recommended.

THE PRODUCTS

Polyfab Brands

The Polyfab range of knitted products has been developed and sold in Australia, the Middle East, and the USA for over twenty-five years, and have a proven track record for performance and longevity, more than sufficient to support the warranties offered. The fabrics are all manufactured from UV-stabilised high-density polyethylene yarn, which is lightweight, but has a high strength to weight ratio.

Selection is available from an extensive range of colours, weights, and different types of knit construction designed to meet specific needs and to maximise shading properties. Because of their effectiveness in reducing the health risk of exposure to Ultra-Violet radiation, the products are endorsed by the Melanoma International Foundation.

The specifications for the products are summarised in **Table One**, each of which have a limited warranty period, and standard warranty conditions. A copy of this is reproduced in **Appendix A**, with Care and Cleaning Instructions reproduced as **Appendix B**.

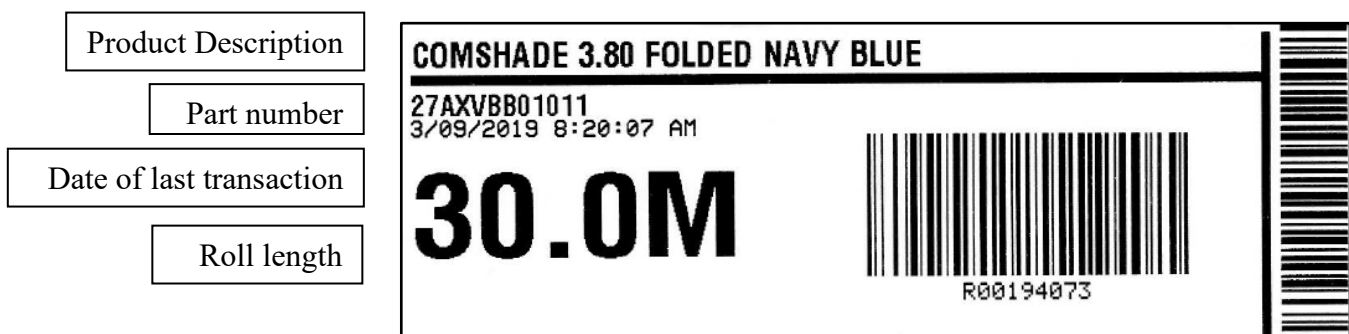
Material handling, logistics and batch tracking

The Polyfab shadecloth products are produced in roll form, and for freight efficiency, have historically been packaged centre folded. The fold has a “memory” which is lost when the fabric is tensioned, but can be an irritant during patterning and fabrication, particularly in the heavier weights. Consequently, some fabricators prefer to be supplied with the roll unfolded, and this option is available in most ranges (refer **Table One**).

Freight companies charge both by weight and cubic volume, and for convenience the relevant dimensions and roll weights are tabulated. These values can be used to calculate total pallet loads, and checked against the Safe Working Load of forklifts or the pallet raking in which there are stored.

The fabric is wrapped around a cardboard core of internal diameter 50 mm. All rolls are labelled both ends at the factory and show details of the range, colour, factory roll number, width, and roll length. Upon delivery to the Nolan Group warehouse, each roll is bar-coded (**Figure One (a)**), which is the linkage to all the records in the supply chain. The “date of last transaction” may be for example, when the container was received, or the roll itself receipted into a particular warehouse.

Figure One (a) – Typical Roll Barcode Label



When the roll or a cut length is sold to a fabricator, a label is attached to the parcel, which is also bar-coded. (**Figure One (b)**), and referenced on the delivery docket and invoice. Hence, the origin of the material can be traced from any of these records, enabling for example, delivery of additional material from the same batch, should this be required.

Figure One (b) – Typical Cut Length Barcode Label



Types of Knit Construction

Knitting is the process of making a substrate with a continuous yarn looped through neighbouring yarns to make a chain of stitches. The two basic categories of knitting are known as “warp knit” or “weft knit”, are illustrated in **Figure Two (a)**. A warp knit has multiple yarns running vertically, each connected to its immediate neighbour (e.g a Tricot knit). A weft knit has a single yarn running in a horizontal direction, looped around the row below.

Warp knits are made on flat bed machines with parallel lines of longitudinal yarns arranged like those in a weaving loom. Each yarn is controlled by a separate needle which loops it onto itself, at the same time as lateral oscillation to and from causes connection to its neighbours.

All Polyfab shade cloth is warp knitted, with two variations, namely (i) monofilament only **Figure Two (b)**, or (ii) monofilament and tape **Figure Two (c)**. The ‘Monofilament only’ knit is popular with fabricators because of its stiffness, and its relatively similar extension behaviour in the warp and weft directions. But, the advantage of the ‘Monofilament and Tape’ construction is that the inclusion of the tape with its wider profile, increases the Shade Factor and UVR block, and therefore shading, which is the general purpose for installing shade cloth. For this reason, all Polyfab shade cloth products that are intended for human protection are constructed of monofilament and tape, with the exception of Architec 400.

However, Architec 400 has a special construction of the extruded yarn, which is oval in shape rather than round. This results in a higher relative surface area of the yarn in the knit matrix, which largely compensates for the lack of tape. Consequently, the UVR Block values of Architec 400 are nearly comparable with the other Polyfab ranges. The right selection of cloth depends on the circumstances, but generally should be based on UVR Block where protection from UV is the paramount concern (e.g a Children’s playground), as opposed to structural efficiency (e.g a car-park). Nonetheless, there is no engineering reason why any of the Polyfab Range cannot be used for either application.

Polyfab shade cloth is knitted with a lock-stitch construction, which provides dimensional stability and minimises unravelling when cut. All finished product (except Comshade FR) is stentored, or heat set, to minimise shrinkage, and to improve lay-flat characteristics, which can be a significant factor in reducing cutting and fabrication costs.

Figure Two (a) – Basic types of knit.

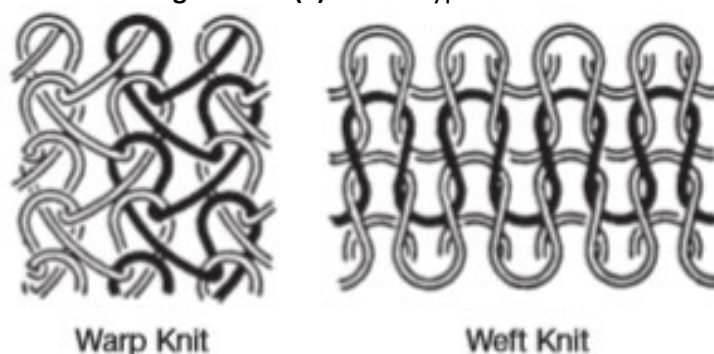


Figure Two (b) – Enlarged image of a monofilament Shadecloth



Figure Two (c) Enlarged image of a monofilament and tape shadecloth

“.....the inclusion of the tape with its wider profile, increases the Shade Factor and UVR block, and therefore shading, which is the general purpose for installing shadecloth”



Table One- Polyfab Shadecloth (Human Protection) Specification

Brand	Parasol	PolyFX	Comshade	Comshade FR ⁽²⁾	Comshade xtra	Architec 400
Weight (gsm)	325	236	330	290	400	400
Width (metres)	3.0	3.8	3.8 or 6.0 ⁽¹⁾	3.8	4.0	3.8
Roll Length (metres)						
Centre Folded	50	30	30	30	n/a	n/a
Unfolded	n/a	50	50 (3.8 m width) 30 (6.0 m width)	n/a	40	50
Roll Diameter (cm)						
Centre Folded	37	26	28	30	n/a	n/a
Unfolded	n/a	28	31 (3.8 m width) 27 (6.0 m width)	n/a	30	34
Roll Weight (kg)						
Centre Folded	50	26	38	33	n/a	n/a
Unfolded	n/a	44	63 (3.8m width) 60 (6.0 m width)		64	76
Freight Cubic (m3):-						
Centre Folded	0.21	0.13	0.15	0.17	n/a	n/a
Unfolded	n/a	0.30	0.37 (3.8m width) 0.44 (6.0m width)	n/a	0.36	0.44
Breaking Force (N/50mm) & Elongation at break (%):-						
Warp	640 (89%)	570 (58.4%)	1170 (68.5%)	680 (42.0%)	1500 (87.0%)	1128 (102%)
Weft	2200 (64%)	1946 (49.5%)	2082 (58.7%)	2000 (51.0%)	2300 (59.0%)	1757 (98.3%)
Tear Resistance (Newtons)						
Warp	179	106	208	122	269	276
Weft	290	174	239	202	262	351
Bursting Pressure (kPa)		2750	3650	2800	4100	4900
Bursting Force (N)	2041	1300	2077	1535	2390	2725
UVR Block (%) ⁽³⁾	87.1% to 95.2%	91.3% to 96.7%	93.8% to 96.2%	91.7% to 97.6%	94.9% to 99.7%	87.8% to 96.0%
Relative Price	1.00	1.69	2.21		2.38	2.44
Limited Warranty Period	Ten Years	Ten Years	Ten Years	Ten Years	Fifteen Years	Fifteen Years

Notes: (1) Available unfolded only in Porcelain, Cappuccino, Aquamarine, Black, Slate, Blue Gum, Midnight Green

(2) Comshade FR is not stentored and is not offered for sale in Australia.

(3) UVR Block varies with particular colour. Refer Table Five for actual value

SHADE PLANNING

The principal objective of constructing a shade structure is to provide shade, but it is surprising how often the planning in this context is overlooked.

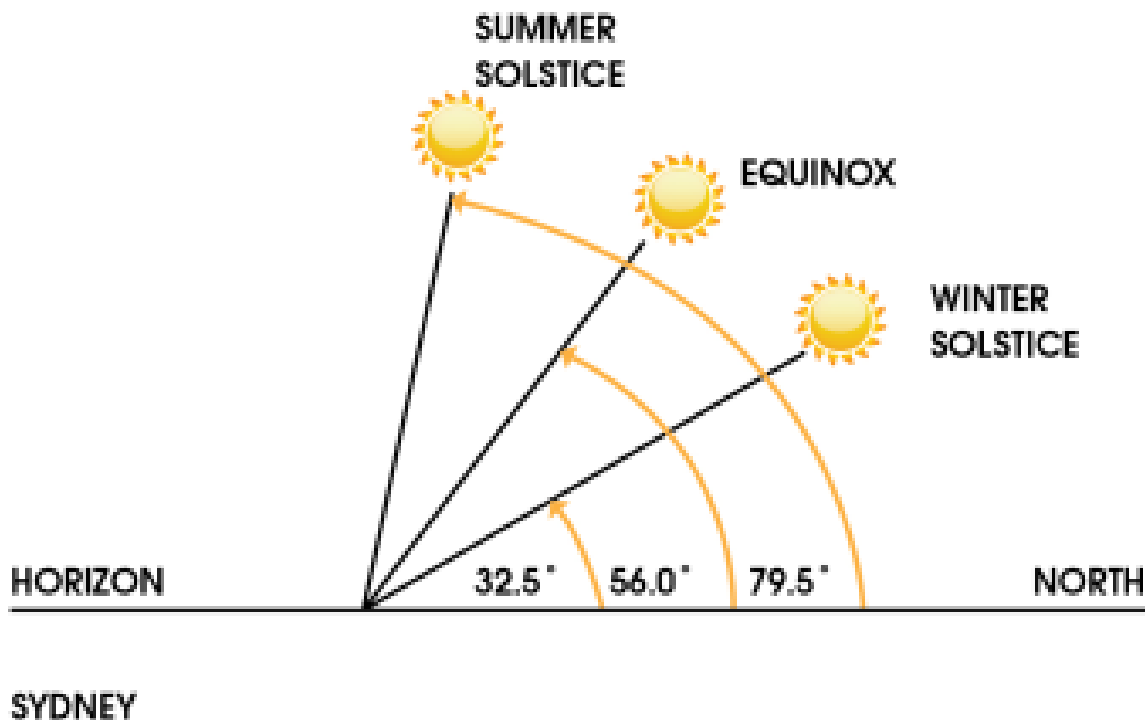
The degree of risk due to exposure to Ultra-violet radiation (UVR) is dependent on the season, time of day and geographic location. The single most important factor is the height of the sun. The higher the sun, the higher the levels of solar UVR experienced. This rather obvious fact usually dictates the base design parameters of a shade structure, but what is often ignored is the potential degree of exposure at earlier and later times of the day. At 4.00 pm in summer, when the sun is well below its noon elevation, the UVR is still sufficient to cause sunburn of the average fair-skinned person in twenty minutes. However, the shade cast by the structure at that time of day may not be providing the protection where it is required.

Four particular days per year are important yardsticks for defining the boundaries of the extent of shadow cast by a structure:-

- The summer solstice – this occurs on the 21st December, and is the longest day of the year. On this day, the sun is at its highest summer zenith at noon; and rises and sets at its furthest point south.
- The equinox – this occurs twice a year on the 21st March, and 23rd September. On these days, the sun at noon is midway between its summer and winter zeniths; and rises and sets due east and west respectively.
- The winter solstice – this occurs on the 21st June, and is the shortest day of the year. On this day, the sun is at its lowest winter zenith at noon; and rises and sets at its furthest point north.

The respective sun angles are dependent on the latitude of the site. The angles for Sydney, Australia (latitude 33 degrees, 53 minutes South) are illustrated in **Figure Three**. Clearly, in terms of designing for shade protection, the summer solstice and equinox are of primary interest.

Figure Three – Solar Azimuth angles for Sydney, Australia



Shading diagrams for a six metre by six metre hypar structure aligned with its low points in a North / South direction, for various times of the day during the Sydney summer solstice are shown on **Figure Four (a)**. As one would expect, the shading area is maximised at noon, but is significantly less at 10.00am and 2.00 pm. Note that the net area beneath the fabric that is in full shade for the whole period between these latter times is relatively limited, but can be identified. This has important ramifications in determining the specific location of the structure relative to the fixtures below it (such as a park dining table or play equipment), or vice versa, as illustrated in **figures four (b), (c) and (d)**.

Figure Four (a)– Shade created by a six metre x six metre hypar structure in Sydney at various times of the day on the summer solstice.





area of shade at 10am (green outline)	area of shade at noon (green outline)	area of shade at 2pm (green outline)	fully shaded area between 10am & 2pm (green outline)
 36.29m ² 21m ²	 36.20m ² 30m ²	 36.09m ² 21m ²	 15m ²

Figure Four (b) – An example of where the design of shade sails may provide only limited shading in mid-morning to children’s play equipment, an area they are intended to protect.





Figure Four(c) A series of overlapping triangles providing effective shading when the sun is directly overhead. Triangles are not as structurally efficient as hypars.



Figure Four (d) An excellent example of shadesails integrated with vegetation to maximise shading at most times of day

Elastic Properties of Polyfab Products

It is important to understand how and why shadecloth behaves as it does when tensioned in two directions at once, which is what happens when a shadesail is installed.

If a fabric is tensioned in one direction only (termed uniaxial loading), it will elongate in the direction of the load, and contract in the perpendicular direction. The applied load is termed stress, and the fabric deformation is termed strain. The applied load is a force, expressed in Newtons (N), or kiloNewtons (kN), and converted to a uniform applied load by dividing it by the length over which it is applied (kN/m). Strain is expressed as a percentage change in length. The convention is that the measurement of strain is positive for elongation, and negative for contraction.

For an elastic material, (i.e. one that returns to its original shape like a spring after an applied load is released), there is a linear relationship between applied stress and strain (Hooke's Law), with the slope of the line termed the Modulus of Elasticity or Elastic Modulus. A material is said to be "stiff" if the line is steep, meaning the Elastic Modulus is high.

If the fabric is tensioned in both directions at once (termed biaxial loading), there will be a positive strain in the direction of the applied loads, and a negative strain in the opposite direction. If the fabric is isotropic, i.e. having the same stress versus strain characteristics in each direction, the positive strain and the negative strain will also be the same in each direction, as will the net deformation of the fabric.

Unfortunately, shadecloth is very anisotropic, and behaves as illustrated in **Figure Five** when stretched in two directions, which is also clearly apparent when the results of Biaxial tests are plotted. It is also inelastic, which means that the application of Hooke's law, which is the basis of engineering analysis, is very approximate.

The Biaxial test results show the net effect of a force that causes elongation in the direction it is applied, offset by the contraction induced by an equivalent force applied in the perpendicular direction. This is illustrated in the biaxial plot of Parasol (**Figure Six**), on which the uniaxial response is also plotted. The test was conducted using a uniform loading ratio (i.e. the same in both warp and weft directions), and ten loading cycles between a minimum of 0.1 kN/m and 2.4 kN/m. The expected pre-stress and applied loads likely to be experienced in field usage would lie between this range of loading.

Under Biaxial loading, the stiffness in the weft direction is increased, relative to the uniaxial case, because of the contraction caused by the very significant elongation in the warp. However, in the warp direction the stiffness remains practically the same as that in the uniaxial case. This is because there is so little elongation in the weft direction, that the contraction induced by it in the opposite warp direction is negligible. All ranges of Polyfab shadecloth behave in this way, and hence under biaxial loading are very much stiffer in the weft direction than the warp. The results also show that the elongation response to applied loading is also non-linear; and exhibits pronounced hysteresis during, and permanent plastic deformation ('stretch-set') after each cycle; although the response starts to approximate linearity and to exhibit greater stiffness (i.e. less deflection under loading) after the first cycle.

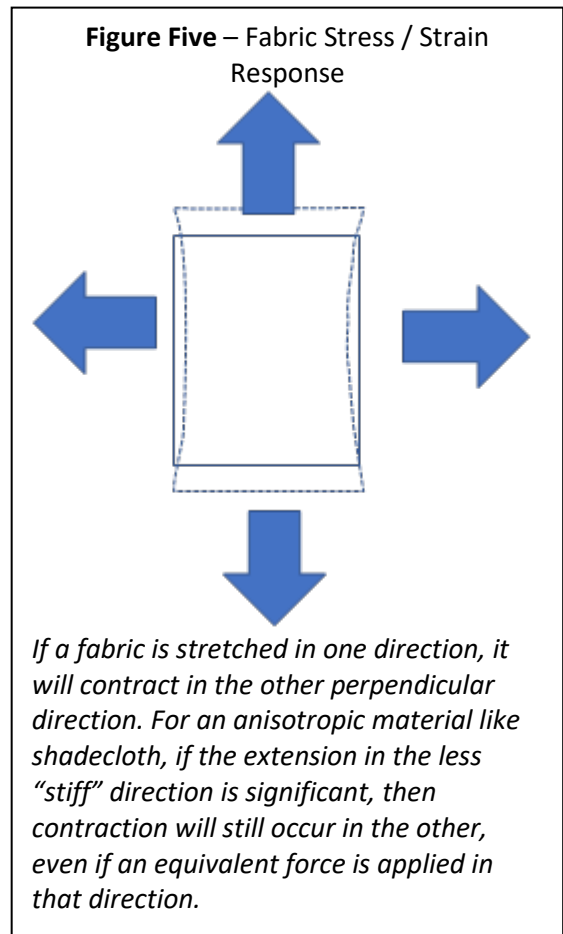
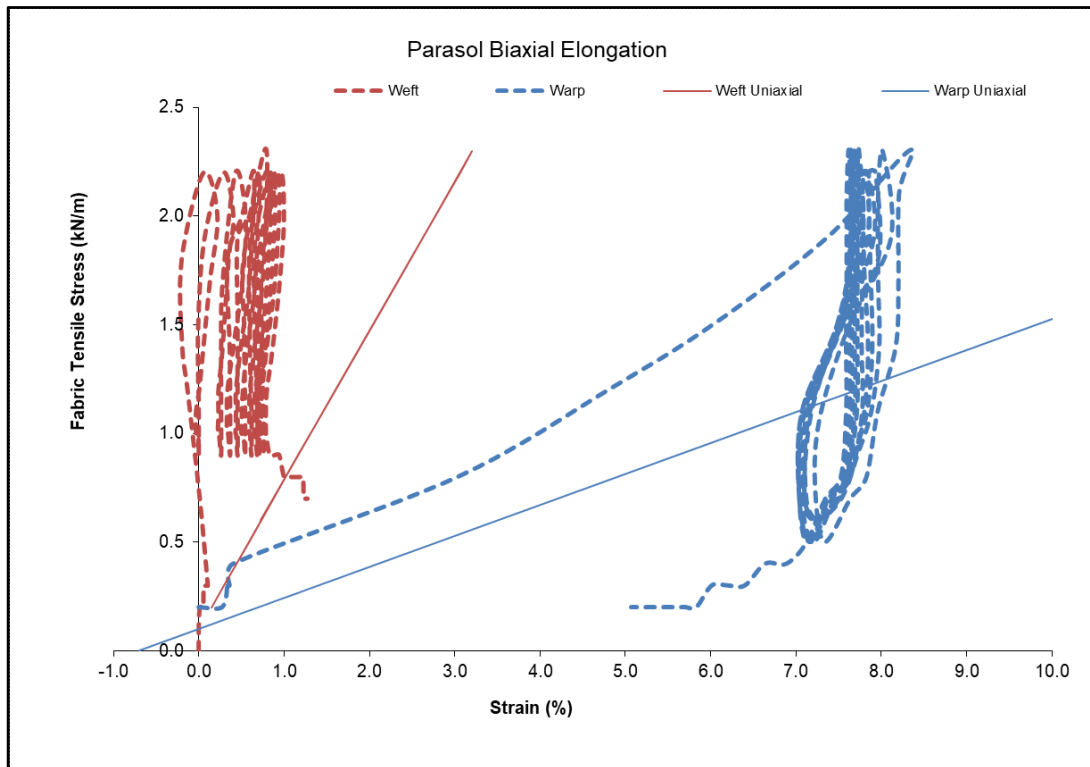


Figure Six – Biaxial test result for Polyfab Parasol, with uniaxial results superimposed



Biaxial Test results for the other Polyfab ranges of fabrics are plotted to the same scale in **Figure Seven** and show that the monofilament knit of Architec 400 has significantly less strain in the warp than the other ranges, which are monofilament and tape. Although clearly not isotropic, the behaviour of Architec400 approximates it, which is possibly why such fabric is favoured by engineering designers.

The Biaxial Test results can be used to derive the Elastic Parameters for the material, using the procedure outlined in **Appendix C1**, and the raw data is available on request.

Fabricators often compare fabrics by 'grunt', that is the ultimate failure loads derived from the uniaxial tensile strength test, specified by AS 2001.2.3, which in practice is not particularly useful. At failure, the material is extended up to 40%, and so strain hardened as to be rendered useless. For this reason, the safe working loads applied to the cloth in tensioning are very much less than the ultimate. By way of example, Polyfab Parasol (under uniaxial loading) has a rated ultimate tensile strength of 12 kN/m in the warp direction, and 21 kN/m in the weft. However, a typical value of pretension used in common shade structures is 0.3 kN/m, which is less than 2.5% and 1.4% of these respective ultimate loads. At these pre-stress loads, a much better indicator of a fabric's structural performance is stiffness.

It is important to note that the biaxial test results are not consistent with the assumptions of linear elasticity in Hooke's law, which is the basic theory behind the relationship between stress and strain in finite element CAD models; and the creep characteristics of the material introduce another complication. Mechanical conditioning would partly remove the worst eccentricities of the fabric's behaviour but is impracticable to execute this on site. Therefore, the computation of the Elastic parameters derived from the data provided should be considered very approximate, and significant allowance in design should be made for additional 'compensation' that undoubtedly proves necessary to take into account the actual complexity of the material's stress / strain relationship. Fortunately, the material is very 'forgiving', and much improvisation in tensioning occurs on site during installation as additional compensation for the pragmatic difficulties of estimating the finished fabric profile.

Figure Seven Biaxial Elongation plots for the Polyfab ranges

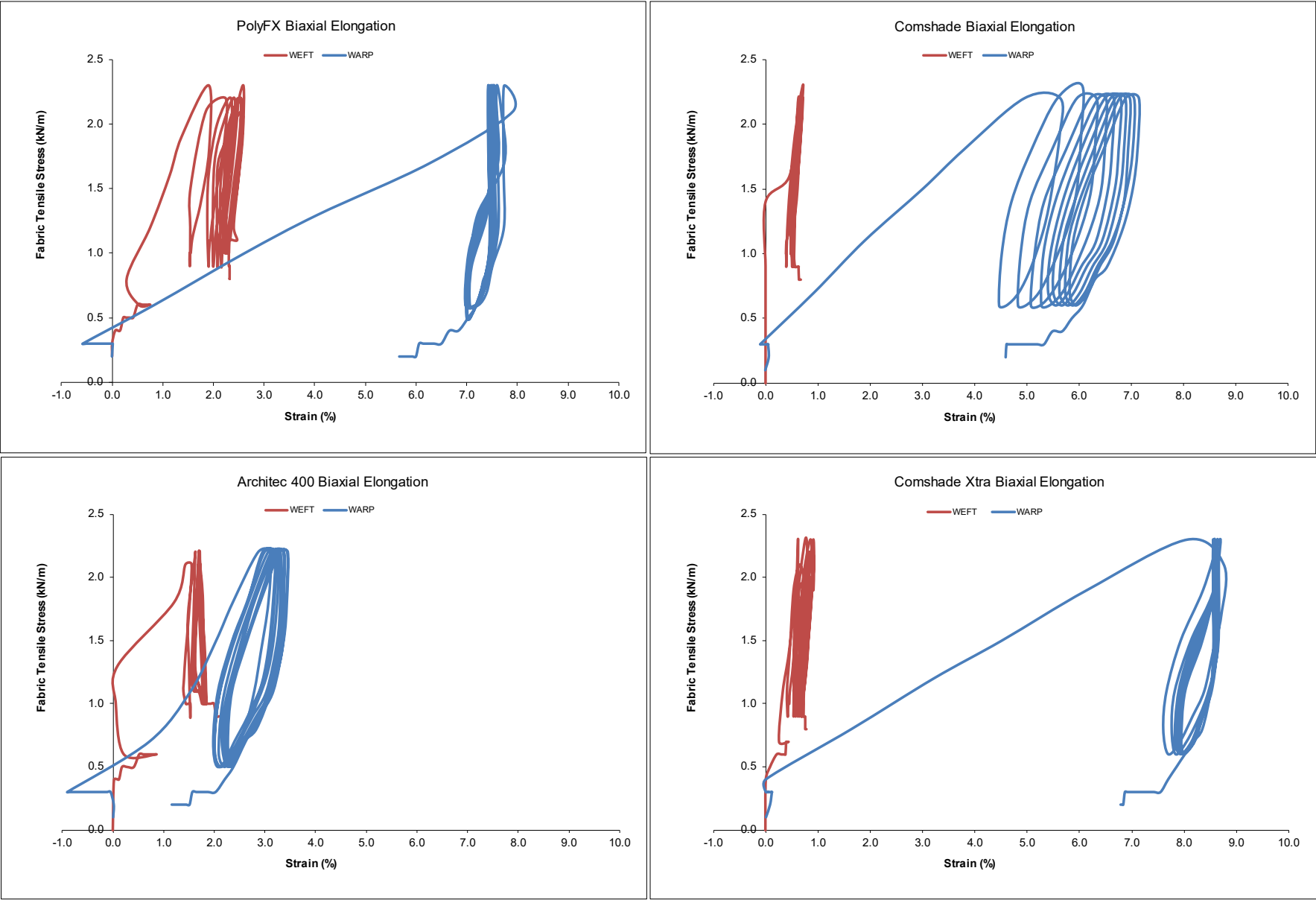
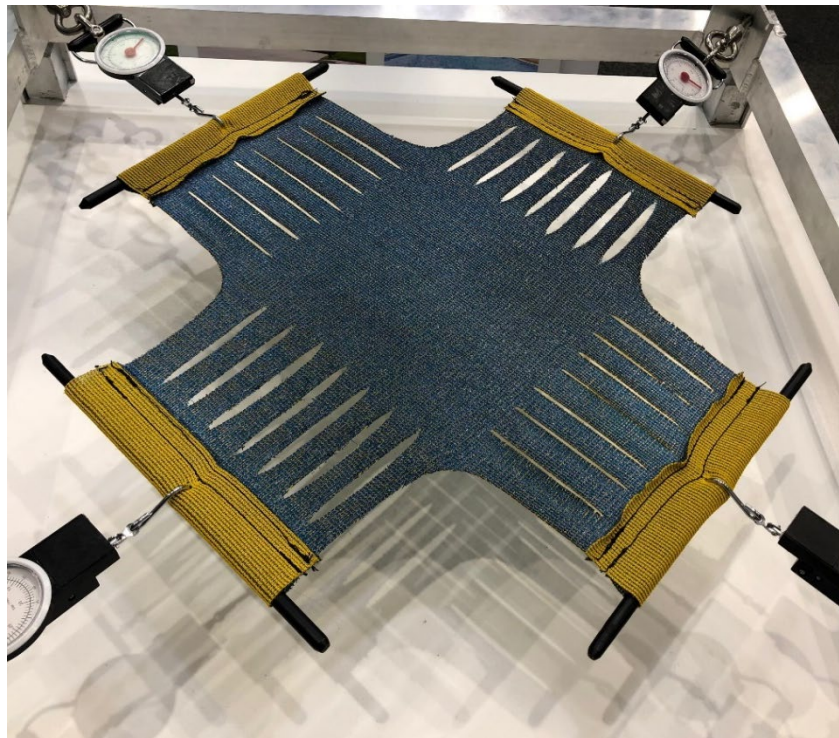


Figure Eight (a) – Uniaxial Test Apparatus



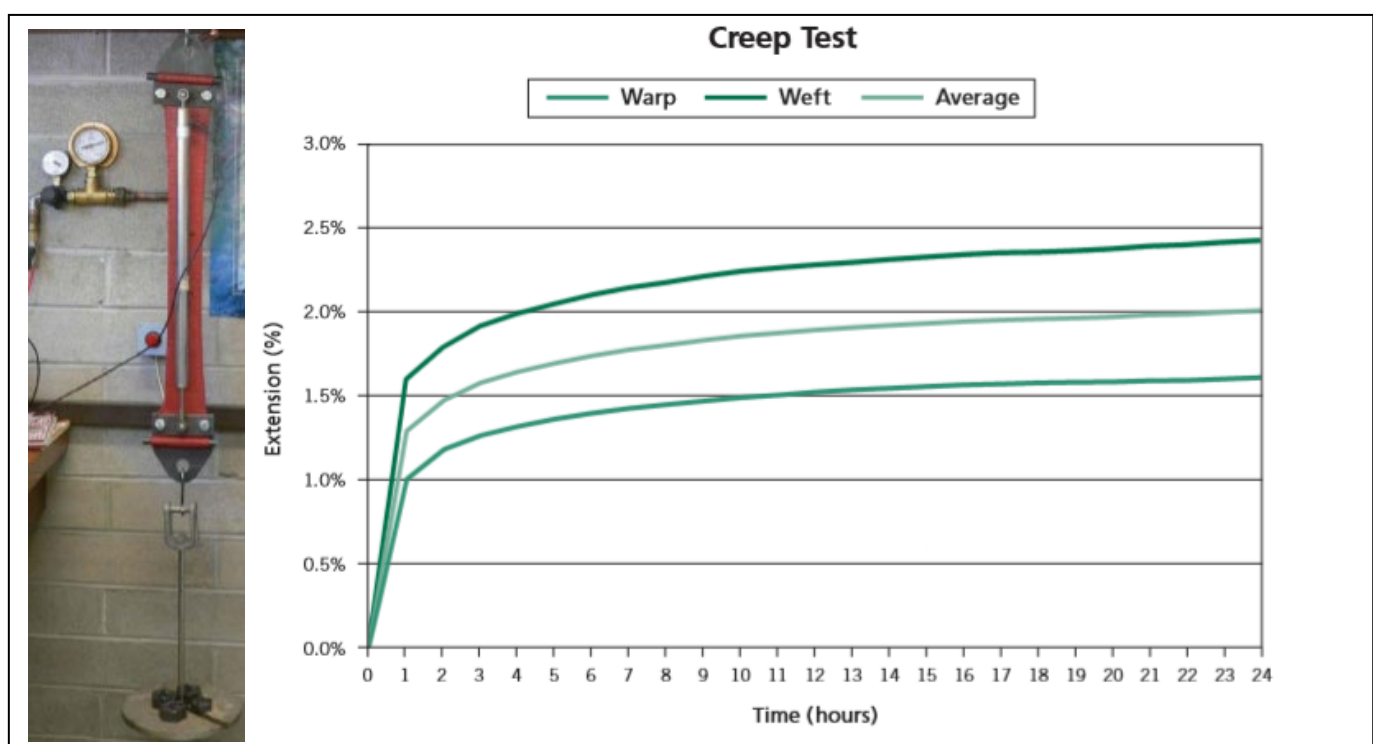
Figure Eight (b) – Biaxial Test sample set-up (photo courtesy of Gale Pacific)



Creep

Note that the biaxial test plots show a very small strain response of the test specimen to loading at the level likely to be applied during pre-stressing. This anomaly occurs because in practice, the fabric exhibits creep, which is a time dependent increase in strain under a constant applied load. **Figure Nine** shows such a plot for Polyfab Parasol under uniaxial loading at a constant load of 0.25 kN/m . At time zero, the immediate response to the applied load is negligible, which is also consistent with the behaviour exhibited in its bi-axial tensile test. However, after one hour, the strain is up to 1.6% in the warp direction and 1.25% in the weft direction respectively. On average, under the same constant applied load, a further extension of 0.5% and another 0.25% occurred after ten and twenty-four hours respectively, with the effect more pronounced in the weft than warp direction.

Figure Nine – Time dependent strain of Polyfab Parasol under a constant load of 0.25kN/m



Design of Supports

The force of wind should not be underestimated and is the reason the supporting structures and cables of large area shadesails appear so robust. Professional engineering advice should always be sought on the design of the supports.

Wind design stresses are in the order of 1.5kN/m, which is still very much less than the ultimate stress of the cloth. Typically then, the wind failure mode is loss of elasticity rather than tear or burst. Failure can also occur for other reasons, such as the accumulation of hail.

Shadesails are invariably attached by a corner to a column or other fitting, and the treatment of these requires some thought. It is crucial that the tensile load in the cable is transferred directly to the supports. The reactive stress in the fabric tends to drag it away from the supports, and reinforcement of the sail at these corner points is recommended. It is best to do this using another

piece of shadecloth, rather than a coated PVC, as the latter's plasticisers can migrate and react detrimentally with the stabilisers in the shadecloth.

Connection to a column without a backstay results in a significant bending or overturning moment being applied to the column, which is resisted by the bolts at the base, and the reactive forces on the side and bottom of the footing. In this cantilevered loading case, deflection in the column can be very noticeable, and is usually the basis for determining column size.

Staying the column reduces both deflection and applied moment, but the axial load is higher. A pin jointed base ensures that the applied bending moment is further reduced, which means an elegantly slim column or a lightweight truss can be used, but consideration must be given to lateral stability. This can be attained by using a tripod as support, or additional guy wires. However, it is not always practical to use stayed columns.

FABRICATION

Tension Applications

The flexibility of shadecloth allows it to be tensioned fairly readily to form a tight membrane, or shaped into anticlastic surface geometry, which is the result of concave curvature in one direction, balanced by convex curvature in the other. The most common example found in shade structures is the hypar (**Figure Ten**). This shape is the natural, curvilinear response to pre-stress loading applied along the edge of the fabric, and the boundary restraints due to the configuration of the supports.

Figure Ten. Schematic diagram of a 'Hypar' Structure.

Note the convex and concave curvature that dictates the finished shape. The example here shows cable stayed, pin jointed columns, which minimises bending in the columns themselves.



With hypar structures, the membrane contributes actively to the resistance to applied loads, such as wind. For this reason, it should be preferred over triangles, which cannot be shaped into an anticlastic surface, and are structurally redundant. Further, mechanical breakdown due to the fatigue induced by wind flap is the most common cause of shadesail failure, and poorly tensioned triangles are more prone to this. The apexes of triangles are also points of stress concentration and require significant reinforcing to alleviate it.

Pre-stress in the cloth is invariably induced by tensioning a cable along the edge of the fabric, which is cut in a curved shape. The flatter the curve, the higher the tension in the cable, which is equal to the radius of curvature times the reactive stress of the cloth (Refer **Appendix C2**). The reactive stress applied by cloth is dependent on its deformation or strain, the characteristics of which are different in the warp and weft directions, which can be a complicating factor in patterning.

Typically, during installation of fabric on a hypar structure, a wire enclosed in a sheath along the edge of the sail is tensioned, thus shortening its catenary (i.e. the curvature between the supports). This in turn applies a uniform stress to the fabric attached to the cable, and the fabric stretches in response. Provided the cable is free to move at the supports (e.g. through a pulley), the tension is constant along its whole continuous length, and therefore the stress applied to the cloth in each direction is the same. However, because the relationship between stress and strain (i.e. the Elastic Modulus) is different in the warp and weft direction, the strain response of the fabric will be different, the extent of which is largely dependent on the alignment of the warp and weft directions relative to that of the applied stress.

Logically, the shadecloth should be fabricated so that the warp and weft are aligned in the direction of the supports, which results in the stress induced by cable tension being applied at a 45° angle across the shadecloth, and hence, the strain response is the same all along the periphery of the shadesail.

Note that unlike a hypar, triangles cannot be stressed in this way, and the strain response along the periphery will be different in at least one direction, no matter how the fabric is aligned. This is one of the reasons why triangular sails are not recommended; the other being that their shape cannot be deformed into the classic anticlastic structure (i.e a concave curve in one direction balanced by a convex curve in the other), which is basic form of all tension structures.

However, if the fabric is aligned as recommended, (i.e. the weft and warp aligned along the axes of the high and low supports), the response to cable tensioning will be the same along the periphery. For this ideal condition, the finished radius of curvature will be equal for each span. Thus, a theoretical engineering relationship exists between cable tension, reactive stress and tensioned chord depth for any given span, derived as shown in **Appendix C2**, as the following formula:-

$$d = \frac{T}{w} - \left(\sqrt{\left\{ 4 \left(\frac{T}{w} \right)^2 - L^2 \right\}} \right) / 2$$

Where:-

d = Chord depth (m)

L = Chord length (m)

T = cable tension (kN)

w = allowable fabric pre-stress (kN/m)

For the same design conditions, it can be shown that the chord depth can be approximated by the simpler formula $d = wL^2 / 8T$ or $d = kL^2$ where k is a constant.

Thus, if one calculates the chord depth for say, the longest span, the proportional value of the expected finished depth of other spans (again assuming equal strain response in each direction) can be determined by multiplying this longest span depth by the square of the ratio of the lengths, as:-

$$d_n = d_1 \times (L_n/L_1)^2$$

where d_n and L_n refer to the depth and length respectively of any other span.

The length of the tensioned cable (i.e. the arc length) can also be calculated from the formula:-

$$\text{Arc length} = 2\left(\frac{T}{w}\right) \sin^{-1}\left(\frac{Lw}{2T}\right)$$

These formulas allow the finished curvature of the shadecloth envelope to be relatively easily calculated and hence, by deducting the cable extension that occurs under load, also the length of the slack cable, which in turn determines chord length of the cutting out pattern.

It should be noted that the planar shape of the pattern is not simply the plan projection of the structure, but the two dimensional form that results in the finished three dimensional shape. Modern CAD systems can readily derive this, but determining the amount of “compensation”, (i.e, the difference between the surface area of the initial pattern and that of the tensioned membrane) is as much art as science.

The amount of compensation to allow for depends on the fabric selected, but it is obvious that in setting out a hypar form, most should be allowed for in the warp direction. Generally, a contraction of four percent is allowed in the warp, and two percent in the weft. Common practice is to align the warp in the direction of the high points, and in larger structures to reinforce the fabric in that direction with webbing or a cable, which limits the strain in that direction. The first connection during installation should be to the high points, with tension subsequently being applied along the axis of the low points.

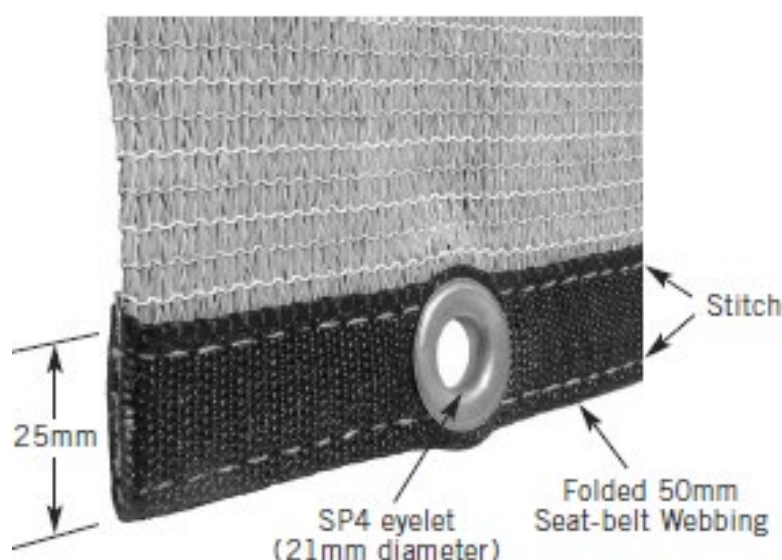
There are a number of ways of making a sheath for a tensioning cable. The simplest is to incorporate it into the edge seam, but this risks the shadecloth fraying as a result of abrasion. A better method is to create a pouch using seat belt webbing, or use the webbing itself as the tensioning medium, which is a method very commonly used in Western Australia. The 50mm width, UV stabilised rayon seat belt webbing has a breaking strength of 20kN. It is therefore suited for use in smaller structures (i.e. <50m²). The webbing can be continuous, and neatly looped at the corners to provide an attachment point to a turnbuckle or other tensioning device. One problem with this method is that the webbing is a lot stiffer than the shadecloth itself, and because of this, the sail can become baggy as the shadecloth deforms with time.

Non-Tension Applications

Even in non-tension applications, the cloth will be subject to windload, which will induce stress in the cloth and the isolated fixing points. For this reason, one must ensure that all fixing points are structurally adequate, and fittings soundly secured. Caution should be exercised when connecting to a stud frame or wall of a building, as these have limited resistance to overturning moment, and there is a real risk of structural damage occurring in a high wind. Preferably, the sail should be supported independently. If the connections have not been specifically designed to account for this risk, it should also be taken down while the likelihood of strong wind conditions exist, to avoid the potentially high loads at the fixing locations.

Ideally the cloth should be supported uniformly along the whole of its edge. Even with isolated connecting points, it is possible to convert the concentrated load to a more uniformly distributed load in the fabric. The recommended method is to fold and sew 50mm of UV stabilised, reinforced rayon seat belt webbing along the edge, and punch SP4 eyelets through this reinforcing at the desired locations, as shown on **Figure Eleven**

Figure Eleven – Method of edge fixing for non-tension applications



Cutting Out and Seaming

When cut, Polyfab shade cloth will fray if the edge is not seamed, particularly if the exposed edge is allowed to flap in the wind. For strength and aesthetic reasons, the edge and join seam should be overlapped twice, and preferably double stitched. A “lock-stitch” is preferred to a “chain-stitch”. Although the latter has more “give”, it can have an abrasive effect on the sewing thread, and in failure tends to “un-zip” along the underside.

The failure of thread in the seams is the most observed problem in sewn shadesail structures, often when the fabric itself still has a lot of life left. This is because even a UVstabilised, 100% polyester thread (such as “SUNGUARD”) loses strength under the action of sunlight, up to fifty percent over five years. PTFE thread, (such as “Solarfix”) has started to become more widely used. Although relatively more costly, it has far more durability and a much longer life than other types of thread.

Details of the Polyester and PTFE threads sold by the Nolan Group are shown in **Table Two**. . Bonded polyester threads comprise a number of filaments bonded together, without twist. They are lubricated and have a protective coating (part of the ‘Bonded’ finish), which enhances abrasion resistance and ply integrity.

Table Two— Strength characteristics of different types of thread suited for shadesail fabrication

Description	Tex g/km	Tensile Strength		Recommended Needle Size		Construction and Features
		kg	lb	US	Metric	
Dabond V138	135	9.0	21.0	22-25	140-200	100% Bonded Polyester. High UV resistance. Bleach, Mildew and rot resistant. Will suffer strength loss (up to 50% over five years) under UV exposure.
Dabond V207	210	14.1	31	25-27	200-250	
Sunguard B138	135	9.5	21.0	22-25	140-200	
Sunguard B207	210	13.6	30.0	25-27	200-250	
Solarfix PTFE	150	4.5	10.0	16-20	100-125	PTFE (Polytetrafluorethylene) Exceptional UV and chemical resistance. Retains initial strength for its working life
Solarfix PTFE	264	7.7	17.0	18-22	110-140	
Solarfix PTFE	300	9.1	20.0	19-22	120-140	

PTFE (polytetrafluorethylene) is a thermoplastic polymer with a very low coefficient of friction, is chemically inert, and very UV resistant. PTFE threads can be a single extruded monofilament, or several filament plies bonded or twisted together. They are basically self-lubricating, and are translucent, thereby readily blending with any fabric colour, although some coloured variants are available.

Thread size is generally distinguished by Tex, which is expressed as grams / kilometre. Obviously, the higher the Tex, the heavier the thread. Metric Number, defined as $1000/\text{Tex}$, is also used but often confused with 'ticket Number', which is simply the manufacturer's reference number. Tex and Metric number can easily be co-related with other commonly used measures such as D'Tex and Denier.

The difficulty of using Tex to compare threads of different composition is that the measure does not differentiate between the relative densities of the base materials. Given that Tex also equals the cross-sectional area of the thread multiplied by its density (per kilometre length), then threads of same Tex but different density will have different diameters.

PTFE has a higher density than polyester, and therefore PTFE threads will have a noticeably thinner diameters than polyester threads of the same Tex, and smaller needle sizes. PTFE also has a lower tenacity than Polyester, and therefore PTFE threads will have less initial strength than Polyester threads of the same Tex. But, unlike polyester, PTFE does not suffer strength loss under the action of Ultra -violet light, and will retain its initial strength over its effective life.

The type and size of the thread is only one the factors that determine seam strength, which is also dependent on the type and weight of the fabric, the stitch and seam construction, the number of stitches per unit length, and the thread tensioning.

STANDARD DESIGN DETAILS

The Concept

Commissioned by Nolan Group, Izzat Consulting Engineers has prepared standard engineering details for a selection of typical shade structures. Each comprises a template with a choice of proportionate dimensions that can be sized up to a shaded area of approximately fifty square metres. In some cases, the templates can be combined to form a much larger composite structure.

There are essentially two design templates available:-

- A tensioned square Hypar structure (drawing number J 6149 S-03), in four sizes – 3 metres x 3 metres, 4 metres x 4 metres, 5 metres x 5 metres and 6 metres x 6 metres; and
- A framed square structure module (drawing numbers J 6149 S-04 and 05), of dimensions 6 metres x 6 metres, which can be erected in isolation or in connected multiples.

Design Parameters and Specifications

The consultant's set of drawings include an outline of the design parameters, and the specifications for construction, including concrete foundations, reinforcement and structural steelwork. Additional specification relevant to a particular template, such as the relevant cable pre-stress applicable, is shown on the drawing for that template.

The crucial design parameter is that of the effect of windload, and Australian Standard AS/NZ 1170.2 2011 is the design code used in this context. As shown on the specification, Izzat has adopted a particular design 'Regional wind speed', which is equivalent to a 500 year recurrence interval for

non-cyclonic regions of Australia, which encompasses all of the continent except coastal regions north of latitude 30° South, that is north of Grafton, and Green Head, on the east and west coast respectively. For cyclonic regions, the adopted wind speed is equivalent to a 20 year recurrence interval. The difference is significant. A 500 year return period is equivalent to an annual probability of exceedance of zero point two percent, whereas a twenty year return period is equivalent to five percent.

The 'Regional Wind Speed' is not the only parameter that determines the design wind pressures. Important also are wind direction, terrain, elevation and degree of shielding by natural topography or other structures; all of which have particular factors developed in the code. This is why the information requested by the consultants (refer 'Certification Request Form') is necessary for determination of the wind design factors specific to a particular site.

Requirements for Access to and Use of the Standard Details

Note that the standard details shown on our website (refer www.polyfab.com.au) are illustrated devoid of dimensions. This is to ensure their proper use, as each design needs to be customised for a particular site. By filling in the 'Request for Certification form', and paying the current consulting fee, an authorised user obtains a licence to use the drawing and design details for a particular project, which is designated a new job number, and its own design certification by Izzat Consulting Engineers. The resultant site specific drawings can be reproduced as required for a council permit, client submission or construction; but cannot be reproduced or used for a different project or location. This is not just to protect copyright, but for safety considerations, as there is some danger in using these standard details without specific site customisation.

Note also that the drawings specify 'Parasol' Shadecloth, and Nolan Group's fittings, details of which are presented in the company's product catalogue. The consultant's design is based on the engineering characteristics of both the cloth and the fittings, and obvious caution should be exercised if alternate products are planned to be substituted, as these may have quite different performance characteristics. For this reason, Izzat Consulting will not certify the standard drawings if the specified products are not proposed to be used, unless the engineering properties of both cloth and fittings are provided. Re-checking the design in this context will entail additional fees.

FLAMMABILITY

Standards

There are more than twelve separate Australian Standard fire tests that are applicable to textiles. Apart from the plethora of choice, the difficulty is the selection of one that is appropriate to the expected use of the material.

Given that shadecloth is invariably used in an external environment, either as a self-supporting structure, or attached to a building, it is logical to use tests that are designed to reflect that environment. There are also building regulations, applicable to shadecloth structures, that specify results for AS 1530 pt III.

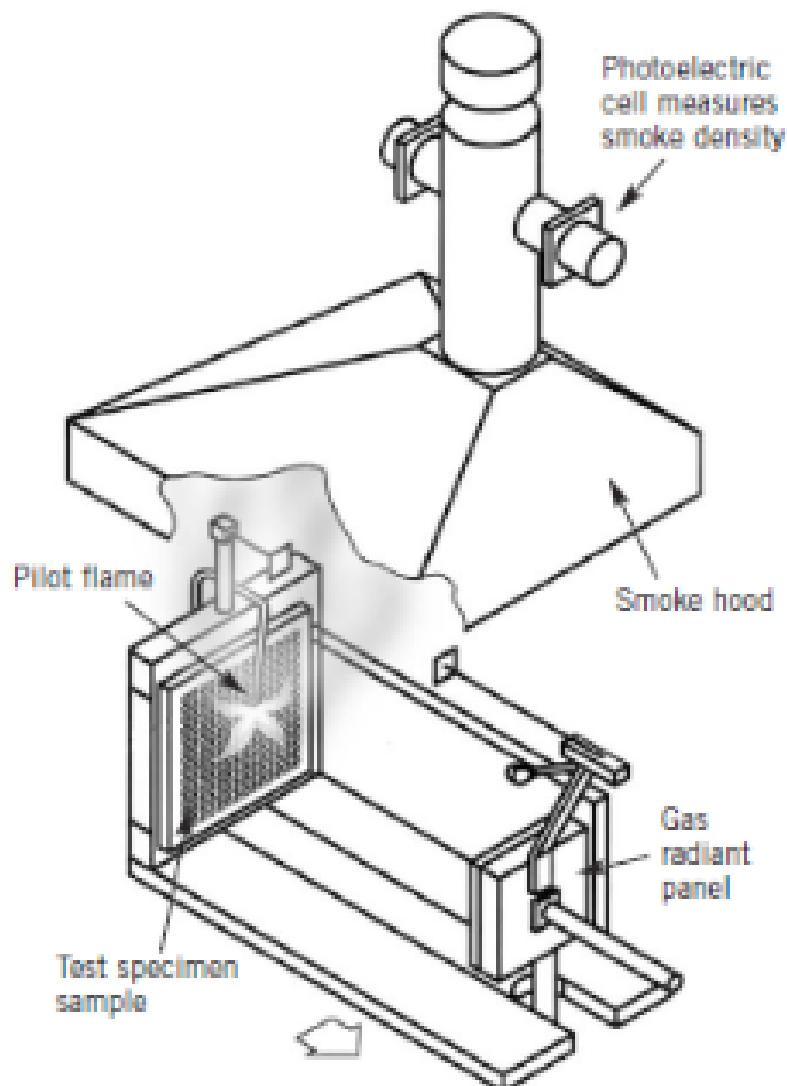
This test is intended primarily for building components, but is widely used to test textiles, despite questions of its relevance to thin, planer forms. There is also some confusion in the marketplace, regarding the meaning of the term 'FR', or 'Flame Retardant', in which context overseas test methods are often quoted. These are usually 'strip burn' type tests, similar to AS 1530 pt II. For these reasons, the appropriate selection of Australian tests for shadecloth would be both AS 1530 pt III, and AS 1530 pt II.

Description of the AS 1530 Pt II and Pt III Tests

AS 1530 pt III is designed to assess the full gambit of combustion risk, namely ignitability, flame propagation, heat release, and smoke emitted. The test entails subjecting a vertically mounted 600mm x 600mm sample to both radiated heat and an ignition source (**refer Figure Twelve**), and its burning behaviour from ignition to extinction is observed. The intense radiated heat causes the sample to emit volatile substances, or even melt, and the ignition source ensures that these catch fire. The results are expressed in the form of four indices, sometimes termed “Early Fire Hazard Indices”, not to be confused with the “Flammability Index” of AS 1530 pt II.

Only two of these indices – the “Spread of Flame Index”, and the “Smoke Developed Index” are referred to in the National Construction Code of Australia. The “Spread of Flame Index” is a measure of how quickly a fire propagates, expressed on a scale of 0 to 10. The higher the value, the worse the result. The “Smoke Developed Index” is also expressed on a scale of 0 to 10, with each increment representing a bifold increase of the smoke emitted.

Figure Twelve -The AS 1530 Pt III test Apparatus



AS 1530 Part II is a “Strip Flame” test in which a small 535mm x 75mm piece (‘strip’) of material is subjected to flame generated by a standard quantity of alcohol, and the burning behaviour observed. An empirical “Flammability Index” is calculated from measurements of how quickly or to what extent the specimen burns, and the heat generated. This “Flammability Index” is expressed on a scale of zero (low risk) to 100 (high risk).

The results of AS 1530 part II and part III flammability tests for the Polyfab Ranges are summarised in Table Three, and copies of the test certificates are available on request.

Table Three – Results of AS 1530 Flammability Tests for Polyfab Shadecloth

Polyfab Brand	Spread of Flame Index (AS 1530 part III) Scale: 0 (low) to 10 (high)	Smoke Developed Index (AS 1530 part III) Scale: 0 (low) to 10 (high)	Flammability Index (As 1530 part II) Scale: 0 (low) to 100 (high)
Parasol	8	5	19
PolyFX	8	5	9
Comshade	7	4	18
Comshade FR	8	6	1
Comshade Xtra	8	5	14
Architec 400	8	5	18

Fire Regulations for Shade Structures

The NCC Volume One classifies buildings according to their intended use. Class Two through Class Nine buildings include all possible types of high density and commercial buildings including multiple occupancy units, boarding houses, nursing homes, schools, offices, shopping complexes, etc. Flammability regulations for these buildings are set out in this NCC Volume.

Following an amendment made to this code in 2018, shadesails that are attached to Classes Two through Nine buildings are classified as an ‘Ancillary Element’, and are required to be ‘non-combustible’ unless located at ground level. In which latter case, the spread of Flame Index must not exceed a value of 9; and The Smoke Developed Index a value of 8 respectively.

All the Polyfab shadecloth ranges comply with this requirement. However, Comshade FR has a very low Flammability Index. As such it is the best performing product in the context of being the most difficult to ignite, and the least likely to sustain combustion once the ignition source is removed.

The issue of compliance for shadesails located on the upper levels of buildings is problematic. ‘Non-combustibility’ is defined by the results of test method AS 1530 part I; and because of the nature of the sample to be tested (i.e. a cylinder of height 50mm, and diameter 45mm), it is simply not possible to test shadecloth using this procedure. Even if it was possible, the stringency of the pass / fail criterion would make it unlikely that any HDPE knitted product would comply.

In summary, there is no issue if the shadesail is attached to the soffit of class Two to Nine buildings just above ground level.

Similarly, A stand-alone tensioned membrane would be classified as Class 10a “non-habitable building”, and like single, detached domestic dwellings (Class One buildings), are not subject to any specific flammability regulatory requirement.

RELEVANT PROPERTIES, TEST METHODS AND THEIR SIGNIFICANCE

Yarn Characteristics

Since the characteristics of the finished cloth are significantly dependent on the properties of the base polypropylene yarn, it is instructive to examine them in some detail. Ethylene is comprised of Carbon and Hydrogen molecules, and has the simple molecular structure shown in **Figure Thirteen**. This becomes a polymer when the basic structure between the dashed lines is linked together repetitively in continuous chain. Low density (LDPE) and high density polyethylene (HDPE) are almost identical except that HDPE is more linear in structure, with less branching of the polymer chains, which results in better tensile properties. The characteristics of polyethylene yarn are shown in **Table Four**.

Figure Thirteen - Molecular structure of Polyethylene

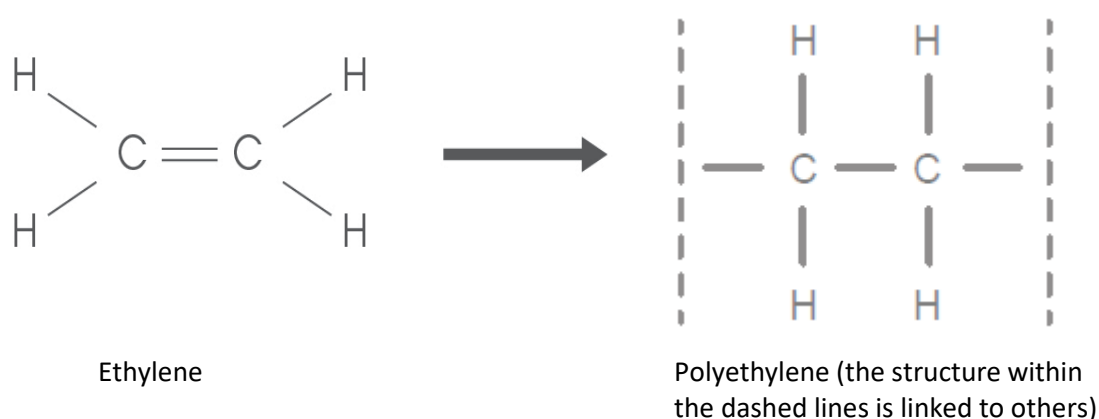


Table Four – Properties of Polyethylene Yarn

Property	Value
Tenacity (grams/denier)	4.0 to 5.5
Melting Point (°Celsius)	110 to 120
Specific Gravity	0.93 to 0.96
Moisture Regain (%)	<0.01
Limiting Oxygen Index	17

Tenacity is a measure of basic tensile strength, which during the yarn's production is maximised by annealing or strain hardening. Specific gravity is the yarn's density relative to water; and moisture regain the amount of water it absorbs when initially dry, then exposed to 65% humidity at 20°C. The respective values of these parameters mean that polyethylene is lighter than water, which gives the benefit of a high strength to weight ratio; and does not absorb liquid, a real plus for stain resistance.

Polyethylene can be broken down by the action of Ultra-Violet light, and without appropriate UV stabilisers, polyethylene yarn would degrade rather quickly. The stabiliser or inhibitor in fact acts as a sacrificial component, like the way zinc is added to provide corrosion resistance in galvanised iron.

Polyethylene is relatively chemically inert, but unfortunately the UV stabilisers are not; and are particularly affected by the group of elements known as halogens (e.g. Chlorine, Bromine, Iodine, Fluorine) which are highly reactive diatomic molecules in their natural form. This is why

concentrated bleach (a chlorine based compound) is not recommended for cleaning, and it is prudent to limit warranty for shade structures suspended over swimming pools.

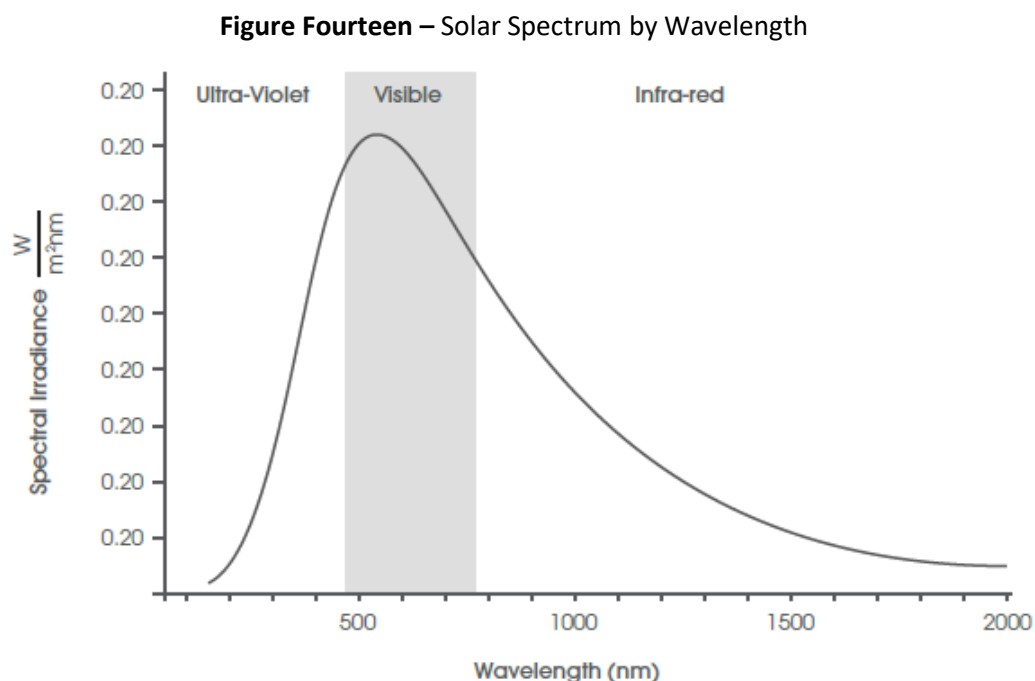
The “Limiting Oxygen Index” (LOI) is the minimum percentage of oxygen that must be present in the atmosphere surrounding the yarn for it to ignite and burn. The proportion of oxygen in the air is normally 21%, and therefore polyethylene, which has an LOI below this level, ignites fairly readily. However, because of its low melting point, the yarn forms molten droplets that fall away when exposed to flame, dispersing the feed source. In practical terms, this limits the flammability hazard of horizontally suspended shadecloth.

Flammability characteristics can be altered by the addition of flame retardants, which unfortunately can be halogen based, and the necessity to use high levels of these to achieve efficacy, not only detrimentally affects stabilisers, but can also have a significant negative impact on the physical and mechanical properties of the yarn.

For this reason, the Polyfab ranges of shadecloth (with the exception of Comshade FR) are not knitted from yarns that have high levels of halogens added, but from those that have just sufficient to meet the National Construction Code Regulatory requirements (**refer Table Three**). Recent research has led to the development of non-halogenated, UV stable, amine based flame retardants, which are effective in low concentrations, and do not affect stabilisers. Once these are field proven, the Polyfab commercial ranges will be FR treated accordingly.

Shade Factor, UVR Block and PAR

To understand the function of shadecloth and the meaning of commonly used terms, one must appreciate the distribution of Solar spectral irradiance by wavelength. **Figure Fourteen** is a smoothed curve of this irradiance as experienced just above the atmosphere, and shows the wavelengths divided into the Ultraviolet, Visible and Infra-red spectra.



Visible light, ranging in wavelength between 400nm and 770nm (nanometres or one millionth of a millimetre), represents only a small proportion of the sun’s energy reaching the earth’s surface. Just below this band of wavelengths is the Ultra-Violet spectrum, and although representing less than five percent of the total impinging radiation, it is biologically the most damaging, especially UVB (of wavelength between 290nm and 320nm).

Hence, for good reason, the Australian Standard for Knitted and Woven Shade Fabrics (AS 4174:2018) distinguishes between these radiation bands in penetration tests on shade cloth. The “Shade Factor” (sometimes reported as “Shade Co-efficient”) is defined as “the percentage of normally incident (i.e. impinging at 90%) radiation between 290nm and 770nm (i.e. both Ultra-Violet and visible light) not transmitted through the material”.

The “UVR Block” is the percentage of Ultra-Violet Radiation, of wavelengths between 290nm and 400nm (i.e. Both UVA and UVB) that is not transmitted. In terms of assessing the degree of protection offered against sunburn, it is the single most important determinant of shade cloth performance.

For nearly 25 years, the industry used “UVR-block” as the quantitative measure of the degree of protection offered. However, the revised standard AS 4174:2018 introduced a new term “Ultra-Violet Effectiveness” (UVE) to replace this former industry guideline. Both are a measure of the ability of the fabric to block ultraviolet radiation and are expressed as a percentage of that passing through it. The two values are highly correlated, essentially measuring the same UV wavelengths, but the UVE calculation is weighted towards those at the lower end of the spectrum that are more biologically damaging.

Not all Polyfab brands have been re-tested to the new standard, and it will take some time to do so, but in the interim it can be assumed that UVR-block is a reasonable approximation of Measured UVE which is different from the “Calculated UVE” values listed in **Table Six**. It is the practice of the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) to deduct the Standard Deviation from the measured UVE in the reporting of its test results.

ARPANSA also require that the following disclaimer be published when its test results are quoted:-
“When shade fabric is used for purposes such as shade structures for human protection, the ultraviolet effectiveness (UVE) may not be an accurate guide to the provided, and may be less than the measured value due to factors including variations in design, stretching of the fabric, the distance of the fabric from the persons, the direction of sunlight, and the physical location of the persons within the shade structure (e.g. at the edge or at the centre)”

The standard AS 4174:2018 co-relates the value of UVE to a “Protection Category” as reproduced in **Table Five**, which has been converted to the more commonly known Ultra-Violet Protection Factor (UPF). With the exception of those listed otherwise in **Table Six**, all Polyfab Human Protection ranges are categorised as “Very Effective” or “Most Effective”.

Table Five– Shade cloth Protection Categories determined by AS 4174:2018

Value of UVE (%)	Protection Category	Equivalent UPF
80.0% to 90.9%	Effective	5 to 10
91.0% to 94.9%	Very Effective	10 to 20
95.0%+	Most Effective	20+

UPF is a directly comparable number to the more familiar SPF or “Sun Protection Factor”, which is applicable to sunscreen lotions, and is a number that generally ranges between 0 and 50. It is a measure of the duration of exposure required to accumulate a sunburning dose of radiation relative to that if no protection was applied. For example, an SPF 30 product will allow only 1/30th of the sunburning dose through the UV filter, and it will therefore take thirty times as long for sunburn to occur. Thus, if it takes five minutes in the noon sun for skin damage to occur without protection, the same degree of damage will occur over 150 minutes, or two and a half hours, if a 30+ sunscreen is applied.

The “PAR transmitted”, (i.e. Photosynthetically Active Radiation) is effectively the proportion of visible light passing through the material (i.e. 400nm to 770nm). It is a measure of how much effective light would reach plant life shaded by the cloth.

The standard also specifies “Cover Factor”, which although determined by the degree of radiation penetration of the specific wavelength 350nm, is designed to be a measure of the percentage area of the cloth covered by yarns and fibre, or density, rather than shading effectiveness.

UPF can be estimated by dividing the fraction of UV transmitted into a hundred and is usually rounded up or down to the nearest half decile (i.e. 5, 10, 15, 20 etc). When converted to UPF, the upper and lower values for the Carbon Black UVR Block tests quoted above, correspond to 10 and 20 respectively, an error of $\pm 30\%$ on the average UPF of 15.

Because of the degree of measurement error, it is conceptually flawed logic to draw conclusions based on small relative differences in UVR Block; or even on the relative degree of protection offered by one particular colour relative to another, based on the comparison of test results.

Nonetheless, the results do vary according to colour pigment used in the cloth. While as a general rule, darker colours (particularly black) are better UV absorbers than lighter ones, the degree of variation implied is not really an indication of colour efficiency, but much more likely the manifestation of measurement error.

The UPF values for shadecloth may seem relatively low, compared to the advertised SPF values of sunscreen, and the recommendations of Cancer Councils for clothing. But these have to be taken in the context of what is technically possible to achieve in shadecloth, and other benefits in terms of visible light transmission, ventilation, and heat transfer.

The expectation that a shadecloth structure by itself is sufficient to provide total protection is misconceived, particularly if it is a tensioned type (as most are), which may open up the interstices in the cloth, and also given the amount of reflected radiation likely to bypass any open form. Nonetheless, shadecloth, in conjunction with other measures, such as wearing a hat or sunscreen, has a cumulative protective effect, and certainly is as good as, or better than the protection often offered by natural foliage.

Table Six (a) – Ultra Violet transmission Characteristics for Polyfab Architec 400

Range and colour	Cover Factor	Shade Factor	UVR Block	UVE	UPF(1)	PAR	Protection Category AS 4174:2018
Architect 400:-							
Black	96.6%	97.2%	96.5%	95%	29	2.8%	Most Effective
Navy Blue	95.2%	92.4%	94.3%	94%	18	8.5%	Very Effective
Cappuccino	96.1%	86.6%	95.8%	95%	24	14.2%	Most Effective
Midnight Green	94.7%	93.1%	94.6%	93%	19	7.4%	Very Effective
Lemon	91.4%	69.1%	91.4%	89%	12	33.7%	Effective
Lime	95.3%	88.0%	95.3%	94%	21	12.7%	Very Effective
Aquamarine	95.2%	91.0%	94.5%	93%	18	10.4%	Very Effective
Orange	94.7%	84.7%	94.8%	93%	19	14.4%	Very Effective
Grape	87.3%	77.6%	87.0%	88%	8	19.8%	Effective
Porcelain	93.5%	73.0%	92.3%	91%	13	31.3%	Very Effective
Slate	95.3%	95.0%	95.2%	94%	21	5.0%	Very Effective
Turquoise	92.6%	84.7%	91.0%	90%	11	17.8%	Effective

Table Six (b)– Ultra Violet transmission Characteristics for Polyfab Parasol

Range and colour	Cover Factor	Shade Factor	UVR Block	UVE	UPF(1)	PAR	Protection Category AS 4174:2018
Parasol:-							
Gun Metal	95.3%	93.5%	95.1%	94%	20	6.4%	Most Effective
Charcoal(2)	93.1%	93.6%	93.0%	94%	14	6.2%	Very Effective
Carbon Black	94.8%	95.4%	94.7%	90%	19	4.4%	Effective
Navy	95.2%	90.9%	93.8%	93%	16	10.0%	Very Effective
Sky Blue	93.9%	91.0%	93.6%	92%	16	9.0%	Very Effective
Forest Green	93.5%	92.5%	93.2%	91%	15	7.6%	Very Effective
Ocean Blue	94.5%	87.4%	93.2%	92%	15	15.5%	Very Effective
Harvest	93.1%	84.5%	92.7%	92%	14	16.2%	Very Effective
Steel Grey	93.3%	85.1%	92.7%	92%	14	15.2%	Very Effective
Yellow	92.4%	74.1%	92.3%	91%	13	27.6%	Very Effective
Terracotta	91.6%	86.5%	92.2%	92%	13	12.7%	Very Effective
Red	91.8%	81.6%	92.1%	92%	13	16.5%	Very Effective
Ivory	93.0%	70.4%	91.5%	92%	12	34.3%	Very Effective
Beach Sand	91.5%	80.2%	91.0%	90%	11	20.8%	Effective
Turquoise	88.9%	78.4%	87.1%	87%	9	24.7%	Effective

Notes: (1) Approximate values only. Converted from UVR Block.

(2) Average of two sets of test results 5/3/18 and 14/3/18

Table Six (c)– Ultra Violet transmission Characteristics for Polyfab Comshade

Range and colour	Cover Factor	Shade Factor	UVR Block	UVE	UPF(1)	PAR	Protection Category AS 4174:2018
Comshade:-							
Navy Blue	97%	95.8%	97.1%	96%	35	4.7%	Most Effective
Midnight Green	96%	94.4%	96.4%	95%	28	6.1%	Most Effective
Slate	97%	96.7%	97.0%	96%	33	3.3%	Most Effective
Black	95%	95.4%	95.6%	94%	23	4.6%	Very Effective
Merlot	95%	93.9%	95.7%	95%	23	5.8%	Most Effective
Porcelain	95%	79.8%	94.6%	94%	19	23.2%	Very Effective
Bluegum	96%	92.9%	96.3%	94%	27	7.3%	Very Effective
Café Noir	96%	96.0%	96.2%	95%	26	4.0%	Most Effective
Aquamarine	93%	85.4%	91.7%	91%	12	16.8%	Very Effective
Rust	93%	87.4%	93.3%	92%	15	11.8%	Very Effective
Sandstone	96%	88.0%	96.2%	95	26	12.5%	Most Effective
Cappucino	95%	89.5%	95.6%	93%	23	10.7%	Very Effective
Light Green	95%	89.1%	95.3%	94	21	11.7%	Very Effective
Copper	94%	88.3%	94.3%	93%	18	11.1%	Very Effective
Lemon	94%	74.6%	94.7%	93%	19	27.6%	Very Effective
Platinum	94%	94.1%	94.2%	93%	26	6.0%	Very Effective

Table Six (d) – Ultra Violet transmission Characteristics for Polyfab PolyFX

Range and colour	Cover Factor	Shade Factor	UVR Block	UVE	UPF(1)	PAR	Protection Category AS 4174:2018
PolyFX:-							
Navy Blue	95%	93.4%	94.8%	94%	30	7.1%	Very Effective
Café Noir	96%	95.9%	96.4%	95%	28	4.0%	Most Effective
Black	96%	96.6%	97.0%	96%	33	3.4%	Most Effective
Lemon	93%	72.2%	93.7%	92%	16	30.3%	Very Effective
Merlot	92%	90.6%	92.8%	92%	14	9.0%	Very effective
Bluegum	95%	91.7%	95.5%	94%	22	8.6%	Very Effective
Slate	95%	94.2%	95.2%	94	21	5.8%	Very Effective
Lime	92%	79.2%	92.7%	92%	14	22.3%	Very Effective
Aquamarine	95%	90.6%	94.7%	94%	19	10.7%	Very Effective
Cappucino	93%	87.1%	93.8%	93%	16	13.2%	Very Effective
Porcelain	92%	73.6%	91.2%	90%	11	30.1%	Effective
Rust	92.0%	86.0%	92.8%	92%	14	13.2%	Very Effective
Grape	90%	79.1%	90.2%	91%	10	18.5%	Very Effective
Orange	94%	83.9%	94.7%	93%	19	15.4%	Very Effective
Sandstone	95%	87.7%	95.3%	94%	21	13.0%	Very Effective
Copper	94%	87.2%	94.6%	93%	19	12.1%	Very Effective
Platinum	88%	88.4%	88.6%	87%	9	11.7	Effective

Table Six (e)– Ultra Violet transmission Characteristics for Polyfab Comshade Xtra

Range and colour	Cover Factor	Shade Factor	UVR Block	UPF(1)	PAR	Protection Category AS 4174:2018
Comshade Xtra:-						
Charcoal	99.7%	99.5%	99.7%	50+	0.5%	Most Effective
Midnight Green	99.6%	98.4%	99.5%	50+	2.0%	Most Effective
Navy Blue	99.5%	98.8%	99.4%	50+	1.4%	Most Effective
Jade	99.1%	98.5%	99.0%	50+	1.8%	Most Effective
Porcelain	99.3%	83.5%	98.9%	50+	19.4%	Most Effective
Ice	98.9%	89.7%	98.6%	50+	11.6%	Most Effective
Bronze	98.4%	92.1%	98.5%	50+	7.1%	Most Effective
Mushroom	98.3%	97.4%	98.3%	50+	2.6%	Most Effective
Aquamarine	98.7%	90.8%	97.1%	34	11.3%	Most Effective
Silver	95.1%	85.5%	94.9%	50+	15.1%	Very Effective

Like all tests, those that determine the shading performance factors are subject to measurement error, and hence the reported results are the average of ten samples taken from a single metre of cloth. The word ‘error’ here is used in its scientific sense, and does not mean ‘mistake’, but differences in test measurements, which can vary by several percentage points, due to variations in the knit profile across the roll. Knitted cloth has an open, loose structure, and small changes in say, yarn tension during manufacture, can have an inordinate effect on the size of the interstices of the finished material, which in turn affect the calculated UV protection factors. This is further exacerbated by variation between production batches

For example, two separate tests on the same colour (Polyfab Parasol Black) undertaken on different dates, yielded results of UVR Block that varied by 3.7% (Refer **Table Seven**). Note that there is no correlation between the variance in UVR Block and that of weight, which itself is the result of vagaries in the knitting process. The distorting effect of this error becomes very obvious if one is converting the results to an equivalent Ultra Violet Protection Factor (UPF), which is common practice amongst some specifiers.

Table Seven – Variation in test results for Parasol Carbon Black

Date of test (each of ten samples)	Sample weight (gsm)	Cover Factor	Shade Factor	UVR Block	UVE	UPF ⁽¹⁾	PAR
5/3/2018	306	91.3%	91.8%	91.3%	91.1%	11	8.0%
14/3/2018	286	94.8%	95.4%	94.7%	94.6%	19	4.4%
Average	296	93.1%	93.6%	93.0%	92.9%	14	6.2%

Thermal Properties

Testing to determine the heat (i.e. Infra-red) transmission characteristics have been undertaken by the CSIRO. Various colour samples of Architect 400, Parasol and Covershade were tested. **Table Eight** shows the average Solar Transmission Values for these colours, which are graphed by range in **Figures Fifteen (a),(b), and (c)**.

Figure Fifteen (a) – Solar Transmission characteristics for Architec 400

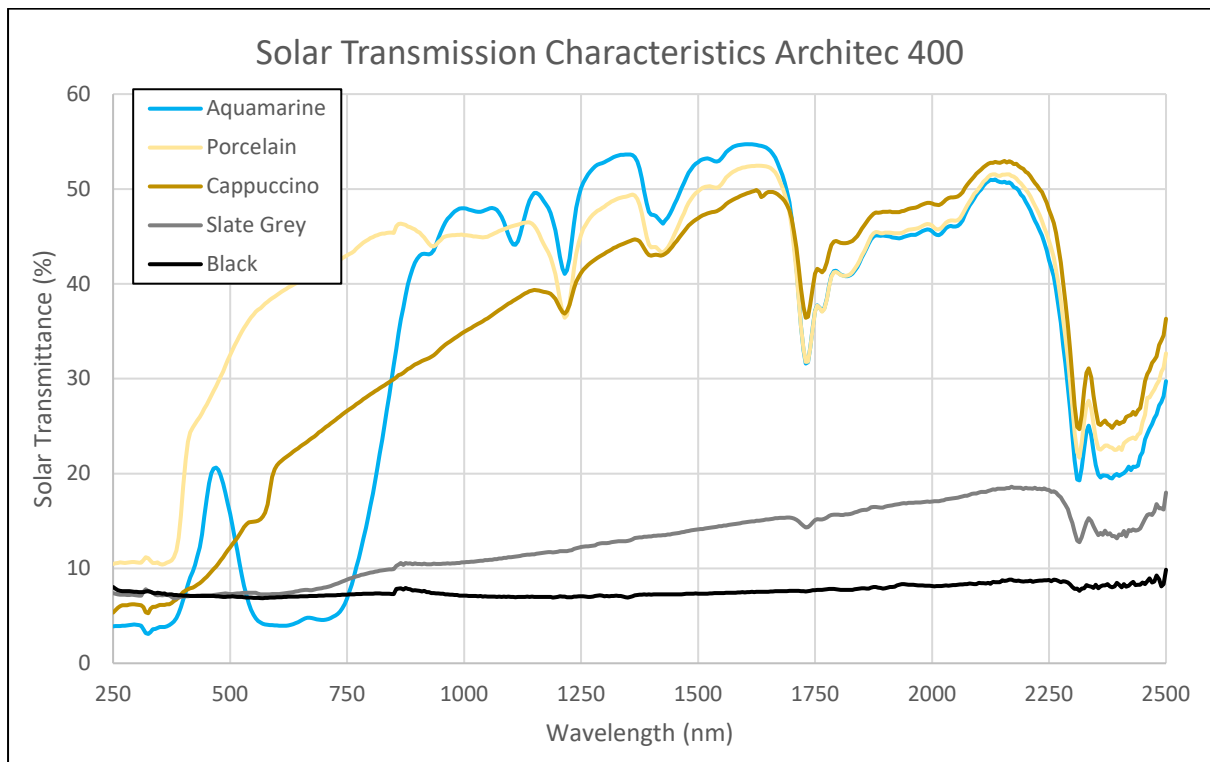


Figure Fifteen (b)- Solar Transmission Characteristics for Parasol

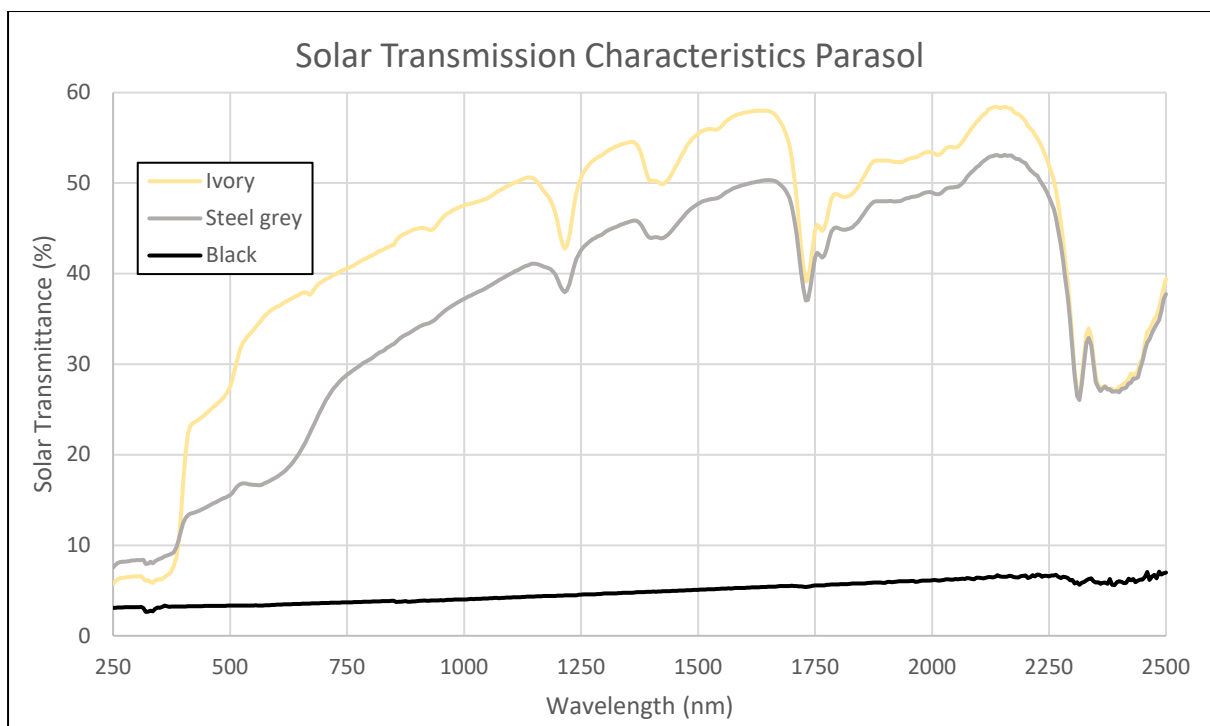
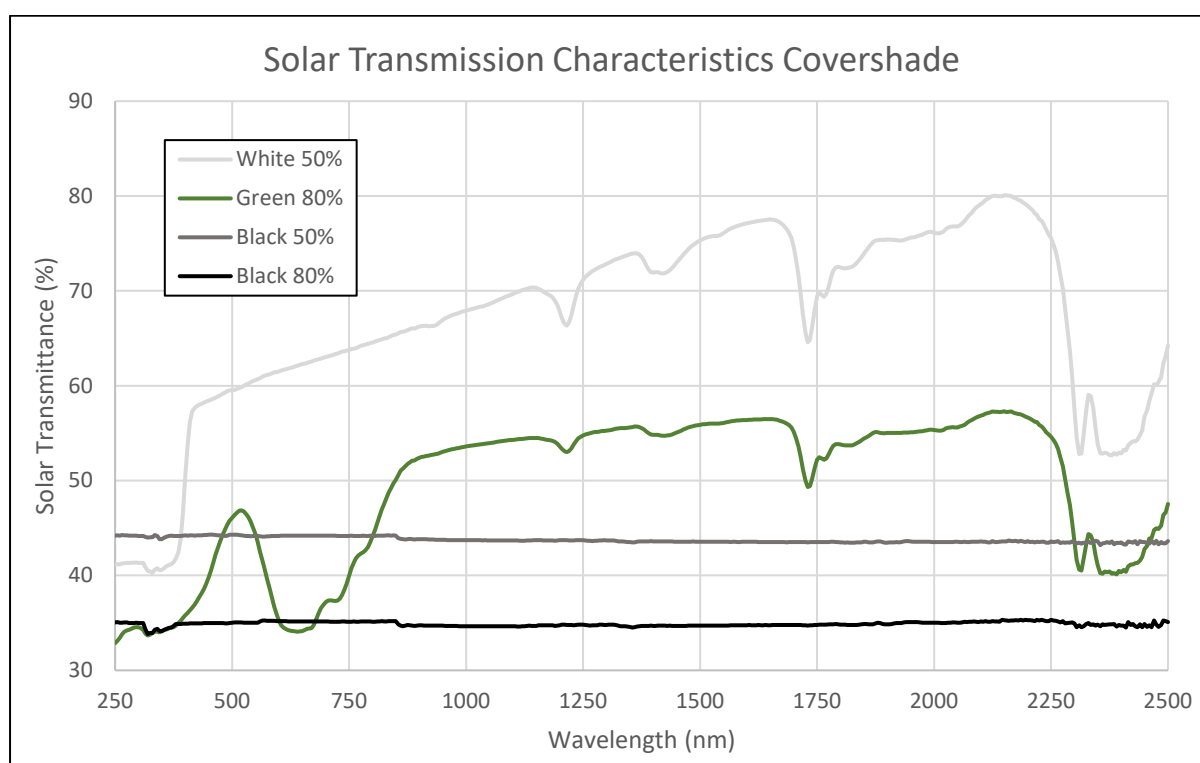


Figure Fifteen (c) – Solar Transmission Characteristics for Covershade



Intuitively, one would expect that the darker colours would have a higher level of heat absorption, and therefore heat transmitted than the lighter ones, and this proved to be the case for all fabrics tested.

Based on the comparative Architec 400 and Parasol results, the type of knit matrix does not seem to be as significant an influence as colour, which implies that the addition of tape to the monofilament does not have as marked an effect on infra-red transmission, as it does on Ultra-Violet.

However, the comparative results for Covershade show that progressively, the more open the matrix, the higher the Solar Transmission. Nonetheless, even a very open matrix, such as Covershade 50%, reflects or absorbs 56% of the impinging solar heat. Parasol and Architect 400 are far more effective, allowing only 3.8% and 7.2% respectively of solar heat to be transmitted through the material.

Table Eight –Weighted Solar Transmission Values

Product	Colours tested								
	Black	Slate Grey	Steel Grey	Green	Porcelain	Ivory	Cappuccino	Aquamarine	White
Architec 400	7.2%	9.4%			34.1%		25.3%	22.4%	
Parasol	3.8%		26.7%			38.1%			
Covershade 80%	34.7%			44.5%					
Covershade 50%	43.7%								63.1%

(Note: Slate and Steel grey; Porcelain and Ivory are respectively similar in colour)

Physical Properties Specified by AS 4174:2018

AS 4174 specifies minimum strength requirements for shade cloth. The test methods however, are different for knitted and woven cloth, and caution should therefore be exercised when comparing test results for different brand products. All Polyfab product is knitted.

AS 4174 stipulates that knitted shade cloth be tested to or AS 2001.2.19, which measures bursting force utilising a steel ball, with result at failure expressed as a force (Newtons). The standard provides a strength classification based on the results of this test, as reproduced in **Table Nine**

Table Nine – Classification of the strength of Knitted Shade cloth by Bursting Force
(as stipulated by AS 4174:2018)

Designation of Shade Fabric	Minimum Breaking Strength (N)
Medium Cover	600
Heavy Cover	750
Extra-Heavy Cover	900
Ultra-heavy Cover	1200

All of the Polyfab ranges exceed the requirement for “Ultra-Heavy Cover” (refer **Table one** for a summary of test results), and therefore comply with AS 4174:2018 in this respect. Although not specified by this standard, the ranges have also had tear and tensile tests undertaken.

Ultimate tensile strength, or Breaking Force, can be tested by one of two methods in AS 2001.2.3 – either Method C “Cut Strip” or Method B “Grab Test”. All Polyfab fabrics have been tested using Method C, and the results are expressed as Breaking Force (Newtons / 50 mm) and extension at break (%). The breaking force of the material is considerably more than its tear strength.

Simplistically, the former is a measure of the ultimate strength of the knitted yarn matrix, and the latter of how difficult the matrix is to separate. Tear strength is tested using AS 2001.2.10, in which a sample is cut partially through, and the force required to initiate and continue tearing measured. The results for the for the Polyfab Ranges are shown in **Table One**. AS 4174:2018 has no minimum requirement for either of these parameters.

Resistance to degradation by light

AS 4174:2018 specifies that shade cloth retain at least 80% of its initial breaking strength after exposure to an intense UV radiation source, namely 500-Watt MBTF lamp, for 2000 hours (tested to AS 2001.4.21). Not all Polyfab ranges have been tested in this way, but field use in harsh environments for over twenty-five years has demonstrated the longevity and stability of these fabrics. However, of samples ‘Parasol’ shade cloth have been tested in this standard, and strength loss determined, as summarised in **Table ten**

Table Ten – Percent increment (+) or decrement (–) in strength after UV exposure (Polyfab Parasol)

Tensile Strength AS 2001.2.3.2	Bursting Force AS 2001.2.19	Tear Strength AS 2001.2.10
Warp: +6.3% Weft: –5.3%	Warp: +12.2% n/a	Warp: –2.2% Weft: +11.4%

Paradoxically, HDPE yarn can experience some increase in strength under the action of UV radiation, but an increment in one direction, and a decrement in the other, as implied by the results in **TABLE Ten**, can be discounted as physically improbable. Based on the standard deviation of these results, a statistical analysis (Student 't' test) shows them to be 'not significant', and therefore technically should be discounted. Thus, there is no evidence of strength degradation due to UV exposure in Polyfab Parasol under the conditions of the test, estimated (very roughly) to be equivalent to six to eight months of field life.

AS4174:2018 also specifies that samples similarly exposed to the same UV test do not exhibit a colour change of less than three on the grey scales, as determined by the procedures described in AS 2001.4.A02. The grey scales consist of five pairs of grey coloured material numbered one to five. The pair numbered 'one' shows the greatest contrast between the shades; and the pair numbered 'five' has no chromatic difference between them. The test procedure is to rate similarly the relative contrast between unexposed and exposed colour samples.

Colour samples of the Polyfab ranges were exposed for 2000hrs to a UVA-340 lamp under the ASTM D7238 standard and then rated to the grey scales following the AS 2001.4.A02 procedures. The results are listed in **Table Eleven** and show that the samples displayed barely discernible colour change after UV exposure, and exceeded the minimum requirements of AS4174:2018 in this context.

Table Eleven – Extent of colour change after 2000 hours of UV exposure

Product	Colour	Grey Scale Rating	Hue change
Architec 400	Lime	4-5	None
	Lemon	4-5	Yellower
Comshade	Rust	4.5	Redder
	Cappuccino	4-5	Bluer
Comshade Xtra	Bronze	4-5	None
	Navy Blue	4.5	Bluer
Polyfx	Sandstone	4-5	Redder
	Copper	4-5	Redder
	Merlot	4-5	None
Parasol	Red	4-5	Redder
	Sky Blue	4-5	None

Chemical Properties

A summary of the chemical resistance of HDPE is contained in **APPENDIX D**. This is general information only, since colour pigment may be affected by a particular chemical, even though HDPE itself may not.

High density Polyethylene is resistant to most acids and alkalis, and fungal attack. It does not absorb water, which is a significant factor in resisting staining and inhibiting mildew growth. HDPE has only a weak resistance to halogens, such as chlorine; and halogenated hydrocarbons. It is also affected by strong oxidising agents, such as hydrogen peroxide; Chlorox (bleach); and some alcohols.

Using such chemicals for cleaning should be avoided. Dirt or mildew is usually the result of contaminants caught in the interstices of the cloth and should be easily removed using a high pressure hose. For stubborn stains, scrub with a brush and a weak solution of household detergent.

GLOSSARY OF TECHNICAL TERMS

Biaxial Loading	Load applied in both warp and weft directions at the same time
Catenary	The curve formed by a cable under tension and constrained by the reactive stress of the shade cloth.
Cover Factor	A measure of the surface area of the cloth that is yarns and fibre
Compensation	An allowance in the design of the theoretical finished surface profile of a tension membrane account for the strain associated with initial pre-stress
Creep	A time dependent increase in strain under constant applied load.
Denier	A measure of weight per length of a yarn namely, grams/ 9,000 metres. Refer also Tex, D'Tex and Metric Number. These can be compared by careful conversion of the units used, which are usually rounded. For example 1100 denier is equivalent to 120 Tex, 1200 D'Tex and Metric Number 8.
D'Tex	A measure of weight per length of a yarn namely, grams/ 10,000 metres. Refer also Tex, Denier and Metric Number.
Elastic Modulus	The relationship between applied stress (a force) and resultant strain (a deflection).
Flammability Index (AS 1530 pt II)	A measure to what extent the test specimen burns and the heat generated, ranging from 0 (low risk) to 100 (high risk).
Flame Retardant or FR	A term used to describe yarns or fabrics that have had their inherent burning characteristics altered by addition of chemical suppressants
Limiting Oxygen Index	The minimum percentage of oxygen that must be present for an object to ignite and burn. A value less than 21 means the object ignites and burns readily.
Metric Number	A ratio of yarn length to weight, expressed as Kilometres / Kilogram. Widely used to differentiate thread size. Refer also Tex, D'Tex and Denier
Newtons	A measure of force, equivalent to a kilogram force, which is mass in kilograms time the acceleration due to gravity. The loading along the periphery of the shade cloth is often expressed as Kilonewtons per metre length (kN/m).
PAR Transmitted	(i.e. Photosynthetically Active Radiation) is effectively the proportion of visible light passing through the material (i.e 400 nm to 770 nm). It is a measure of how much effective light would reach plants shaded by the cloth.

Polyolefin	A commonly used chemical nomenclature that describes a family of similar hydrocarbon polymers, the most well known being polyethylene and polypropylene.
PTFE	An abbreviation of the chemical compound polytetrafluoroethylene, and commonly used to describe thread constructed from it.
Shade Factor (Shade Co-efficient)	The percentage of ultra violet and visible light, i.e. radiation of wavelengths between 290nm and 770nm not transmitted through shade cloth
Smoke Developed Index (AS 1530 pt III)	A measure of the smoke emitted, on a scale of 0 (low risk) to 10 (high risk)
Specific Gravity	The ratio of an object's density relative to water. A value less than one means the object is lighter than water
Spread of Flame Index (AS 1530 pt III)	A measure of how quickly a fire propagates, expressed on a scale of 0 (low risk) to 10 (high risk).
Stiffness	A measure of the relative propensity of a fabric to deform under load.
Tenacity	A measure of a yarn's tensile strength.
Tex	A measure of weight per length of a yarn namely, grams/ 1,000 metres. Refer also D'Tex, Denier and Metric Number.
Uniaxial Loading	Load in one direction only.
UPF (Ultra-violet Protection Factor)	A measure of the duration of exposure required to accumulate a sunburning dose of radiation relative to that if no protection is available
UVR Block	The percentage of Ultra-Violet Radiation, of wavelengths between 290nm and 400nm, not transmitted through shade cloth
UVE (Ultra Violet Effectiveness)	A measure of the ability of fabric to block ultraviolet radiation. It is similar to UVR Block, but with a weighting in the measurement towards the wavelengths that are more biologically damaging.
Warp	Longitudinal direction along a roll of fabric. Also known as the "machine Direction".
Weft	Horizontal direction across a roll of fabric. Also known as the "Fill" or "cross-direction".

APPENDIX A Formal Warranty

POLYFAB PRODUCT WARRANTY Shadecloth for Human Protection

The Nolan Group warrants that the Polyfab brands of knitted shadecloth, namely Parasol, Polyfx, Comshade, Comshade FR, Comshade Xtra, and Architec 400 are specifically designed to be used as shadecloth for human protection, and are guaranteed to be supplied free of defects.

‘Free of Defects’ means that the products meet their published descriptions and technical specifications, and are homogeneous in appearance after allowance for minor variance, such as tie knots or twisted yarn that do not affect physical properties, but are the unavoidable result of the knitting process. The specifications for all products, including overall weight per square metre, have a tolerance of $\pm 10\%$ on published values, due to the variances inherent in production and scientific error in the methods of test.

The Nolan Group further warrants that the products will perform satisfactorily when used in its design context in the temperate climatic conditions experienced throughout Australia.

‘Satisfactorily’ means with continued but gradually diminished utility over its expected life, due to the unavoidable effects of Ultra-Violet Radiation and Weathering, such as colour variation, strength loss, and dimensional change. The measure of acceptable deterioration in this context is determined by Australian Standard AS 4174 – 2018 “Knitted and Woven Fabrics”, Section 3.3 “Resistance to degradation by light”. Extreme climatic conditions, particularly high temperature and humidity may accelerate this inevitable product degradation.

‘Design Context’ means the products are fabricated and installed to the certified design and specification of a licensed Structural Engineer; or according to the Standard Details available on the website www.polyfab.com.au, certified for the particular location by Izzat Consulting Engineers; and the product is maintained under the required tension over its expected life, without excessive stretching or overloading during installation.

‘Expected Life’ is at least the period covered by warranty, provided the product is installed correctly, and cleaned and maintained as recommended. The warranty period for strength loss is TEN YEARS from the date of installation for Parasol; TWELVE YEARS for Polyfx, and Comshade; and FIFTEEN YEARS for Comshade Xtra and Architec 400.

The warranty period for colour change, in excess of that allowed under Australian Standard AS 4174-2018, is TWO YEARS for all products.

The warranty specifically excludes mechanical fatigue or damage due to wind load, and damage attributable to faulty design or installation, such as abrasion by sheathed cables, or tear caused by undue concentration of stress at supports; to storm or cyclone events, including hail loading; and to vandalism.

The Nolan Group’s liability under the warranty is limited to replacement of the material only; or its equivalent cost, both options with a discount on value for the time the fabric has been in place, on a pro-rata basis as follows:-

- | | |
|---|--------------|
| • The first third of the warranty period | Nil Discount |
| • The second third of the warranty period | 50% Discount |
| • The final third of the warranty period | 75% Discount |

Liability for any consequential loss, including labour and installation, is expressly excluded.

In the event of a claim, proof of purchase must be provided. In the event of a dispute, the determination of the manufacturer or recognised industry association is the sole basis on which replacement or refund is made.

This limited warranty shall under no circumstances override legal guarantees that may be required under the Consumer Act. The warranty is not transferrable and applies only to the original purchaser.

APPENDIX B Care, Cleaning and Maintenance instructions

Heavy Duty Shadecloth is an Industrial Textile made from High Density Polyethylene (HDPE) yarn, which has Ultra-Violet Stabilisers and colour pigments incorporated into the structure.

HDPE is resistant to most acids and alkalis, and fungal attack. It does not absorb water, which is a significant factor in resisting staining and inhibiting mildew growth. These characteristics make HDPE ideal as a base yarn for a lightweight, strong shadecloth. However, it has only a weak resistance to halogens, such as chlorine; and halogenated hydro-carbons. It is also affected by strong oxidising agents, such as hydrogen peroxide; chlorox (bleach); and some alcohols.

Using such chemicals for cleaning should be avoided. Dirt or mildew is usually the result of contaminants caught in the interstices of the cloth, and should be easily removed using a high pressure hose, which should be used judiciously, to avoid physical damage to the yarns and thread. For stubborn stains, scrub with a brush and a weak solution of household detergent.

Careful consideration should be given to the environment in which Polyfab shadecloth is used. For example, when suspended over a swimming pool, it will be exposed to chlorine emissions, and its effective life may be reduced.

The shadesail should only be installed by a company or individual that has appropriate experience and accreditation from the Specialty Textiles Association, Lightweight Structures Association of Australia, or similar body; to the design and specification of a licensed civil engineer.

It is important that the shadesail remains under adequate tension to minimise the possibility of fatigue cracking due to wind-flap. Re-tensioning will be necessary if the shadesail becomes loose and sloppy.

APPENDIX C1 Derivation of the Elastic Parameters for shade cloth

Elastic Theory

The general relationship between stress and strain (Hooke's law) for knitted shade cloth, assumed to have different elastic response in each direction and negligible shear stress, can be expressed in two dimensional matrix form as follows:-

$$\begin{bmatrix} \sigma_{ww} \\ \sigma_{ff} \end{bmatrix} = \begin{bmatrix} E_{ww} & E_{wwff} \\ E_{ffww} & E_{ff} \end{bmatrix} \cdot \begin{bmatrix} \epsilon_{ww} \\ \epsilon_{ff} \end{bmatrix}$$

where σ_{ww} and σ_{ff} are the stresses; ϵ_{ww} and ϵ_{ff} the strains; in the warp and fill (i.e. weft) directions; and with the "hindered" stiffness matrix being

$$E = \begin{bmatrix} E_{ww} & E_{wwff} \\ E_{ffww} & E_{ff} \end{bmatrix}$$

The term "hindered" describes the situation where the strain response induced in the lateral direction is restrained, such as in a biaxial test.

The matrix relationship can be re-expressed as linear equations: -

$$\sigma_{ww} = E_{ww} \cdot \epsilon_{ww} + E_{wwff} \cdot \epsilon_{ff} \quad \text{----- equation (1)}$$

$$\sigma_{ff} = E_{ffww} \cdot \epsilon_{ww} + E_{ff} \cdot \epsilon_{ff} \quad \text{----- equation (2)}$$

The values E_{ww} and E_{ff} are not the same as the Elastic Moduli, namely E_w and E_f which are "unhindered", where the strain response in the lateral direction is not restrained, such as in a uniaxial test. The relationship between the "hindered" and "unhindered" values can be derived from the Compliance matrix "C", which is the inverse of the Stiffness Matrix.

$$\begin{bmatrix} \epsilon_{ww} \\ \epsilon_{ff} \end{bmatrix} = \begin{bmatrix} C_{ww} & C_{wwff} \\ C_{ffww} & C_{ff} \end{bmatrix} \cdot \begin{bmatrix} \sigma_{ww} \\ \sigma_{ff} \end{bmatrix}$$

For orthotropic materials (i.e. different properties in each direction)

$$C = \begin{bmatrix} 1/E_w & -\nu_{fw}/E_f \\ -\nu_{wf}/E_w & 1/E_f \end{bmatrix}$$

Since $E = C^{-1}$, then:-

$$\begin{bmatrix} E_{ww} & E_{wwff} \\ E_{ffww} & E_{ff} \end{bmatrix} = \begin{bmatrix} C_{ww} & C_{wwff} \\ C_{ffww} & C_{ff} \end{bmatrix}^{-1}$$

and by inverting C above:-

$$C^{-1} = \begin{bmatrix} \frac{E_w}{1 - \nu_{wf}\nu_{fw}} & \frac{\nu_{fw}E_w}{1 - \nu_{wf}\nu_{fw}} \\ \frac{\nu_{wf}E_f}{1 - \nu_{wf}\nu_{fw}} & \frac{E_f}{1 - \nu_{wf}\nu_{fw}} \end{bmatrix}$$

Hence $E_{ww} = \frac{E_w}{1 - \nu_{wf}\nu_{fw}}$ and $E_{ff} = \frac{E_f}{1 - \nu_{wf}\nu_{fw}}$ ----- equations (3) and (4)

It is a property of Elastic materials that the matrix is symmetric, i.e. $E_{ffww} = E_{wwff}$ and therefore:-

$$\frac{E_w}{\nu_{wf}} = \frac{E_f}{\nu_{fw}} \quad \text{----- equation (5)}$$

Substituting equation (5) into (3) and (4) respectively:-

$$\nu_{wf} = \sqrt{\left(1 - \frac{E_w}{E_{ww}}\right) \cdot \frac{E_w}{E_f}} \quad \text{----- Equation (6)}$$

And also:-

$$\nu_{fw} = \sqrt{\left(1 - \frac{E_f}{E_{ff}}\right) \cdot \frac{E_f}{E_w}} \quad \text{-----Equation (7)}$$

With simplifying assumptions, the four variables E_{ww} , E_w , E_{ff} and E_f for the Polyfab ranges can be derived from the Uniaxial and Biaxial test results; and the Poisson's ratios ν_{wf} and ν_{fw} calculated by substitution in the equations (6) and (7). Again, these are not the same as the "hindered" Poisson's ratios, calculated for the case where $\sigma_{ww} = 0$, and $\sigma_{ff} = 0$ in equations (1) and (2) respectively, and which if needed, can also be related to the "unhindered" values through the inverted Compliance Matrix C^{-1} above.

The standard uniaxial test reports provide only the load and extension at failure; but the graphics associated with the tests confirmed that an approximate linear relationship exists between the two. Thus, the slopes (i.e. E_w and E_f) can be calculated from the starting co-ordinate and the load and extension at break reported in the standard test.

The test data reported in Table One is derived from the Australian Standard AS 2001.2.3.1 – 2001. The test is carried out on a strip of 50 mm width, with a pre-tension load of five Newtons. Thus, the starting and finishing co-ordinates of the tests can be determined, and the Modulus is simply the slope of the line between the two points.

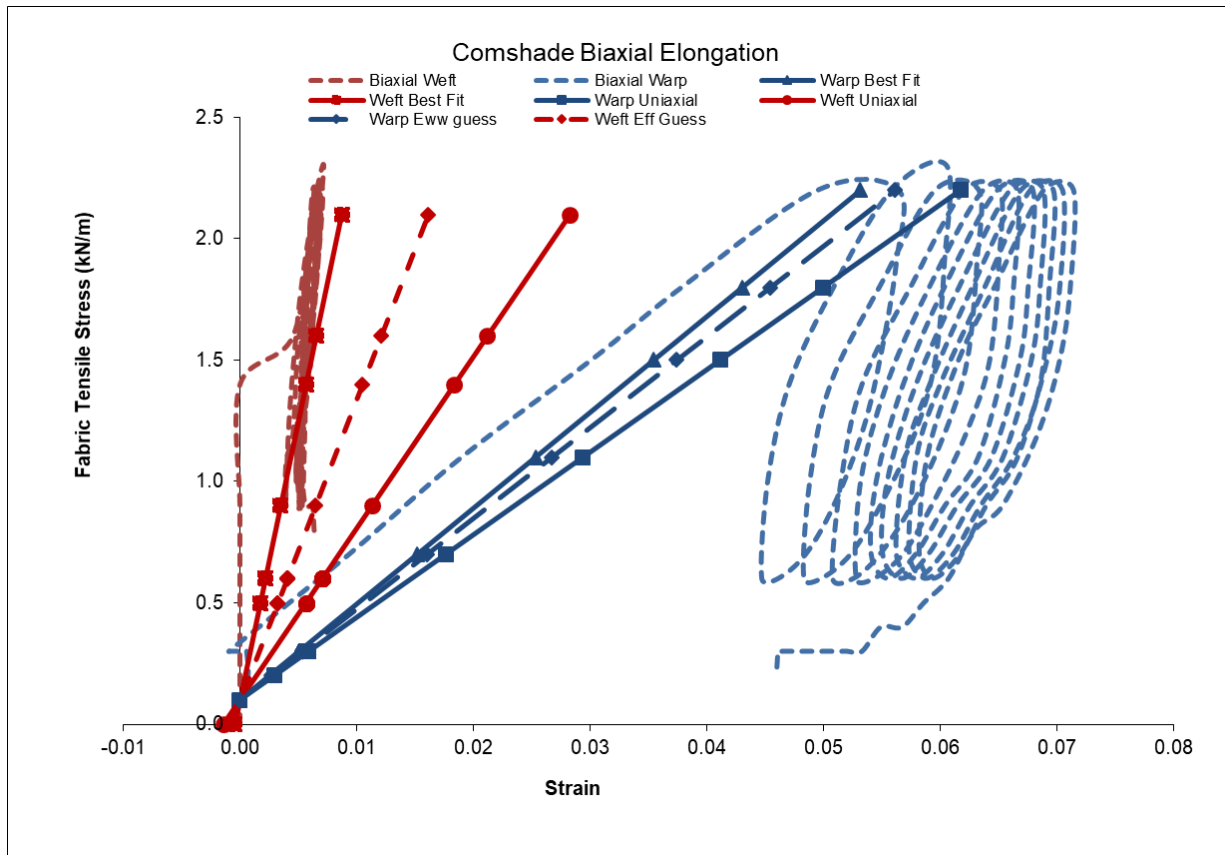
The "hindered" values (i.e. E_{ww} and E_{ff}) need to be derived iteratively, assuming these slopes must lie between those of the uniaxial tests, and those of the Biaxial test results fitted using the least squares method. This latter slope represents the best actual fit to the test results, and the stresses calculated from this linear equation should match as closely as possible the outcome of applying equations (1) and (2).

However, the procedure needs to be used with caution, as the fitting of the curves is approximate at best, and there is a range of possible estimates for E_{ww} and E_{ff} , particularly if there is non-compliance with the constraint $\frac{E_w}{\nu_{wf}} = \frac{E_f}{\nu_{fw}}$.

For these and similar reasons, the method should be considered a guide only and engineers should apply their own best judgement in deriving the parameters.

Typical results for Polyfab Comshade using the procedure is shown in the following table, with the graphics overleaf.

Product	E_w (kN/m)	E_f (kN/m)	E_{ww} (kN/m)	E_{ff} (kN/m)	ν_{wf}	ν_{fw}
Comshade	34.0	70.8	37.4	123.8	0.33	0.69

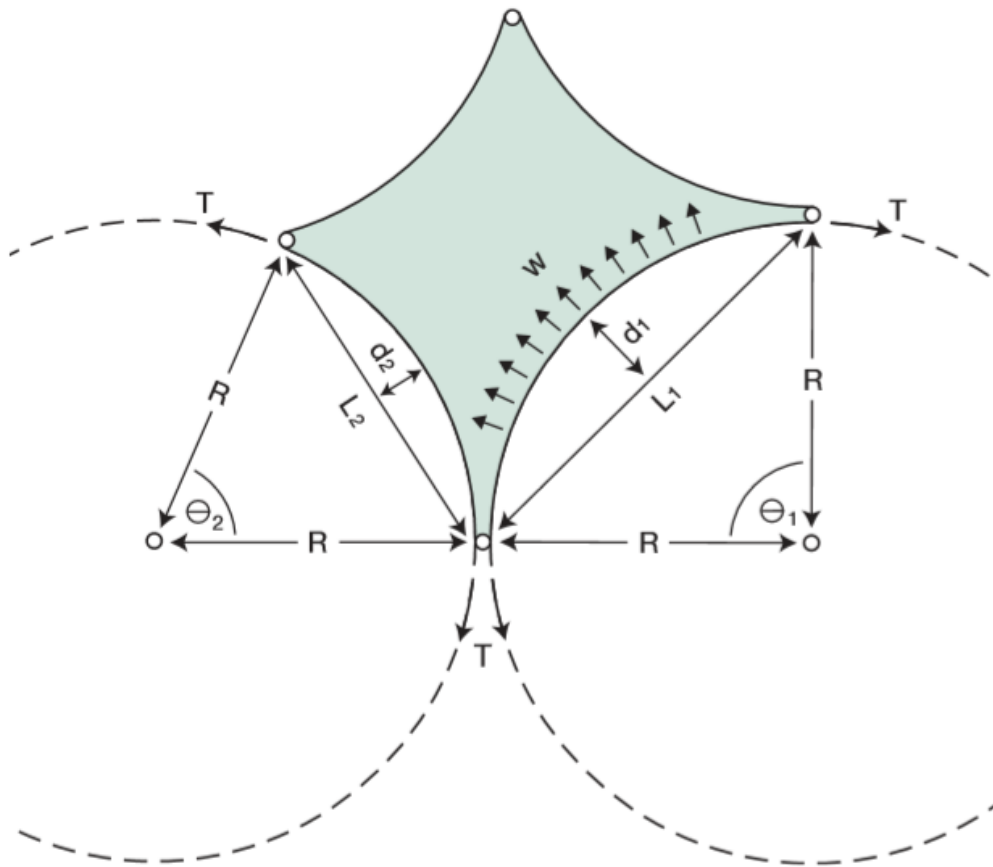


Technical references:-

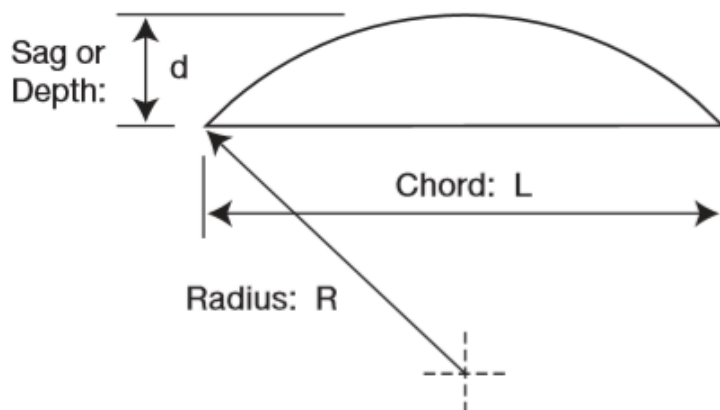
1. "Tensile Membrane Structures" ASCE/SEI 55-16
American Society of Civil Engineers 2017
ISBN 978-0-7844-1437-8
2. "Tensioned Fabric Structures - A Practical Introduction"
Edited by R.E. Shaeffer, American Society of Civil Engineers 1996
ISBN 0-7844-0156X
3. "European Design Guide for Tensile Surface Structures"
Brian Forster Marijke Mollaert
2004 Tensinet
ISBN 90 8086 871X

APPENDIX C2 Relationship Between Cable Tension and Curvature

For design conditions of uniform reactive stress, and constant cable tension, the radius of curvature is the same for each span.



Hoop Stress $T = R \times w$
 Where $T = \text{Cable Tension (kN)}$
 $R = \text{Circle Radius (m)}$
 $w = \text{Applied Stress (kN/m)}$
 Therefore Radius: $R = \frac{T}{w}$ **Equation No. (1)**



Equation No. (2)

$$\text{Sag: } d = R - \frac{\sqrt{4R^2 - L^2}}{2}$$

Substitute (1) into (2) Then:

$$d = \frac{T}{w} - \frac{\sqrt{4\left(\frac{T}{w}\right)^2 - L^2}}{2}$$

APPENDIX D Chemical Resistance of High Density Polyethylene at 20° Celsius

S= Satisfactory

L=Limited Resistance

U=Unsatisfactory

T = Testing possibly required

Agent	Concentration (%)	Resistance	Agent	Concentration (%)	Resistance
Acetaldehyde	40%	T	Butyric Acid	20%	U
	100%	U			
Acetic Acid*	10%	S	Calcium Chloride		S
	20%	S*			
	50%	S*			
	>80%	L*			
Acetic Anhydride		U	Calcium Hydroxide		S
Acetone*		S	Calcium Nitrate		S
Acetophenone		T	Calcium Sulphate		S
Acetylene*		L*	Carbon Bisulphide		U
Andipic Acid*		S*	Carbon Disulphide		U
Allyl Alcohol	96%	S	Carbon Tetrachloride*		U
Allyl Chloride		S	Carbonic Acid		S
Alum		S	Chloral Hydrate		U
Aluminium Chloride		S	Chlorine Gas*		L*
Aluminium Fluoride		S	Chlorine Liquid		U
Aluminium Hydroxide		S	Chlorine Water*	20%	S
Aluminium Nitrate		S	Chlorobenzene*		L*
Aluminium Oxychloride		S	Chlorosulphonic Acid*		U
Aluminium Sulphate		S	Chromic Acid	10%	S
				50%	S
Ammonia (Dry Gas)		S	Chromium Plating Solution*		S
Ammonia (Liquid)*	100%	S*	Citric Acid	10%	S
Ammonium Carbonate		S	Copper Chloride		S
Ammonium Chloride		S	Copper Sulphate		S
Ammonium Fluoride*	25%	S	Cresol		U
Ammonium Hydroxide	25%	S	Crude Oil*		U
Ammonium Nitrate		S	Cyclohexanol		S
Ammonium Persulphate		S	Cyclohexanone		U
Ammonium Phosphate		S	Dibutyl Phthalate*		T
Ammonium Sulphate		S	Dioxane*		U
Amyl Acetate*	100%	L*	Ether		U
Amyl Alcohol	100%	S	Ethyl Acetate*		L
Aniline*		S*	Ethyl Alcohol	30%	S
				100%	S
Antimony Trichloride		S	Ethyl Ether*		L*
Aqua Regia*		L*	Ethylene Bromide		U
Barium Chloride		S	Ethylene Dichloride		U
Barium Hydroxide		S	Ethylene Glycol		S
Benzaldehyde*		U	Ferric Chloride		S
Benzene		U	Ferrous Chloride		S
Benzyl Chloride*		T	Ferrous Sulphate		S
Benzoic Acid*		S	Fluorine Gas*		L*
Benzyl Alcohol*		T	Formaldehyde*	30%	S
Borax		S	Formic Acid	10%	S
				50%	S
Boric Acid		S	Freon 12*		S
Bromic Acid	10%	S	Gas Natural*		L*
Bromine Liquid*	100%	L*	Gasoline (Petrol)		L
Butane*		U	Glycerol (Glycerine)		S
Butyl Acetate*		L*	Glycol		S
Butyl Alcohol*		S	Heptane*		L*

*Note: Chemical resistance to the compounds highlighted deteriorates at higher operating temperatures

APPENDIX D (Continued)
Chemical Resistance of High Density Polyethylene at 20° Celsius

S= Satisfactory

L=Limited Resistance

U=Unsatisfactory

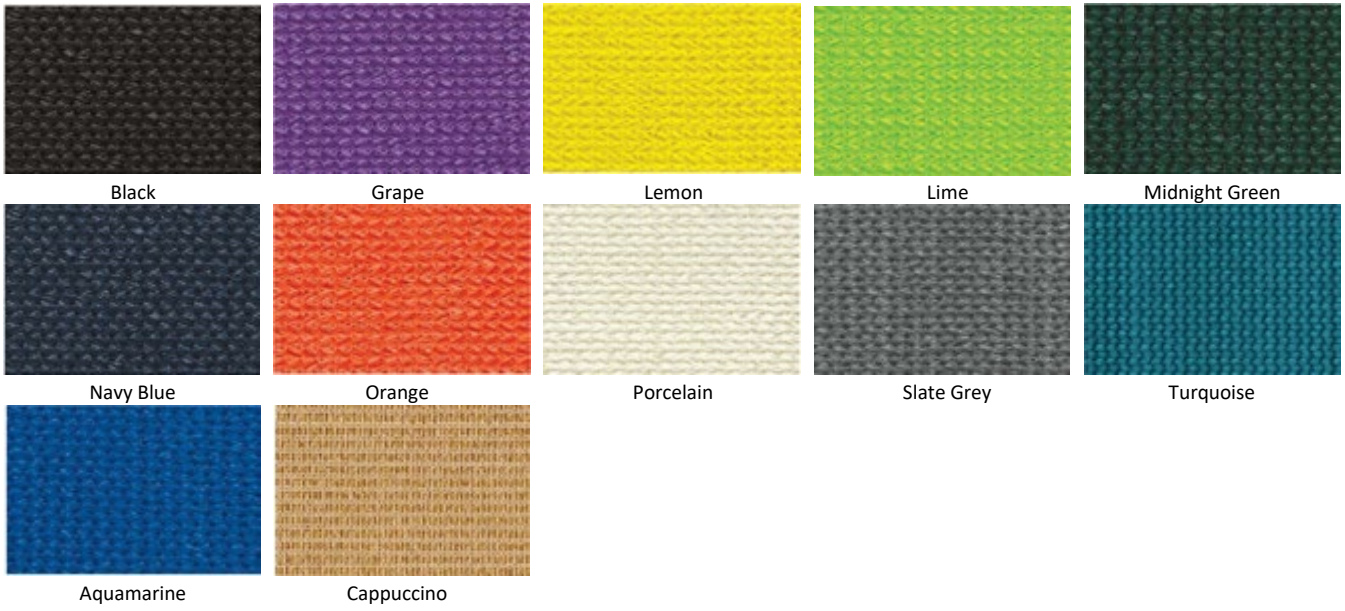
T = Testing possibly required

Agent	Concentration (%)	Resistance	Agent	Concentration (%)	Resistance
Hexane*		U	Propyl Alcohol		S
Hydrochloric Acid	20%	S	Propylene Dichloride*		U
	40%	S			
Hydrocyanic Acid		S	Pyridine*		S*
Hydrofluoric Acid*	25%	S	Salt (Sea) Water		S
	40%	S			
	100%	S*			
Hydrogen Peroxide*	30%	S	Silicone Oil*		T
	90%	L			
Isopropyl Alcohol		S	Silver Nitrate		S
Kerosene*		L*	Soaps (In Solution)		S
Lubricating Oils*		L*	Sodium Acetate		S
Magnesium Chloride		S	Sodium Bicarbonate	10%	S
Magnesium Sulphate		S	Sodium Bisulphate		S
Mercuric Chloride		S	Sodium Carbonate		S
Mercury		S	Sodium Chlorate		S
Methyl Alcohol	100%	S	Sodium Chloride		S
Methyl Ethyl Ketone		U	Sodium Hydroxide	10%	S
				50%	S
Methyl Sulphate*		U		20%	S
Methylene Chloride*		U	Sodium Hypochlorite*		S
Mineral Oils*		S*	Sodium Nitrate		S
Naphtha		L	Sodium Sulphide		S
Naphthalene*		L*	Sodium Thiosulphate	25%	S
Nickel Chloride		S	Stannous Chloride*		S
Nickel Sulphate		S	Stearic Acid	100%	S
Nitric Acid*	10%	S	Sulphur Dioxide*		S*
	100%	U	Sulphuric Acid *	10%	S
				50%	S*
				95%	L*
Nitrobenzene		U	Sulphurous Acid	10%	S
				100%	S
Oleic Acid		S	Tartaric Acid		S
Olive Oil*		S*	Tetrahydrofuran*		L*
Oxalic Acid	10%	S	Thionyl Chloride		U
Phenol*		L*	Toluene		U
Phosphoric Acid*	10%	S	Trichloroethylene		U
	75%	S			
Photographic Chemicals		S	Tricresyl Phosphate*		S*
Potassium Bicarbonate		S	Trisodium Phosphate		S
Potassium Carbonate		S	Turpentine*		U
Potassium Chloride		S	Urea		S
Potassium Hydroxide*	10%	S	Vinegar		S
	50%	T			
Potassium Nitrate		S	Xylene		U
Potassium Permanganate		S	Zinc Chloride*	10%	S
Potassium Sulphate		S	Zinc Sulphate		S
Propane*		U			

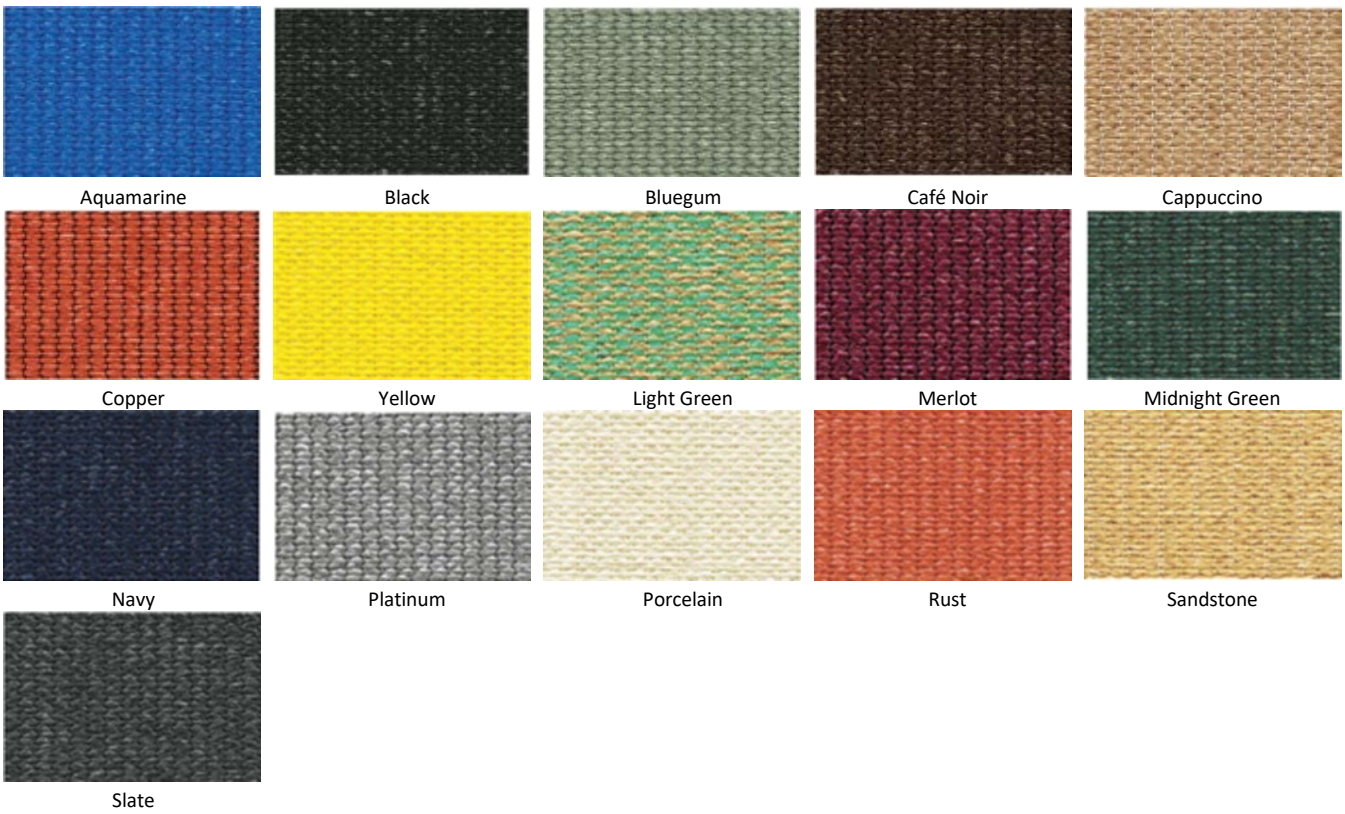
*Note: Chemical resistance to the compounds highlighted deteriorates at higher operating temperatures

APPENDIX E Colour Pallets

Architect 400



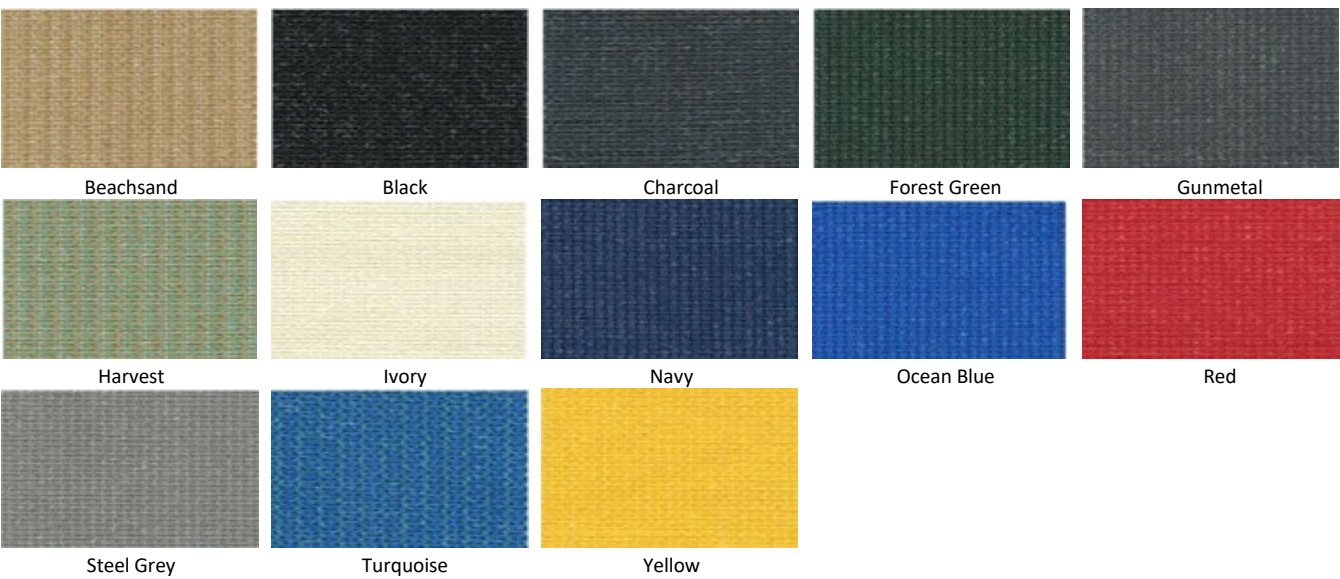
Comshade



Comshade Xtra



Parasol



Polyfx



SYNOPSIS OF THE TECHNICAL GUIDE SERIES

How to Tell a Good Yarn – Textile Manufacture and Testing Technical Guide Number One

The textile and flooring products mainly used in an outdoor environment are first classified by their basic construction and design function. Then the processes of production and finishing are described, including the implications on product performance of different types of yarn and yarn blends, the matrix of the weave, coating lamination and finishing. The products included are canvas, PVC coated or laminated polyesters, coated polyolefins, clear PVC, knitted shade cloth, expanded vinyl, leather, polyurethane fabrics, needle punched carpet and tufted carpet tiles.

A description of the test procedures used to assess quality attributes are described, and linked to the published specifications of the products; including the relevant Australian Fire tests and the outcomes required by the National Construction Code for Commercial Upholstery, Awnings and Outdoor Blinds, Shade and tension Structures, Flooring and Temporary Structures. A glossary of technical terms used in the textile industry is also included. Although specific to the brands sold by the Nolan Group, the information is sufficiently generic to be applicable to similar products generally used by fabricators in the Textile Conversion Industries.

Shady Characters – Polyfab Shade cloth for Human Protection Technical Guide Number Two

Beginning with the basics, the two different types of knit construction which fundamentally affect the relative shading efficiency of the various Polyfab brands, or indeed any brand of shade cloth are described and illustrated. Then the concept of shade design, with the need to accommodate the daily and seasonal movement of the sun, is noted, with the consequent risk of lack of protection highlighted.

More technical information is provided on engineering design, including the behaviour of the fabric under two dimensional loading, how to derive the Elastic Parameters from Biaxial Testing, and guidelines for fabrication and installation. Standard design details for a typical hypar and frame supported structure have been developed, and the procedure for gaining engineering certification for the use of these drawings anywhere in Australia is explained.

The specifications of the Polyfab products are compared with the requirements of AS 4174 – 2018 “Knitted and Woven Shade Fabrics”, including physical properties and the degree of UV protection. The ratings outlined in that standard and how they are integrated into the product warranties are explained. Additional technical information such as Solar heat transmission, flammability and chemical resistance of the products are also included.

What Blind Freddy Knew – Awning and Outdoor Blind Fabrics Technical Guide Number Three

The primary aim of this guide is to detail the information supporting the Nolan Group’s “Fit for Purpose Statement”, which is in turn designed to clarify the specific meaning of the terms used in the Consumer Act of 2011, and the Nolan Group product warranties.

The terminology related to the different types of Awnings and Blinds is explained and illustrated, as is the basic construction and finish of the fabrics typically used, their specifications, as well as guidelines for fabrication and installation; and care and maintenance. Fabrics included are Acrylic and Polycotton Awning Canvas, PVC coated polyester mesh, and Flexible Clear PVC.

The results of the testing for Solar Absorption, Reflection and Transmission for Vistaweave Mesh (to US standard ASHRAE 74-75 1988) and Dickson Acrylic (to European Standard EN 14500 and EN 14501), are provided and ranked by colour.

Head above Water - Marine Fabrics and Fasteners

Technical Guide number Four

In their dealings with the consumer, the Marine Trimmer has a difficult task in explaining the severity of the boating environment, particularly the effects of UV exposure on fabrics and flexible clear PVC. Starting with illustrations of the types of canopies and the terminology used to describe them, this guide progressively details information relevant to the materials commonly used. Based on protracted laboratory testing, the detail of which is contained as an appendix, it contains a simple table that outlines the comparative characteristics of different canopy materials, which is designed to facilitate appropriate product selection.

Included are product specifications, guidelines to fabrication of canopy materials and flexible clear PVC, Marine carpet and hull lining, upholstery; together with the appropriate use of foam underlay, fasteners, zippers, adhesives and thread. Detailed care and cleaning instructions, and copies of product warranties are provided. The warranties are formatted to the Nolan Group's "Fit For Purpose Statement", and relates the detail of the product's specification to the terms used in the Consumer Act of 2011.

Got you covered – Polycotton Canvas, Coated or Laminated Industrial and Architectural Fabrics

Technical Guide Number Five

Proofed cotton canvas was first developed for use by the British Army in the Crimean War, and has been used ever since for temporary outdoor protection. The invention of polyester did not just improve the matrix of canvas, but coupled with PVC, allowed the development of synthetic tarpaulin and tenting fabrics that are widely used in transport, agricultural covers and structures. Similarly formulated polyolefin fabrics provide a lighter weight option.

This guide goes into the detail of the composition and structure of these types of fabrics, their technical specifications, and chemical resistance. It provides advice on product selection and fabrication, including allowance for dimensional change, welding and functional design, such as avoiding tear, flex cracking and potential mildewing. The reasons for the complexity of printing on plastics is explained, and also why the common practice of cutting 'wind holes' in banners is unnecessary.

The concept of anticlastic geometry, which is integral to the design of tension structures, is discussed; and European guidelines for fabric classification, fabrication tolerances and pre-stress are included; together with an explanation as to how biaxial tests results can be interpreted. References are provided to the calculation of Elastic Parameters for the Sattler "Atlas" range available with biaxial test results, which are available on the Nolan Group's website.

Similarly, the concept design of Grain Bunker Storages is provided, and a calculator that allows the sizing of covers and groundsheets for particular crops and stack heights has been developed and is also available on the company's Website.

Not Flawed – Commercial Carpet, Carpet Tiles and Acoustics

Technical Guide Number Six

Designed for Architects and Specifiers, this guide provides the technical data necessary to support the environmental guidelines of the Carpet Institute's Certification Scheme, which in turn underpins the Green Building Code rankings. It also contains the detailed product specifications and results of performance testing, including those of flammability required by the National Construction code. Similarly formulated materials are used as acoustic walling, and data regarding the effectiveness of these products is presented.

Nolan Group Locations





Nolan Group

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