

# **Fabric Life – Expectations and Experience**

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## **INTRODUCTION**

Tensile structures incorporating architectural fabric have been built and used for many years, with the earliest air structure designs dating back to the early 1900's.

However it is really only since the early 1970's that improvements in fabric technology and design procedures have brought tensile structures into common use in buildings.

Unlike most other building products such as steel, concrete, timber, aluminium and glass, fabrics used in tensile structures have a limited history and the long-term performance of these early structures is only now able to be observed over periods compatible with other building materials, ie 30 – 50 years.

This paper does not attempt to make an exhaustive review of the thousands of structures erected since the early 70's, but focuses on a few structures with which the author has some experience or knowledge.

The materials considered range from early Teflon-coated fiberglass (refer figure 1 –University of La Verne Sports Science and Athletic Pavilion – built in 1972) to PVC-coated polyesters with acrylic or pvdF coatings, to knitted high density polyethylene monofilament fibre fabric, commonly known as shade cloth, (refer figure 2 – shade cloth canopies at a resort in Northern Victoria).

The actual performance of these fabrics is a factor in determining whether their use is considered successful or not. The expectations of the owners and the part they play in maintaining and operating their structures is another.

## **EXPECTATIONS**

Fabric 'life' is a very subjective term. It is expected that materials exposed to the elements will deteriorate, due to factors including:–

- U V degradation
- degradation due to other environmental factors (chlorine, pollutants, unsuitable cleaning agents, etc).
- accidental physical damage, (bird strikes, falling objects, impact by construction or maintenance access equipment)
- deliberate damage (vandalism or imprudent acts such as setting fires nearby).



*Figure 1 – University of La Verne Sports Science and Athletic Pavilion (California)  
Erected 1972, photo taken 2007*



*Figure 2 – Shadecloth canopies at resort in Northern Victoria  
Installed 1997, replaced 2006*

In looking at the expectations which owners may have about the life of fabrics, it is useful to examine typical warranties offered by the major manufacturers.

This is a question often asked by clients considering the use of fabric structures; although warranties do not necessarily provide an accurate indication of fabric life.

### **FABRIC MANUFACTURER WARRANTIES**

Warranties typically offered on common fabrics can be as follow.

#### **Shadecloth(1)**

- 10 years against significant UV degradation of the shadecloth , typically restricted to replacement of fabric
- sewing threads can be obtained with guarantees against defects and damage by exposure to sunlight, for up to 15 years, with the guarantee covering the cost of thread and customary expense of repair for any article sewn completely with the thread.
- quality fabricators offer warranties on defects in workmanship for up to five years

#### **PVC-coated polyester, (including acrylic and PVDF surface treatments)(2,3,4)**

- usually 10 and up to 12 or 15 years, covering significant loss of strength, loss of water-tightness, reduction of fire resistance.
- typical warranties cover replacement of fabric only; on a pro-rata reducing basis. Some cover a pro-rata reducing component of the total cost of removal, refabrication and re-installation of the membrane. This can be very important as the removal, refabrication and reinstallation costs can easily vary from twice to several times the cost of the fabric on the roll. The various manufacturers may offer different or extended warranties depending on the project and the client's requirements.
- generally an application has to be made for each specific project for the fabric used in that project to be covered by the fabric manufacturer's warranty. Some manufacturers will automatically offer a warranty when an application is made for a structure, other manufacturers require the warranty to be applied for and approved prior to the fabric being ordered and fabrication commenced.
- typical information required to be provided in a warranty application includes details of the project, the area to be covered, the proposed fabric, the location, diagrams and drawings of the project, who the engineer and fabricator are and any local environmental factors such as pollution levels, nearby industries, and exposure to traffic fumes.
- claims under warranties must be made in writing within defined periods of time from when the defect becomes noticeable and must provide evidence of purchase and a copy of the warranty agreement including batch and roll numbers.
- some manufacturers require a minimum 1m<sup>2</sup> sample of the affected fabric (which may be problematic unless a sample piece of each batch is installed at each site under matching conditions for use on any future claim).

- warranties often do not cover wear and tear, deterioration caused by exposure to harmful agents or conditions, incorrect or irregular cleaning, faulty installation, pretension or design, faulty manufacture, seaming problems, damage due to high wind loads or other unusual factors, mould growth due to inadequate air circulation and differences in levels of translucency between batches.
- some extended warranties offered at additional cost cover 100% of the total costs of removing, refabricating and replacing the membrane for defined matters over the warranty period, whilst some cover solely the cost of the fabric.
- it should also be noted that some issues experienced with surface coatings on fabrics are not strictly covered by the warranties and compensation for deterioration or losses becomes a matter of negotiation between owner, contractor and fabric supplier.

### **Teflon Coated Fibreglass**

- warranties offered on Teflon-coated fibreglass typically extend over a 10 year period, and are limited to the original cost of fabric. Some are on a pro-rata reducing basis and some are not. Some cover only fabric replacement, others cover total cost of reinstatement but limited to the value of the fabric originally supplied.

### **CONTRACTOR WARRANTIES**

Warranties offered by the contractor are generally determined by the building contract under which the project is constructed and a defects liability period of 12 months is common. Builders are also obliged under various legislation to provide further warranties in relation to structural performance or waterproofing for various periods as defined by legislation. This can vary from state to state and certainly will vary between countries.

In practical terms most gross manufacturing defects (eg poor welding, improper coating of steelwork, cables not properly manufactured) are likely to become apparent within contractual or statutory warranty period, but where the defect arises from the original manufacture of the fabric it may take some years to become apparent.

When this happens the builder or contractor generally has to rely on the warranty offered by the fabric manufacturer. This can become interesting because unless the faulty is explicitly covered by the terms of the warranty, assistance or compensation relies on the attitude of the fabric manufacturer. For example with fabrics suffering coating defects as some have, questions of 'fitness for purpose' arise, and this goes back to not only to the wording of the warranty, the legislative requirements, and common law precedents, but also to the how well the owner's expectations and requirements have been defined as part of the original contract. This can easily become a very grey area.

## DESIGN ISSUES

Fabric structure performance and life should not be compromised by design issues but unfortunately some structures have been known to suffer premature failure due to a lack of rigorous engineering design. This is more common with smaller structures and shadecloth structures, but can happen with larger structures if design issues are overlooked.

Common design problems can include

- poor surface shape or a lack of pretension allowing ponding and failure due to rainwater collection
- failure of supports due to inadequate assessment of loads developed by the fabric membrane
- damage to fabric caused by excessive deflection, vibration or fluttering, usually as a result of inadequate pretension
- poor detailing leading to overstressing of fabric (often in a tearing mode) either in-service or during installation or handling

Whilst no procedures can provide an absolute guarantee that design issues will not arise, prudent clients and project managers will ensure their structures are designed and certified by engineers with detailed knowledge, specialist experience, and a comprehensive track record with design of tensile structures (LSAA consulting engineer members are generally a good place to start when seeking a suitable engineer).

Even within the quite narrow field of tensile structures there are areas of particular expertise, as design and detailing for coated fabrics such as PVC-coated polyester and Teflon coated fiberglass require quite different approaches to knitted shadecloth. Because a designer may be expert in large coated fabric structures this does not necessarily mean they will be experienced with shadecloth structures, where the design imperatives of scale and economy can be much more stringent. Any competent engineer experienced with tensile structures should be able to design a shadecloth structure which is structurally adequate, but designing a structure which is not only structurally adequate but economically competitive in the marketplace can be another issue.

## OWNER EXPECTATIONS AND MAINTENANCE

The essential factor in a tensile structure being considered successful is the expectations and input of the owner or operator. Whilst tensile structures can be remarkably resilient to abuse or neglect, they will certainly provide better performance and give better service life if they are properly cared for by the owners.

The 'life' of a fabric can be a very subjective matter. If a fabric membrane is installed in an application where the top surface is not visible from any close location, and variability of transmitted light is not a major concern, then a build up of soiling and dirt or a loss of gloss may not be an issue. Indeed anecdotal evidence suggests a persistent coating of dust on the Yulara 'sails in the desert' structures allowed the membranes to survive in extreme UV conditions from when they were installed in 1984 until their replacement in the last few years.

However, if a high gloss retention and top surface shine is important to the owner, structures benefit from being cleaned regularly. Some warranties require structures to be cleaned at not more than 12 month intervals, and some projects constructed by the author have maintained a reasonable level of surface gloss over more than 10 years with regular cleaning on a 6 to 12 month interval.

Periodic inspection is essential and regular cleaning can contribute to an improved fabric life, although recent advice from some manufacturers is that excessive cleaning can in some circumstances lead to deterioration in fabric life.

Different fabrics also respond differently to soiling and cleaning. Some fabrics can display distinct lines of soiling, and it is not clear whether this is due to the fabric itself, or due to factors associated with manufacture and handling. The author does note, however that fabrics from some manufacturers do tend to display this effect when fabrics from other manufacturers, which to the author's knowledge are manufactured and handled in exactly the same manner, do not.

## EXAMPLES AND CASE STUDIES

### Shadecloth

**Case Study S1**, shadecloth structure utilising 5 membranes totaling about 1200 square metres in area, over a resort swimming pool in Northern Victoria. (refer figure 2 earlier in this paper). This was first erected in 1997, as a replacement for membranes of different materials, construction and design, which had suffered structural failure a short time after installation. An elegant design, utilising a number of layered profiles overlaying each other and generally inclined to the north, the structure allows sunlight penetration to the pool areas during winter and cooler months whilst providing several layers of shadecloth for increased shade density in summer.

By late 2006 the membranes were suffering deterioration due to a combination of stitching deterioration under UV, physical damage due to vandalism and bird strikes, and seams being highly stressed by unauthorised access by a number of people climbing on the panels at one time.

They were replaced with new membranes utilising improved stitching with a guaranteed 15 year UV resistance and hopefully will provide many years of reliable service.

**Case Study S2**, a shadecloth conic at a primary school in the northern suburbs of Melbourne, erected in 2000. This suffered some deterioration of the shadecloth around webbings, possibly due to UV deterioration, but also possibly due to birds pecking at the fabric, seeking insects or spiders at the peak (refer figure 3). The structure was taken down in 2006 and the damage repaired, and is still in service.



*Figure 3 – Shadecloth structure at School, installed 2000, repaired 2006*

## PVC-coated Polyester

**Case Study P1**, an iconic project in the northern suburbs of Adelaide, the first stage constructed using a pvc-coated polyester with acrylic lacquer in 1996, and a second stage using a different manufacturer's fabric in 2001. These structures were regularly cleaned, generally at least once and usually twice per year. Soon after installation some coating problems were experienced with the second stage and the membranes were replaced. The first stage fabrics are still in place although one panel suffered mechanical damage from a boom lift being used during cleaning in 2006. A significant tear occurred, and the membrane was taken down and a section of a panel replaced. This provided an opportunity to have the fabric tested to see how it had performed over 10 years. Comparison of the original specified properties and the measured properties is presented in table 1 (courtesy of Mehler(2)).

Property	SAMPLE	Specification
Total weight gsm	760	~800
Tensile N/5cm	2949/2388	~3000/3000
Tear N	280/200	~ 300/300

*Table 1 – tested properties of PVC-coated Polyester after 10 years of exposure in Adelaide*

This indicates a slight but quite reasonable deterioration in physical properties. The decrease in tensile strength is low and the tear strength acceptable considering the years of exposure. Flexibility was considered as 'medium/hard' which is expected after 10 years.

What is more obvious however, is the visual appearance, and there was a quite distinct difference in gloss, colour and translucency between the original fabric and the replacement fabric, which was of a similar grade although with a weldable pvdf coating instead of an acrylic coating (refer figure 4)



*Figure 4 – repair of tear in PVC-coated Polyester membrane, installed 1996, repaired 2006*

**Case Study P2.** This was a small twin conic erected in 1990 and was to the author's knowledge the first application of a PVDF/PVC coated polyester fabric in Australia. The structure was designed by the author and the fabric selected as a trial since the small scale minimized economic consequences if the fabric performed poorly. It has now been in place for nearly 17 years and is still performing well, having been cleaned and relocated on a few occasions (refer figure 5).



*Figure 5 – twin conic in pvc-coated polyester with PVDF, erected 1990, photo October 2007*

**Case Study P3.** PVC-coated polyester structure with PVDF surface, erected in 2000, suffered a severe failure of the PDVF laminate in late 2003, not affecting structural integrity, fire resistance or water-tightness, but causing a reduction in gloss of the surface and an unsightly appearance as dust and soil builds up under the delaminating coating. This requires regular cleaning to remove the delaminated coating, when hopefully a uniform appearance will be restored. (refer figure 6)



*Figure 6 – delamination of surface coating on pvdf/pvc-coated polyester, installed 2000, coating issue arose at end of 2003*

**Case Study P4,** A barrel vault canopy of erected in December 2001, showing considerable soiling in defined lines, but not at valleys, prior to the first clean in June 2004 (refer figure 7). The fabric was installed taut at pretension levels of 1.5x1.5 kN/m and has no wrinkles or defects, but soiling was apparent at lines which may have been where the fabric was folded during manufacture, transport and installation.. The soiling cleaned off and a uniform glossy surface was restored with normal cleaning following recommended procedures.



*Figure 7 – soiling in lines on surface of weldable PVDF/PVC-coated polyester*

## Teflon Coated fibreglass

**Case Study T1**, The Sports Science and Athletic pavilion at University of La Verne, California. Erected in 1972, this was one of the first Teflon-coated fiberglass fabric structures ever built. The author reported on this structure in 1985(5) (refer figure 8), when it was still performing well. Recent advice from the owner(6) is that it is still performing well, 35 years later, and the fabric has not lost a significant amount of its original gloss. The interior liner did not last as well as the exterior fabric and has been recently replaced.



*Figure 8 – University of La Verne Sports Science and Athletic Pavilion (California)  
Erected 1972, photo taken 1985*

**Case Study T2**. A private residence in the Yarra Valley had an atrium of 400 m<sup>2</sup> covered with square based conic using Teflon-coated fiberglass, built in 1982. Advice is that it is still performing well, 25 years later. It is regularly inspected and cleaned each few years

## CONCLUSIONS

Fabric life is very dependent on the acceptance of the owner of the appearance of the fabric. Many fabrics will still perform in terms of structural capacity and watertightness, many years after their surface may have lost a substantial amount of gloss and may be appearing quite dull.

The life of an individual project cannot be predicted with certainty since it is dependent on so many variables, but some examples indicate that:–

Shadecloth can reasonably be expected to last 7–10 years but owners should consider budgeting for replacement after that time. Stitching is a critical item and due consideration should be given to use of UV resistant stitching and protection of stitching by the means of construction (especially when webbings are used)

PVC-coated polyesters seem to have a reasonable service life of at least 10–15 years, and some may last for many more years. Cleaning and environmental factors can have a significant effect.

Teflon-coated fibreglass seems to last at least 20–25 years and may last much longer. Capital costs may mean that life-cycle costs may be cheaper if one uses PVC-Coated polyester and replaces it periodically, but this is dependent on a many factors including ease of replacement, disruption during the process, and original project costs.

Generally fabric structures will provide good value as long as owners approach projects with realistic expectations.

Less expensive products tend to have a shorter life but be easier and less expensive to replace.

What is essential with any fabric structure is for the owners to have realistic expectations about the performance of the solution they choose, have it properly designed, and follow recommended maintenance procedures.

In this manner we trust that fabric structures will continue to provide good service, excellent value, and eye-catching architecture in more and more projects over the coming years.

### **Acknowledgments and references**

1. Gale Pacific and Oasis Tension Structures, for information on shadecloth fabric
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