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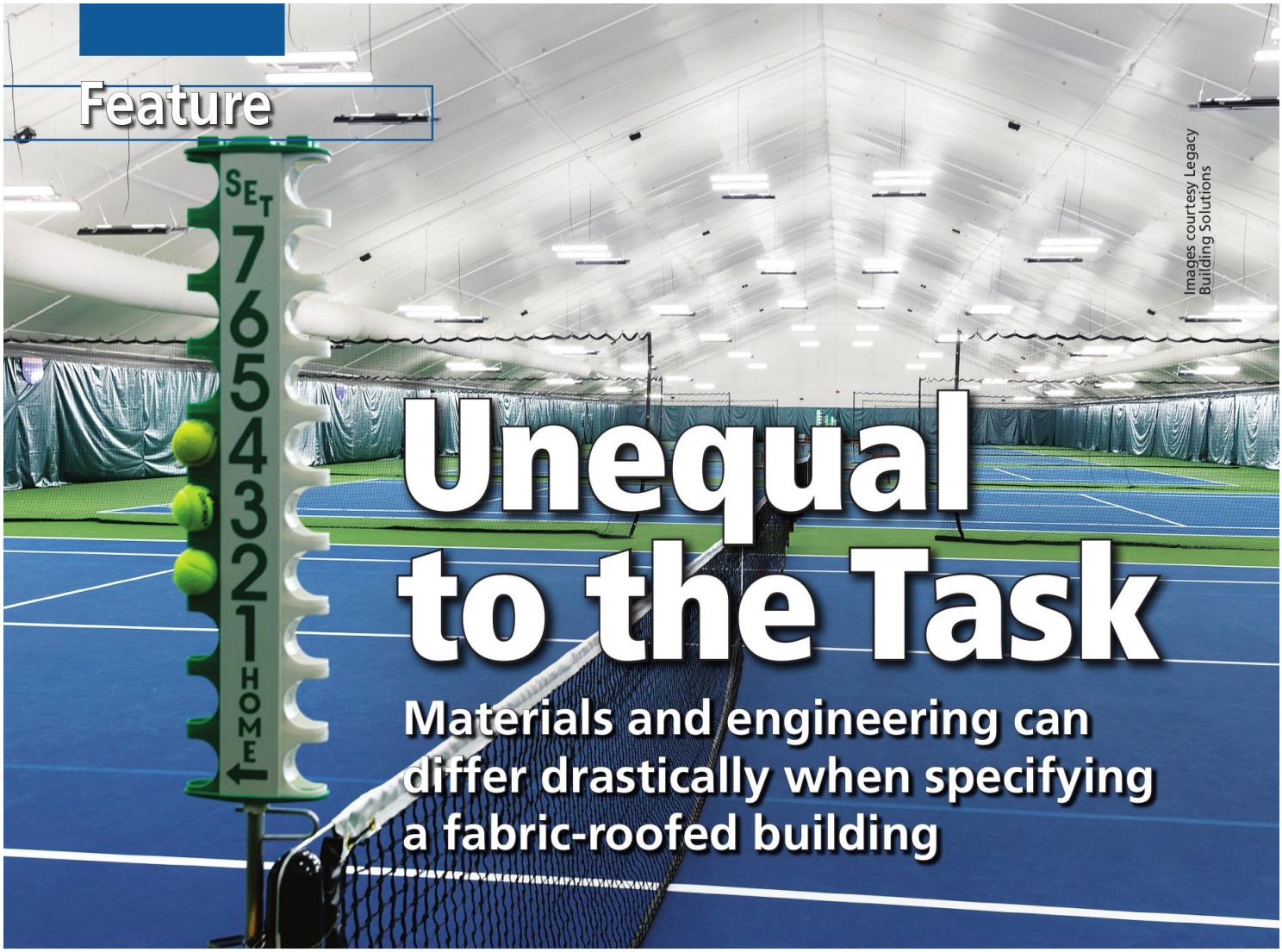


Images courtesy Legacy Building Solutions

Unequal to the Task

Materials and engineering can differ drastically when specifying a fabric-roofed building

By Nathan Stobbe

Language is an amazing concept. Somehow, we have the ability to comprehend thousands of words and an infinite number of sentences constructed by billions of people. Sure, miscommunications arise often—at times people are not interested in trying to understand what others are saying—but for the most part, language provides a common wavelength for all to talk, explain, discuss, argue, and share. Yet, language can be quite limiting when similar terms are applied to radically different things.

For instance, the term "fabric building" (or fabric structure) has existed for decades to describe any permanent or temporary structure utilizing fabric cladding for its roof and sidewall exterior. The phrase has always been used broadly, but today it covers a wide array of applications and engineering styles, to the point where "fabric building" is not an adequate description.

For the purposes of this article, fabric building refers to any code-compliant structure Canadian Standards Association (CSA) S367, *Air-, cable-, and frame-supported membrane structures*, defines as a "frame-supported membrane structure." Such buildings today range from simple hoop structures suitable for a backyard carport to permanent ones employed as world-class sports facilities. The materials used on the building's construction, including the fabric and frame type, determine the building's purpose and practicality. Both aspects have recently benefitted from game-changing innovations brought forward to the market.

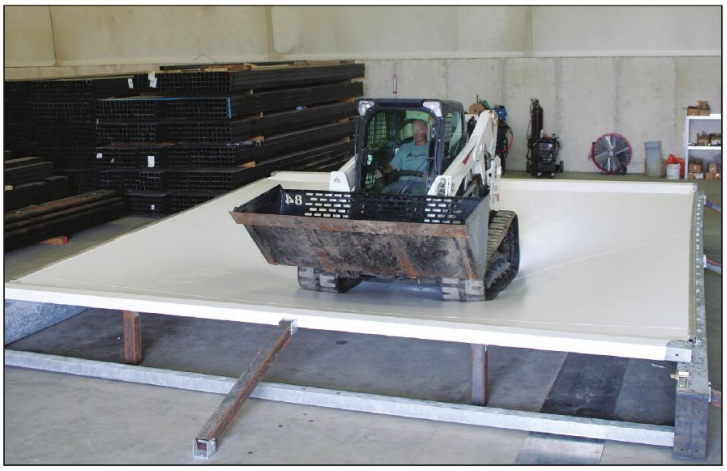
Fabric selection

For starters, there is the architectural fabric itself. Fabric roofing has been known to provide a multitude of benefits. While the fabric itself contributes only a negligible R-value, the roof's high solar reflectance

and thermally non-conductive properties contribute to keep it cooler than a conventional roofing system. At the same time, many fabrics offer a degree of translucency allowing sunlight to permeate the inside of a structure, effectively providing natural daylighting, and reducing the need for electric lighting in many situations. Fabric's permeability is also a natural fit for addressing building applications with high humidity (*e.g.* grain storage) and inherent corrosion risks such as environments used for salt or fertilizer storage.

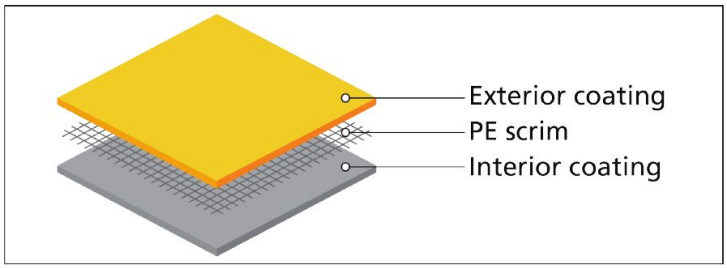
However, the word "fabric" when used in the context of a building is still a mystery for many. One of the most common questions from the uninitiated is around the issues of strength and durability; after all, how can fabric withstand severe weather events or just general wear-and-tear over a long period of time?

A simple example to help explain fabric strength is a backyard trampoline, a toy, which holds up well under constant duress—whether it is a hailstorm or a family gathering where children, small and big, bounce up and down for hours. Fabric building suppliers have even taken to more dramatic demonstrations of strength, such as driving skid loaders across suspended sheets of material, a feat no one would ever dare attempt on comparable structures with metal sheeting, which is weaker in comparison. Still, not all engineered fabrics are equal.

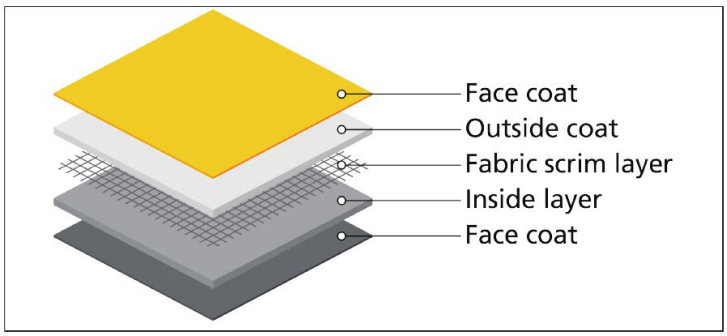


Fabric's strength can be seen in everyday examples like trampolines, or through more dramatic demonstrations like driving skid loaders across suspended sheets.

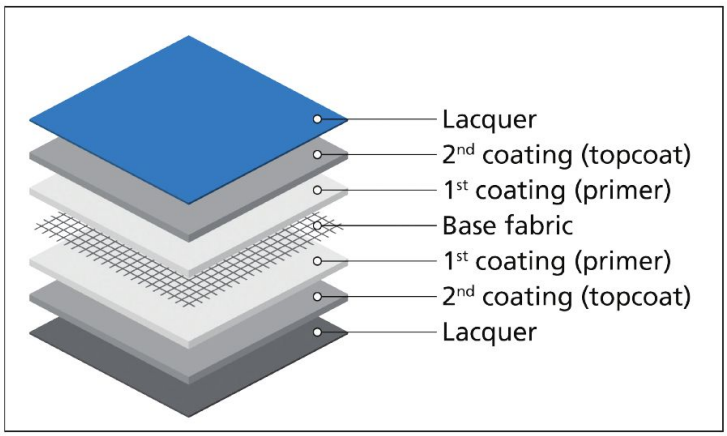
Perhaps the most widely employed fabric roofing material in North America for more than 25 years



Popular in the light commercial marketplace, a standard polyethylene (PE) fabric comprises the three layers shown in the image above.



Containing a heavier, longer-lasting yarn, polyvinyl chloride (PVC) fabric is a go-to material for high-end projects such as athletic complexes.



A seven-layer polyvinyl chloride has been developed to provide better performance at a price point similar to polyethylene fabrics.

is polyethylene (PE). Employed by many building manufacturers and especially popular in the light commercial marketplace, PE fabric is:

- easy to work with;
- supplied in wide rolls; and
- typically carries a 15-year warranty.

Another common fabric is polyvinyl chloride

longer-lasting yarn. However, there is a corresponding higher cost as well or, at least, there was.

An advanced PVC fabric was introduced to the market in 2017 with the goal of providing high strength and performance while remaining cost competitive with PE products.

A standard PE fabric comprises three layers—a scrim layer containing the weave and a primer coating layer on the top as well as bottom to seal in the scrim. The advanced PVC is similarly constructed, but with seven layers—a high-strength woven fabric in the middle, primer layers applied to each side of the base fabric, and then a topcoat layer (the actual PVC gives the product its shape and flexibility) is added to both sides. Lastly, a lacquer layer goes on the top and bottom to seal the fabric, deliver a smooth and slippery finish, and provide more durability.

Independent testing has shown this advanced PVC fabric to have more than twice the tensile strength of traditional PE material, and it retains the strength after years of exposure to weather. The fabric is self-cleaning and has up to 12 per cent translucency.

Rigid-frame provides design flexibility

Recent developments in fabric technology were preceded by a key advancement in fabric building framing when rigid-frame engineering was introduced several years ago. In contrast to fabric structures traditionally utilizing hollow-tube, open web truss framing, rigid-frame designs use the same structural steel I-beams found in most conventional construction projects.

The main advantage of this design is it provides far more engineering flexibility. Where web truss fabric buildings are often only offered in standard sizes, the rigid-frame process allows every structure to be designed to specific customer needs.

For example, if a building requires a hanging load supported by a frame (*e.g.* conveyor or fire suppression system), these parameters are accounted for from the very start by the finite element analysis software used to design the building. This allows engineers to modify and optimize each frame based on the actual loads that will be on it, rather than taking a worst-case approach and over-engineering an entire building to accommodate those loads.

When attempting to accommodate the same loads with a web truss design rather than a steel frame

Another common fabric is polyvinyl chloride (PVC), which generally has been the go-to material for high-end projects such as athletic complexes, military structures, and certain industrial facilities. PVC has higher tear strength than PE, as it contains a heavier,

thicker steel, frame width, and flange depth instead of changing bay spacing. A different frame can be built every time without adding any cost to the design cycle.

Beyond hanging loads, rigid-frame design allows the exact length, width, and height of a building to be specified down to the inch—an option not available with open web truss designs. Asymmetrical building designs, a wide variety of door options, variable column heights, insulation, ventilation,

I-beam engineering allows fabric buildings to be specified to exact custom dimensions, including offset peaks and variable column heights.

Fabric roofs provide high solar reflectance and thermally non-conductive properties while offering a degree of translucency for natural daylighting.

with a web truss design rather than a steel frame, suppliers may be forced to set up special jigging or change bay spacing between frames to handle additional loads, still with no guarantee it will achieve the desired result. I-beam construction simply uses variations like

and many other loads and features can also be easily applied with rigid-frame design along with alternative exterior cladding options like steel or brick. Additionally, solid beam engineering provides straight sidewalls, clear spans, and tall overhead clearances—maximizing the usable square footage inside the building and allowing the owner to take advantage of additional interior space.

Securing fabric

No matter the type of frame a building employs, the attachment system used to secure the fabric can drastically impact the project's lifespan.

Mono-covers, as the name implies, use a simple, large piece of fabric draped over the building and attached only at the ends and sides. This is a clear engineering weakness, as fabric is not designed to handle wind and other loads without support. During wind events, unsupported fabric has been known to tear, allowing the elements into the structure and, in extreme cases, causing building failure. Issues can range from unintended loading on the building frame to replacing the entire cover if any part of the membrane becomes damaged. Mono-covers are easy to install and relatively inexpensive, so they are suitable for small or temporary applications.

A panel attachment system is commonly employed. Fabric panels are shipped to the site in specified widths—6-m (20-ft) wide is typical, but it varies depending on the manufacturer—and then are slid through an aluminum keder channel to connect to each frame.

The traditional challenge with this method has been effectively attaching the aluminum extrusion channel to the frame. Many installers use self-drilling fastener screws (tek screws), which can lead to a variety of problems, including:

- tek screws sometimes get over-torqued during installation, causing the heads to shear off or the threads to strip out;
- motion-type pressure from wind or snow can make the extrusion susceptible to fatigue at pressure points because of the screw's small heads and aluminum's flexibility; and

Unlike metal buildings, fabric-roofed structures are inherently resistant to corrosion, making them ideal for salt or fertilizer storage.

aluminum's flexibility, and

- water can settle into the hole created in the aluminum around a tek screw, leading to corrosion.

However, the biggest challenge or flaw in this process in the opinion of many suppliers is the need to disconnect secondary bracing and literally pull trusses out of plane to install the fabric as well as apply horizontal tension to it. Flexing the building's frame after it is up leaves the building vulnerable

to wind damage and safety concerns during installation.

Rather than depending on tek screws, one can employ a fabric attachment system with stronger 12.7-mm (½-in.) diameter bolts to clamp a keder rail to the top flange of the structural steel frame. This method contributes to corrosion-resistance and greater longevity, as it eliminates any areas where water could accumulate.

Additionally, it allows fabric panels to be pulled into place with the properly calculated tension in both directions—horizontal and vertical—without removing any secondary bracing or pulling the frame out of plane. The frame can be permanently in its place during panel installation, which helps maintain the proper fabric tension throughout the structure's life cycle.

Installation using this method is also faster and safer. The time to build the framework for a fabric structure will be comparable to a traditional metal-clad building. However, once the framing is up, the fabric panels are easy to handle and quickly pulled in by an experienced crew, rather than painstakingly aligned and attached with multiple fasteners like metal panels.

The cladding portion of fabric building installation can take as little as one-third the time of a metal structure. When it comes to deciding between a conventional brick-and-mortar building and a fabric structure, there is a greater difference in erection time.

Quality control

in their own facilities to cut fabric or produce steel beams.

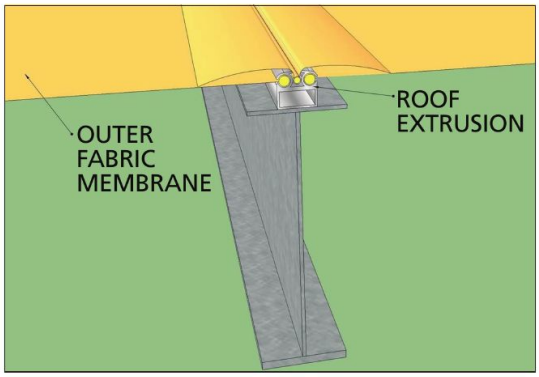
Particularly with panel systems that are sliding into extrusions, the tolerance for variation in the fabric is extremely low. The correct pretension is calculated into every panel to ensure proper post-installation tension on the building. Having a temperature- and humidity-controlled warehouse helps workers ensure compliance with fabric material specifications such as tear strength and elasticity.

There is also the practical matter of timely project delivery. Manufacturers who produce their own materials are better positioned to meet tight deadlines or simply avoid unnecessary backlogs based on supply issues that are out of their control.

Quality control

As engineering and installation methods have grown more sophisticated over the years, the demands on quality control in the material manufacturing process have increased as well.

In years past, it was accepted practice for fabric building manufacturers to rely on third-party suppliers to provide all building components. But the need to meet tight fabric tolerance requirements and control the material quality has prompted some manufacturers to invest



It is common to apply fabric in 6-m (20-ft) wide panels, which are slid through an aluminum keder channel to connect to each frame.

Some building suppliers have invested in their own temperature- and humidity-controlled manufacturing facilities to ensure compliance with material specifications and to monitor quality.

Attachment systems utilizing stronger bolts, rather than screws, allow the fabric panels to be properly tensioned horizontally and vertically without pulling the frame out of plane.

an airtight barrier to keep the frame out of contact with elements that may be corrosive to the steel, such as salt or fertilizer. A liner also works as an extremely good vapour barrier to seal off any insulation behind it. Lined buildings typically include a cavity ventilation system to prevent moisture build-up on the frames.

Coming together

Simply look at the standard fabric structure offerings of 20 years ago and the best of those constructed today and it is easy to understand why the term "fabric building" has so many different connotations in the engineering community.

Manufacturers have successfully taken the very best features of diverse building styles and married them together. Modern fabric buildings now actually have much more in common with traditional architecture. They are conventional buildings happening to have a fabric membrane. This reality is making it possible for more industries and building users to reap the benefits fabric roofing continues to offer.

Parameters for hanging loads from a rigid-steel frame can be accounted for from the start using finite element analysis software.

Interior liners

For buildings that require insulation or are housing corrosive materials, an interior liner could be added. Liners essentially serve the same purpose on the inside of the building frame as the fabric cladding serves on the exterior.

In addition to providing a clean, smooth interior finish hiding the structure's framework, liners provide

Nathan Stobbe is general manager of Legacy Building Solutions. Over the course of his career, Stobbe has overseen sales and construction of more than 35,000 fabric structure buildings in 21 countries. He has served as member of the original committee for developing Canadian Standards Association (CSA) S367, Air-, Cable-, and Frame-supported Membrane Structures, *and as co-founder of the Membrane Structures Manufacturers Association (MSMA). He also holds several patents for fabric structure construction. Stobbe can be reached via e-mail at legacy@legacybuildingsolutions.com.*