LEGACY
BUILDING SOLUTIONS

WHITE PAPER

FABRIC STRUCTURE MATERIALS & APPLICATIONS

OVERVIEW

Fabric structures are more than the basic hoop buildings of the past. Options now encompass everything from simple buildings put together in a few hours to large, permanent structures with custom architectural features to suit any application. Understanding the materials used in fabric structures and how they work together is key to purchasing high-quality, long-lasting buildings.

INTRODUCTION

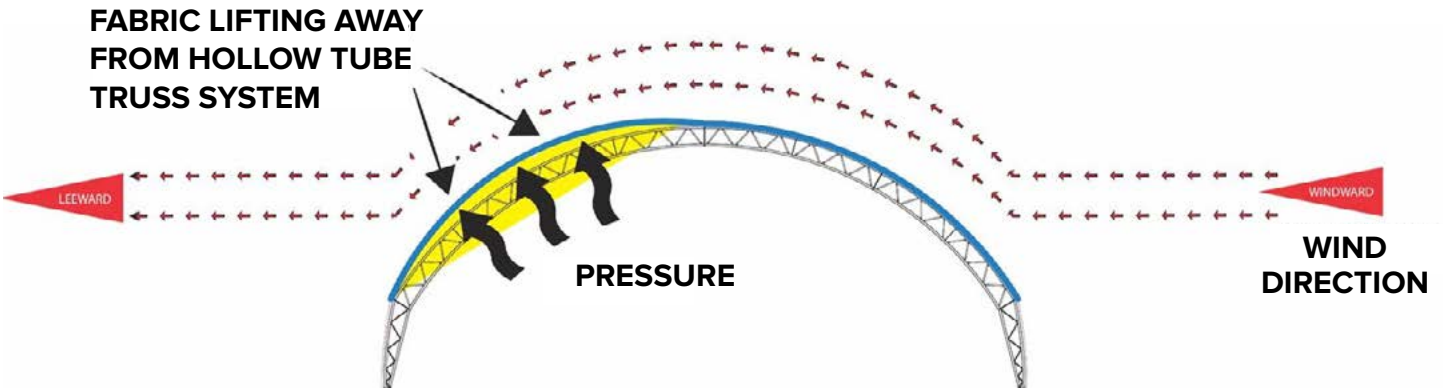
Fabric structures have range from simple buildings suitable for backyard use to large-scale buildings used for industries as diverse as manufacturing, aircraft hangars, sports centers and bulk material storage.

With all these options, it is crucial to determine the best building type for your use. Three important factors that determine the type, quality and longevity of a fabric structure are the installation method, fabric and frame.

INSTALLATION METHOD

The three most common fabric structure installation methods are:

1. **Monocovers**, which use a large fabric cover that is attached to the end frames of the building
2. **Attached monocovers**, which use a large fabric cover that is secured to each frame
3. **Individual fabric panels**, which are attached to each frame using a keder rail



MONOCOVER BUILDINGS

Monocover buildings use one large sheet of fabric, which is stretched over the roof and walls and secured at the end frames and the foundation. The distinction is in how the middle frames are treated.

In unattached monocover buildings, the fabric is unsecured in the middle of the building and rests on the trusses. During installation of these buildings, the fabric is pulled over the building and tensioned at each end using belting or ratchets. These buildings are easy to install, sometimes as a weekend project for the building owner. The primary advantage of unattached monocover buildings is that they are less expensive – the reduced engineering and lower installation time mean a lower initial price.

Unattached monocover buildings have several disadvantages. Because the large fabric sheets are attached at the end trusses only, horizontal tension forces on the fabric are transferred to the end frames, making it difficult to maintain proper fabric tension along the length of the building.

Wind will cause suction on the leeward side of the building, causing the cover to completely lift off the trusses. The excess pressure on the fabric is known to cause tearing and other damage. But perhaps more importantly, this system can apply significantly more force to the end frames of the building than they may have been designed to withstand, potentially causing failure of the end frames.

Some manufacturers of unsecured monocover buildings try to increase the size and lifespan of the roof by lacing the cover directly to the purlins or secondary bracing. While this can extend the life of the cover by holding it tighter to the frames, it may reduce the effectiveness of the secondary bracing. During wind events, the fabric pulls the bracing laterally while under compression. During the most critical moments of a wind event, the secondary bracing may be compromised as it deflects as a result of out-of-plane pressures that the bracing may not have been designed to take.

Many unattached monocover facilities are built using open web trusses. Open web trusses are made of tubular steel chords with tubular steel or steel angles placed intermittently between the chords to act as “web members.” Thin wall hollow tubes also present challenges, including chord plastification, which can cause the webs to punch through the steel tube cords and damage the truss. Corrosion can also begin inside the hollow tubes, which is undetectable and untreatable until it is too late. This can negate the non-corrosive properties of the fabric, which is one of the most popular benefits of fabric structures.

ATTACHED MONOCOVER BUILDINGS

Attached monocovers also use a single fabric panel stretched over the roof and walls. The fabric is attached to the end frames using a keder rail and attached to the center frames with lacing or straps. This is a relatively new building style, produced by Legacy Building Solutions and known as Eco buildings. Eco buildings use a rigid steel frame, which is never pulled out of plane during the installation process. Because the fabric is secured to all of the frames, it is never lifted off the frames and pressure is distributed equally among framing members that are engineered to support it.

In typical individual panel fabric buildings, the keder rail is attached to the trusses using small self-drilling fasteners, also known as tek screws. This system does not allow for horizontal movement of the keder rail system for tensioning, so the installer is required to either flex the truss or use telescoping purlins to move the frame during fabric installation. The other challenge with this system is that it is dependent on all of the fasteners being installed with proper torque – tek screws are often over torqued, thus reducing the hold down capacity due to human error. Additionally, the small tek screw heads create flex points in the aluminum keder extrusion creating possible failure points.

SEPARATE FABRIC PANELS

The newest type of individual fabric panel building uses rigid steel frames and a separate panel attachment system, where each fabric panel – typically 20 feet wide – is secured to the frame using a keder attachment system. These buildings use an attachment system that is patented by Legacy Building Solutions. In this system, a keder rail slides horizontally on the top flange of the frame, eliminating the need to detach or flex frames during the fabric installation process. The extrusion is attached to the frame with half-inch bolts, eliminating the challenges of the tek screw while allowing for the very important horizontal tensioning after the frame is fully secured into place. The roof panels are attached together to create a waterproof, sealed exterior membrane. The system also uses horizontal mechanical tension to stretch the fabric to the recommended level, keeping it taut and preventing any friction for the life of the building. This system provides regular support and tension for the fabric both vertically and horizontally, which is critical to ensure a wrinkle- free finish and a long fabric life.

The advantage of this system is that the cover is completely waterproof. There are no tiny holes from bolts or screws like on a metal building roof, which can allow drips and leaks over time

Another significant advantage of this system is increased safety during construction. Frames are completely braced and all cross cables installed and tensioned prior to installing the fabric onto the building. The frames do not need to be flexed or bent in order to allow for the fabric to be properly installed. Safety is always first during construction – a vital consideration on many commercial and industrial sites.

The separate panel system allows for greater pre-tension on the width of the panels, which means more uniform tension and longer lifespan for each panel. There is also greater vertical or “up and over” tensioning because the fabric is tensioned in a straight line, not around any radiuses.

The disadvantage of this system is that the fabric panels used in keder rail systems must be manufactured within tight tolerances. Some manufacturers simply do not have the expertise and equipment needed to maintain these tight tolerances. Monocovers typically do not have as tight tolerances as more variation of the fabric cover size can be accounted for during installation.

FRAME

Legacy fabric structures using the individual panel and attached monocover systems are constructed with rigid I-beam steel frames, as opposed to the open web trusses used in most fabric buildings. With the solid steel frame, the design options are nearly unlimited, opening up the possibility of overhangs, soffits, lean-tos and other designs that are difficult and expensive to do using mass produced trusses.

All rigid-framed buildings typically use the same engineering principles, whether the building uses steel or fabric cladding. The steel frames are solid members, consisting of fabricated I-beams. The rigid frames are engineered to withstand environmental loads, as well as additional loads from ancillary systems including conveyors, mezzanines, bridge cranes and other equipment. Experienced engineers can customize these solid frame buildings using finite element analysis software and manual quality checks. Secondary support comes from purlins and cross-bracing.

The main difference between fabric-cladded and steel-cladded buildings is how the material integrates with the frames. In a metal building, steel sheets are screwed to secondary members like purlins or girts which in turn bolt to the rigid frames, creating an exoskeleton that structurally aids the frames. In a fabric structure, the fabric is attached to the frame via a keder rail. Though the fabric is a redundant brace to the frames outer flange it is not included when designing the frame. The purlins are the only lateral support the rigid frame anticipates in the design process. Additionally, cables and steel rods are attached to the frame to transfer longitudinal wind forces through the roof and into the walls, eventually terminating in the foundation. Before engaging an engineer on a fabric structure project, be sure they have the experience required to determine the loads from the fabric and add them to the other forces as needed.

FABRIC

There are several types of fabric on the market. When installed and tensioned properly, fabric has strength, weather resistance and longevity that is greater than building materials such as metal cladding, shingles or siding. However, it also has some unique advantages that can't be matched by other building materials.

Each type of fabric varies in light transmittance, strength and weight, as well as other properties. An experienced consultant will help you find the best fabric for your application. Standard fabric tests include the grab tensile, strength tensile and tongue tear tests. The manufacturer should have the results of these tests readily available for each of the fabrics you are considering.

One of the best-known advantages of fabric cladding is the natural light. Humans and animals have a natural attraction to sunlight, making the building more appealing to employees and customers. Legacy's exclusive ExxoTec™ PVC fabric has up to 16% translucency – which on a sunny day will allow enough light into the building to safely work without the use of artificial lights. Many building owners will find that the savings on lights installed and powered will be a significant over the life of the building.

The ambient light creates a more pleasant working environment. There are no dark, shadowy corners, just glare-free natural light throughout. This is especially beneficial for buildings such as sports centers, entertainment venues, warehouses, workshops and maintenance facilities.

Fabric has properties that make it inert to corrosion, and ideal for corrosive or marine environments. This corrosion resistance also makes it a cost-effective choice for storing harsh materials, such as fertilizer, salt or mining ores. In corrosive environments, fabric is proven and warrantied to outlast many other materials.

In corrosive environments, the steel frame should be treated with a corrosion resistant material, such as hot dip galvanizing. The ultimate in corrosion protection is when a fabric liner is installed in the building. Installing a fabric liner keeps the corrosive material, even fine dust, out of contact with the building frame. The steel is then protected from internal and external corrosives.

Fabric can also make the interior of the building more comfortable, as fabric has thermally non-conductive properties. Unlike steel, fabric does not magnify the outside temperatures, maintaining a more consistent interior temperature. Metal cladding will radiate temperature variations, creating an interior that is colder in winter and hotter in summer. Flexible fabric also minimizes air leakage, resulting in a building which is much more efficient to heat or cool. Metal buildings are constantly contending with air leakage through screw holes and seams, which is often the number one contributor to heat loss within a building.

Superior acoustics are another advantage of fabric buildings. Rather than reverberating background noises, fabric will dampen them. This means concert venues and sports centers have clear, crisp acoustics – keeping focus on the event. Noises created by mechanical systems mounted on or beside the building are deadened by the building material, providing high-quality acoustic attenuation in the event space.

Time and cost savings are another advantage of fabric. Fabric panels are installed in about one-third the time of steel sheeting – allowing construction crews to get in and finish faster. This also reduces the costs of wages, equipment rentals and living allowances during installation.

FABRIC BUILDING REPAIR

In industrial applications, the flexibility of fabric also provides some protection from collision. Unlike some conventional construction, when the fabric is damaged it is easy to repair by the building owner or by trained crews. Heat welding will restore the fabric to nearly 100% of its original strength. Most repairs are completed quickly to minimize downtime and return the building to normal working order.

Fabric structures are also relocatable. Because there are no penetrations in the fabric, the cover is pulled from the keder rail, rolled up and trucked to a new location. At the new site, the fabric can be unrolled and fed back into the keder track. Relocating is relatively easy compared to metal buildings, which have thousands of holes in the cladding that make it very difficult to re- use the steel sheets.

Another way that fabric structures save time and money is with a reduced need for maintenance. There is no paint, no shingles and no siding to repair and replace. Properly installed fabric panels never need to be re-tensioned. The fabric will last for decades, and the steel frame is designed to last for generations. No building can guarantee a lifetime of maintenance-free operation, but fabric structures easily outlast many competitors.

Of course, all buildings are vulnerable to damage, whether from collision with heavy equipment or from a fire. Fabric structures using separate fabric panels ensure that in the unlikely event a section of the fabric is damaged, only the damaged areas need to be replaced. Monocover buildings have a greater probability of requiring a completely new cover, which comes with a higher cost and increased downtime.

Fabric buildings are also self-venting. In the presence of heat or fire, PVC fabric will melt away from the flame rather than feed the fire. Often, most of the damage from a fire is caused by excessive heat buildup. When the fabric melts away, it allows the heat to escape and drastically reduces the damage to the building. The ventilation also provides an escape route for smoke, which is one of the most deadly elements of a fire.

EXXOTEC™ FABRIC

PVC fabric is one of the best-known architectural fabrics. Legacy uses an exclusive PVC fabric called ExxoTec™ - when compared to other PVC and polyethylene fabrics, ExxoTec™ has superior strength and performance characteristics. ExxoTec™ fabric is made of a woven inner layer, called scrim. The scrim is the basis of the fabric and provides the strength. Both sides of the scrim are protected by a primer, a protective coating and a topcoat lacquer. The primer layer is designed to inhibit bacteria, mold and UV rays as well as enhance the bond coating. The top coat helps prevent UV rays from penetrating the inner layers, provides a waterproof barrier and provides protection to the scrim. The final layer of the fabric is a lacquer. The clear lacquer has two primary roles: to keep plasticizers within the PVC from coming out, and to provide a smooth, self-cleaning surface. ExxoTec™ is also flame retardant in accordance with NFPA 701 large and small scale tests and California Fire Marshal requirements.

FABRIC MANUFACTURING

But the quality of the fabric is only one piece of the puzzle. How the fabric is treated during manufacturing and installation is equally important.

Fabric panel manufacturing is the process of taking fabric from the manufacturer's roll, cutting it and preparing it for attachment to the frame. Each roll of fabric should be inspected as soon as it arrives from the manufacturer. Any visible imperfections, including discoloration, should be immediate cause for removing the fabric from the manufacturing area. After the visual inspection, the standard fabric tests should be completed. Once the fabric has passed all quality inspections, panel manufacturing can begin.

Panels must be measured to tight tolerances that account for the precise amount of stretch present in a given fabric. Precision manufacturing is especially important when using individual fabric panels, as the size of the fabric is what provides the biaxial tension on the panel and prevents excessive movement and premature wear. Once the panels are cut and aligned, individual pieces of fabric are welded together using hot-air, wedge or RF welding systems. The strength of the fabric weld should be the same as the strength of the fabric itself. Once the fabric panels are manufactured, they can be rolled and packed for shipping to the building location.

Where the fabric panels are manufactured is nearly as important as how. Fabric panels will perform best if the manufacturing facility is kept with proper temperature and humidity parameters to ensure the optimal weld strength and proper panel sizing. Each panel should also be labeled with the location on the building before it is shipped. This will not only save a significant amount of time and confusion on the jobsite, it will help ensure that the panels are installed correctly.

If you don't have the opportunity to tour the factory floor, there are a few ways to verify the quality of the fabric panel manufacturing. Quality certifications including ISO 9001 are good indicators that the manufacturer has an established process for manufacturing the panels.

When properly tensioned, structural fabric creates a taut, weatherproof surface. When applied to the inner flange of the frame, it also creates a barrier between the interior of the building and the frame. This is especially useful in highly corrosive environments. The interior liner keeps even fine dust and particles from settling on the frame, preventing pitting and damage to the frame. Access panels can also be welded into the fabric, which allows the building owner to inspect the frame periodically without opening the frame to the interior.

Fabric liners are also used in insulated buildings. Adding a liner to the underside of the insulation protects the building and insulation, as well as provides a clean, bright finish on the interior of the building.

All buildings require a foundation. As permanent buildings, industrial fabric structures require a permanent foundation. Reputable fabric structure manufacturers will be upfront about the need for a foundation and supply options starting at the first consultation. There are many foundation options available ranging from traditional CIP concrete to helical screw piles.

CUSTOMIZATION OPTIONS

After the basics of frame, fabric and foundation are in place, it's time to start customizing the building. Fabric buildings using rigid I-beam frame technology are designed with the same engineering checks and balances as steel buildings, allowing for many of the same customization options.

Fabric pairs nicely with other cladding materials, which can be applied to all or part of the wall. Depending on the building application, some owners may choose to add materials such as steel, concrete or window panels along the wall. These claddings can be used for additional security, design code requirements or aesthetics.

Most fabric buildings have a roof pitch of at least 4/12. This pitch expedites the process of snow sliding off the roof. Steep roofs also allow extra room for conveyors and catwalks. Monoslope roofs are popular when a building is being added to an existing structure.

Another roof customization option is an offset peak. Offset peak buildings are designed with the highest point not in the center of the building. Offset peaks are used to put conveyors in the best location, and may also be used when the building will have a lean-to. Many buildings with offset peaks are used for storing bulk material such as fertilizer, agricultural commodities and salt.

Ventilation lets the building breathe. Proper air ventilation will vary significantly based on application and ranges from simple gravity systems to powered fans and vents. Overhangs, which are typically only available on rigid-framed fabric buildings, allow for soffit ventilation to aid in the natural ventilation of the building or to provide attic ventilation in an insulated building. Combined with rooftop exhaust vents, soffit vents can provide a maintenance-free gravity ventilation system. Other ventilation options include endwall vents, powered fans and even open-air pavilions. When combined with the non-conductive properties of fabric buildings, ventilation may create a building interior that does not require any other climate control system.

Insulation is available for occupied buildings. In independent studies, insulated fabric buildings have been shown to be 20% more efficient to heat and cool as compared to similarly insulated metal buildings because of the non-conductive and airtight qualities of fabric.

Solar power combined with battery storage and a back-up generator system may supply enough energy to completely eliminate the need for expensive grid connectivity. Combining a renewable power source with energy-efficient buildings allows reliable business operations in even the most remote locations – including far northern areas and mining sites. The roof of a fabric structure can be customized for a building-integrated solar power system consisting of either crystal silicon or thin-film solar cells. The steel frame runs parallel to the panels, preventing uplift which can damage the panel.

CONCLUSION

Purchasing a fabric structure means specifying every aspect of the building, including the fabric, frame and attachment. Taking the time at the beginning of the project to determine the best materials and methods for your use will ensure you get long-lasting, cost-effective solution for your needs.