PRESSURE STABILIZED CABLE STRUCTURES

Tomorrow's Structures Today

By

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Introduction

Anyone who has been in the building construction business for any length of time realizes that there are many different ways to build a building along with many different kinds of materials. Why should one be interested in learning about a new structural technique along with new materials? The answer can be given in one simple word:

Benefits

These benefits are so numerous and substantial that one would be remiss to ignore them.

The key one is reduction of cost and it can be both initial investment, as well as, operating cost, which continues for the life of the structure.

Another benefit would be simplicity of design and maintenance, which results in ease of application and time savings.

Safety is inherent in the design and refers both to means of construction, as well as use of the final article.

Being environmentally friendly is important in that it tends to be "green", saving on energy and minimizing use of non renewable materials.

The elimination of problems created by efficient modem construction is a side effect which naturally occurs.

Last, but not least, is the improvement of attitude of the users of these structures, which results in faster learning, getting well quicker, purchasing more, etc. depending on the application.

These are just the most obvious benefits of applying this advanced construction system to conventional buildings. Other unique capabilities will be discussed later, such as, the ability to build extremely large free span structures economically; the ability to include inside landscaping, and indoor sports facilities with natural grass playing fields; the ability to do conventional construction without weather considerations, etc.

Important Note:

These structures are often confused with the older heavy fabric air supported structures, since they both rely on air for their structural integrity. However, they are fundamentally different and do not perform the same way. It is like trying to compare propeller airplanes with jets. They both fly, but the jet can fly higher, faster and more economically, especially in the larger sizes. The heavy fabric structures tended to simulate buildings that required lights and were not ventilated, and often were not even occupied. These advanced structures rely on steel cables for their strength and tend to simulate the outdoors, with its sunlight and fresh air, but without the wind, rain or snow. These pressure stabilized cable structures are acceptable where air supported structures are not.

History

In order for one to feel comfortable in applying a new concept, he must understand it thoroughly. Every application can be different and he must be able to recognize where it can be used advantageously. No one concept answers all problems. However, this is a new tool and can be effectively used to solve simply what might otherwise appear to be almost impossible.

If one knows how the system evolved, he can readily follow the logic to where it is today and know he can apply it even further.

This is not the invention of a new science. It did not require a breakthrough in physics. It came from the combination of technologies of different fields, which have not previously worked together. This method of development is a fast way of making progress that is reliable, quick and economical. It came from the combining of tire technology with aerospace technology and air supported structures.

An engineer, Bob Pierson, in the tire division of the R&D department of Goodyear Tire and Rubber Company, decided he could improve the performance and reduce the cost of air supported structures by using tire technology of that day. He reasoned that tires were made of inner tubes, which had no strength, and casings, which carried all the strength. Why not make the building of steel cables and use inexpensive vinyl sheet to retain the air? He further reasoned that since the vinyl could come in many different colors, as well as, without color, it could let light inside the structure. He applied this to a home.

The structure was made of steel cables, spaced about as wide apart as the width of the vinyl rolls. One side of the structure was the garage, the center was the front yard and the other side was the living quarters. On the two sides he used vinyl with white pigment, so that they would be reflective and in the center he used clear vinyl with no pigment so all the light came through. Inthe center part he planted grass and installed a swimming pool. The vinyl sheets were mechanically attached by hand to the steel cables, and a fan inflated the structure. (The cables were anchored to the ground, to resist the uplifting effect of the internal air, which was at a small pressure above ambient.) See Fig.1 & 2

They had a young couple live in the structure for a while and note its good and bad features. The young lady used to vacuum the carpets and then hose the yard from the living room. It was all under one roof. There were no supports inside. The rooms only used low dividers. The trick was to try and get invited to a "bubble" party.

From this early experiment, they decided to build a greenhouse and worked with a local farmer, Dick Pretzer, and the Ohio State University Agricultural Department. Here they learned the importance of maintaining a uniform temperature and the need for high ventilation rates. They also learned that one could bring in farm machinery and farm it inside as he would outside, minimizing hand labor. See Fig. 3

Goodyear made a market analysis and determined that their tire salesmen were not the ones who could sell these structures, so they put the idea back on the shelf The farmer they had worked with, however, wanted more of the greenhouses and convinced Goodyear to let him start a new company and put them on the market. The new company was called Environmental Structures, Inc. and Goodyear turned over all their patents and know-how for stock in the new company. I was head of R&D at Goodyear's Aerospace Division and went with the new company as VP. of engineering.

The first greenhouse we made had 100 changes from the one Goodyear had built. Ninety nine were improvements, one was not. We knew we wanted more ventilation, so we just doubled the size of the vents, which seemed logical. It turned out that this was disastrous. It increased the pressure loads on the vents and made them harder to operate and actually cut down on the opening. What we wanted was larger openings, not larger vents. We went back to the drawing board and redefined the problem. The new vents we developed were so simple, balanced, and easy to operate automatically that one can't imagine how we could have worked so hard on the old style greenhouse type vents.

Applications and Manufacturing

A one acre greenhouse was designed, 100'x450 ' and we thought we would standardize on it. Our salesmen tried to sell it. The first customer had only 93', not 100' and we wanted the sale, so we made one 93' wide. The next one had 115' and he wanted to use it all, so we made a structure 115' wide. It took three before we made one 100' wide in New Jersey. The next one was for Texas, so it had to be bigger than the one in New Jersey, so we added 50' to the length. We soon realized that we already had standardized on our method of manufacture and it was easy to make it whatever dimension the customer wanted. Since then, no two have been alike except the twin domes we made for the X-File movie. We make whatever best suits the application.

Key is the manufacturing technique, which lends itself to large structures. It was found that for structures with a clear span of about 40 'or less, it was often more cost effective to use conventional construction. Once the clear span gets larger, cost of conventional construction goes up with the span and at an increasingly faster rate. With this construction technique, it goes up at a very slow rate. The larger structures soon become prohibitive in cost and this stays low, making the difference substantial. See Fig. 4

The covers for these structures are made of steel cables built into the seams of the cover material. These cable must be very flexible, since they are folded up into the cover for storage and transportation . The cables take the design loads, so they must be sized and located in the cover accordingly . The cover material usually comes in rolls of a specific width which defines the cable locations . In the manufacturing process, the cables are stretched out to their full length and the seamer is on wheels and tracks making the seam and simultaneously including the cable.

This is a relatively fast process, and must be, because there are so many feet of seams to be made. Depending on the material, the seamer may be a stapling machine or a dielectric welder . The cover is fabricated and folded right onto the shipping pallet. By moving the seamer instead of the material, very large structures can be fabricated, since only one panel at a time is handled. Covers as large as 65,000 pounds in one piece have been made this way. Transporting them by truck must be planned, since at this weight trucks are being overloaded . Larger structures may have to be made in pieces or on the site, depending on the size and application. Now in the planning stage is the enclosure of an entire golf course of over 200 acres and it appears that this one will be fabricated on the site to minimize transportation problems. See Fig. 5

Since making very large structures is the most attractive from an economical standpoint, that is the area where new business can be developed. It is possible to economically enclose areas never even considered practical previously. However, to fabricate these structures one needs a room as long as the longest cable, even though it does not have to be very wide. This is an ideal shape for a temporary esi structure and that is what is being considered for the on site fabricating facility for the golf course structure.

Single piece covers of 3-4 acres can be made in a factory and transported by truck to the site. Here they can be assembled into larger single pieces. If they are fabricated at the site, they can be almost any size. By making the enclosures in a single piece, it is possible to move them around on the site by floating them on a cushion of air. Size and weight become secondary.

The general practice is to prepare the site in advance before bringing the cover. This means the foundation or anchor system is installed along with all the doors, fans, heaters, controls, etc. This is the type of work a general contractor would perform and with which he is thoroughly familiar. All the wiring and plumbing must be complete and checked out, because once the cover is installed, the system is operational. All of this work is around the perimeter of the site, and often the floor is left to be completed after the cover is erected. It is best left as just a flat area.

The cover, with the structural cables built in and numbered, is spread out over the site and each cable is attached to its respective anchor, also numbered, by a hand operated shackle. It has been preplanned that when the cover is spread out it will result in each cable end being close to its termination point. This entire operation is very quick and usually takes place in less than a day. (It is important, however, to note that a calm day is necessary, since this would be one very large sail if caught by the wind.) Once the cables are attached, the air can be turned on and the cover will erect itself After it is erected, the workmen can go around and seal the cover by use of a press-on seal. The fabric must be installed loose, so that the cables take the design loads. Once erected, the control system regulates the internal pressure according to the wind velocity and the structure is no longer vulnerable.

Design Considerations

As pointed out by a roofing expert, this is really a roof. Sometimes it goes all the way to the ground and at other times it terminates on a wall. However, the integrity of the roof depends on the internal air at a slightly elevated pressure, so providing that air becomes part of the roof The older heavy fabric air supported structures did this by sealing up the entire structure and bringing the air in through a blower which was set to create an internal air pressure required to resist the highest wind load anticipated. This was perfectly adequate for their first enclosures, which were protections over large radar installation. No daylighting or air changes were needed.

In the first esi installations, which were greenhouses, sunlight and fresh air were necessities. The covers were made of steel cables and the vinyl material was a window clear film. Since the cables took up less than 1% of the surface, this was a big improvement over the conventional greenhouse, which often used up 20% of the surface for support structure. However, the air supply system had to be changed so that good ventilation could be provided economically.

Ventilation

Two major changes were effected. First, the blowers, which move a small quantity of air at higher pressure, were changed to fans, which move large quantities of air at low pressures and secondly, the internal pressure was regulated according to what was needed structurally to resist the outside wind velocity . On only rare occasions did the structure need the high internal pressure, so it operated very economically on whatever it did need. This required that a wind velocity sensor be installed along with a control panel, which determined which fans operated. Since the higher pressure required for the high winds could not be provided be the fans, some of the fans were equipped with a second fan in tandem, which when turned on raised the pressure through that fan without increasing the volume. (This is essentially how a jet engine operates. It has a whole series of fans in tandem and increases the air pressure through the engine in that manner.)

The fans were then distributed along one side of the structure and vents were located opposite to them so that a slight breeze could be created in the structure. All the air entered on one side and exited on the opposite side. Ventilation rates up to a change a minute through the crops were possible. A simple control system was designed so that opening and closing the vent could be regulated by the temperature and turning on the fans would be controlled by the wind velocity requirement of internal pressure. This large ventilation capability and simple control system, permitted the elimination of the need for airlocks on large vehicle doors. When a door was opened, the system automatically replaced the lost air by turning on fans and when it closed they were turned off again.

The entire structure is no longer vulnerable to small holes as is a conventional air supported structure. It can sustain large accidental damage areas without concern. Once this automatic high ventilation system is incorporated, it provides many other useful benefits. For instance, if the structure were unattended for a week end, an alarm circuit is included so that if someone tried to enter, through a door or a hole, a fan would automatically replace the lost air and send a signal that an entry was attempted.

It also makes the structure an ideal fire fighting system. If the structure is equipped with sensors along the vent wall, and a fire occurs anywhere in the structure, a sensor would be activated and one can immediately know the fire location. A fire fighter could approach the fire from the fan end in clean air and put it out without it spreading to other parts of the structure. This is because of the slight breeze with known direction in the entire structure. (Incidentally, this breeze is usually not fast enough to pick up papers from a desk, but could be noticed by the movement of smoke if one were smoking.)

Another benefit of this ventilation system is that by providing the inlet fans with filters, the inside of the structure can be kept clean, since its slight positive pressure prevents infiltration of dust and dirt. (Actually, with the proper filter, this could become a "safe haven" from terrorist attacks.)

This good ventilation system prevents the occurrence of "sick buildings" and "mold", which have become present in many modem buildings today. It tends to have a drying effect, which can be easily handled with a simple evaporative cooling system. The movement of air, provided by ventilation , is the natural way to get true creature comfort rather than be providing cold air, so it reduces air conditioning costs.

Doors

Because of the slight positive pressure inside this structure, a conventional hinged door would have a tendency to swing open or shut depending on the way it is mounted . This could be a problem for personnel doors, so balanced doors are used. These fold in such a way that they are easy to operate. For vehicle doors, overhead or roll up doors work well. In ordering them, one has to take into account the pressure they must withstand . Usually, revolving doors, which are not bothered by the pressure difference, or airlocks with balanced doors are used for personnel. These airlocks can come in sizes which will accommodate a wheel chair. Balanced exit doors with panic hardware are available, and these also can come in sizes that will handle a wheelchair. Usually, esi supplies the doors as part of their package.

Lighting and Heating

During the daytime, much of the lighting and even a substantial part of the heating can come directly from the sun at no cost through a translucent cover material. When one gets too much of it, the lighting can be modified with shade and the excess heat can be vented back to the atmosphere very economically. Throwing away the excess might strike one as a waste, but realize that this was obtained at no cost. It was "free" from the sun and not paid for in the use of costly energy. Taking advantage of the solar energy is the difference, since it is usually completely wasted. As new developments occur, it may be possible to even increase this solar usage, which comes from an unlimited energy source.

The daylighting is already producing benefits in personnel attitude.

The amount of lighting produced by the sun is much larger than what is normally provided with artificial lights in the daytime. However, in the evening and at night, artificial lights could come on automatically when needed, giving optimal energy savings. These lights could be located internally or from the outside through the cover as best fits the application. If the lights were internal, such as in a store, the cover itself could be back lit to produce an outside advertising screen. This could be an added feature not readily possible with other structures.

If the lights are outside and operating through the cover, such as in a sports facility, it would not matter if it were day or night, the playing field would be flooded with shadow free light. (This could be on a natural grass playing field with perfect grass, because it could be watered and cut optimally, not dependent on weather. Imagine, no mud.)

Because of daylighting, it would be possible to landscape the interior of any structure to add to the outdoor feeling and use plants to get their benefit. These plants would not have to be taken out periodically to get refreshed, but could be attended inside as if in a greenhouse. An item not easily measured , but appears to be significant is the uplifting effect on people of daylighting in any structure. It has been shown that people learn better, get better quicker, feel more enthusiastic and are happier in daylighting rather than under artificial lights. So for whatever the application, there would be additional personal benefits.

Heating is another solar benefit that is obtained at no cost. Sometimes in the summer the sun produces an excess of heat and, as mentioned above, it is economically vented out. At other times, such as in the winter and at night, supplemental heat is added. Depending on the source of the heat, it might be through heat exchangers or by direct fire. The heat can be brought in along with the make up air or it can be by recirculating the inside air. A certain amount of make up air is always required to make up that lost to leakage and through the vents. Bringing in heated air retains a uniform interior temperature . Modified roof top heaters are used, which automatically bring in heated outside air when needed and switch over to recirculating the air when make up air is not required.

To operate most efficiently, it is often possible to let the air stratify and treat only that part that is occupied . At the same time, this stratification can be put to work when required. Since heat tends to rise, it is often permitted to collect at the top of the dome. In the summer, this is excess heat and it is left undistrurbed. In the winter, it can be used to melt a freezing rain or wet snow, by single layering the double layer cover, eliminating the insulation properties , and that extra weight can drain off as water . In addition, the heated make up air can be directed upward across the top and back along the floor area to create a very uniform temperature in the occupied areas. All this can usually be accomplished without duct work, taking advantage of pressure differences which cause air movement.

This structure is unique and novel and lends itself to innovative use of natural forces, which tend to keep construction and operating costs low. It can be treated as if it were the outdoors, where it is an ambient environment and special spaces can be created inside of it. For instance, if an office or other occupied space is required, where a particular temperature and humidity is needed , it can be partitioned off and air conditioned separately, using conventional units mounted in the partitions and exhausting into the ambient environment.

Safety

This is perhaps one of the safest structures ever constructed . It has already been described as a fireman's dream house, as far as fire fighting is concerned. The cover is made of materials which do not support combustion, so if a fire starts from something else, the cover will not burn or contribute to the fire. Ifthe temperature is high enough, the cover material will melt and a hole form, through which any smoke generated is exhausted.

The ventilation system is already sized to be able to handle a very large hole automatically.

The cover itself, usually weighs less than a quarter of a pound per square foot. This includes the double layer of fabric and the steel cable built into it. In the winter time, this is so light that the temperature difference between the inside and outside can support it as if it were a hot air balloon , even if there were no excess pressure to support it. In the summertime, if it were to come down, it would do so slowly, like a parachute and one could walk around under it and easily support it with his arms.

Normally however, one fan must be running at all times to keep the cover in its designed position. This means that in the event of a public power failure, an automatic emergency generator is provided so that the fan system is unchanged. With power failures as common as they are today, it is a safety feature to have ones own power on hand. These generators are usually sized to handle the entire building system as though nothing had happened. Once a generator is planned, making it larger, enough to handle other items, is a very economical factor and often an owner will have it handle his entire operation. An example of this was a farm in New Jersey, which had an esi greenhouse. The generator was sized to handle the entire farm. One day the owner called to say they had an ice storm and the entire area was without power. He was operating normally. He said that one day the generator paid for itself.

There was an esi patio enclosure in Niles, Ohio at a place called Tin Pan alley during the time that a tornado passed through there. The entire town was without electrical power for about 10 days. The automatic generators came on and the owner of the installation said they were the only place open and were feeding all the rescue workers.

TYPICAL APPLICATIONS

Wherever one looks, he can see places where an outdoor environment might be an improvement over an activity that is now placed inside a building.

Greenhouses

It has already been mentioned that greenhouses were our first venture into the advanced cable structures, and these required an innovative approach, since the farmer must watch every penny . This meant getting the maximum sunlight while economically providing unifonn high ventilation and heating. The resulting structures grew exceptional crops. Award winning cactus plants were grown in Ohio. The champion orchid was grown in Japan and top grade tomatoes were grown in Texas. It was actually shown in these structures that a shadow free sunlight produced better crops than a window clear cover could produce.

The greenhouse type structures were also used to clean up contaminated environments. As an example, at the Weyerhaeuser truck shop in Raymond , WA, petroleum products had gotten into the soil and had to be removed . By bringing the earth into this type of structure, mixing it with chemicals and letting the sunlight act on it, they were able to cleanse all the earth at the site and did not have to take any of it to a landfill. The project manager said it was the most exciting and satisfactory project he had ever worked on in his 39 years with the company .

Pool

A natatorium or indoor pool is often enclosed with glass to get an outdoor "feel". The architects of a fitness center in Portland, Oregon wanted the pool they built into their structure to be available all year regardless of the weather and to represent an outdoor environment including the sunlight, fresh air and view of the surrounding mountains . The results were written up in Progressive Architecture.

In this particular case, a window clear double layer cover was used over the pool area. High ventilation was provided and the inlet air was heated in the wintertime so that the pool area was comfortable all year. With the window clear cover, sunlight was provided inside whenever it was available outside and the life guard had to use an umbrella inside even as he would have had to do if he were outside. For all practical purposes , he was outside, except there was no wind, rain or snow.

The air was brought in on one side and vented out on the opposite side. This created a very small breeze inside that removed any odors and had a drying effect. It also provided comfort even in the direct sunlight.

Multipurpose Room

In Minnesota, a lodge and conference center, added a room to one side of the building . This room was used for many different activities. There were times when it was fitted for basket ball and tennis. At one end was a section equipped with exerciser machines . Since it was connected to their kitchen, there were times when it was used for formal dinners.

Since a road passed by the end of the structure, it was built with a flat end wall that was skinned with window clear film so that it became a big picture window to the forest beyond. In that end wall was a large truck door that permitted the entry of fire fighting equipment for a trade show on that subject. The room was bathed in shadow free sunlight and could be used year round with its outdoor environment, but no wind, rain or snow.

Sports On Natural Grass

The first indoor golf driving range in the U.S. was made by esi. It is interesting to note that it was for a British person who was looking for someone who could build a triangular shaped structure. He had been trying to use old tennis court enclosures in England. He wanted to place the tees along one side and use the opposite corner as the target area. He got together with a couple of people in Michigan, where we made a number of indoor golf driving range structures. We left the natural grass inside and it grew beautifully .

These structures were often lighted at night through the cover from lights mounted on poles located on the outside. One such facility included, besides the golf driving range on natural grass, a running track, snack bar, lavatories, office, pro shop, maintenance building and portable softball backstop . This was used for many activities and festivals were guaranteed successes, because there were no rain days. They even flew hot air balloons inside to license them for sale. (The competition claimed they could do the same thing, but the grass always died, since they could not bring in sufficient light. Therefore, they went to carpets and many golf domes were built that way.)

The applications mentioned, so far, were for year round use. However, it is possible to make temporary structures that are erected for use during the bad weather only, since these are easy to erect, take down and store. One person found that he could rent a closed driving range in the winter and enclose it. He could then open it for business, using the same tee stations and retaining the grass. He would store the structure in the summer and bring it out in the fall. He did this for ten years and made a nice business from it.

Unique Applications

Instead of taking the dolphins at Cedar Point to San Diego for the winter , a portable dome was provided which could be quickly erected over their swimming area. The environment inside was retained with summer outdoor conditions with the sunlight corning through the cover and good ventilation with heated air. The dolphins thought they were in San Diego and they remained in Ohio and were trained all winter in the same home they performed in during the summer. They did not have to go through the trauma of the move.

For an application like this, stainless steel cables were used, since the dolphins swim in salt water. Also, a lifting ring was installed in the dome to simplify the erection and take-down procedure. Each time a structure is built, it is designed for that specific application, merely utilizing the overall principles of the pressure stabilized cable structures.

A couple of professors wanted to start a new business testing electronic equipment to determine the radiation patterns that exist when they operate. To do so, they wanted a structure with no metal in it, so the cables in this one were made of a plastic material. They located a site in the center of a forest in the Amish area, because the Amish do not use electricity and they wanted minimum interference with their tests. Since they had not planned on growing anything inside, the cover was made primarily of a white reflective material with clear panels as skylights. One panel was made of window clear material so that they could see the forest from the inside. As it turns out, one section of the test area was not paved and natural dirt existed there. The owner planted geraniums and they made a beautiful background for the wedding reception that was held in the structure.

FUTURE CONSIDERATIONS

As pointed out earlier, the big potential uses of these advanced systems are in large structures, which would be uneconomical or impractical using conventional construction. Large is a relative number, so it will be defined here as free span structures greater than 100' wide, and any length. The width is the key dimension and the length is just a repetition of what has been defined for the width. The upper limit is not yet known, but it is based on how far one can practically string a cable. At the present time structures with widths of 1000' and 1200' are under consideration.

Where considerable benefits could be made over conventional construction would be in the use of skylight roofs for big box buildings for distribution centers and stores. Here one would not only bathe the area in day lighting, uplifting personnel attitudes, but also doing so at a reduction in initial cost and continued operational costs. The results would be increased sales and more satisfied workers. At the same time one would be using solar energy for lighting and heating, giving the structures a "green", environmentally friendly system. It would change the present cave like atmosphere of low ceilings to more of a cathedral like environment.

At the present time, people are spending as much as $100,000,000 extra on a stadium roof to make it open up to let the sunlight in. An esi skylight roof could do this at a significantly lower cost and eliminate shadows at the same time. Grass grows in an ideal greenhouse enviromnent in this type of structure, with no mud, which stays clean having no infiltration of dust or dirt. It can even be equipped to be a "safe haven" in the event of a disaster.

As sizes increase to where conventional structures are not even considered, again these advanced clear span cable structure are still practical. Stadiums capable of housing a NASCAR crowd and track are now under consideration. Of course, the good ventilation to handle the exhaust fumes and the echo-free construction for the noise are two of the beneficial features of this construction. This would replace I beams with webs 30' deep, we were told, would be required for clear spans on these structures.

To enclose an entire 18 hole golf course for year round play regardless of the weather, the added feature of the needed sunlight can be provided. This is now being considered for two areas, one in Edmonton, Alberta in Canada and another in Tunica, Mississippi. Full size regulation courses can be built inside for practical costs.

Structures of even larger sizes are now being considered, however, they have not yet been engineered as far as the above mentioned systems. These would have to be fabricated on the site, in one of these temporary structures, since they would be too large and heavy to transport . Even providing the materials would require rethinking the way materials are handled. For instance, cables that are now ordered in thousands of feet, would be ordered in hundreds of miles. The growth in size is gradual, but the upper limits are still far off, and the potential applications are limitless.

CONSTRUCTION SITE COVERS

One of the major applications of esi pressure stabilized cable structures is the encapsulation of an entire construction site to eliminate weather considerations . Keeping the wind, rain and snow from entering the site and providing a relatively constant temperature with good ventilation and daylight makes an ideal working environment. It is possible to make the enclosure large enough to store the materials on site, a special separate warehouse is not required . This gives one two additional advantages: The working materials stay nice and dry and clean and no materials or tools "disappear".

Looking at specific examples will show some of the variables that can be included in the operation, providing even more benefits than just weather protection.

One of the first applications was to enclose a site in the Buffalo area in the wintertime to permit construction of a chemical plant. Fig. shows the site before the enclosure has been erected. The ground is covered with snow, water and ice and the enclosure is seen accordion folded on the platform . The next view, Fig. , shows the structure erected.

Notice the people, which will illustrate the relative size. The next view, Fig. shows the interior, where all the snow is melted and the inside is bright, warm and dry. Notice the coat rack.

In this particular application there was the possibility of a poison gas leak at the site. This gas would be heavier than air, so it would run along the ground. The fan inlets, therefore , were located about 10' off of the ground to be sure clean air would enter the enclosure.

Since the enclosure is under a slight positive pressure, all leaks are outward and there is no infiltration. This became the "safe haven" for the site, where everyone would go in the event of a poison gas leak.

This is just an additional benefit of this type of construction. With the proper inlet filters it can become a "safe haven" from local contaminates or terrorist attacks.

The usual benefits of use on any construction site is the daylight shadow-free interior, as well as, the fact that one is free of wind, rain or snow, regardless of the ambient weather conditions. The temperature can be set to what is most desirable and the ventilation rate can be provided so that there is no problem from vehicle exhaust or fumes from operations like welding or other manufacturing processes. Large vehicle doors can be provided without the need for airlocks, because the ventilation system can replace any air lost through the large opening.

Size is no problem. The next three Figures show the outside, inside and open door of a large waste site being prepared. In Fig you will see that the enclosure is primarily made of a white reflective material to minimize on the heat build up inside. At the same time, large clear panels are used to get good daylighting inside for excellent shadow-free working conditions . In Fig you can get an idea of size. These are the real machines, not Tinker Toys. Notice the excellent working conditions.

The third photo, Fig , shows one of the trucks going through the large vehicle door without any airlock. Beside the door are large fans that are replacing any air lost through the opening. When the door closes, the air then passes through the structure and out a vent at the opposite end. This is all done automatically by sensors that determine which fans are activated and which vents are used, in accordance with the wind velocity to assure that the structure is at the proper internal pressure.

Since each structure can be economically custom designed to match a need, it is even possible to build around obstructions. The next picture, Fig , shows a large structure in the yard of a big steel mill, in which a giant coke oven was fabricated. This structure had to pass underneath a conveyor that could not be moved and around various posts, etc. The cables were so sized that the contour resulted in the required shape. Fig shows the inside of that structure. The tiny specks on top of the endwall are people, which show the relative size of the structure.

In this case extra benefits resulted in them being able to make the protective structure large enough to warehouse all their materials inside, and even complete the entire construction and test fire the oven before taking down the construction cover, because of the excellent ventilation properties. Normally, when they use a conventional steel building for the construction cover, they have to remove it to complete the piping and test fire the coke oven. These extra benefits are big time and money savers at no extra cost.

Again the versatility of the design concept results in extra benefits not possible with conventional construction . It was possible in this instance to design the cover in two pieces, so that when the inside work was done, the cover could be dropped on top of the oven and workmen could walk across the top, cut the cover and disconnect the cables. This let them remove the cover in half a day, where it ordinarily takes 30 days to take down a conventional steel building protective enclosure.

Sometimes it is even possible to use this unique technique to save a conventional structure which has problems. A number of years ago, a beautiful palace was built for the Shaw's daughter in Iran. It contained a large dome, made of structure and panels. It turned out that the change in temperature in the area was so large that it constantly broke the seals and permitted it to leak rain inside. esi was asked if it could provide a protective cap over the dome, which would not hide its beautiful features, but would prevent the water leakage. esi provided a one foot high pressure stabilized cable structure with window clear ESIFILM as the cover membrane. The next picture, Fig , shows the dome, and the following picture, Fig , shows a close up in which you can see the cables supporting the film. From a distance, this cover is practically invisible and the original dome shows through. Since the esi dome was water proof, it solved the problem of the other dome.

The versatility of the concept is one of its main features, giving the architect free rein.