ABOVE GROUND "CAVES"

ICONS OF THE CALIFORNIA WINE COUNTRY

By Gary Black

A ride through the townships of Lancaster Pennsylvania will provide a picture of rolling hills, verdant with crops surrounding the large Amish barns that stand like mountains in the landscape. Similarly, a ride through Vermont will bring you in touch with the grand old stone barns erected by the Shakers in a bygone era. England will strike you with its tithe barns like the Great Coxwell, a soaring structure dating from the 11th century—a structure of such simple beauty that HRH Prince of Whales once called it one of the most beautiful buildings in England.

These structures share multiple qualities. They are large, in most cases the largest human construction in the vicinity. But they are at the same time gentle, showing a deep respect for the surrounding landscape. They are authentic, devoid of veneers which are applied to make them look like something else. They are intensely functional and practical, and their form expresses that fact through the structure and the materials, which in most cases were derived locally from the stones or timbers found on the land.

Figure 1 ***Loggia at Wine Country Estate Designed and built by ISI 2001***

The wine growing regions of California are in need of large storage facilities for barrel and case storage. While underground caves provide an ideal environment they are not practical in every situation. Above ground storage facilities, which would have the same strict requirements for maintaining temperature and humidity, could provide the required space and like the Amish barns potentially function as icons of the wine-making industry. It has been difficult, however, to find a suitable construction system that integrates the technical, practical, and aesthetic requirements. The most common approach; to use a standard steel "butler building," and outfit it with enough layers of insulation to keep energy costs within reason, will never conjure up romantic images of the wine makers art.

What is needed is a new form of construction that can produce a large structure of enduring stature – a building standing in the ancient tradition of architecture – that resolves the strict requirements for an above ground wine storage facility. The ideal structure would be cost effective, energy efficient, have outstanding structural performance, particularly in response to seismic shaking, and be an investment that will last into the next century and beyond.

The "Spar and Membrane" construction system,[1] a unique combination of straw-bale, steel, and concrete is capable of providing above ground cave structures of great size and elegance which are expressly suited to maintaining the interior environment necessary for wine storage. Unlike other straw bale solutions, the Spar and Membrane system uses *no* wooden posts embedded in the walls. Further, it does not rely on the straw for structure, nor require any kind of special permits for building approvals. It is not size restrictive. Hundred thousand square foot structures with forty foot and greater eaves can be constructed, making the system practical for complete winery facilities including those incorporating multi-level tank layouts. The double wall concrete shell provides an unprecedented level of thermal, structural, and fire performance, while promoting architectural adaptation to various sites, building types, and the aesthetic preferences of individual wineries. It is architecturally suited to construction of cellars, visitor's centers, administration buildings, and villas as well as warehouses to create a holistic building ensemble.

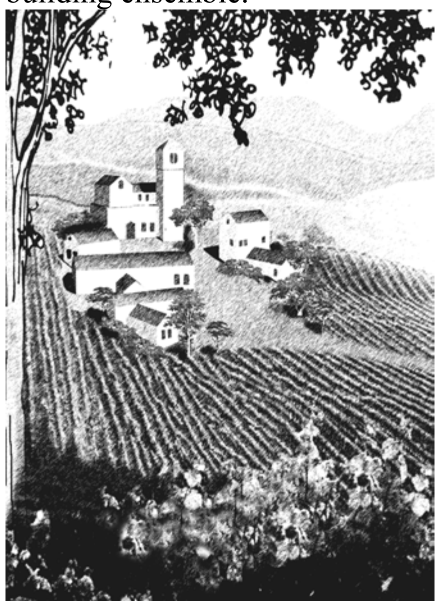


Figure 2 *Bale-built Winery complex.*

The Spar and membrane wall system produces a masonry wall that is nearly two feet thick. Whether left rough, cut with a wooden float, or toweled into a smooth finish the geometry produces a building with deep reveals around entrances and windows -- reveals that are reminiscent of an age when buildings were made to endure. The gently undulating wall communicates its authentic underpinnings. The roof, with its large overhangs to shelter the walls strike a primal chord and harmonize with the landscape in a way that flat roofed buildings fail to do.

The basic spar and membrane structure is similar in construction cost to the super insulated butler building, and is substantially less expensive than other masonry construction types, including concrete block. Figure 3 compares the upfront construction cost of three building types; (i) Spar and membrane, (ii) super insulated Butler building, and (iii) concrete masonry block for a ten thousand square foot storage facility on a flat building site. The costs include foundations, walls, windows, doors, roof, and basic wiring. The same level of finished concrete floor and exterior roofing material was assumed in all three cases. Environmental control systems are location dependent and have been left out of the calculation. However, as will be shown below, the Spar and membrane system outperforms other construction types in terms of energy usage. This further reduces the upfront construction costs of the Spar and Membrane because smaller systems can be specified to maintain thermal equilibrium, requiring less cost for the units and electrical service needed to power the units.

Building shell Cost Comparison* ($/sf)

Spar Membrane	Insulated Butler buildi	Insulated CMU
$57	$66	$91

*Excludes site development and equipment costs
Costs are for 2001 in Northern California

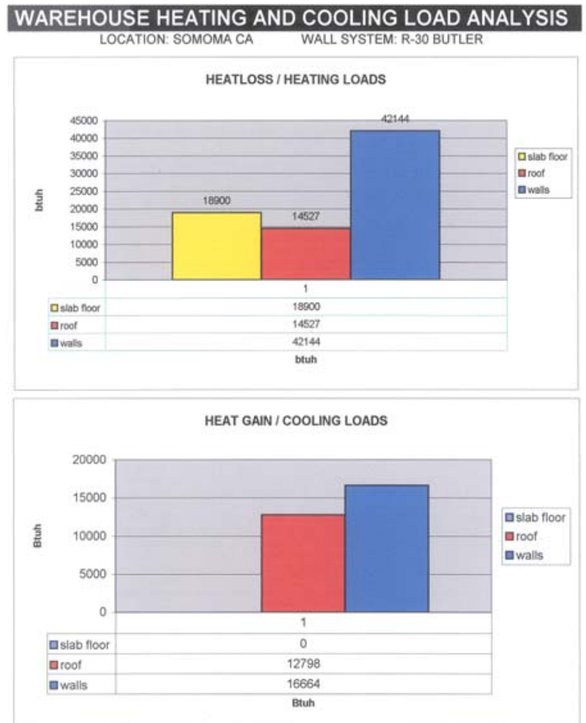
People have appreciated the thermal properties of masonry buildings for centuries. Thick mud adobe walls, stone walls, and rammed earth walls help to control the interior climate of a building through their inherent ability to "store" thermal energy

[1] Developed by Gary Black, licensed professional engineer, president of Integrated Structures Inc. and professor of architecture at the University of California, Berkeley's College of Environmental Design. The system has been extensively tested under his guidance at the Universities Earthquake Engineering Research Center and has been employed in the construction of four projects, including residences, a church and a vineyard estate. It is currently under consideration for construction of a five story mixed use building in California.

and release it at a later time. It is this property known as thermal storage or thermal mass that functions best in Mediterranean climates. These climate zones have hot days and cool nights. The solid masonry walls "store" the cool from the nighttime and "release" it during the day. Conversely, it also stores the heat from the day, releasing it during the night. Climate control systems that utilize thermal storage techniques rely on the day-night temperature swings. When the daytime temperature and night time temperature have less of a differential the thermal storage will not be effective in controlling the interior climate. In these cases it is necessary to incorporate some form of insulation in the wall to create a thermal shield between the inside and outside. Super insulated steel buildings use this approach. Caves are basically thermal mass storage climate control systems, but because of the huge thickness of earth, they also offer insulation from the outside temperatures.

Similar to cave structures, the spar and membrane system incorporates *both* thermal mass *and* insulation into its wall structure. The unique distribution of mass and insulation, enable the construction to outperform both traditional thermal mass solutions, and super insulated wall approaches. The spar and membrane wall structure is composed of three layers; (i) an inner concrete membrane having a minimum thickness of three inches, (ii) a central core constructed of California rice straw bales stacked in a running bond, and (iii) an exterior concrete membrane, also having a minimum thickness of three inches. Thermally, the wall works as follows. Imagine a nighttime temperature of 55 degrees Fahrenheit followed by a daytime temperature that reaches 100 degrees Fahrenheit. Let us assume, for the sake of demonstration, that the wall has likewise reached a temperature of 55 degrees, and that the interior storage space is at 55 degrees. As the day begins the daytime temperatures will rise. In response to the rising temperature, the exterior membrane will begin absorbing the energy and raising in temperature. Because of the large amount of thermal mass, however, the temperature of the concrete membrane will rise much more slowly than the outside environment. In other words there will be a lag between the temperature of the outside and the temperature of the exterior membrane. As the temperature of the membrane rises above 55 degrees, the heat, which always flows from high to low will begin making its way toward the interior of the building. The speed of its movement will be severely restricted by the straw-bale, which provides insulation values in the range of R34- R48. Before the outside heat can reach the interior membrane and begin raising its temperature the sun will have set and the nighttime cooling will begin. The heat will begin flowing toward the exterior and the mass will cool down.

It is the precise distribution of thermal mass and insulation that gives the spar and membrane wall its extraordinary thermal performance. The two membranes act like thermal flywheels, and the insulation offers thermal resistance. The exterior membrane provides thermal inertia that must be overcome before heat will begin flowing toward the interior. The interior membrane provides thermal storage, helping to maintain a constant temperature in the facilities interior. The straw-bale provides an insulated separation between the two thermal masses. Figure 3 shows a thermal performance comparison between a super-insulated (R-30) steel facility and a spar and membrane facility of the same size using weather data for Sonoma, California. Gains and losses are in BTU per hour.



Although relatively infrequent, earthquakes and fires can, and do, cause millions of dollars in property damage each year. The spar and membrane construction system is extremely resistant to earthquakes – exceeding code values in some building types by as much as 300%. Contrary to intuition about the combustibility of straw, the spar and membrane construction is also fire resistant. After the bales are stacked a special x shaped rebar (the spar) is inserted at the head of each bale. The spar not only connects the two membranes together, it connects them in a manner that forces them to work together structurally. It uses the same structural principals that are use to make stress skinned panels such as the wings of airplanes. The resulting wall can resist eight thousand pounds of earthquake induced shear per linear foot of wall, and has an out-of-plane stiffness that is thirty times greater than a solid six inch concrete bearing wall. With proper design, the structure's additional capacity can be utilized to help stabilize large storage tanks against earthquake forces. This would, of course, would reduce, or in some cases eliminate altogether, the cost of base anchorages for these tanks.

The same properties that give the system superb thermal performance also give it excellent fire resistance. To truly appreciate the fire performance, do the following experiment. Take a standard plastic sandwich bag and fill it with water. Next take a match, or lighter and try to burn a hole through the bag. You can heighten the anticipation by holding the bag over one of your friends as you do this. To everyone's surprise the bag will not burn, no hole will form, and no water will leak. The water absorbs the heat protecting the flimsy plastic. Concrete contains bonded water as part of its chemistry. When fire attacks it the water acts much like the water in the experiment absorbing and dissipating the heat. Before the concrete can burn, or even heat up, this water of hydration must be evaporated. Driving out the bonded water requires an enormous amount of heat energy. However, if the fire is hot enough, long enough the exterior membrane will begin to break down exposing sections of straw. Straw that is compacted into a bale form, however, is not susceptible to fire in the same way that it is when loosely packed. Trying to ignite a straw-bale is like trying to ignite a log. As charring occurs it insulates the underlying layers, making them harder to ignite. The straw will insulate the inner membrane against attack by the fire. Even if the fire did penetrate the straw it would still have to go through the inner membrane, a concrete wall with considerable amounts of bonded water. Preliminary analysis places the fire resistance of the spar and membrane wall somewhere between two and four hours, a rating that far exceeds that of any exposed steel building.

A building is more than an investment of time and money. It is an icon of an era, both a product and embodiment of the functional, social, and economic forces that shaped it. Timeless buildings – those that remain through the ages -- are unique constructions. They sit perfectly in their particular environment, reaching out with wings of light that capture the landscape to create courtyards and terraces. They are the product of local resources and talents. They are a reflection of the values of the people that made it.