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LEARNING FROM ANCIENT TECHNOLOGY:
ANCIENT TECHNOLOGY RELEVANT TO CONTEMPORARY ENGINEERING AND CONSTRUCTION:
The Interrelationship of Building and the Environment

NOTE: THIS PAPER IS TO BE A POWER POINT PRESENTATION WITH SLIDES OF PHOTOGRAPHS AND DRAWINGS TO ILLUSTRATE THE IDEAS I DISCUSS.

Introduction and thesis statement. Today we speak of 'technology' and think solely of digital, computer-related ways of learning, communicating and designing. Are we throwing the baby out with the bath water? As we extend the developments of the Industrial Revolution, must we forget knowledge accumulated by pre-industrial societies? Much of that information is vital to our understanding of the natural world. Many of the techniques applied in ancient times can help us today to have effective, economical and healthful construction. I propose that education take a new look at the solutions in earlier times, to better understand the effect construction and the environment have on each other, and to build upon those ancient experiences. Twenty-first century technology can then serve us more effectively.

Current concerns, extremely serious in my opinion, include global warming, failing water supply, the loss of agricultural land, undue reliance on trade with other area of the world, and a general lack of planning for the future. Aside from global warming, which is directly related to the world-wide use of fossil fuels and thereby an outcome of the Industrial Revolution, these concerns are in many cases the same as the factors which contributed to the collapse of earlier civilizations. The Mayans in the Yucatan peninsula depleted their water supply and grew too large for their agricultural capacity. Easter Island people poured their resources into giant statues, until they finally could not even build boats to fish or trade. Deforestation with the resulting erosion and loss of wood for fuel and construction was a factor in the Anasazi collapse. So we can learn, hopefully, what not to do. And today I'd like to concentrate on the positive – what we may be able to learn from earlier people about benign ways to construct and design.

Sustainability – the current buzz word - is what we want to accomplish. The challenge is to achieve the most with the least – the most decent living conditions with the least dependence on non-renewable resources. Also, we need to be able to survive tsunamis, hurricanes, human destruction. If we plan for the worst case scenario – a disaster – we will avoid the crushing expense of repairing the buildings and infrastructure after a disaster. We can provide at least survivable conditions for people in transition. In addition, we can greatly reduce ongoing expenses and "ordinary" repairs of the buildings.

I will borrow a phrase from Alex Wilson who has been researching "green" materials for many years in the interests of a healthy world and healthy people. Wilson uses the term "Passive Survivability". If we can devise ways to ride out disasters when the power is out and fossil fuels unavailable, we are well on the way to using these passive strategies as a foundation for more complex solutions We may also find that in the best of times we benefit from lower operating costs and more durability.

Sustainability has four major goals: first is to provide decent living conditions for all people; second, to reverse the current level of fossil fuel use; third, to attain self-sufficiency; and fourth, to renew the land. I would like to concentrate on the areas closest to construction and design, although these goals are all closely interrelated. In many cases, we can learn from the ancients. There are examples from around the world of strategies, often passive strategies, that provide comfort, use little or no fuel, and enrich the land for the future.

Siting and Thermal envelope: The ideal site for an energy- efficient house in the colder areas is tucked into a south-facing hillside, protected from north winds by the hill behind, and it is above the valley bottom where cold air settles. In warm locations, it may be better to place the house on a breezy hilltop or in the valley by a river. (Image) The location itself may be a solar trap, as the Anasazi settlements of our Southwest. There the buildings are nearly invisible on a shelf of a cliff facing south for the winter sun. The overarching cliff face protrudes enough to shelter the buildings from the high summer sun. In an urban setting, the site should be analyzed for both potential solar gain and for issues rising from the different sides of a large building: one side may have too much solar heat, while another side lends itself to increased window space for daylighting. When the designer knows the particular site's physical issues, his designs can achieve a sophistication possible with current technology. For example, a large midtown office building may be best served with windows having different u values and heat gain values in different areas.

The thermal envelope of a building must be not only heavily insulated, but tight in resisting air infiltration. Sad to say, our current residential choice of a wood (or metal) stud frame house is challenged when it comes to energy. Too many small pieces, too many connections – which mean too many ways that air can get in and out, so that heat goes where we don't want it. Buildings that have a monolithic aspect fare better. (Image) Whatever it takes to keep warmth inside in the winter – whether an earth berm, cave dwelling, or a complete wrap of heavy insulation – that's where we start. (Image) Along the Dordogne River in France, prehistoric people sheltered under the cliff face at the entrances to the caves known for the earliest paintings. (Image) At Cappadocia in Turkey, wind-carved caves were developed into complex communities. (Image) In Pennsylvania early settlers built both bank barns and banked houses with the lower floor cut into a hillside and protected by earth on three sides. (Image) The Pascagoula Country Club, buffered by its earth berms, fared well when nearby buildings were destroyed in last summer's hurricane and floods.

Today the challenge is to create a building that has little or no uncontrolled air infiltration. It should also be heavily insulated in all parts of the country, as cooling needs can be just as important as heating needs. The kinds of insulation used at various times around the world include extra blankets of felt for the yurts in Mongolia to sod in the Midwest to hay bales, which I've used myself around the lower edge of my house. (Image) The voles and mice loved it! The best part was – yes, it did insulate – but then last spring I recycled the hay into mulch for my garden and didn't have to weed at all. We can continue to develop kinds of insulation with the goals of (1) a continuous envelope, (2) fire resistance, (3) non-poisonous when it does burn, and (4) high R value. It may be that an exterior system such as Stow or Dryvit is most effective as it wraps the outside walls continuously.

Reduce cooling load: In large office buildings as well as many large multifamily buildings, the heat generated by people and cooking and equipment puts more demand on the cooling system than the cold weather demands of heat. Before running to the air conditioning system, before congratulations on a more efficient piece of equipment, laudable though that Energy Star label may be, design every possible passive strategy to reduce the cooling load. These ideas often seem unsophisticated in their 'low-tech' approach, or they require a small amount of client monitoring, or there is an unfamiliar first cost. Thinking long term, the cost is usually reasonable – especially since fossil fuel prices will only rise in the future. Too much 'work' for the resident? In my opinion, it's an asset to be connected to the environment even by so small an action as adjusting the louvers or closing insulated curtains when the sun goes down. And techies can always have these chores handled automatically if they choose. In the field of lowering the cooling load, we have many precedents. Windows can be shaded, as they have been for centuries, by the overhanging roof, seasonal plantings on a trellis, shades, shutters, and an infinite number of designs. (Image) Le Corbusier took this idea seriously enough to design his well-known *brise soleil* fixed sunguards in sunny southern France. (Image) The Temple at Karnak, Egypt, built in 1300 BCE, filters the brilliant light into the hypostyle hall through vertical fixed louvers, perhaps the earliest example of clerestory lighting. (Image) In dry climates, an effective cooling strategy is to use a flat roof as a pond, which cools as it evaporates during the day. A drip evaporation can be effective also, as when water flows down a flue slowly enough to evaporate on the way, cooling the area around the flue. (Image) In dry climates, an effective cooling strategy is to use a flat roof as a pond, which cools as it evaporates during the day. Whatever other strategies you use, buildings should be insulated from the sun's heat, and heat absorption minimized by white or light-colored roof and walls.

<u>Natural ventilation</u> exploits several passive strategies: cross ventilation; the stack effect; and hot air rises. To achieve cross-ventilation, we only need to have openings – usually windows, transoms, or doors - on more than one wall of a room or of an apartment. There is usually a difference of temperature on different sides of a building. One is in the sun, another shaded; one side is more in the open catching breezes, another protected and still. So there will naturally be movement. (Image) Louvered openings, placed specifically for ventilation, help to develop air movement. Depending on the prevailing wind direction, the openings should be designed low in the wall in the direction most likely to pick up wind; and then high in the opposite wall, encouraging the warm air to rise more swiftly. High ceilings bring relief as warm air collects there. A fan using relatively little energy disperses the warm air, also creating a breeze. (Image) The "dog trot" cottage design in New Orleans and many areas of the south is built with a central open passage simply to facilitate air movement through and around the house. (Image) Many houses in warm areas did not have glass in their windows – they never had the need to be fully enclosed, but welcomed cooling air flow. When storms hit, these openings are protected with sturdy wooden shutters, and these often include operable louvers so they serve several functions: protection from rain and high wind, partial ventilation, privacy, and air flow.

The stack effect is the phenomenon of warm air rising with more speed as the channel or chimney or flue is higher. Openings and flues operating on these principles have been known since earliest times and are still successful today. (Image) A duct rising through a multi-story building will pull the air up and out. (Image)

In mild climates, the transitional areas between indoors and out can be the most pleasant places to be: porches, balconies, loggias, stoops. (Image) They give a combination of shaded protection from the sun, openness to any air movement, access to the kitchen perhaps, and the possibility of relating to the community whether by observation or visiting with passersby. In any climate, the transitional shaded space is popular seasonally. It offers an alternative to being closeted with the air conditioner. The porch or trellised patio becomes an additional room for dining or relaxation. It encourages development of the outdoor space with plantings, important not only aesthetically but as cooling agents also. (Image) Trees transpire and moisten dry air. They prevent erosion. Trees provide shade and protection from cold winds. Deciduous trees then accommodatingly lose their leaves so south-facing windows can let in the sunlight and sun heat. (Image) A trellis, heavy with vines and clusters of grapes, provides lovely filtered shade as well as juice or fruit or wine.

Reduce heating load: in addition to the thermal envelope as a major factor in reducing the heating load, there are other considerations. A design that is compact, with few corners on the house, will present less surface area to the elements. Logically, the sphere first, and dome second, use the least energy, all other factors such as orientation and insulation being the same. The igloo is the most effective shape to give maximum interior space and minimum exposure to the cold. Windbreaks of evergreen trees to block prevailing winter winds are effective. (Image) An airlock entry to provide a sealed transitional space between outdoors and the building interior will save energy. The revolving door serves the same function for large buildings with many people using an entrance. Controlled air exchange that provides fresh air that is conditioned.

Daylighting: the use of natural light whenever possible. The savings in energy and the invigorating effect of sunlight are two reasons to encourage controlled natural light. This requires a balance between enough and too much. As mentioned above, the Egyptian filtered temple light was an appropriate solution for that climate. In many southern locations, the concern is with shutters and shades. Here in the north, we prize older buildings for their generous windows and higher ceilings. Studies have shown that school children work more effectively in classrooms with plenty of natural light. Office people prize the corner window. Success in daylighting comes from varying the glazing according to the location in a building and the climate. It requires sensitivity to the local conditions. This is an area where development of new types of glazing gives us the ability to fine-tune our light – sun protection, heat retention, but plenty of daylight for an optimal environment.

<u>Solar gain</u>: We need to remember that the sun is the prime source of energy. Providing heat and light, creating winds, nourishing plants – the sun is life. If we can take advantage of its power, we are ahead of the energy game. The sun emits enough energy to provide the earth with all its needs – if we only knew how to capture that energy.[1] The largest percentage of sun power is captured by passive solar heat gain into buildings. The next most effective solar gain is to heat water. Third is the electricity captured by photovoltaics.

We can collect the largest percentage of solar power at any one time in any one place by using it to heat a building directly. When in Greece the forests were all cut for fuel and construction, people built with a southern orientation to take advantage of solar heat in the winter. One building blocking the sun from another can be a major disadvantage. Sunshine that comes through glass areas in the cold months is changed into heat within the building. In order to capitalize on this energy, we use thermal mass to store the heat. Thermal mass is simply material that absorbs energy and radiates it back out slowly. Adobe houses of the southwest use the thick adobe walls to serve as thermal masses and dampen the effect of very hot and very cold temperatures. (Image) There are various additional strategies, such as a concrete slab with insulation below; an insulated area of rock storage below the concrete slab; ductwork leading from the rock storage into living space; a Trombe wall collecting heat behind a glass wall and releasing the heat at night; or a sunroom that allows heat to move into living space behind or above it. (Images) Given good exposure to the winter sun, all of these systems work passively. They also lend themselves to refinements of control and monitoring assisted by current technology.

The second most effective way to use the sun's energy directly, after passive heating of a building, is to heat water. A black surface absorbs heat while a white one reflects heat. A hot water collector can be as simple as a black plastic bag overhead that releases hot water onto a person by gravity. Using this principle on a larger scale, I can imagine a series of black tanks on

[1] Strong

the rooftops here in the city, preheating water for building heat or domestic use. In coordination with the idea of heating the building, the water that flows through radiant floor piping is at a relatively low temperature compared to hot water or steam systems; therefore, it is compatible with solar energy. Most hot water systems use collector plates to heat a medium that doesn't freeze, and that circulates in a pipe through the hot water tank. "Heat rises" is a useful principle that moves material – air and water - without a pump. The Romans relied on that principle to operate their baths, the center of Roman life. Evacuated tube collectors are particularly efficient in capturing solar energy. (image) The collector plates, on a south-facing roof of the correct pitch or on the ground, have a low inlet for the cold water and a high outlet. As the water's temperature rises, it flows to the top of the collector and from there to the storage tank. Gravity, the force that is constantly with us, can supply the stored water to living spaces below. Insulation maintains the heat, and a mixing valve should be included to prevent scalding from water that is too hot. Whether the solar power is used to preheat water or as the sole power source, it's important initially to provide this aspect of heating water for times when the electric power is out. Ever sit in your car on a sunny winter's day and appreciate how the sunlight is turning into sun heat through the windshield? There aren't as many sunny days in the winter, but solar energy is still with us ready to work.

Let's face it, or, I can admit it –we are very dependent on electricity. I also really like my hot shower. Washing clothes in the stream or even with a washboard - has no appeal at all. So – we need to generate electricity by "renewables": the sun, the wind, water. Wind power has run pumps and other equipment for centuries in Holland. (The Dutch also build levees that by and large stay up.) We are starting now to develop wind farms, where the towers are so tall that farming can take place underneath. Hydropower can be as mighty as Hoover Dam or as unintrusive as small plants on our many streams and rivers. Recently I visited a hydroelectric plant in Wappingers Falls. Part of the river flows through the original channel to support wildlife. A dam and canal deflect water into a large pipe that runs into the turbine building. There the water generates electricity without pollution or damage to the environment. It is quiet. The water returns to the riverbed without heat – and it generates enough electricity constantly to supply 2,200 homes. A proposal shows how using the water in our New York City aqueduct and reservoir system could easily replace the disastrous Indian Point nuclear power plant. A choice to develop hydropower on a relatively small local scale could make the difference between the sustainability of our culture or its annihilation. And thinking of another aspect of the Aqueduct system: the water flows by gravity and it is maintained in purity by strict regulation of land use in the watershed areas that feed the system. What a sustainable way to provide water to this enormous city!

Photovoltaics is the third method by which we gain energy from the sun – in this case transforming the energy into electrical power, or direct current. A strictly twentieth century discovery, photovoltaic cells are becoming more efficient and affordable every year. To continue the survivability concern, photovoltaics can provide enough electrical power to run pumps and other small appliances. This can be crucial in disaster events. European Union countries are far ahead of us in the field of photovoltaics. I have seen slides of PV installation in walls, and in a pattern of opaque and filtered light on large expanses of glass, and integrated with new roofing. In our time, Stephen Strong has designed photovoltaics for a community in Mass. The roofs that are oriented advantageously have photovoltaics providing electricity to the group as a whole.

Form and Structure: If we are planning for structures that can withstand storm damage, if we can wean ourselves from the gambler's instinct that "the chances are ….", we might rethink the form and structure of a building. (image) In the case of hurricane damage, for instance, on the Mississippi coast I was struck by the shoddy impermanent way we typically build. The most "high end" houses immediately facing the Gulf were telling examples of the way we build for the illusion of durability. But it was a delusion – the brick façade like a stage set. Hurricanes have been known forever in many Caribbean islands; there houses are typically of reinforced concrete block or poured reinforced concrete. (image) The strength of a steel frame is of little use unless the envelope and connections can provide the same degree of durability. (image) It may be that the form of the structure itself affects its survivability; possibly this octagonal portion remains because it doesn't present a flat wall to the forces. I've heard that two round buildings were the only ones to survive a hurricane in Homestead, FL. It is certain that the towers of Manhattan generate strong winds in their canyons. "But wouldn't stronger buildings be more expensive?" a friend asked. Of course, the initial cost is higher, but consider the expense thee people face now. Consider the insurance companies!

When gunpowder was discovered in China centuries ago, people were delighted to be able to produce spectacular fireworks of celebration. Later, as we know, gunpowder led to more deadly warfare. The material we call gunpowder became a means of destruction although first invented for pleasure. Mario Salvadori, author of Why Buildings Stand Up, states hopefully that industrial technology will help to make better living conditions for people worldwide. That seems naïve to me now as we become more and more aware of the extensive damages to our lands that we so easily bring about. People make choices; we all choose according to our beliefs. What are our choices today? How do we decide what is important to study, what are the benefits to us of our courses, our current technology?

It is useful to look at historical events not simply for general information but to see whether there is anything we might find to directly apply to our decisions and choices today. I hope this is a case for hands-on learning and for a close reading of accomplishments in the pre-industrial era. I propose a kind of process that starts with the solutions used before mechanization, and then refines or adds to these solutions with contemporary techniques.

Since my brief volunteer time in January in hurricane damaged areas of MS, I feel even more strongly that we must design and build with the local environment as our first consideration. We need to move beyond the framework of the up-front cost "bottom line". Will it be more expensive to build a house that is hurricane proof? Of course – but how expensive are the disastrous effects of wind and water? Again, thinking of expense – are there strategies that might be both cost effective and sustainable and permanent? What have people been doing for centuries to be comfortable – sheltered, warm or cool, and clean? In pre-industrial ages designers and engineers seem to have worked with nature with less damaging impacts than today. They were technologically successful in ventilation, lighting, structural stability, circulation, and other aspects of successful engineering design. **<u>The elegance of simplicity: engineering for less impact and more regeneration.</u>**