

Integrating Building Systems and Technologies: Organic Architecture and Ecological Design

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Abstract: Social and ecological concerns are leading architects, designers, engineers and builders to explore various materials and technologies to meet our needs while minimizing our impact on future generations. Around the world we are creatively developing and exploring new models of construction and integrating old techniques with new materials and technologies to produce more environmentally responsible and socially appropriate solutions. We are seeing an increasing number of buildings that integrate high and low tech solutions to create spaces that are more self-reliant and environmentally responsible, while also more in balance with the patterns, cycles and systemic methods of Nature.

This paper will look at patterns in Nature that can assist us in creating more harmony in the built environment and will provide information and examples of projects that move towards this ideal through the use of alternative construction materials, efficient and appropriate energy, water and waste water treatment systems, daylighting, active and passive solar technologies, integrated green spaces, use of green roofs, and other ecological design ideas. We will look at a variety of important concerns and the impacts of our design and planning decisions in relation to increasing social awareness and environmental responsibility in our public and personal choices. We will also explore some of the current models and built examples of forward looking and responsive architecture and planning to help us understand these concerns and inspire our commitment to pursue greater social and environmental responsibility in these choices.

Keywords: green architecture, green construction, alternative energy systems, ecological design

1. INTRODUCTION

Social and ecological concerns are leading architects, designers, engineers and builders to explore various materials and technologies to meet our needs while minimizing our impact on future generations and their ability to meet their needs. Around the world we are creatively developing and exploring new models of construction and integrating old techniques with new materials and technologies to produce more environmentally responsible and socially appropriate solutions. We are seeing an increasing number of buildings that integrate varying levels of both low and high technology solutions to create spaces that are more self-reliant and environmentally responsible, while also more in balance with the patterns, cycles and systemic methods of Nature.

With our current scientific understanding of global warming patterns and human impact on the environment, along with increasing human populations and energy needs while also experiencing shrinking fossil fuel energy supplies, it is clear that we are wise to work hard to lessen our negative impact on the natural world while conserving

our shrinking resources and developing appropriate long range alternative energy sources. It is a challenge and a necessity to deal with these concerns in order for human populations to continue to flourish.

2. THE NATURAL WORLD AND THE BUILT ENVIRONMENT

2.1 Learning from Nature

In modern times humans have moved away from our direct reliance and personal understanding of natural cycles and, in general, we have tended to increase our isolation from Nature and the natural world. In spite of our efforts to separate ourselves from Nature, we are still wholly reliant on the natural environment for our ability to survive in the long term. As a means to promote the health of the natural world - and human and animal populations that rely on a healthy environment for our survival - while developing the built environment required for human populations, we can look at patterns in Nature to assist us in creating more harmony between the built environment and the natural world.

By increasing our awareness and respect of the natural world and striving to reduce or reverse

negative environmental impacts of human populations, we can make more appropriate decisions to help us meet our needs while not reducing the ability of future generations to meet their needs. The integration of lessons learned from Nature and our efforts to understand and minimize our negative impacts will influence our built environments to be designed with increased awareness of energy usage in their construction and operation. Architects, designers and engineers will take into account and be responsive to the site conditions of the particular project and foster a shift that will exercise the power of the pen - better design - in recognizing and confronting this most important global issue of the impact of our built environments on the natural world.

2.2 Models developing around the world

There are a growing number of contemporary examples of projects that move towards these ideals through the use of alternative construction materials, efficient and appropriate energy systems, water and waste water treatment systems, daylighting, active and passive solar technologies, integrated green spaces, use of green roofs, and other ecological design ideas.

We will look at a variety of important concerns and the impacts of our design and planning decisions in relation to increasing social awareness and environmental responsibility in our public and personal choices. We will briefly overview the basis of Organic Architecture and examine the overlap of contemporary ecological design ideas to complement and inform our decisions regarding the design of the built environment. We will also explore some of the current models and built examples of forward looking and responsive architecture and planning along with specific energy and mechanical systems alternatives and green building technologies to help us understand these concerns and inspire our commitment to pursue greater social and environmental responsibility in these choices.

3. "ECO" LOGICAL BUILDING

3.1 History and basics

Ancient humans relied on Nature to provide them with food and shelter and often looked to Nature for lessons to increase their skill and abilities to provide "better" levels of food and shelter as these cultures developed. We can see examples of human shelter around the world that work with the natural aspects of the site such as early cave dwellings etched into a rock facing towards the sun to make use of the radiant heat - or away from the sun if their location was a hot and arid environment. The 1st century BC Roman Architect Marcus Vitruvius in his "10 Books on Architecture" in Book I, Chapter 4 underscores the importance of picking a good site when he states, "we must diligently seek to choose the most temperate regions of climate, since we have to seek healthiness in laying out the walls of cities."^[1]

In traditional and ecological design, there is also a high reliance on the use of local, native and readily

available resources such as earthen construction materials like "cob" and "adobe bricks" two building methods using local sand, clayey soil and straw, or the use of bamboo poles and thatch roofs to create more open shelters in tropical environments. Because of necessity and wisdom along with a culture based on Natural principles, traditional societies more often made appropriate and careful use of their natural resources to meet their needs and to assure they could meet their needs in the future.



Image 1: Cave dwellings in Chaco Canyon, Southwest USA

Contemporary projects are increasingly putting to use construction techniques that are bringing back into use some of these materials or reinterpreting old materials in new ways. Some projects meet code and earthquake resistance requirements while using traditional materials by integrating more technological aspects such as metal cables, bolted connections and modern hold down connectors and engineered foundations. There are also a wide range of products available that are more environmentally responsible versions of modern materials such as the use of "fly ash" - a waste product from electricity production using coal - in concrete mixes to replace an equal percentage of Portland cement and in the use of high recycled content steel in steel framing materials.

3.2 Organic Architecture and Ecological Design

There is an overlap of concerns and concepts in what is generally termed "Organic Architecture" and the developing concepts of "Ecological Design" that strives for greater understanding of human interaction with and impact on the environment. For Organic Architecture, look to the work of Frank Lloyd Wright and apprentices from his architecture schools at Taliesin. As stated by Encyclopaedia Britannica Ready Reference 2004, Mr. Wright is "often considered the greatest U.S. architect of all time (and) his greatest legacy is 'organic architecture,' or the idea that buildings harmonize both with their inhabitants and with their environment."^[2] There are many examples of work by Mr. Wright and his students and workforce at his Taliesin compounds in Wisconsin and Arizona that detail these concerns and concepts and provide inspiration in designing for today's clients to those that continue in this vein.



Image 2: Taliesin West Court, Arizona, USA
Designed by Frank Lloyd Wright

Those designers that are continuing the evolution of this type of Organic Architecture are integrating contemporary research and technologies and Ecological Design ideas while still striving to maintain an aesthetic and personal appeal to those that occupy the spaces. Some of the basic Ecological Design concepts as related to creating architectural space that we should consider include;

- Minimize site impact, maintain native vegetation and natural features of the site as much as possible
- Minimize building footprint when possible
- Integrate solar design and natural ventilation to decrease building energy loads and increase user satisfaction
- Consider the life cycle costs of structural materials, mechanical needs, energy, water and waste treatment systems
- Specify non-toxic building materials and finishes, including concerns about the manufacture and disposal of materials
- Specify efficient mechanical, electrical and plumbing systems to minimize use of energy resources
- Create places that people love and care for to prolong the effective use and upkeep of the place



Image 3: Yen House, California, USA
Designed by Ken Kellogg

3.3 Contemporary integrated buildings

Today we have a wide variety of examples of buildings that are integrating materials and technologies to minimize their negative social and environmental impacts. Some of these projects emphasize the natural and implement low tech solutions while others lean towards the more technological and mechanistic and integrate high tech and high efficiency systems. These projects include residential, commercial and industrial buildings. In the United States, the LEED rating system developed by the US Green Building Council is advancing the ability to assess and qualify green building projects.



Image 4: Inland Revenue Headquarters Nottingham, England, by Michael Hopkins and Partners

Contemporary projects that are notable include the Inland Revenue Headquarters in Nottingham, England, which makes excellent use of natural ventilation and daylighting within the building. These elements are used to not only reduce the energy load of the building, but also put to architectural effect as powerful elements of the building. At a smaller scale, projects such as Arkin-Tilt Architects design for the, Caner/Beier Residence in Northern California makes extensive use of recycled materials in the building such as recycled fir trusses and salvaged cypress flooring, while using hybrid technologies such as sprayed earth construction for the exterior walls of the project and terrazzo made of recycled glass.



Image 5: Caner/Beier Residence, Napa County, California, USA, by Arkin-Tilt Architects

Being primarily created in the US Southwest, the Earth Ships as developed by Mike Reynolds, his son Jonah and their associates around Taos, New Mexico are excellent examples of the integration of low tech and high tech concepts to create a low impact, but modern house. Through design these projects strive to minimize environmental impact in construction and operation. They include the use of a high percentage of recycled materials in construction – used automobile tires, empty glass bottles and other materials – to minimize the consumption of new raw materials. The Earth Ships also rely on the careful design of the project in relation to it's setting in the natural environment for passive solar heating and cooling, natural ventilation and water conservation, coupled with the integration of alternative energy sources such as wind power and solar electricity.

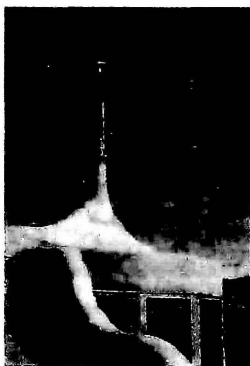


Image 6: Earth ships, Taos, New Mexico, USA as developed by Mike Reynolds and associates

4. GREEN BUILDING TECHNOLOGIES

4.1 Wide range of alternatives

There is a growing range of alternatives available for use in environmentally responsible construction. The market for environmental products is on an explosive growth trend. New products from high recycled content structural concrete panels to waterless urinals are coming on the market at an increasing pace as the interest in these products gains popularity with individuals, commercial industries and institutions for their economic as well as environmental returns. Integration of green building technologies is beginning to help us balance social, economic and environmental concerns as we build in the modern world.

4.2 Earthen materials

Cob is one of the oldest building materials known to be used by humans. There are examples of buildings using the same basic earthen material in Europe, Africa, Asia, and the Americas. The material can be made into balls, bricks, tiles and plasters but generally consists of sand as the building block, clayey soil as the mixing and bonding agent and straw to give fibrous strength to the material. This

material can be made into walls, benches, flooring material and artistic uses. Many places such as the Wright Organic Resource Center (WORC) in Malibu, California, teach various earthen construction techniques in hands-on workshop settings.

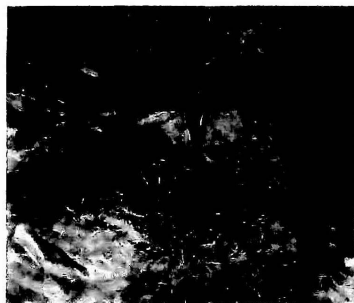


Image 7: Mixing straw into a batch of cob material, Malibu, California, USA, WORC

A range of bricks from earthen material can be made and used in an environmentally responsible manner. Brick domes and earthen shelters are being developed at California Institute of Earth Art and Architecture (Cal-Earth) in Hesperia, California. Use of feed bags and sand bags to create structures has led to the development of a material termed "superadobe" by it's developer. Superadobe uses a continuous tube material that is filled with earth from the local area that is mixed with a small amount of Portland cement. These tubes are then stacked on top of each other to make load bearing shear walls for the structure.



Image 8: Making a superadobe wall, Hesperia, California, USA, Cal-Earth

4.3 Blocks and concrete applications

Other types of green building technologies include materials such as "Rastra" or "Eco-Block" which generally consists of a recycled content Styrofoam block unit that is moulded and then stacked to have the interior cells filled with concrete according to manufacturer's specifications. This creates a

structural wall that is plastered or stuccoed to finish on the exterior. These products can create a strong wall with very simple construction that also results in a high insulation value. The Rastra block has been shown to be effective in multi-story buildings and has undergone extensive testing to certify the structural capacity of the building system.

Projects that need to use concrete can green their project and also create a stronger concrete by including fly ash in the specification for the mix. Fly ash is a waste product of electricity production using coal. This silicate material is collected from the coal burners and, until recently, sent to landfills. This material is similar at the molecular level to the natural volcanic ash used by the Romans to create their concrete piers and aqueducts and other elements. This previously discarded material can be used to replace an equal amount of Portland cement in a concrete mix and will also enhance certain properties of the concrete. The fly ash has several key attributes that make it superior to typical Portland cement. First, Portland cement has a high embodied energy - it takes a great deal of energy to make it - and also the fly ash bonds with the free lime in the concrete while increasing the resistance of the concrete to sulphate attack in the long run.



Image 9: The Parthenon used volcanic ash to bond the sand and aggregate material, Rome, Italy

4.4 Bamboo applications

Bamboo has been used by humans as food, tools and construction needs for a very long time. There is a rich history and tradition of building techniques and aesthetic result from ornate to utilitarian across Asia, South America and the Tropics. Construction techniques are being developed in Colombia, South America by Simon Velez and Marcelo Villegas and subsequently in California, USA by Darrel DeBoer and Gale Goldberg among others. These techniques make use of bolted connections to create strong, efficient structures and satisfy code and earthquake resistance requirements. The "node" where this bolted connection is made is filled with mortar to create a moment connection that - given an accepted minimum strength for the bamboo to be used - can be assessed for structural stability by the building code analyst or inspector. Bamboo also makes beautiful and durable flooring that is highly cost competitive.



Image 10: Bolting roof to bamboo purlin, University of Oregon, Oregon, USA, Ecological Design Center

5. CHANGES IN SYSTEMS

5.1 Taking responsibility

A large responsibility of the architects, designers, engineers, and builders in the 21st Century will be to minimize the wasteful use of our energy resources. In construction, operation and maintenance, the built environment uses a larger percentage of our natural resources than all other aspects of human development. We must learn to use the systems and cycles of nature to enhance our existence and provide for our needs. We must curb our appetite for increasing amounts of energy and work to create buildings and their mechanical and electrical systems that minimize energy required from outside sources.

5.2 Solar Electricity

Building and architecturally integrated solar power systems are already becoming an increasing sight across the globe. At a current cost in the Southwest United States of about \$7.50 - 9.50 per installed watt, with government assistance installations are showing up on warehouse roofs, as car parking lot canopies, façade elements and on residential properties. With current energy prices - depending on system capacity and use patterns - these systems pay off their costs in saved electric bills in 6 - 9 years and will last a guaranteed minimum of 20 - 30 years and more.



Image 11: Earth Island solar electric warehouse, Chatsworth, California, USA, solar by PermaCity Corp

5.3 Wind Power

We must also continue our push towards the use of wind power, both at an industrial scale and in our communities and homes where possible. At the small scale, wind power generators can be the perfect complement to a solar electric array. In some climates where the winter storms set in and the sun is not intense enough to create a sufficient supply of solar electric power, there is often an increase in the wind velocity which could be put to use if a wind generator where also installed. In this way, we have listened to and learned from the cycles of nature to better meet our own energy needs.



Image 12: The author preparing to install a 1 kilowatt wind generator, Maui, Hawaii, USA

At the larger scale, new wind power facilities are being developed at an increasingly hectic pace. Industrial scale wind power has finally approached the same cost per kilowatt of coal powered plants and 1 to 10 kilowatt generators for residential uses and large - up to 2 megawatt - generators are being integrated into community and regional power grids at a steady pace. This trend appears to be set to continue as new wind power sites are being developed off-shore, in the deserts and in high wind canyons and mountain sites by private and government oriented entities.

5.4 Diversity of approaches

The integration of local power sources such as wind energy, solar electric, and ground thermal heating and cooling where they are feasible must increase. Large scale wind, solar and geothermal facilities to bolster and eventually replace fossil fuel power plants must gain more momentum and international, national, corporate and institutional support. Following this path will contribute to our ability to meet our growing needs while, perhaps, also learning that we don't need as much to be successful.

This diversity of approaches will operate on the small and large scale and will work towards the coordination but decentralization of energy production and distribution. These efforts will count on the further evolution of hydrogen production and fuel cell

technologies and other methods of capacity and storage building that will work to spread out our reliance on our energy sources. These efforts will call on the industrialized and developed world to make changes and fund the research and development of cleaner technologies, while also counting on the developing nations who may still be closer and more reliant on the natural world to embrace and even demand the implementation of alternatives that are the most socially and environmentally responsible.

6. CONCLUSION

The conscious and conscientious integration of Nature and a shift in focus towards social and environmental responsibility will take a considerable amount of effort. Respect for Nature and natural cycles grounded in this approach will influence the planning, design and construction of the built environment we choose to create for ourselves. As new projects are developed and built, our abilities to be more in tune with Nature increases. The projects each bring new lessons to teach with them and our understanding of the pitfalls to be aware of and the possibilities to do better advances.

Through integrating building systems and technologies to minimize environmental impact and create more sustainable built environments we are stepping up to the most dynamic and important challenges for the designer in the 21st Century. Our focus in this regard as outlined here is directed towards the creation of aesthetically delightful and personally inspiring Organic Architecture while striving to embody the concepts of ecological design and our commitments to social responsibility. The integration of low and high technologies and the wide range of available material and product selections, structural and building technologies and mechanical, electrical, water and wastewater systems creates opportunities for compelling architectural expression.

As architects, designers, engineers, and builders, our ability to interpret the natural attributes of the site and to synthesize the relevant ecological concerns with stakeholder and community issues so that we create built environments that balance social, environmental and financial concerns is increasingly important. Each design decision we make can come on either side of being more - or less - responsible. It is up to us to study and learn as much as we can about these concerns, possible solutions, developing technologies and reemerging techniques. As an industry our design choices make enormous social, environmental and financial impacts that we need to take into account. It is our responsibility as well as a most exciting challenge and we must make careful and appropriate choices and use our pens wisely!

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