ASES2011_0343

MAHARISHI UNIVERSITY OF MANAGEMENT SUSTAINABLE LIVING CENTER: INTEGRATING ANCIENT AND CONTEMPORARY STANDARDS FOR SUSTAINABLE DESIGN

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ABSTRACT

Fig. 1: Rendering of the completed building

Maharishi University of Management's Sustainable Living Center, in Fairfield, Iowa is the first building in the world to integrate LEED Platinum, Living Building Challenge. Building Biology, and Maharishi Vedic Architecture ^{SM}. The building is designed to be a living laboratory that supports the curriculum taught in the classroom. It will house offices, classrooms, laboratory and greenhouse for the University's four-year Sustainable Living Program, and is off grid for water, sewer, and electricity. The building integrates wind energy, PV energy, solar thermal for heating and cooling, outsulation , whole tree structural system, daylighting, local materials, earth tube cooling, on-line monitoring, edible landscaping, verandas for window shading, compressed earth blocks, night time flushing, and more. Architects include Innovative Design[1] of Raleigh, North Carolina and Jonathan Lipman AIA & Associates[2].

This paper explores the design, financing/fundraising and construction process to date for the building. The building is scheduled for completion in the summer/fall of 2011.

Fig. 2: South wall, March 2011

1.BUILDING OVERVIEW

The building provides classroom and office space for the four-year Bachelor of Science program in Sustainable

Living at Maharishi University of Management (MUM)[3] in Fairfield, Iowa. The program currently has 5 full time faculty, 75 full time majors, and 20 minors. The building is designed to be a living laboratory that supplements and supports the curriculum taught in the classroom. In addition, it has 6,900 ft^2 on 1 floor, with 3 classrooms, a laboratory, 8 offices, a kitchenette, an integral greenhouse, and 1200 ft^2 of outside verandas (see floor plan and elevations below). The building dimensions are 83 feet by 83 feet, not counting extensive east and west verandas and a north porch that can be used as classroom space in good weather. The building has a central atrium corridor that provides daylighting to the interior of the building and runs the entire east-west width of the building. A separate 500 square foot building houses inverters, batteries, and a back up biodiesel generator (students operate a biodiesel coop and the generator will run oil biodiesel made on campus).

The building site occupies part of former parking lot for the University library. The building is, as far as we know, the first in the world to attempt to meet these four standards: LEED platinum, Cascadia Living Building Challenge, Building Biology, and Maharishi Vedic Architecture[4] (also referred to as Maharishi Sthapatya Veda®). The building is currently under construction, and is expected to cost $450 per ft^2. Completion is scheduled for Summer/Fall 2011.

2. NEED FOR THE BUILDING

The department required more space due to growth from 6 students to 75 over the last 5 years. The department considered a number of options for additional space including retrofitting existing buildings before settling on constructing a new building. Maharishi Vedic Architecture (one of the four standards being met by this building) favors new construction over retrofits.

3. IOWA CLIMATE AND RENEWABLE RESOURCE DATA

The building is located in Fairfield, Iowa (latitude 40 degrees). Fairfield has a continental climate with hot, humid summers, cold winters, and occasional violent windstorms and tornados. Fairfield has a heating dominated climate (6048 hdd base 65, 550 cdd, base 70 1971 – 2000 average) with winter low temperatures of -10 deg F and summer high temperatures over 100 deg F.

Annual rainfall is 36 inches with most of the precipitation occurring during the growing season. Average annual wind speed is 12.77, with an annual wind energy density of 195 watts/m^2 (max month is April at 282 watts/m^2, min month is August at 92 watts/m^2) The USDA growing zone is at the cold end of zone 5. Average annual insolation is 4.85 kwh/m^2 /day (maximum month is July at 6.16 kwh/m^2 /day, minimum month is December at 3.41 kwh/m^2 /day). Monthly details for heating degree days, cooling degree days, maximum/minimum temperatures, rainfall, wind speed (120 feet), and insolation levels used in the design calculations for the Sustainable Living Center can be found in reference 5.

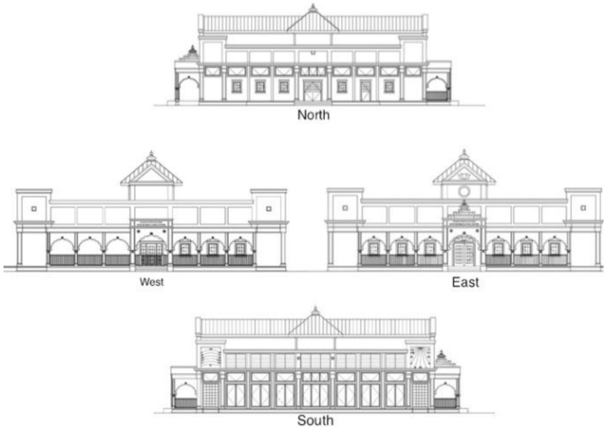

Fig. 3: Elevations

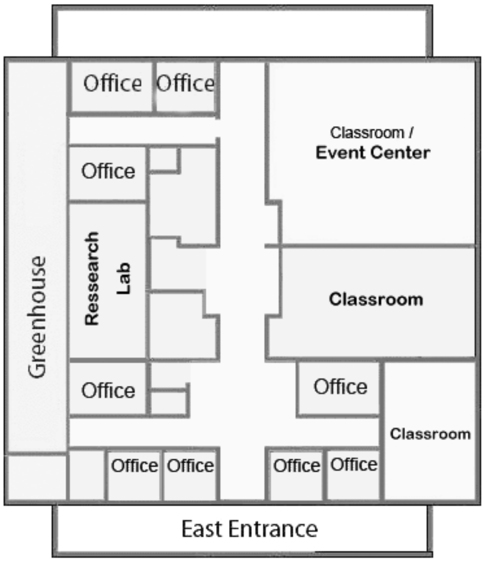

Fig. 4: Floor plan

4. BUILDING SYSTEMS OVERVIEW

4.1 Building Structure and Materials

4.1.1 Building Envelope

Building exterior walls are stick frame construction with 8 inch studs, 24 inches on center. They are sheathed on both sides with plywood. The 8 inch stud walls are filled with cellulose insulation (r-3.7 per inch). There is a 2 inch thermal break gap between the exterior wall and an interior wall of 8 inch wide compressed earth block (r- 0.3 per inch). The wall assembly is 18 inches thick. The calculated R value of the wall assembly is 32[5]. Exterior finish is Portland cement based stucco. The interior finishes are earth and lime plasters.

The roof trusses are supported by the north and south exterior walls and by 20 inch diameter aspen roundwood (whole trees) at the center of the building, engineered, manufactured, and installed by Roald Gunderson and Whole Trees Architecture[6]. Interior partitions are made of earth block or CMU (concrete block is used adjacent to rest rooms, the greenhouse, and the water storage tank) and are not load bearing. The roof is insulated with cellulose insulation and has an r-value of 60.

Fig. 5: Exterior wall Cross section

The floor is slab on grade with 4 inches of compacted gravel underneath 3 inches of foamglas[7] insulation (r-3.44 per inch) and 6 inches of concrete and has an r-value of 21. PEX radiant in-floor tubing with six-inch spacing is placed on top of this and then covered with finished floors of stamped concrete in high traffic areas or adobe in lower traffic areas. The foundation is insulated with two inches of foamglas insulation on the outside.

4.1.2 Passive Solar

A sunspace/greenhouse within the thermal envelope of the building provides passive solar gain. There is 560 square feet of south facing glazing. The glazing is made by Serious Materials and has a SHGF and visible light transmittance of 0.75. For the greenhouse windows, center of glazing r value of 3.88 There is no overhang; summer overheating issues are expected to be addressed through ventilation of operable windows. Windows opening and closing will be automated and controlled by the building HVAC controller. There is no provision for distributing passive solar gain to the rest of the building, except for what is gained by conduction or through doors and windows to the rooms that adjoin the greenhouse. The greenhouse/sunspace is 10 by 60 feet, and is within the conditioned space. The greenhouse back wall is made of CMU (concrete block) for thermal mass. The greenhouse will also have in-ground planting beds along the back and front walls with a 3-foot wide concrete paver path in between. As part of the building envelope, the greenhouse will be heated in winter and cooled in summer. The greenhouse will support agriculture courses, grow food for the building kitchenette, and start plants for student gardens.

4.1.3 Glazing and Daylighting

Daylighting is designed to cover 2/3 of the daytime occupied hours to minimize electrical and cooling loads. 50 footcandles is the level targeted for classrooms and offices.

Windows were purchased from Serious Materials. Windows on the east, west, and north sides of the building have two layers of glass and two layers of heat mirror glazing, with a center of glazing R value of 10. Windows on the south have two layer of glass with 0.75 SHGC and visible light transmittance with a center of glazing R value of 3.88. Windows are favored on the south and east and minimized on the west and north. Maharishi Vedic Architecture requires lots of east light. The goal is to admit daylight to all normally occupied areas of the building, including rest rooms. Daylighting strategies include a roof monitor with atrium that runs east-west over a corridor in the center of the building, lower view and higher daylighting windows in most rooms, and ceilings and light diffusers designed to direct light where needed. The combination of extensive daylighting, LED bulbs with occupancy and daylight sensor, and self illuminating exit signs yields a calculated lighting load[5] of 0.1 watts/ft^2.

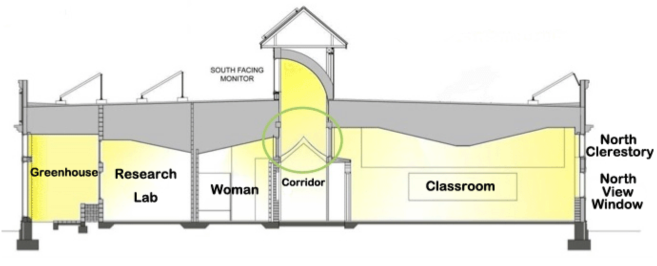

Fig. 6: Day lighting scheme

4.1.4 Thermal Mass

Building thermal mass is listed in the table below. The outside building envelope is light mass stick frame construction, with interior walls made of compressed earth block (26, 000 blocks, 600 tons), made from unstabilized earth.

TABLE 1: Building thermal mass

Item	Specific Heat	Weight	BTU/degree F
Earth Block (interior walls and partitions)	.25 btu/lb per degree F	1,200,000 lbs	400,000
Concrete floors	.3 btu/lb per degree F	520,000 lbs	171,000
Water Tank	1 btu per lb per degree F	5000 gallons (40,000 lbs)	40,000

There is a 2 inch air gap between the outer insulation wall and the inside thermal mass wall. Earth with the proper mix of clay and sand was found at another building site excavation on campus and students built the blocks using a Powell and Sons compressed earth block machine rented from Midwest Earth Block[8]. Thermal mass is used to store energy from the 1,500 square feet of active solar thermal arrays, surplus solar and wind energy, and greenhouse passive solar gain. A 5000-gallon water tank provides hot water storage for space heating, domestic hot water, and desiccant cooling. The table below gives the energy storage potential of each storage.

Additional thermal mass comes from ½ inch thick earth plasters and concrete block interior walls adjacent to restrooms the greenhouse, and the water thermal storage tank.

4.1.5 Plasters, Paints, Finishes

Exterior finishes are portland cement based plasters. Interior finishes include earth plasters, lime plasters, lime washes, milk based paints, and natural pigments. See below for plaster and paint descriptions.

Earth Plasters: Earth block was used as the base material for earth plasters with sand and cow manure added in. Cow manure is traditionally used in plasters because the urea, lactic acid, and enzymes from the digestive process bind and harden the plasters.

Milk Based Paints: Milk from an organic dairy was curdled then the curds were dried and crushed into a powder. The powder was then mixed with lime putty.

Pigments - For white, lime washes and kaolin clay were used with wheat paste. Other pigments include iron oxide (red), local clays (brown), turmeric (orange), and commercial pigments from American Clay.

Fig. 7: Compressed earth blocks

For more details on plasters, paints, and finishes used in the building, see building web site[5]. Plaster mixes were developed by Keith Lindauer. Mr. Lindauer was also the plaster and natural finishes sub-contractor.

4.1.6 Energy

4.1.6.1 Energy demand

Building heating and cooling loads were modeled using DOE-2. The building worst case daily average hourly heat loss is 56,000 btu per hour , with peak loads to 100,000 btu/hr (-10 degree outside temperature). Annual electrical energy requirement is 25,444 kwh. Entire building energy use is estimated at 12.3 kbtu/ft^2 /yr.[5]

4.1.6.2 Efficiency measures

Efficiency measures include LED lights with occupancy and light level sensors, high efficiency appliances and office equipment, a variable speed drive fan in the fresh air system, dual flush toilets (0.8/1.6 gpf), low flow fixtures, and an air-to-air heat exchanger.

4.1.6.3 Electricity

The building is off-grid. Electrical loads are met by a combination of photovoltaics, wind, and a biodiesel emergency generator. Students operate a biodiesel coop that makes biodiesel from waste vegetable oil. Annual electrical loads are estimated to be 25,444 kwh (2.75 kwh/ft^2/ year)[5]. The electrical energy systems include 5 kw of photovoltaics, a 15 kw wind generator on a 100 foot tower, 10 kw of inverter capacity, 1200 amp-hours of lead acid battery storage, and a 7.5 kw biodiesel fueled generator. Estimated annual output is 53,000 kwh. As of the date of this paper (March 2011), 2 kw of PV , 880 amphours of battery storage, and three 3,600 watt (10.8 kw total) Outback inverters have been installed. System DC voltage is 48 volts, and the system provides 240/120 volt split phase power to building loads. Estimated monthly energy production from solar and wind, monthly loads, and any deficiency that must be met by the back up generator. Are available on the building web site[5]. Solar production and wind production were modeled using the Iowa Energy Center[10] web based energy calculators. NREL's PV Watts web site[9] gives significantly lower annual PV energy estimates (1291 kwh /kw/yr for PV Watts vs 1611 kwh/kw/yr for Iowa Energy Center). Excess electrical energy will be fed into the 5000 gallon hot water storage tank.

4.1.6.4 Thermal Energy

Thermal energy is used for space heating, space cooling, and dehumidification. Thermal energy is collected by 1500 square feet of solar thermal collectors and stored in 5,000 gallons of water and the mass of the building (600 tons for earth blocks alone). Two collector types are employed: 500 square feet of evacuated tube collector and 1000 square feet of Solargenix XCPC non-imaging concentrating collectors. These will provide the higher water temperatures needed by the desiccant cooling system (160-190 deg F)

Space heating is accomplished through 1500 square feet of solar thermal collectors, passive solar gain, surplus PV and wind power, and a back up generator. An air-to-air heat exchanger is used to minimize heating and cooling requirements for fresh air. Space cooling is accomplished through night time flushing combined with moisture being removed from the air by a Ducool liquid desiccant cooling system made by Advantix[11]. The desiccant system does latent cooling – shifting the comfort zone with lower humidity and higher sensible temperature. Domestic hot water is stored in an 80 gallon tank and heated by pumping it through a coil in the main 5000 gallon solar thermal storage tank.

Thermal energy storage consists of a 5000 gallon water tank, 600 tons of compressed earth block, and another 200 tons of miscellaneous mass in the building.

4.1.7 Water

Water supply for the building is from rain, which is collected off the roof, stored in a 6,500 gal underground tank, particulate filtered, carbon filtered, passed by a UV light, and pumped to taps, drinking fountains, and toilets. Water usage for human consumption and toilets is estimated at 200 gallons per day (73,000 gallons per year) with another 50,000 gallons for use in the greenhouse and in maintaining the edible landscaping surrounding the building. The amount of rainwater that hits the roof of the building is 157,000 gallons /year (average annual rainfall is 36 inches). Monthly estimates of rain supply and water demand can be found on the building web site[2].

4.1.8 Black and Greywater Treatment

Black (toilets) and grey water (all other wastewater) are not separated. Daily combined black and grey water loads are estimated to be 200 gallons per day. Both are treated onsite with an anaerobic digestion (septic) tank, where the solids settle out. Liquids are then further treated aerobically by a peat moss based system made by Ecopure /Planetcare[12]and are then sent to drip irrigation. The Ecopure system typically kills more than 99% of fecal coliform bacteria. The output of the Ecopure unit is certified for direct surface discharge in some jurisdictions. The peat is typically replaced once every 10 years.

4.1.9 Edible Landscaping, Food Production, Rainwater Infiltration

The building is designed to have a beautiful and functional landscape. Surfaces are designed for permeability and infiltration. Storm water is treated and infiltrated on site using permeable paving and a recirculating water feature/wetland. The interior greenhouse will allow classes to experiment with propagating and growing annual and perennial edible plants all year round. Outside, the landscape will be an economic botanical garden filled with plants that are beautiful and have many uses - edible, medicinal, craft, dye, timber, fuel. Perennial native edibles species include mulberry, service berry, native plum, walnut, hickory, paw paw, and persimmon. Watering will be from the output of the waste water system. Once established, water requirements of the landscape will be minimal. The majority of the 36 inches of average annual rainfall falls during the growing season. Students are required to have a small annual vegetable garden for one year. Student garden beds will be located adjacent to the building, and will be a living demonstration of a wide variety of gardening techniques, including no-till deep mulch beds, biointensive, and conventional organic gardening techniques.

5. WHY OFF GRID

The building will be off-grid for water, electrical energy, and sewage treatment to demonstrate that it can be done for a commercial building. There are many places in the world, and even some in the U.S., where the grid is unreliable. As climate change and peak oil are already upon us, it will be of increasing value to construct buildings to be as selfsufficient as possible. However, being off-grid rather than grid-tied presents some technical and philosophical challenges. The rational for most net zero grid-tie buildings is that any energy needed from the grid will be offset by energy put into the grid at other times, therefore resulting in no net fossil fuels being burned. Often, winter shortfalls are made up by summer surpluses, so netting is done on an annual basis. In addition, without a grid tie, energy production goes to waste during times when storage is full and energy production exceeds energy consumption. With a grid tie, this energy can be put on the grid, thus offsetting the use of utility fuels. In effect, this fuel is “stored “for use when the building has to purchase grid energy. Nevertheless, a grid-tie also means significant utility generating resources have to be committed and available to provide energy when needed for an on-grid building. In Iowa, 70% of electrical energy is produced with coal. Because a grid tie building may demand energy during peak times (either summer or winter), widespread use of grid tie buildings could be used to justify continued use of existing coal fired and nuclear plants and the construction of new ones. Also, a grid tie building requires less care in the design of systems that use energy. Too often the philosophy is to install enough PV to match the annual energy requirements of the building while ignoring efficiency or when peak demands occur. While designers of grid-tie buildings have the option of designing a low energy building, off-grid buildings require designers to be wise in how energy is used, generated, and stored. While the SL Center will not draw power from the grid, it will have the ability to send excess energy to either a hot water storage tank or to the adjacent library building.

6. SUSTAINBLE BUILDING AND MAHARISHI VEDIC ARCHTECTURE

Vedic architecture, also called Sthapatya Ved, is an ancient system for the design of buildings with the goal of taking best advantage of the influence that the site and building have on the occupants. The major influence is the path of the sun from east to west. The sun is of primary importance in both modern high performance design and in Sthapatya Ved. Other influences include the earth’s electric and magnetic fields, bodies of water, the orientation of the entrance of the building, the shape of the building, the placement of rooms in the building, the slope and aspect of the site, neighboring bodies of water, the influence of the moon, planets, and other celestial bodies and many other factors . The goal is to put the occupants in tune with the laws of nature for the site, providing the best conditions for the health, happiness and good fortune of the occupants.

Typical design features include an east entrance, a fence, and an ornament called a kalash on the roof of the building. Maharishi Vedic Architecture (MVA)[4] is Sthapatya Ved that has been revived and reinterpreted by Maharishi Mahesh Yogi (the founder of Maharsihi University of Management). While Sthapatya Ved is from India, the principles that MVA requires are universal to any site on Earth and are not based on local climatic considerations of India. The influence of local climatic conditions is what good high performance design is about, and high performance design is recommended by MVA. In order to ensure that the principles are applied properly and the effective results are obtained, MVA certification requires the use of a certifying agency. The certifying agency requires building owners to sign non-disclosure agreements, which prohibit discussion of details of the MVA parts of the project. Some MVA requirements, like not using recycled materials in the building (recycled materials can be used in landscaping) conflict with some of the other certifications, but MVA compliance can still be certified without compromising LEED, Living Building Challenge, or Building Biology certification. Modern sustainable design principles are incorporated as part of Maharishi MVA recommendations, but are not required for MVA certification. Adding MVA to modern concepts of sustainability is a next step in the development of healthy, living buildings that have a positive influence on the occupants and, as far as we know, this is the first building to integrate all of these principles at a deep level.

7. STANDARDS THE BUILDING MEETS

Certification standards for four building philosophies were incorporated: 1) LEED, the current industry standard for green buildings, consists of a multilevel rating process intended to verify performance in metrics such as energy savings, water efficiency, CO2 emissions reduction, and indoor environmental quality. 2) The Living Building Challenge (LBC) advocates the most advanced principles of sustainability in the built environment possible today, and consists of seven performance areas: site, water, energy, health, materials, equity, and beauty. 3) Building Biology (BB) is mainly concerned with the interaction between the built environment and the health of the occupants. 4)

Maharishi Vedic Architecture (MVA) is an ancient system that uses factors such as building materials, orientation, proportion, and placement to enhance the well-being of occupants at both concrete and subtle levels of awareness.

An extensive chart has been developed that compares these philosophies and demonstrates that the Sustainable Living Center will include almost all of the features in all four of them. See reference 5 for details of this chart. Even though the certifications are surprisingly different, for the most part there is no conflict between them. A notable exception is that MVA does not allow use of post-consumer recycledbuilding materials (to avoid any influence of previous occupants), contrary to most modern green building practices. In addition, LEED and LBC value an east-west orientation to maximize solar exposure, whereas MVC places a greater value on a north-south orientation in order to face the rising sun. Both principles were served in the SL Center by adopting a square structure.

8. DESIGN PROCESS

The initial broad parameters of the aesthetic design and programming (including daylighting and room uses and placements) were performed by Jon Lipman & Associates in consultations with MUM faculty, students, staff, and members of the Fairfield community starting in early 2005. However, there was no formal, organized building charrette. Rather, a series of ad-hoc meetings were held over a period of several months to arrive at a consensus that the building should include the highest levels of energy efficiency and Maharishi Vedic Architecture. Gradually, David Fisher, as the Director of the Sustainable Living Program, emerged as the primary advocate for the building, and Dal Loiselle of Evergreen Homes and Developments as the building developer. The initial feasibility study was completed in December 2005, the costing study in December 2006, and an MAI appraisal in June, 2007. In July 2006 Innovative Design of Raleigh, N.C. was retained as the technical designer of the building. The final aesthetic design and floor plan of the building was a collaboration between Innovative Design and Jon Lipman and Associates.

Innovative Design was responsible for the integration of systems and technical design. Along the way a number of design modifications or additions were made, including most prominently the decision to be off the grid in all ways and the adoption of LEED, LBC and BB. These features considerably increased the challenge and cost of the building. However, they were considered desirable for quick and easy recognition that the building featured the highest levels of environmental, social, and healthy building practices, and to set a new standard for building selfsufficiency. After studying the feasibility of a number of sites for student access, suitability for wind and solar energy, solid ground, and amenability to landscaping, a site was chosen that partly overlapped a large parking lot. The foundation was laid in July 2009, but further construction was delayed due to recession-related funding challenges, and did not re-commence until February 2010; it has continued ever since and is now 80% complete.

9. APPROVAL PROCESS

Although the University administration liked the idea of the building from the first, in 2005 it was concerned mainly with the funding and construction of the much larger, new student services building. Gradually, as that building was completed, and as the enrollment in the Sustainable Living program (which began in 2003) began to increase rapidly, the administration became more actively involved in its development. There was no formal procedure for approval. Rather, the initial design and subsequent modifications and certifications were approved as the need arose by the University’s administration and, less frequently, President and Board of Trustees. Because of the University’s broad commitment to sustainability, there were no serious points of contention between the primary advocates of the building and the Administration.

10. COSTS AND FINANCING

The initial cost estimate was based on adherence to principles of Maharishi Vedic Architecture, daylighting throughout the building, and energy efficiency, the use of renewable energy, and the schematic design was completed in August, 2006, by Innovative Design. This estimate, completed by Stecker-Harmsen (Ames, Iowa) in December, 2006, was $1,787,706 ($259 per ft^2). However, it did not include subsequent expenses following decisions to add certifications for LEED, BB, and LBC, and to be off-grid in all ways. These and other design modifications, including whole tree structural support, have gradually increased the final estimate to $450/sq. ft as of this writing. Financing for the initial feasibility study ($5,000), costing study ($2,950), and MAI appraisal ($6,000) was covered by donations. More sizable donation ($50,000 - Jeffrey Abramson); and $400,000 - Eric and Mary Sue Schwartz) made it possible to complete the design work and the foundation. Following a construction hiatus due to the recession, additional funding came from grants ($50,000 - Kresge Foundation; $100,000 - Wege Foundation); a bank loan - $1,700,000; another sizable donation ($200,000 - Steve Guich), and a number of smaller donations ranging up to $20,000. As this goes to press there is a shortfall of around $900,000.

11. CONSTRUCTION PROCESS

Pre construction work started in 2004. Construction started in the summer of 2009. A construction manager oversees all aspect of the project. A special groundbreaking event is required for Maharishi Vedic Architecture, which occurred in summer 2008. The foundation was placed in the late summer of 2009. Exterior walls went up next. Unmilled round wood columns were installed along the central corridor, and roof trusses are supported by the outside walls and by the central round wood columns. Design changes were approved by Masaki Furukawa at Innovative design and by the construction manager. At the start of construction in 2009 it was estimated that the building would be completed in 6-9 months. Design changes, financing, and other delays extended the construction time to approximately 2 years.

12. THINGS WE WOULD DO DIFFERENTLY

For the next campus building, we would most importantly hire an outside professional facilitator to run a design charrette, so that all stakeholders could have productive input in a time-efficient manner; it would also prevent costly design changes as the project proceeded. Second, it would be preferable to raise all the funds needed to complete the building in advance, so that all phases of construction could be conducted in the most cost-efficient manner possible rather than being subject to vicissitudes of the economy or other elements that bear on funding. Third, we would keep much more meticulous, dated notes on all meetings and activities throughout the entire project so as to minimize having to reconstruct them later.

13. SUMMARY

The full significance of this building will most likely not be realized right away. It is a building that teaches not only for the team that has put it together, but also for students, the building industry, and people anywhere who value utility self-sufficiency and more local sourcing of building materials. By being day-lit, off all grids, and meeting the four certifications, it sets a bold new standard for what can be accomplished and should thus be an inspiration to anyone who wants to have a building as completely sustainable as possible. It also helps to introduce building philosophies that have received little attention to date, at least in North America: Building Biology and Maharishi Vedic Architecure; we expect both to become increasingly influential in the building industry in the coming years.

14. ACKNOWLEDGEMENTS

We are very grateful to Dal Loiselle, Building Developer, Masaki Furukawa and Mike Nicklas of Innovative Design, and Jonathan Lipman for their exceptional support and work during this project. We also acknowledge the administration of Maharishi University for their support throughout the process, and Meeraf Mamo and Lu Li for their help with formatting and editing the manuscript.

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