Cassandra Landry

Marquette Climate & Sustainable Design Research

The average annual snowfall in Marquette Michigan is 143.3 inches (NOAA Climate Data); this is a lot of snow. Marquette is located on the southern shores of Lake Superior in Michigan's Upper Peninsula. With buildings using 37% of the U.S.'s energy and 67% of our electricity (U.S. Department of Energy "Foundation", 1) an important question for architects and builders to ask in Marquette is "what sustainable building systems work in the U.P.'s harsh climate?" According to Elizabeth Wilhide, sustainable design is "the use of resources with maximum efficiency, at a rate that does not compromise the needs of future generations" (9). In this paper I will explore passive design, a number of natural building materials and some of the latest alternative technologies. While there are hundreds of systems that could be studied, I am choosing a few that I personally wish to learn more about.

The climate in Marquette and the rest of the U.P. can vary greatly from day to day and sometimes even from hour to hour. While visiting Marquette this past June (2005) an example of this occurred; one day it was 99 degrees and very humid, the next it was raining and only 62 degrees. This is a thirty seven degree drop in less then twenty four hours. Any sustainable building systems will need to work in temperatures as low as -34 degrees and as high as 99 degrees, this does not include the wind chill or humidity levels that drastically affect temperature. These systems will also have to deal with the inclement snow; adding a substantial load to structures and requiring systems to manage standing water while melting occurs.

Passive design is considered to be the foundation for energy efficient buildings (U.S. Department of Energy "Foundation", 2). The U.S. Department of Energy defines passive design as "methods for heating or cooling buildings...in which thermal energy flows by natural means (i.e. without pumps or fans)" (U.S. Department of Energy "Passive Handbook", 1). Passive design uses local climate and seasonal conditions to heat, cool, and provide light in a building through strategies such as natural ventilation, direct heat gain, and daylighting. In order to use these methods of energy conservation it is important to take this into consideration from the beginning of the design process.

A building's orientation is very important to passive design. In order to take advantage of the sun and wind one must understand their impact on the site. In the winter the object is to maximize the amount of sun that gets into your building to maximize the heat gain and natural lighting. In the summer it is important to block the sun, so as not to overheat your building. Interestingly, the exact opposite is the case with wind. In the summer the wind can be used to cool your building with natural ventilation, while in the winter it will cause substantial heat loss. The wind in Marquette comes from Lake Superior from the north west most of the year (NOAA Climate Data). During the design process it is important to come up with a way to block the wind in the winter and use it in the summer. In North America a building should be oriented with longer facades facing north and south. The south façade will receive the most sun, so this side should have more openings to capture the sun's heat. Thermal mass, walls or floors usually made from concrete or stone, is used to store the sun's heat during the day and slowly release it during the night. The south side of the building doesn't receive any direct sunlight so there should be fewer openings on this side; however the natural light that comes into the south façade is better for daylighting so it is important to take this into account and balance the openings around the building. The summer sun is at a higher angle then in the winter, allowing sun shading devices to be constructed on the building to block the sun during the summer months. This is to protect from heat gain, and could be as simple as a roof overhang (image 1).

A bioclimatic chart combines the high and low temperatures with relative humidity to identify potential passive solar heating and cooling techniques for a specific climate (Brown, 35). The chart is set up to keep a building in the "comfort zone" for the average human. Looking at Marquette's bioclimatic chart with data from the National Oceanic & Atmospheric Administration, we can ascertain that a building in Marquette would benefit from natural ventilation in the summer and passive heating in the winter (image 2).

While thinking about sustainable design it is important to combine the buildings components to create what the Department of Energy calls a "whole building" approach to sustainable design. This usually starts with passive design as the frame work, and adds alternative technologies where appropriate. A system that may work in the U.P.'s climate is geothermal heating. One type of geothermal heating uses ground heat to keep a buildings temperature stable. This system works because the temperature under the surface of the earth (below the frost line) is always between about 50 and 60 degrees. A geothermal heat pump circulates liquid through a system of pipes buried in a loop under ground and then pumps the warmer air into the building (image 3). In the summer the process is reversed so that the warm air is extracted from the building (U.S. Department of Energy webpage). An example of a geothermal heating system used in Michigan is the Immaculate Heart of Mary Motherhouse located near Detroit. This system was set up in 2000 during renovation of the existing Motherhouse (GLREA).

Solar energy can be harnessed in two ways, photovoltaics, which provide electricity, and thermal solar energy systems, which provide heat (Wilhide, pg 34). There is enough solar energy to provide 10,000 times over the amount needed for the earth, and even in cloudy climates like Britain there is more then enough (Whilhide, 33). Photovoltaic collectors, the most common of which are solar panels, change radiant solar energy into electricity which is stored and used later. There are many examples of solar panels in Michigan and the Upper Peninsula (image 4). The Jungworth family lives near Marquette, and have used solar panels for all their electricity needs for over ten years. The panels have always worked well in the climate as long as the snow and ice was not allowed to form on them (Lake Jungworth).

Solar heaters are set up to use the sun to heat water that is used to heat the building through radiant heat systems (floors and ceilings). There are passive and active solar heaters. The problem with these systems is that they work best when not needed, when the weather is warm and there is a lot of sun available (Reynolds, Stein, 613). This system would not work well in Marquette winters. It would most likely freeze, causing internal problems within its structure.

Fuel Cells produce electricity from an "electrochemical reaction between hydrogen (that contains fuel) and oxygen" with only water vapor and heat as waste (Alternative Energy Sources). This seems like a valid technology for this region; the waste heat from the fuel cell could be harnessed for winter heating needs. The Michigan Alternative Renewable Energy Center (MAREC) is one of the first buildings to use a fuel cell to help power their 25,000-square-foot facility in Michigan (Grand Valley State University webpage) (image 5).

There is a large problem to overcome, however, although this technology has been around for a few years it is still new and complicated. There are many types of fuel cells available, with no one system having its bugs fully worked out costs have been stubborn to lower. It has been difficult for architects and builders to choose a system and run with it in their projects because of this. With a purely climatic view in mind fuel cells may work well in the U.P., they produce energy out of clean hydrogen. However, due to the fact that the costs are so high for such an experimental alternative system it may not be appropriate for the economy of the U.P., which has shrank a great deal since the mining boom in the early 20th century (Rydholm, 123).

Green roofs have been growing in popularity in the United States over the past few years. They are a mixture between a natural building material and a modern technology. Originating in Scandinavia's vernacular architecture, they consisted of earth and sod. The Germans innovated this technique and have been using them widely in their country since the 1980's. The modern definition of a green roof is a "layer of living vegetation" located on a roof system. These roofs usually consist of the structural system, a roofing membrane, the membrane protection, insulation, a drainage system that doubles as a root barrier and water storage space, a growing medium, and vegetation (Johnson, 36). There are two main types of green roofs. An intensive green roof is one that is available as an outdoor space for people. They require much more structure then regular roofs. An extensive green roof is one that is only for a thin layer of soil and vegetation. This system also needs added structure, however not as much (Boivin and Challies, 37).

Historically sod roofs were extremely common in Scandinavian countries where the climate is similar to that of Marquette. They were used because it was a cheap material that had strong insulation qualities. Current versions of these can be found all over Europe, Canada and the United States. One of the most well known examples of green roofs in the United States is the Chicago City Hall (image 6). This green roof was planted in 2000, and ninety-five percent of the vegetation lasted through the first winter. In the summer when the city is very hot and humid the average temperature on the vegetated roof is 86 degrees while on black tar roofs the average temperature is 168 degrees (Ccmecki, 79).

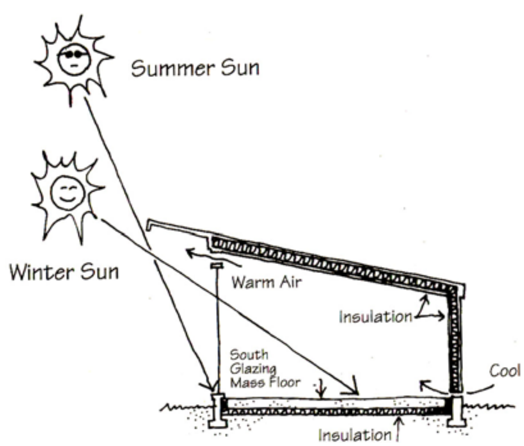
The main benefit for having a green roof in the U.P. is that they add to the roofs insulation, greatly reducing the energy consumption of the building for heating and cooling. This offsets the added price of the extra structure. Green roofs also help detour the amount of runoff water coming from a site. This is good in Marquette because it is located near a large body of water, Lake Superior.

The first code-approved straw bale structures were built about a decade ago, since then straw bale construction has been used in every state in the United States. Currently the U.S. has more straw bale buildings then any other country (Kennedy, Smith, and Wanek, 188). Straw is used both as a structural building material, stacked like giant building blocks and tied together with steel rods, and as infill between post-beam construction (Wilhide, 25).

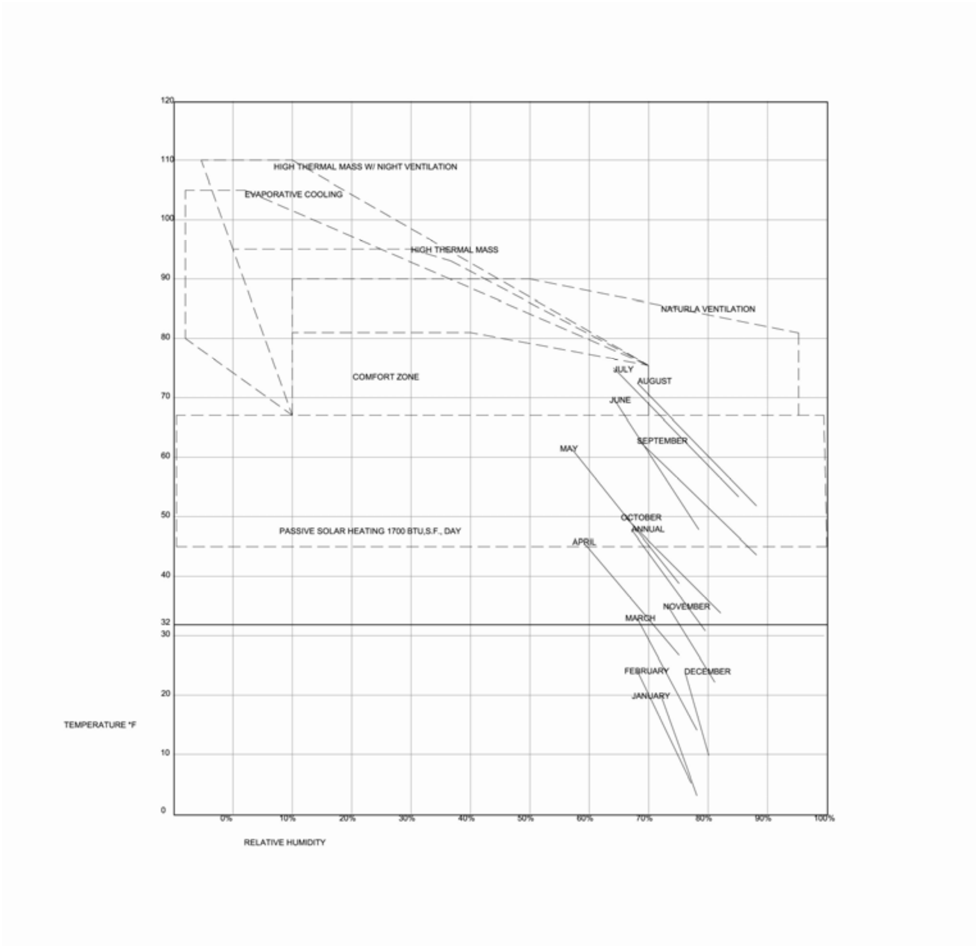
The number one enemy of straw is moisture, which causes fungal growth at about 80% relative humidity (Kennedy, Smith, and Wanek, 190). This makes it crucial to protect the construction from water with large overhangs and proper window and door detailing. Something else to keep in mind is that finishing stucco and plasters should be breathable to allow moisture to escape (Wilhide, 25). Straw bale construction seems unfeasible in Marquette's climate because of the risk of mold, however because the insulation properties of straw are so high it is important to look at ways to make it work. The average R-Value for a 2x6 stud wall construction with r19 batt insulation is R 15.4. Straw Bales have an R-Value of 42.7 with a 23" bale (Kennedy, Smith, and Wanek, 64). As added protection from water and standing snow, a double wall system or rain screen could be used in conjunction with proper detailing and overhangs (image 7).

There are many techniques that can be used to design sustainably that will work in Marquette's harsh climate. Passive design can be used to lower overall energy costs and can be mixed with alternative technologies and natural building materials to add extra savings. This will help ensure that future generations will not be robbed of vital resources. It is important to choose the right systems for Marquette because of the extreme cold and hot humid weather. Geothermal heating and photovoltaics are some alternative technologies that will work well in this climate whereas fuel cells and solar heaters will only cause problems. The same is true for natural building materials. Green roofs work well in cold climates to help stabilize interior temperatures because of their insulation qualities. With the possible problems of straw bale construction it is important to understand how to build with it in order for them to work in Marquette. In the end it is always important to choose and mix technologies in the appropriate manner so that the most energy efficient architecture can be achieved.

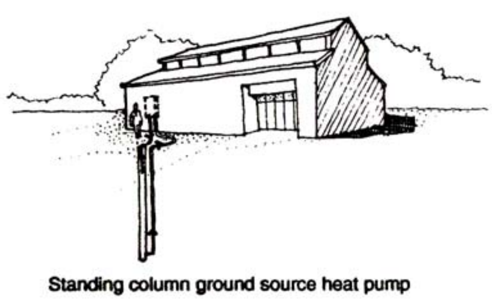
IMAGES



1. Passive Design Diagram (Brown, Dekay, 23)



2. Marquette Bioclimatic Chart

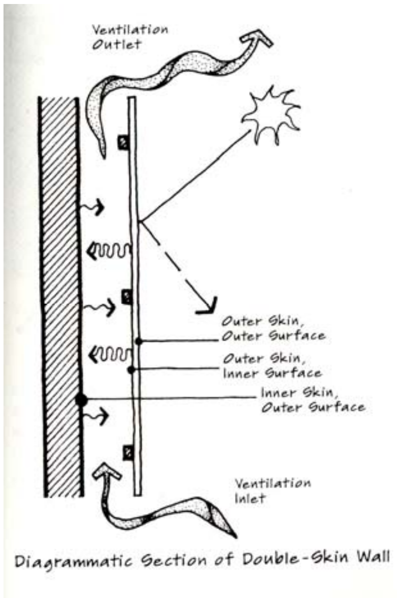


3. Geothermal Heating (Reynolds, Stein, 421)

4. Vincent & Helen Bunker Interpretive Center, Grand Rapids Michigan

5. MAREC Fuel Cell

6. Chicago City Hall Green Roof



7. Double Skin Wall (Brown, Dekay, 227)

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