How sustainable was Connecticut’s historic Saltbox house?

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Abstract – This paper addresses passive sustainability as the dominant characteristic in the creation of a critically regional residential design. Intricately tied to regional locations by materials and design, the American Colonial Saltbox house (1700) realized an innovative response to extreme climate conditions. While the research considers the innovation and efficiency of this sustainable precedent, in theory, there are few empirical studies to verify the attainment of passive design success. Utilizing computer modeling and energy simulations, this paper explores the performance and efficiency of this historic prototype. Was the Saltbox actually as sustainable as the theoretical model suggests? The paper will report the findings of these computer simulations, testing the sustainable validity of this historic prototype.

Keywords – colonial architecture; historic precedent; saltbox, sustainable design; passive solar

1. INTRODUCTION

Historic buildings are important precedents often considered by designers, contractors, and home-owners when constructing contemporary residential projects. Based on the cultural heritage and use of traditional building methods, these models are often valued academically by historians and architects. Antique buildings provide a link between current residents and their past culture. In many cases, they provide social, emotional, and lifestyle continuity for local people, whether in the form of historical artefacts or, as you can see in the slide, pastiche simulations. Often, historic buildings are preserved via drawings, photographs or written commentary. However, only a few empirical studies have investigated the physical performance of the physical attributes of these structures and their value as sustainable prototypes.

A previous study evaluated the attic and its effect on the energy performance of historic buildings [Fabbri & Brunetti, 2015]. This study found that the space-controlled (especially attic-controlled) heat transfer between indoor and outdoor spaces; thereby, contributed to the heat loss saving in the building. The strategy of space ventilation, and the benefits of the ventilated attic for controlling high levels of energy consumption in historic buildings has also been discussed in a review study conducted by Al-Obaidi et al. (2014). The influence of the ventilated spaces on the building performance of the buildings has also been investigated [Dimoudi et al., 2006]. Nevertheless, none of the existing studies evaluated the overall building performance, or how sustainable the historic Saltbox house model
was throughout the year. As a result, this paper investigates the sustainability of Colonial buildings, using a Connecticut Saltbox house as the case study.

2. BACKGROUND TO THE STUDY– COLONIAL SETTLERS

When English settlers first landed on the shores of the new world in 1620, they confronted on-going challenges along the frontier. These environmental challenges directly contributed to the manner in which the settlers built their houses during the latter part of the century [Bock, 2001]. While their intended destination was the Virginia colony, a location with a relatively temperate climate, storms blew the Mayflower off course during the ocean crossing [Philbrick, 2006]. When the Colonialists arrived in late December, the New England climate was cold. A lack of provisions and freezing temperatures resulted in the death of almost half the initial Mayflower party.

As the colonists established settlements, the shelters they constructed mimicked the heavy-timber and "wattle-work" of English cottages familiar to them from their homeland [Colkert, 1985; Nevill, 1889]. A simple cottage plan consisting of two rooms, a "hall" and a "parlour," separated by a fireplace was introduced [Garvan, 1951; Newcomb & Foster, 1932]. The first floor was mirrored with two sleeping rooms above. The Gleason House (c. 1650) in Farmington, CT, provides a fine example of traditional English houses as shown in Figure 1 [Alsop, 1986]. While this precedent served its purpose in providing shelter, it did not adequately address the extreme variation in seasonal temperature and the related snow and rainfall [Baker, 1994]. During the next half-century, residential architecture in New England was radically modified, actively responding to the settlers' new, harsher environment.

The New England Saltbox house was introduced around 1670, and eventually became the prototype for residential construction throughout the northern colonies [Bock, 2001; Builder, 2001]. The Lt. John Hollister House in South Glastonbury, CT, 1675 provides a fine example of a Colonial Saltbox (Figures 2, 3, 4). Initially introduced as various service spaces sheltered under lean-to roofs, the style was solidified when a permanent service bay was added to the back of the house [Walker, 1996]. The extended back roof gave the new structure a form...
similar to an English “Saltbox,” and thus the name was coined [Shelton, 1901]. While the new kitchen, pantry, and garret provided much needed spatial enhancements, the form also responded to the harsh northern winds, warning southern sun, and cool cross breezes.

In organization, form, and detail, the Saltbox house utilized multiple aspects of passive solar design. The design of the Saltbox house incorporates an east-west orientation, a cluster room plan, mud-filled thermal collector walls, direct solar gain rooms, a convection heat loop, various shade layers, and a central masonry thermal mass [Pollard, 2000]. In combination, these design strategies create a system to collect, store, and distribute heat, with numerous aligned openings to provide natural ventilation throughout the year [Builder, 2001]. The clustering of rooms around the thermal mass of the chimney allows for isolation and expansion of living space with barrowed heat throughout the day and night [DeKay & Brown, 2014].

Figure 3. Hollister House. Plan.

Figure 4. Section, Hollister House, (1675) Glastonbury, CT.

Figure 5. Site Orientation: Seasonal Shade Umbrella & Solar Envelope [Sawruk, 2017].
When located on an inclined hill, with tall deciduous trees to the east, south, and west, and evergreens to the north; the Saltbox house theoretically becomes an ideal microclimatic construct for a seasonal living (Figure 5). “The front yard thereby serves as a shaded retreat in summer and fall, while the form of the Saltbox shields it from the winter winds, creating a loosely defined “winter court” or sunny, protected outdoor room through till spring” [Sawruk, 2017]. If one considers this vernacular residence through a lens of sustainability, one can consider the extent to which this structure addresses its environment. Did Colonial Americans realize a prototype that bares reconsideration in our currently emerging climatic energy crisis? Is the Saltbox house a truly sustainable prototype?

3. CONSTRUCTING THE MODEL

To explore the merits and relevance of the New England Saltbox, the study constructed a digital model of the ideal Colonial Saltbox and assessed its qualities using energy modeling software. This study utilized a 2018 ‘standard” Revit computer-aided design (CAD) program to generate a three-dimensional model in digital space. The Saltbox model followed an existing, and previously delineated historical precedent, the Hollister House (1675) of Glastonbury Connecticut, which was modified to reflect an ideal site and plan arrangement, with traditional Colonial construction methods (Figure 6). The modeling process began by reviewing the historic measured drawings, and programming the wall typology by establishing the wall structure and building materials. Exterior walls were developed to establish the building perimeter, with the interior walls and fireplace massing added after. The CAD “mass-in-place” feature allowed the
unique form of the fireplace to be established, which was then extruded to realize its final configuration. The “wall-by-face” feature allowed the chimney plane to be assigned specific masonry wall characteristics. For the modeling, the building is considered to be naturally ventilated in the summer months, with the fireplace is regarded as the source of heating of the living spaces during the winter months.

The second floor was created similarly, with the roof being generated from the walls of the second floor. Colonial doors and windows were added in relation to the historic precedent, while modifications were introduced to conform to the historic period and theoretical ideal. For example, the current Dutch, double-hung windows installed in the early 1800s, were substituted with small-scale, beveled-glass, casement windows, typical of the eighteenth century English building customs. After completing the overall form, each room within the model was assigned an individual delineation per floor (P01–P04), and the building was placed on a digital site (Figure 7). The site location reflected the ideal topographic slope, sun orientation, and landscape features to support a passive solar design.

4. PROTOTYPE ANALYSIS

Sefaira architecture and Sefaira systems energy modeling programs were used in conjunction to analyze the ideal CAD model [Sefaira, 2017]. Once the CAD model was completed, the prototype was uploaded to the Sefaira analytical program.

A general geographic location of Glastonbury, Connecticut was specified to provide climatic constraints. Data input for the CAD model included wall, floor, and roof R-values; glazing U-values; solar heat gain coefficients; solar shading design features (i.e., building overhands and landscape features); and a human coefficient of five individuals (Table 1). While the cooling parameters could be set to consider natural ventilation, a limitation of the Sefaira program consisted of the program defaulting to a “heating and ventilation only system 9” identification to represent the chimney mass.

Based on representative Colonial seasonal room utilization, two zoning compositions were defined for the research analysis. During the summer months, the entire interior was considered. During the winter months, a smaller footprint of three adjacent internal spaces consisting of the kitchen, parlor, and chimney mass were considered. To begin the analysis, set points of heating and cooling during the calendar year were determined, and the Sefaira program output hourly data for the entire year of dry bulb temperature.

Table 1. Sefaira U-Values of Building Envelope

<table>
<thead>
<tr>
<th>Building Envelope</th>
<th>Assembly</th>
<th>U-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall: Timber Framed Mud Filled</td>
<td>Masonry</td>
<td>4.98</td>
</tr>
<tr>
<td>Window: 0.5m x 0.6m Each</td>
<td>Single Pane Glass</td>
<td>4.03</td>
</tr>
<tr>
<td>Roof: Wood Deck, Shingle Roof</td>
<td>Wood Deck</td>
<td>4.98</td>
</tr>
<tr>
<td>Floor: Hard Wood Deck</td>
<td>Hard Wood</td>
<td>4.98</td>
</tr>
</tbody>
</table>
5. FINDINGS

External temperature data for the study was derived from the aggregate of the geographical location, recorded over multiple decades. The average external temperature was reported monthly from January (#1) through December (#12) (Figure 8). From this data, it was determined that January (#1) was the coldest, with an average monthly temperature of –4 °C (24.8 °F), and July (#7) was the hottest, with an average monthly temperature of 25 °C (77 °F). Based on Colonial (1700) concepts of dress and habitation, a winter comfort level of 15–20 °C (59–68 °F) was utilized in this analysis.

![Figure 8. External Temperature by Month for Connecticut, USA](image)

The Sefaira systems energy-modeling program revealed the temperature by room, by season, based on the average external temperature (Table 2). During the winter months, the average temperature in all rooms maintained an average temperature of 14 °C (57 °F). While this temperature is below the study comfort level, by a few degrees, the researchers believe that with added clothing or additional heat, any of the rooms could be brought up to an acceptable comfort standard. In turn, the analysis revealed that three spaces, the kitchen (2P01), the southwest front room (2P04), and the front room on the second floor (3P03) all reached an internal temperature of +22 °C (+72 °F). The cooking fire in the kitchen accounts for this room’s increase in local temperature, while solar gain throughout the day accounts for the increased temperature in the southwest rooms. The indoor temperatures in these three spaces are above our study winter comfort level of 15–20 °C (59–68 °F), and within a current comfort level of 22–25 °C (72–77 °F). The thermal environment of most of the spaces in the building tends to be cooler than the thermal environment of non-historic buildings. Therefore, while additional resources could be expended to make only one room within the house habitable, it is more likely that the cluster plan arrangement provided for a reduced living space during the winter months, with two or three rooms serving the needs of the entire family. Other spaces could be closed off, or accessed on a temporary basis, as needed. These results support the initial hypothesis of a modified winter habitation footprint.
Additionally, during periods of the extreme drop in temperature, below –10 °C (14 °F), residents may have taken shelter in the basement room, where the surrounding ground would have maintained an average temperature of 8–15 °C (46–59 °F) [USDA, 2018]. While the basement was not designed to support daily habitation, it did provide a “safe space” during harsh winters, especially if firewood became scarce or unobtainable. With additional clothing, blankets, and shared body-heat, Colonial settlers could easily survive underground for a day or weeks with little or no heat.

Through the spring and fall seasons, the room temperatures ranged from 14.4 °C (58 °F) to 21.4 °C (76 °F) and generally fell within the Colonial comfort level of 15–20 °C (59–68 °F). The findings supported the study hypothesis that during these six months, the entire house could be used for habitation, with only a modest need to ventilate or heat individual spaces. Additionally, these temperature changes could also be easily addressed by inhabitants with the simple addition or subtraction of clothing.

Table 2. Data Analysis: Interior Temperature by Room during Seasons

<table>
<thead>
<tr>
<th>Variables/Spaces</th>
<th>P01 (Floor 2)</th>
<th>P02 (Floor 2)</th>
<th>P03 (Floor 2)</th>
<th>P04 (Floor 2)</th>
<th>P05 (Floor 2)</th>
<th>P02 (Floor 3)</th>
<th>P03 (Floor 3)</th>
<th>C01 (Floor 2)</th>
<th>C01 (Floor 3)</th>
<th>External Weather</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Temperature (°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>March – May (Spring)</td>
<td>22.1</td>
<td>15.2</td>
<td>14.4</td>
<td>21.1</td>
<td>14.6</td>
<td>14.5</td>
<td>22.1</td>
<td>14.7</td>
<td>14.6</td>
<td>10.0</td>
</tr>
<tr>
<td>Jun. – Aug. (Summer)</td>
<td>30.8</td>
<td>26.7</td>
<td>24.2</td>
<td>27.8</td>
<td>24.1</td>
<td>25.5</td>
<td>30.6</td>
<td>24.3</td>
<td>24.2</td>
<td>23.0</td>
</tr>
<tr>
<td>Sept. – Nov. (Fall)</td>
<td>21.4</td>
<td>15.1</td>
<td>14.8</td>
<td>20.6</td>
<td>15.1</td>
<td>14.5</td>
<td>21.6</td>
<td>15.0</td>
<td>14.9</td>
<td>14.0</td>
</tr>
</tbody>
</table>

Through the spring and fall seasons, the room temperatures ranged from 14.4 °C (58 °F) to 21.4 °C (76 °F) and generally fell within the Colonial comfort level of 15–20 °C (59–68 °F). The results supported the study hypothesis that during these six months, the entire house could be used for habitation, with only a modest need to ventilate or heat individual spaces. Additionally, these temperature changes could also be easily addressed by inhabitants with the simple addition or subtraction of clothing.

During the summer months, July-August, the external temperature range was usually from 21–25 °C (70–77 °F), with July being the hottest of the months, with
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an average temperature of 23 °C (74 °F). However, it was common for extreme temperatures to reach 35 °C (95 °F) during periods of the month. Utilizing a thermal comfort level of 22–25 °C (72–77 °F), the entire house was analysed for daily habitation. The analysis revealed that all the rooms except the entry, pantry, and southwest bedroom averaged between 24 °C (75 °F) and 26 °C (79 °F), with mean temperature at or above the comfort level (Figure 9). The kitchen with its cooking fire, and the southeast sleeping room with its prolonged sun exposure, both averaged above 30 °C (86 °F). As such, during July, the interior of the house was often uncomfortable and not conducive to daily activities. This situation lends credence to the need for a “summer retreat” in front of the house, a clearing created by planting deciduous shade trees. The trees shaded both the south side of the house and its landscape. When it became uncomfortable inside, furniture was moved outside, and regular activities continued unimpeded. To reduce the interior heat, outdoor “kitchens” allowed for cooking without increasing interior temperatures. In the evening, the temperatures would have cooled some, allowing the settlers to move back inside and comfortably sleeping throughout the night.

In this way, the design of the Saltbox is not merely the building itself, but also the immediate and surrounding landscape.

Figure 9. Data Analysis: Interior Temperature by Room in the Summer Months.

In a similar manner to the extreme temperatures in winter, if extreme temperatures in summer became unbearable, the settlers could once again retreat to the basement and sleep comfortably. With an average temperature of 8–15 °C (46–59 °F) [USDA, 2018], this space would be a cool alternative to the hot and humid sleeping rooms above. It is interesting to note, that as utilities (firewood or coal) became more available and abundant, many families refrained from building basements or constructed only small “root cellars.” Whether this is due to construction costs or social status is not known, but as the Saltbox became a preferred prototype, fewer and fewer Colonialists constructed basements.
5.1 LIMITATIONS

While the Sefaira energy modeling software was utilized for this analysis, the program did not allow consideration of the chimney mass and the heat distribution by individual fireplaces. Additionally, it did not allow for a full analysis of the natural ventilation throughout the building, nor during various calendar months. Finally, the software did not enable us to consider the temperature-moderating effects of the earth’s immense thermal mass realized by the basement rooms, which would have provided an alternative heat source or habitat during extremely cold and hot temperatures.

To overcome the limitations, the researchers have recently garnered a University of Hartford Coffin Grant to purchase a license for the computer software program DesignBuilder by EnergyPlus needed to conduct further scholarly research work on structural/mass timber and sustainable buildings. The software is a state-of-the-art tool for analyzing building environmental performance including energy, carbon, lighting, comfort, and cost performance of buildings under different weather scenarios. By running additional computer simulations, the researchers hope to refine the building’s environmental performance analysis, including the daylighting, temperature swings, relative humidity, thermal mass, carbon emissions, and more refined comfort levels of the entire building. Additionally, the new software allows for the consideration of current and future weather scenarios. For instance, with the provision of the software and the appropriate weather files, the researchers can conduct weather simulations, for extended periods or specific situations.

6. CONCLUSIONS

The researchers speculate that with limited utility resources (heat or ventilation), most Colonial settlers, out of necessity, accepted a wider range of temperature in their comfort level than we do today. Additionally, layers of dress, traditional at the time, allowed for a simple modification of individual comfort. The Saltbox plan provided for many rooms clustered around the thermal mass of the fireplace, which provided direct and barrowed heat to individual rooms. While not a large residence, the five spaces generally allowed for a distribution of activities and some level of personal privacy. However, during times of extreme temperatures, Colonial settlers found it necessary to reduce their habitable footprint, retreat underground, or move outside. A finely tuned machine for living, the Saltbox house provided multiple means of modification with doors and windows organized for both isolation and aligned cross ventilation. Direct solar gain at various times of the year, served as both an asset and disadvantage. Shading via roof and floor overhangs, along with tree foliage modified some solar gain in summer. As such, the orientation, location, and landscape related to the house were all essential components of the overall function and passive solar design. While many aspects of the building’s passive design would still be available on any building lot, the ideal site added considerably to the building’s sustainability.

In conclusion, it is evident from this study that the New England Saltbox house is a very sustainable structure, providing a flexible plan arrangement while being
able to respond to extreme shifts in weather and temperature. With its intrinsic ability to provide comfortable shelter, it would naturally become the precedent for European immigrants settling throughout New England. In many ways, the Saltbox can still serve as a precedent today. Contemporary homebuilders could utilize the intrinsic passive solar design characteristics of the model, modernize the plan, and enhance it with recent technology and material innovation. In this way, what was once old, can and will be new again.

7. REFERENCES


Note
The following Figures were obtained from Isham, N.M. & Brown, A.F., Early Connecticut Houses: An Historical and Architectural Study, Providence, RI: Dover Publications, Inc., 1965, originally published by The Preston and Rounds Company, 1900: Figures 1, 2, 3, 4.