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COMPARISON OF BUILDINGS IN ANCIENT TIMES WITH MODERN GREEN BUILDING PRACTICES

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Since the focus on sustainable development in 1980s, there has been an increased awareness for well-defined green building standards worldwide. Before the advent of much of the modern green construction standards and practices, ancient European buildings had implemented many features that would be considered green today. Ancient European construction used vernacular architectural, which incorporated climate responsive designs and solar architecture. In some instances, ancient building practices have been used to improve modern building materials, such as brick and concrete. These aspects of green buildings in ancient Europe can provide ample opportunity for research today. The goal of this paper is to analyze building designs, materials, and methods used in ancient Europe and compare these practices to current green building guidelines. The scope of this paper includes examining preexisting literature on building practices in Europe before 1800AD and analyzing two case study buildings in light of LEED green building guidelines. Finally, a comparison matrix of green building features, in ancient European buildings and in modern LEED buildings, is developed. It is hoped that such comparison will provide an insight into the relevance of ancient building attributes in modern green building practices.

Keywords: Sustainable design and construction, Green building guidelines, LEED, Ancient European buildings.

1 INTRODUCTION

Since the focus on sustainable development in 1980s, there has been an increased awareness for well-defined green building standards. Construction industry has a large environmental impact, creating between 40-50% of greenhouse gases and consuming nearly 40% of materials, in the global economy. These statistics, combined with the global environmental awareness, have accelerated the integration of green building movement in the construction industry worldwide (Ramaswamy and Syal 2016).

Before the advent of much of the green construction standards and practices that are in use today, ancient Europeans had implemented many features that would be considered green today. For example, Ancient European construction used vernacular architectural design, which incorporated climate responsive designs and solar architecture. The ancient Greeks also used solar architecture as a method to control the impact of the sun on buildings. Ancient Europeans placed importance on designing buildings to maximize comfort and health and of occupants (Sinou 2011).

There have been several instances of materials that have been improved by studying ancient building materials. Ancient building practices have been used to improve building materials, such as brick and concrete. As Yang (2013) points out, using ancient roman concrete techniques can improve the lifespan of concrete and decrease carbon footprints. These areas of green building in ancient Europe provide ample opportunity for research. Modern construction is continually striving to find new technology to increase sustainability and green techniques. By looking to the past, one can learn lessons that can help today including innovative and efficient design, methods and materials that can be implemented today at lower costs with greater efficiency. Therefore, there is a need to analyze ancient materials and practices to explore if they may help deliver innovations in sustainability today.

This paper focuses on the ancient European construction and the innovations that have been delivered from that region. It analyzes building designs, materials, and methods used in ancient Europe and compares those practices to current green building practices. The scope of this research includes examining preexisting research regarding ancient building practices in Europe before 1800AD and selecting and analyzing two case study buildings in the ancient Europe in light of today's green building guidelines. Finally, a comparison matrix of green building features, in ancient European buildings and in modern LEED buildings, is developed. It is hoped that such comparison will provide an insight into the relevance of ancient building attributes in modern green building practices.

2 ANALYSIS OF CASE STUDY IN CADIZ, SPAIN USING LEED RATING SYSTEM

A multi-family residential building in Cadiz, Spain was analyzed to compare ancient building practices with current Leadership in Energy and Environmental Design (LEED) standards. The building is a 4-story dwelling in the heart of Cadiz, Spain, designed with a central courtyard. Narrow streets separate the buildings in Cadiz, which allows facades to have shading and access to solar radiation at different times throughout the day. The walls and a flat roof are constructed using ostionera stone and a lime mortar. The roof is also coated with a layer of soot, clay and lime and covered with ceramic tiles. The majority of the openings are doors and balconies, not windows. The balconies have a shading systems that can be used in multiple ways throughout the year to either increase of decrease solar heat transition through the balcony opening. Openings to the courtyard provide lighting and ventilation into the dwellings. With this design, it was found that comfortable conditions could be achieved nearly 88 percent of the year without additional heating or cooling techniques (Rubio-Bellido *et al.* 2015).

This case study was scored using LEED V4 guidelines and points were awarded to the case if the outlined LEED criteria was met, if the case information met the intent of the LEED category, or if the category criteria was satisfied based on assumptions about the case (USGBC 2016). Below is a description of points awarded in each section. A detailed scoring analysis can be found in Sayer and Syal (2017).

2.1 Location & Transportation

A total of six points was awarded for Location & Transportation because of the density and walkability of the site. Points were awarded in the following categories: Surrounding Density & Diverse Uses (three points), Access to Quality Transit (one point), Reduced Parking Facilities (one point), and Green Vehicles (one point). Due to the city being surrounded by water and the assumption that the lot would not qualify as a high priority site, no points were awarded for the categories of Sensitive Land Protection and High Priority Site. Bicycle facilities also received no points since the building was constructed before the 18th century.

2.2 Sustainable Sites

A total of ten points were awarded based on the assumptions that a site assessment would have been completed before construction (one point), courtyard space provided outdoor/garden space equivalent to 30% of the site (one point), and rainwater management for a Zero Lot Line project was accomplished (three points). A point was also awarded for Light Pollution Reduction since no exterior lighting was used. No points were given for Heat Island Reduction because the ceramic tiles used on the flat roof would not have met the necessary Solar Reflectance Index (SRI) requirements. Protection and Restoration of Habitat also received no points because there was no green space provided on the site, aside from the courtyard.

2.3 Water Efficiency

Very few points were awarded in Water Efficiency because the measures outlined in LEED involve technologies not available at the time of construction. For this reason, Indoor Water Use Reduction, Cooling Tower Water Use, and Water Metering were not awarded points. Outdoor Water Use Reduction, however, was awarded two points because no irrigation was required for the minimal landscaping on site.

2.4 Energy & Atmosphere

Based on assumptions and LEED intent, a total of 23 points were awarded for Energy & Atmosphere. Points were not awarded in the Advanced Energy Metering, Demand Response, and Renewable Energy Production categories because the technology was not available at the time of construction. Two points were assigned for Enhanced Commissioning based on the assumption that occupants were trained and familiarized with the shutter system, which was used to control solar gains and maintain thermal comfort. Maximum points (18 points) were awarded in the Optimized Energy Performance category because this building uses no electricity, therefore meeting the intent of the category to increase building performance. Points were also allocated for Enhanced Refrigerant Management (one point) and Green Power & Carbon Offset (two points) because no refrigerants or grid power were used.

2.5 Materials & Resources

The materials used in this case study building consisted largely of stone or brick and lime mortar. Due to the durability and use of local bio-based materials points were awarded in the Building Life Cycle Impact Reduction (three points), Environmental Product Declarations (one point), Sourcing of Raw Materials (one point), and Material Ingredients (one point). While the intent of all of these categories was met, standards outlined by LEED could not be confirmed with the information available. No points for Waste Management were given due to lack of information about construction waste.

2.6 Indoor Environmental Quality

A number of factors contribute to the Indoor Air Quality of a building. First, the use of balconies and courtyards provide natural ventilation, views the outdoors, and natural light. These attributes allow points to be awarded in the following categories: Enhanced Indoor Air Quality Strategies (one point), Daylight (two points), and Quality Views (one point). In addition to the benefits listed above, the balcony has a system of blinds used to maintain thermal comfort. Through the use of this system the occupants obtained comfortable conditions 88 percent of the year without additional heating or cooling methods. Because of this one point was awarded for Thermal

Comfort. As mentioned in section 2.5 Materials & Resources, natural stone and mortar were the primary materials used, so three points were allocated for Low-Emitting Materials. The final point received was for Acoustic Performance. While background noise for HVAC systems would not be present in this building, some street noise may be heard because of openings for balconies and courtyards.

Based on the above-noted discussion, the analysis of this case study with LEED credits led to following results:

- Points awarded based on LEED criteria – 10
- Points awarded based on LEED intent and/or assumptions – 43
- Total possible LEED points – 53 (qualifies for LEED Silver)

3 ANALYSIS OF CASE STUDY IN RAVENNA, ITALY

A second case study building, the Classense Library in Ravenna, Italy was used to compare current Green Building Guidelines with the ancient building practices to determine the sustainability of vernacular construction. The climate of the area is consistent with a subcontinental climate zone. The building consists of multiple rooms, corridors and courtyards. For the purpose of this case, three rooms (the Great Hall, Dante Hall, and Holy Fathers Hall) were monitored. Details of the analysis are available in Sayer and Syal (2017).

Analysis of this case study with LEED credits led to following results:

- Points awarded based on LEED criteria – 8
- Points awarded based on LEED intent and/or assumptions – 46
- Total possible LEED points – 54 (qualifies for LEED Silver)

In each of these case studies, there were a number of LEED points that do not directly line up with ancient building methods. If no equivalent technology was available, and the intent of the LEED category did not clearly align with the construction methods no points were awarded. Examples include, Indoor Water Use Reduction, Cooling Tower Water Use, Water Metering, and so on. However, under the Location and Transportation category (Access to Quality Transportation, Bicycle Facilities, Reduced Parking Facilities and Green Vehicles) while the technologies were not available, the intent of each category was satisfied without technology by locating the building in a city center. Therefore, LEED points were awarded.

While assumptions had to be made, and certain technologies were not available at the time of construction, the analysis results demonstrate that the original design, construction and materials utilized in this ancient dwelling would qualify it as a sustainable building under current LEED Green Building Standards.

4 COMPARATIVE MATRIX

The comparative matrix, shown in Table 1, outlines out the similarities between the six main categories of the LEED V4 guidelines and buildings based on the vernacular architecture in ancient Southern Europe. The intent of each LEED category is explained, along with examples of how both modern and ancient buildings meet the desired outcome for each category.

Table 1. Comparative matrix - LEED buildings and ancient European buildings.

Green Building Attributes	**LEED Buildings** (Da Silva and Ruwanpura 2009, Todd *et al*. 2013, USGBC 2016)	**Ancient Building** (Rubio-Bellido *et al.* 2015, Andretta *et al.* 2016)
Location & Transportation	This category is intended to encourage developers to minimize the effect of development on the site and encourage alternative methods of transportation. Bicycle facilities, low-emitting vehicles, and parking facilities are the three points in this category most often awarded on LEED projects, whereas points for surrounding density only accounted for points in about half of LEED certified projects.	As seen in both case studies, many ancient buildings were located in a city center where occupants and patrons could easily walk to and from a variety of destinations. These ancient cities had homes, shops and municipal buildings that were all within walking distance. The design and density of these cities allowed residence to easily travel to a number of places, even without the modern transportation methods available today.
Sustainable Sites	These credits are intended to save and revitalize natural habitats, while incorporation of open space, rainwater management, heat island reduction and light pollution reduction. Points for open space and the reduction of heat island effect are most often awarded in this category.	A variety of case studies have shown that the use of courtyards in ancient buildings not only provides light and air flow, but allows for green space. These courtyards also allow rainwater to collect on-site instead of draining into streets.
Water Efficiency	This category encourages the reduction of water consumption throughout the building and landscaping. Both outdoor and indoor water use reduction are points received by the majority of LEED projects through the use of native landscaping and low flow fixtures.	Due to the lack of water technology at the time of construction, the literature related to this category is sparse. However, because of the time period, it can be assumed that water consumption was relatively low in comparison to modern standards. The use of native plants and vegetation in courtyards and other grounds ensured the need for limited irrigation.
Optimized Energy Performance	These credits are intended to encourage innovative ways to reduce energy consumption. Some points for optimized energy performance are met by nearly all LEED buildings, due to an increase in energy standards and the ease of demonstrating improved building performance. Over half of LEED projects also receive points for enhanced refrigerant management and enhanced commissioning as well.	Ancient buildings were inherently energy efficient, due to the lack of energy consuming technologies available at that time. Techniques such as passive solar design, building openings and thoughtfully selected materials helped vernacular dwellings to achieve thermal comfort in a variety of climate zones.
Materials & Resources	This category intends to promote the use of sustainable materials and reduce material and waste. It focuses on local, renewable materials and waste management in the construction and the operations phases. The majority of LEED projects receive points for Material Recycled Content, Construction Waste Management, and Regional Materials.	The materials used in ancient buildings comprised of locally sourced materials such as timber, stone or bricks. The benefits of these materials include the low transportation needs, high durability, and therefore a reduction of life-cycle impact compared to typical modern construction.
Indoor Environmental Quality	This category focuses on the health and comfort of the indoor environment by encouraging the use of low-emitting materials and improving thermal comfort, daylight and views throughout the building. Low-Emitting materials, Thermal Comfort and IAQ Management during construction are the categories most often seen awarded points on LEED certified projects.	The materials used in case studies are naturally low-emitting, resulting in no pollutants from such materials. The incorporation of passive solar design, careful consideration for building openings, incorporation of courtyards, and the thickness of wall materials are all examples of vernacular architecture techniques that improve thermal comfort, daylight and quality views.

5 SUMMARY AND ANALYSIS

Based on the above analysis and discussion, it can be inferred that both, modern LEED buildings and ancient European buildings have sustainable features, however the methods to obtain sustainability have evolved due to technology in the industry. Nevertheless, the methods demonstrated through ancient construction can be utilized to enhance sustainability in modern buildings and provide additional insight into improving today's green building practices. Some examples include: using locally available materials such as, bamboo leaves, thatched mud, and stones, traditional architectural concepts such as provision of a central open courtyard which allows direct sunlight and air into the interior spaces, maximizing the use of low-emitting materials, construction techniques from such as double layered masonry walls with sand filling the gaps which act as insulators in buildings envelopes to ensure thermal comfort, and so on. A combination of ancient building practices and modern technologies and methods would help increase the reach and impact of the green building movement globally.

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