Ancient vernacular architecture: characteristics categorization and energy performance evaluation

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Abstract

Building has significant impacts on the environment and natural resources. The emerging world energy and environment challenges demand a substantial revolution of building design philosophies, strategies, technologies, and construction methods. Vernacular architectures, built by people whose design decisions are influenced by traditions in their culture, have been gleaned through a long period of trial and error and the ingenuity of local builders who possess specific knowledge about their place on the planet, and thus are valuable in promoting climate-specific passive building technologies to modern buildings. This study introduced an approach to categorizing distinct vernacular regions and evaluating energy performance of ancient vernacular homes as well as identifying optimal constructions using vernacular building techniques. The research conducted an extensive computer energy modeling for a number of representative ancient vernacular architectural characteristics observed for different climatic regions. The vernacular test subjects were compared against those established according to the International Energy Conservation Code and those generated by the optimization software. The simulation results of the energy models suggest that considering traditions seen in ancient vernacular architecture as an approach to improving building energy performance is a worthwhile endeavor and a scientific guidance can help enhance the performance. The study indicates that, although many vernacular dwells exist in the world, it is challenging (but desired) to package vernacular architecture traditions and quantitative design knowledge to modern building designers. This project is the first part of a much larger project that intends to create a knowledge base of vernacular building traditions that will include information about not only the energy performance of traditional building techniques, but also address areas of cost, material availability and cultural traditions.

1. Introduction

Buildings account for 45% of worldwide energy use, 80% of potable water use, and 50% of the timber harvest in North America. They also account for about 40% of municipal solid waste and 30% of U.S. greenhouse gas emissions that contribute to global warming and acid rain [1]. The emerging world energy and environment crises demand a substantial revolution of building design philosophies, strategies, technologies, and construction and management methods. In most developed countries, architects design the majority of new buildings. However, when one looks collectively at the world’s buildings both now and throughout history, it becomes clear that professional architects designed a very small percentage of structures. In fact, Oliver [2] of the Oxford Institute for Sustainable Development estimated that over 90% of all structures in existence today were designed by the people who use them, not architects. The number of dwellings associated with this estimate includes approximately 800 million dwellings.

Vernacular architecture is used to describe structures built by people whose design decisions are influenced by traditions in their culture. Vernacular architecture varies widely with the world’s vast spectrum of climate, terrain and culture. It contains inherent, unwritten information about how to optimize the energy performance of buildings at low cost using local materials. Over the course of time, vernacular dwellings have evolved to respond to challenges of climate, building materials and cultural expectations in a given place. Vernacular traditions have been gleaned through a long period of trial and error and the ingenuity of local builders who possess specific knowledge about their place on the planet, a commodity that is becoming increasingly scarce in our era of remote communication and outsourcing. As such, there is value in understanding and applying attributes seen in ancient vernacular architecture to new buildings.

A great deal of literature was found on the topic of vernacular building traditions. The most extensive document by far is the Encyclopedia of Vernacular Architecture, a 4000 page collection of...
research by over 750 authors from 80 countries compiled by Professor Paul Oliver of Oxford University and published in 1997 [3]. With two volumes categorized by climate and the “vernacular responses” of a plethora of cultures and another volume focused on materials, resources and production, it is the world’s foremost source for research in the area. Another noteworthy text is *A Pattern Language: Towns, Buildings, Construction* [4], which draws conclusions about a basic language of architecture (similar to Carl Jung’s archetypal patterns) that has evolved out of vernacular building traditions over the course of human history.

This study is particularly interested in the energy-saving implications of vernacular architectural traditions. The *Encyclopedia of Vernacular Architecture*, a subset of its essays called *Dwellings* [2], and several academic papers were used in conjunction with photographs found online to help identify vernacular test subjects and define constructions. The book *Anthropological Linguistics: An Introduction* by the renown, and some say controversial, linguist and African anthropologist Z.J. Zhai, J.M. Previtali / Energy and Buildings 42 (2010) 357–365 research by over 750 authors from 80 countries compiled by Professor Paul Oliver of Oxford University and published in 1997 [3]. With two volumes categorized by climate and the “vernacular responses” of a plethora of cultures and another volume focused on materials, resources and production, it is the world’s foremost source for research in the area. Another noteworthy text is *A Pattern Language: Towns, Buildings, Construction* [4], which draws conclusions about a basic language of architecture (similar to Carl Jung’s archetypal patterns) that has evolved out of vernacular building traditions over the course of human history.

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2. Categorization of vernacular architecture regions

To create a comprehensive knowledge base about vernacular architecture using analysis, one must start by creating a list of test subjects derived from influences that make the test subjects unique. Since vernacular traditions are shaped strongly by culture, weather and geographic location, it makes sense to divide the world into distinct regions each with a unique combination of these three traits. Building materials also strongly influence vernacular building traditions, but introducing maps of materials would make a list of vernacular regions untenably large. And, although a map of timber resources and a map of soil conditions (which could be used to denote the availability of clays and stone) are available from the United Nations Food and Agriculture Organization, no world-wide mapping of indigenous building materials was identified. Thus, this study focuses on a regionalization of vernacular architecture based on climate, cultural heritage and continent, with a goal of creating a manageable number of vernacular regions (e.g., 100) that can be explored by a limited number of researchers over a limited time-frame.

2.1. Mapping climate zones

Mapping climate zones is no trivial exercise. Much work continues to be put into classifying the earth’s locations based on weather. German climatologist Wladimir Köppen (1846–1940) developed a classification system that is generally accepted as the most accurate method of mapping world climates. It includes 14 zones separated by temperature and humidity. However, the Köppen climate zone map was found to be considerably complex for the purpose of this research and a simplified map based on the Köppen climate classification system developed by de Dear [6] was chosen (Fig. 1). The de Dear map combines tundra and ice cap regions, as well as some arid and semi-arid, and some tropical and sub-tropical locations. The de Dear map was thought to be an acceptable compromise, especially considering its use was accepted in a 1997 ASHRAE (The American Society of Heating, Refrigerating and Air-conditioning Engineers) study entitled *Developing an Adaptive Model of Thermal Comfort and Preference* [6]. It would be ideal to utilize a simplified world map with ASHRAE climate zone definitions, upon which the IECC was developed. Unfortunately, none was found to exist.

2.2. Mapping cultural heritages

Given the migration of peoples and the temporal nature of national borders, the question arises of how to map cultural heritages. A relatively accurate method generally accepted by anthropologists is the tracing of language families. A language family is a grouping of languages based on linguistic similarities. While religions, geographic locations, regional languages and even skin color change within a related people, basic language traits

Fig. 1. A simplified map of world climates [6].
such as syntax, phonetics, and semantics are strong indicators of a shared cultural heritage. Some language families are consistent with rather obvious migrations of peoples such as the Amerind Group which connects indigenous peoples from Canada to Patagonia. Other language families suggest surprising cultural relationships between people separated by vast distances such as the Dene Caucasian group whose languages stretch across three continents and include Dagestan spoken near the Caspian Sea, Mandarin and Cantonese spoken in China, Basque spoken in Spain, and the Athabaskan languages spoken by the Navajo and Taos peoples of North America.

A map of language families was drawn from the Evolution of the Human Language Project (aka The Tower of Babel), a compilation of linguistic research started by Sergei Anatolyevich Starostin in 1997 and continuously augmented by other linguistics researchers as new data becomes available. Like the climate zone mapping, the question arose of how much detail to include in the map of language families for this project. To keep the number of vernacular regions close to 100, it was decided to use the first level of language families for all groups other than Eurasiatic which was broken into second level language families. The resulting map includes 17 language families with a good distribution across continents (Fig. 2).

2.3. Combining maps to identify unique vernacular regions

Combining the de Dear climate map and the map derived from the Evolution of the Human Language Project, resulted in 114 vernacular regions that contained a unique combination of language family, climate and continent (Table 1). The visual mapping process resulted in fairly acceptable boundaries for each vernacular region as each region highlights an area where one would likely find a unique example of vernacular architecture. Certainly, like the boundaries of climate and language families themselves, the vernacular regions identified are also rather loosely defined. For categorization convenience, the study developed a nomenclature for the vernacular regions, by combining acronyms for each climate zone, language family and continent into a hyphenated code. The sequence was chosen for no particular purpose to be Climate Zone–Language Family–Continent; for instance, SD–AM–NA stands for Semi Desert–Amerind–North America.

3. Characteristics of ancient vernacular architecture

Once the framework for classifying vernacular regions was in place, a literature review of ancient vernacular architecture and extensive photo search for vernacular dwellings were conducted to better understand the constellation of vernacular building traditions and identify primary building characteristics to be explored. Fifty-nine types of representative ancient vernacular dwellings were identified and selected with at least two cases in each climate zone. The following paragraphs brief the architectural characteristics and trends in the cases observed.

3.1. Envelope construction

Constructions used for building envelopes can be generally divided into two categories: massive and lightweight. It should be noted that many vernacular dwellings observed combine massive walls with lightweight roofs, most frequently thatch roofs. As the
climate becomes hotter and more humid, lightweight building envelopes and construction materials become more prevalent (Fig. 3).

3.1.1. Massive constructions

Because of their ability to store and reradiate heat, and reduce infiltration by creating a tight envelope, massive structures were the most common vernacular dwellings observed in cold climates. However, massive dwellings were also found in desert climates with extreme diurnal temperature variations. Given the proper thickness, a massive envelope will reverse the temperature extreme of the desert climate inside a dwelling, transferring heat absorbed externally during the day into the structure at night, and then doing the opposite during the night. Massive dwellings in desert climates will also often have loose infiltration to take advantage of dry winds.

Examples of massive wall constructions include rubble and earth, wood covered with packed earth, rammed earth, adobe bricks, large wood timbers, and large stone with earth or mortar as the binding agent. Dwellings observed with massive walls often included massive roofs which were built using traditional engineering solutions passed on from generation to generation such as stone arches and corbelled domes. However, thatch roofs were also seen in many massive vernacular dwellings. Corbelling is the practice of laying down stone or wood in concentric circles in the shape of a dome. Unlike the arch, it is found in virtually every indigenous culture. Another common massive construction technology observed in Asia, Africa and North America is the use of adobe bricks. Adobe bricks are made in forms with a mixture of soil containing clay, sand, gravel, water and will frequently include straw. Adobe brick making is a non-trivial skill passed from generation to generation of craftspeople, and as such, its presence in the three aforementioned continents suggests an anthropological connection between cultures, but could also be an example of parallel evolution of a technology.

Turf houses are dwellings that are covered with soil on which plants are allowed to grow, most frequently grass (turf). Pit houses are all or partially below ground and frequently are also covered by turf. Turf houses were seen most commonly as dwellings in northern latitudes while pit houses were seen on every continent other than Australia. Turf and pit houses should also be included in the massive construction category, but it is important to note that they may not experience the same diurnal temperature effects unless a portion of their envelopes thin enough to feel the effects of the sun and night sky.

3.1.2. Lightweight constructions

At the other extreme are non-massive, lightweight structures made with thatch, wood, bark or bamboo. Lightweight structures were frequently observed in temperate and hot climates. They are commonly combined with loose infiltration to facilitate natural ventilation. Portable structures used by nomadic people such as tents, lean-tos, tepees and yurts also fall into this category. The use of thatch appears to be especially prevalent; it was found on every continent other than Australia (probably because of the nomadic nature of Aboriginal Australians). Thatch is dried grass or reeds that are bound together and layered on top of a wooden or bamboo frame. The most common application of thatch in recent European traditions is for roofs, but many cultures, including prehistoric Britons, used thatch for the entire structure. Analogous to hair or fur, thatch is an excellent insulator that easily covers virtually any shape: it is appropriate for climates ranging from cold to hot, and humid to dry.

3.2. Roof material

Roof materials in vernacular dwellings included stone (slate), tile, thatch, bark, skin, felt, wood or turf (Fig. 4). Further supporting its value in vernacular building traditions, thatch showed up the most frequently, but not in tundra and sub-arctic regions where vernacular roofs are most commonly made from large wood timbers covered with turf. Considering thatch’s excellent insulating qualities, one would question why it is not seen in extremely cold climates. One clue may be a similar roof tradition seen among the Navajo of New Mexico. Navajo hogans support a large mass of dry, packed earth placed on top of massive timbers. What both the tundra and the desert have in common is the inability to support the growth of tall grasses or reeds. As such, no thatch is available in either of these locations. However, it is important to note that turf, although not as thick and rarely as dry as thatch, must provide some insulating benefit. Tile roofs are a common site in vernacular architecture, but have very poor insulating quality. Thus, tile roofs are combined with thick wood, masonry or earthen layers except in cases of mild environments like the Mediterranean where terracotta tiles were developed by the Romans in conjunction with mortar.

3.3. Ceiling structure

Like today, two types of ceilings are indicative to vernacular dwellings: vaulted and flat. Vaulted ceilings were observed more frequently than flat ceilings. Flat ceilings were seen to be predominant in multi-story dwellings most likely because of the expense required to build vaulted ceilings on each floor. In hot and humid climates, vaulted ceilings appear to play an important role in cooling by allowing stratification of air through buoyancy—allowing hot air to gather above occupants and cool air to rest near the floor. However, there are many cases of vaulted ceilings in cold climates.
climates, as well. It is not clear why this is the case, but since all vernacular dwellings observed had open fire pits, one could postulate that vaulted ceilings allowed for the stratification of smoke.

3.4. Room structure

Most vernacular dwellings are single room structures. In cold climates, a single fire pit was used for warmth; therefore a single, large, central room was a logical preference. In warmer climates, where fire was not required to warm the dwelling, single rooms facilitate the construction of tall vaulted ceilings to allow for air stratification. Of course, cultural traditions influencing family structure are also factors. For instance, on the Indonesian island of Bali, boys and girls have separate single room structures within a walled area called a karang while on the island of Sumatra, also in Indonesia and in the same climate zone, entire families live in the single, lofted chambers of Batak houses.

3.5. Building shape

Rectangular shapes were slightly more prevalent than round floor plans in the samples of single family dwellings observed and aspect ratios varied between 1 and approximately 1.5. However, it should be noted that many vernacular traditions respond to large extended families or multiple families living together. Examples are Native American Longhouses once seen in the Northeastern part of North America, the Viking Turf Houses built in Newfoundland and Scandinavia, and the Taos Pueblo. One may postulate that in cold climates, there would be more instances of rectangular houses with east-west axes oriented take advantage of solar gain. Possible evidence of this observed in Nepal, but for the most part, this was not found with vernacular houses. This is probably because vernacular dwellings have no glazing and, in northern latitudes, fire was the primary source of heat—and more effective with square floor plans.

3.6. Building story

Since heat rises, one would expect to encounter multi-story structures in all cold climates. This may be the case for houses built over the course the last few centuries, but it is not the case for earlier vernacular architecture. It appears that multi-story structures were primarily built for defensive purposes such as the Taos Pueblo in New Mexico, or the Berber castles of Morocco, or perhaps because of the scarcity of land. Traditional multi-level structures were observed in all mountainous locations—places where buildable land is a premium.

3.7. Window

Large windows are uncommon in vernacular architecture because glazing was not available en masse until the 19th century. The majority of vernacular dwellings have no windows whatsoever. Instead, in most traditional houses (which as previously mentioned are single rooms), doorways act as fenestration bringing in light and air. However, small windows are more common in massive, multi-room dwellings in arid climates and larger windows were observed in the temperate climate near the Mediterranean Sea. In both cases, glazing was supplanted by shutters, which act to decrease infiltration and solar gain. Another vernacular alternative to glazing are window “grills”. An example of a Rajasthan window grill was provided in the section describing infiltration. Another type of window grill is the mashrabiyya found in Egypt. Made from carved wooden pegs, mashrabiyya bring in light and air, but prevent direct solar gain and visual access to the building interiors during the day. In Japan translucent shoji screens are combined with heavy wooden panels called amando, which are opened in good weather to bring in light.

3.8. Infiltration

Air exchange and natural ventilation are key elements used to control the temperature of vernacular homes. As such, in cold climates where tight infiltration is important for keeping heat within the dwelling, virtually no wall penetrations were found, save for a hole in the roof to allow smoke to escape and for light to enter during the day if weather conditions allow it. On the opposite extreme, in hot climates very loose infiltration allows for natural ventilation. Good examples are the Zoroastrian “wind catcher” dwellings of ancient Persia in present day Iran along with the intricately carved window screens of Rajasthan, India—both desert locations with reliable winds.

In the jungles of Indonesia, where wind is infrequent and humidity is high, natural ventilation is achieved through buoyancy bringing cool air up from shaded areas of earth under the dwellings. The traditional Toraja houses on the island of Sulawesi illustrate this technique. Raised above the ground, very large eaves extend outward creating a large area of shaded ground all day. A thick roof made from layer upon layer of bamboo provides excellent insulation used to trap cool air in the single chamber of the house and allowing it to stratify. The close proximity of the houses to each other also enhances shading.

3.9. Relationship to ground

Fully or partially subterranean dwellings were observed most frequently in cold climates, occasionally in very hot dry environments and never in humid climates with the exception of the earth lodges of the Plains Indians in the North American Midwest where the climate is categorized as Humid Mid Latitude. However, there are clearly hot and cold weather extremes in the Midwest. As such, the observations suggest that some vernacular traditions leverage the steady temperature of the earth as a method to reduce temperature fluctuations of the dwelling. Underground chambers that were not used as living quarters, such as today’s basements, did not appear in any of the vernacular samples observed, suggesting that basements are a relatively recent invention. Indeed, the efficient use of space consistently observed in vernacular dwellings is contrary to the concept of rooms like basements that are infrequently used by occupants or used to store building systems not available to vernacular builders. In temperate and tropical environments, all vernacular dwellings were observed to be above ground with many of those in humid climates elevated above the ground. As mentioned in the section on infiltration,
elevation above the ground allows for ventilation through the floor for cooling.

3.10. Shading

The overhangs present in the set of vernacular dwellings considered look like they serve several purposes, but because of the scarcity of glazing in windows, few eaves shade interior spaces. Instead, eaves appeared to be used for shading walls, the ground around dwellings, for protecting walls from water. It is also important to note that many vernacular dwellings observed had no overhangs because they were shaped like a cone or dome, and as such, the roof and walls were a continuous surface.

Eaves were seen frequently in hot climates on dwellings with non-massive walls suggesting they are used for cooling the structure. For climates with high diurnal temperature ranges, like Morocco and Tunisia where massive walls are common, eaves were never seen. In cold climates, overhangs appear to only serve the purpose of protecting the structure from rain or snow. Around the Mediterranean and other places where courtyards are common, overhangs play an important role in cooling porches and balconies, but shutters appear to do the work of shading windows. In Switzerland, large wooden chalets have substantial eaves that clearly prevent snow from massing around the structure. In Nepal, roof overhangs are only seen on rammed-earth and adobe brick buildings whose walls would disintegrate with a preponderance of direct rain.

In addition to eaves, the position of homes relative to each other plays an important role in controlling shading. In areas where solar gain can be utilized through massive walls, vernacular structures were observed with minimal shading on any side that was not connected or within a few feet of another building or hillside. There were no cases where all building sides were shaded in cold regions. On the opposite end of the temperature scale, courtyards and narrow streets were observed to be more prevalent in vernacular dwellings of hot climates. Courtyards are particularly effective in climates with extreme diurnal temperature. They act like cups holding air cooled at night for use during the day. It should also be noted that courtyards also provide outdoor areas that are well protected from distractions or dangers outside the home.

4. Energy performance of ancient vernacular architecture

After summarizing and categorizing the primary characteristics of ancient vernacular architecture, this study further analyzed the energy implications of these features to overall building energy consumption. The research employed a state-of-the-art building energy simulation and optimization tool – BEopt – developed by the U.S. National Renewable Energy Laboratory [7] to model test subjects in two selected vernacular regions for each of the eleven climates zones. The energy performances of the buildings with observed vernacular building features were compared against those built according to the International Energy Conservation Code and those generated by the optimization tool. A representative location within each vernacular zone was chosen from the list of weather files on the U.S. Department of Energy web site and the IECC requirements were specified according to the ASHRAE climate zone classification for the location. These locations include: Ulaangom, Mongolia (CS–AL–AS); Kiruna, Sweden (CS–IE–EU); Kharga (Oasis), Egypt (D–AA–AF); Las Vegas, NV, USA (D–AM–NA/D–DC–NA); Eagle, CO, USA (HA–DC–NA); Cimone Mountain, Italy (HA–IE–EU); St. Louis, MO, USA (HML–AM–NA); Kwangju, Korea (HML–KJA–AS); Tallahassee, FL, USA (HS–AM–NA); Osaka, Japan (HS–KJA–AS); Oakland, CA, USA (M–AM–NA); Granada, Spain (M–IE–EU); Casablanca, Morocco (SD–AA–AF); Jaipur, India (SD–IE–AS); Resolute, NU, Canada (TIC–EA–NA); Reykjavik, Iceland (TIC–IE–EU); Havana, Cuba (TS–AM–NA); Madras, India (TS–DR–AS); Wellington, New Zealand (WCM–AUC–AU); Dublin, Ireland (WCM–IE–EU); Kuala Lumpur, Malaysia (WE–AUC–OC); Bangalore, India (WE–IE–AS).

4.1. Reference cases

A 1200 ft² dwelling model with a flat roof and a basement (Fig. 5) was established with basic attributes shown in Table 2. The model was one story with the exception of those representing multi-unit vernacular dwellings seen in the hill towns around the Mediterranean, hill towns of the European Alps, Native American Pueblos of the American Southwest and desert dwellings of North Africa, which were modeled as 1200 ft² two-story dwellings. The wall to ceiling height was set at 9 ft, a size that seemed reasonable compared to the typical home wall height. Although glazed windows were never seen in ancient vernacular architecture, it was included in the energy models because glazing is a requirement for modern people. The window-wall-ratio was held constant at 16% evenly distributed on all sides of the house model for both the IECC reference case and the optimal case. As a conservative compromise, infiltration was set as the standard “Tighter” option in the program with a fractional leakage area (FLA) of 0.00015 for the reference case. Basements are not commonly seen in vernacular constructions and are not prescribed by the IECC. Nonetheless, a 4 ft basement was included in the reference case and added as an option for optimization along with an uninsulated slab on grade, and uninsulated basement. The rationale behind adding a basement was simply to address the...
question of whether or not a basement helps or hurts energy use in different locations. The IECC prescriptions were followed when specifying the building envelope characteristics for the model for each climate zone.

4.2. Vernacular cases

For vernacular cases, the same building model was used but building envelope characteristics were specified according to the observations of sample dwellings in specific vernacular regions. Window area and infiltration option were also varied consistently with samples observed in the research.

4.3. Optimal cases

A series of vernacular constructions for walls and roofs observed in the research were loaded into the optimization tool as alternatives to be used by the automatic optimization process. Other alternatives optimized were the proximity of neighbors, infiltration, basements vs. slabs, and eaves. Each option used is listed in Table 3. The thermal properties of vernacular materials were identified according to the ASHRAE Handbook of Fundamentals and few research articles (e.g., [8]). Lightweight constructions and loose infiltration options were not considered in cold climate locations for obvious reasons. There were also a few instances where the program was not allowed to use materials not available in a given region for the optimization, such as, thatch not being an option for the Continental Subarctic region.

The optimization tool uses a sequential search technique [9] to test various combinations of alternative building characteristics to reach the maximum energy saving. To compare energy performance for different areas, the simulation set the capital, installation and maintenance costs to zero and energy costs were left as $0.08/kWh and $0.80/therm for all locations. This indeed leads to the comparison and optimization of pure operating cost. Thus, the simulation results are more meaningful in terms of relative significance rather than absolute values.

4.4. Simulation results

Figs. 6–8 present the simulated heating, cooling and total energy performance of the vernacular and the optimal cases compared with the IECC reference cases. As shown, the optimization tool was able to find a combination of vernacular constructions that exceed the IECC reference case every time. The IECC cases show the overall better performance than the vernacular cases, which indicates that the codes provide valuable instructions for designing an energy-efficient house. In fact, the codes were also

<table>
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<th>10’</th>
<th>20’</th>
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<tr>
<td>Walls</td>
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<td>Earth and wood 18’</td>
<td>Earth and wood 24’</td>
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<tr>
<td>Basement</td>
<td>No basement</td>
<td>Uninsulated basement</td>
<td>4 ft R10 Exterior</td>
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<td>None</td>
<td>1’</td>
<td>2’</td>
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<td>Roof (ceiling)</td>
<td>Earth and wood 12’</td>
<td>Earth and wood 18’</td>
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</tr>
<tr>
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<tr>
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<td>No slab</td>
<td>Uninsulated</td>
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</tbody>
</table>

Table 3

Vernacular attributes used in automatic optimization process.
established on the basis of many previous practices and scientific researches.

It should be noted that quite a few vernacular constructions appear to beat the IECC reference case. Result analysis shows there are 38% of vernacular instances with less cooling loads than the IECC cases, 29% of vernacular instances with less heating loads than the IECC cases, and 19% of vernacular instances with less total energy than the IECC cases. In addition, there are 19% of vernacular cases with slight more cooling loads (<10%) than the IECC cases and 24% of vernacular cases with slight more heating loads (<10%) than the IECC cases. One example of such successful vernacular case is for a dwelling in North Africa. In this case, both an all thatch
structure and all earth and wood structure exceed the reference case by 10% while a dwelling with earthen walls and a thatch roof provides the highest energy savings. These three types of constructions are all widely seen in North African vernacular traditions.

In nearly all scenarios, the optimization tool selected a thick packed earth or wood and earth wall, a thick thatch roof, and a basement. Even though earthen walls have a lower overall insulation value than other vernacular constructions they were selected because of the thermal storage capacity—further demonstrating the value of mass in improving energy performance in all climates. Fig. 9 presents the comparison of the optimal and observed vernacular walls. Obviously, the observed vernacular walls have more diversity in types than the optimal ones, which is understandable because the simulation only considers the energy performance of walls. In reality, the availability and cost of local materials may play a much more important role in material selection.

5. Conclusions

This research performed an extensive analysis and computer energy modeling for a number of representative vernacular architectural techniques and features summarized for different climatic regions. The study presents an integrated approach to categorizing distinct vernacular regions in a manageable scale. The simulation results of computer energy models suggest that building codes (i.e., IECC) can provide valuable instructions for designing an energy-efficient house. These codes, in fact, are developed on the basis of many previous practices and scientific researches. In the meantime, considering special building traditions seen in ancient vernacular architecture as an approach to improving building energy performance is a worthwhile endeavor. For instance, the simulation indicates that using vernacular materials, such as, earth walls and thatch roofs, will improve the performance of buildings. The energy-saving value of integrating vernacular building attributes into contemporary construction practices will be much broadly manifested when other building criteria (e.g., cost effectiveness and safety) can be evaluated simultaneously.

The computer optimization tool appeals promising in find a combination of vernacular constructions that exceed both the IECC reference case and the observed vernacular case, revealing the potential rooms for improvement on building codes and vernacular architectures. However, the computer optimization only considers the energy performance of building without considering the availability and cost of local materials as well as culture contexts of building characteristics.

This project is the first part of a much larger project that intends to create a knowledge base of vernacular building traditions that will include information about not only the energy performance of traditional building techniques, but also address areas of cost, material availability and cultural traditions. Cost of labor as well as the cost and availability of local building materials vary widely and dynamically across the globe but are critical for assessing feasibility of integrating vernacular techniques into contemporary buildings. In addition, differences in human behaviors in diverse vernacular regions and dwellings should be considered in analyzing the energy implications of vernacular building technologies. The same occurred to the region-related specific building codes such as building safety requirements (e.g., for earthquake reinforcement and fire retardation).

In a world that is seeing the rapid dissemination of mass-produced homes and buildings designed by teams of architects and engineers sometimes thousands of miles away from the building site, there is a threat that vernacular traditions that help define the cultural make-up of a people and a place will be lost. The challenge to preserve these valuable techniques and cultures will be to package this knowledge in such a way that vernacular traditions become widely known to modern designers and builders.

References