Straw Bale Construction and Building Codes

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With today's emphasis on sustainable building construction, straw bale construction methods have received renewed attention in the United States. With any new or unusual building product or method, building codes play an important role in their acceptance. This paper looks at straw bale construction and how building codes have affected its implementation. The lessons learned with this specific construction method can be extended to other types of non-conventional construction. Several specific issues concerning straw bale construction are addressed as this construction technique is attractive in developing countries where affordable housing using local raw materials is essential. In these areas, where building codes do not exist, experimentation with new techniques is often easier and product or method development can occur much faster.

Key Words: Straw Bale Construction, Sustainable Construction Methods, Building Codes

Introduction

When it comes to housing, most Americans desire a home that is both attractive and comfortable without relinquishing the functional and durable requirements. At the same time, many are finding that quality housing is becoming less and less affordable, which can be directly attributed to dwindling resources and greater regulations on conventional building techniques. In addition to becoming more regulated, the world is becoming more attentive to liability issues when it comes to building. Because of this, introducing new materials or reviving traditional methods of construction is becoming more and more difficult (Benge, 1998). In order to counteract the increasing cost of construction, performance-based building codes are necessary to accommodate alternative building methods. Performance –based building codes can allow for less expensive buildings while still satisfying regulatory officials.

Discussion

One alternative building practice being considered today is using straw bales as a building material. This unique construction technique has not only a proven track record of producing resource-efficient and energy-conserving homes, but doing so without sacrificing quality and affordability (U.S. Department of Energy, 1995). Initiated in the U.S. in the mid 19th century, straw bale construction is a practical building technique but has been historically underutilized. About 10 years ago, the idea of using straw bales to construct cost effective wall structures began gaining in popularity, but at the same time, brought with it a plethora of jokes and reservations. There appears to be a trend today of an increased approval for and use of this building technique by the building sector (U.S. Department of Energy, 1995).

Historical accounts conclude that there are two core elements that accompany straw bale construction and helped give rise to the recent movement: 1) intentional recycling of waste and/or the available natural materials and 2) reduced energy use. Straw bale advocates, builders and 'green' conservationists alike have been encouraged by the aforementioned principles, but are still frustrated by the regulated building codes, or lack thereof (Henderson, 2007).

Even with all the benefits of using straw bales as a building material, there are many individuals who maintain uninformed, preconceived ideas about the technique. As a result, this paper will focus primarily on the inhibitor to the success of straw bale construction, namely official building codes, in addition to the other concerns raised by those opposed to the practice. In addition to building codes, the main concerns can be summarized in the form of the following statements:

- Straw bale buildings are not **Fire Resistant**.
- Buildings made of straw will have **Moisture and Rot Problems**.
- Straw bale construction can easily be compromised by **Mice and Other Pests**.
- Buildings made of straw can't be **Structurally Stable**.
- Straw bale construction is not **Cost Effective**.

Building Codes

Taking everything into account, the transcending barrier to success and standardization of this building practice are building codes. There are basically two types of straw bale construction: 1) Nebraska-Style, which is load bearing and 2) Post-and-Beam. Still standing in good repair, the first post-and-beam house was constructed in 1938 (Henderson, 2007) and Nebraska-style construction has been used since the early 1800's. These early recorded straw bale homes were built in areas outside main cities and towns or simply – 'off the grid' (Henderson, 2007). Because of this fact, building codes did not apply and city amenities like sewerage and water lines were non-existent. Contrary to its counterpart, timber-based construction has been historically regulated with codes, which allowed straw bale builders freedom to experiment with innovative building practices, but never fostered an environment for standardization.

Once again, there has been a recent trend to legitimize straw bale construction. In order to accomplish this, building codes are not only necessary, but mandatory. Permission, for the most part, has been granted to homeowners and advocates over the years, but a uniquely tested and validated building code is still desired. Three significant reasons for this desire include the following:

- Besides basic building permits, insurance and bank loans are tied to and based on building code requirements.
- Credibility would be granted to the technique in all building sectors if building codes could finally be standardized.
- Both activists and conservationists desire to not only ensure the success of the technique, but alleviate the many arguments against the practice, which furthermore improve upon its reputation.

As is the case for any unusual building technique, there is a required evaluation period by the local code enforcement before any permit will be issued. The current practice is approached by reviewing another code agency's actual approval of the technique or a position on experimental permits. If incapable of finding any other agency's approval of the technique, test data will more than likely be required. Most data on this topic can be found relatively easily, but the tests must have been completed by a reputable independent laboratory (Straw Bale Registry, 2008).

Ideally, the use of standardized International Congress of Building Officials (ICBO) testing would validate the straw bale specifications, in addition to the practice as a whole. The difficulty lies in fitting an ill-structured design/build technique into a normative framework where safety issues can be properly established (Henderson, 2006). Kathryn Henderson further expounds on the ICBO testing when she stated, "The cost is paid by the developing industry…where farmers aren't in position nor have any desire to conduct such tests". As a result, there has been a severe lack of funding for the required testing, directly resulting from a lack of advocacy groups pushing the approval process with any significant clout in the industry. Establishing straw bale criterion, such as the standard for concrete masonry units, or CMU's, continues to plague the straw bale building code process.

As expected, there has been differing expectations for the experimental permits granted to states and there continues to be a great deal of misunderstanding between advocates and building code officials when collaboration is required for writing standards. David Eisenberg, a respected engineer and a claimed "guru of straw bale building codes" has recognized that in order for alternative building techniques to succeed in establishing building code, the relationship between advocates and building officials is vital (Henderson, 2006). David further expounds on this argument by stating the following:

"Whatever attitude and expectations you take into the building department that's what you will find. If you go looking for a fight there will be one waiting for you. But if you go looking for help and in a cooperative mood with an expectation you will get help, the odds go way up you are more likely to have that kind of experience, depending on who you are. They can be whoever you expect them to be and it will be based on how they are treated in that relationship" (p. 262).

The success of Arizona and New Mexico in establishing written standards for building with straw bales was directly related to the local interactions between the differing parties. In other words, the collaborative nature of straw bale advocates and helpful building code culture in these states, laid the groundwork for future building permits and the foundation for an accepted building code. These interactions were dependent upon and supported by patient testing and meetings, which helped provide the necessary written and visual material and contributed to the education of the appropriate building officials (Henderson, 2006).

All this to say, the goal has been to establish a performance-based building code, which many advocates believed to have been easier to acquire compared to that of prescriptive-based code. Performance-based building codes are unique in that they have been used to help facilitate the standardization of alternative or diverse construction methods. While providing cheaper buildings, this type of building code has also been helpful in satisfying regulators, lawyers and conservationists alike (Benge, 1999).

Retired chief building official of Arizona, Leroy Sayre, has suggested that establishing purely performance-based codes may be impossible stating, "As long as they (advocates) can show the building technique will meet the fire safety and structural materials of the code, what difference does it make what the material is made of…it can be made of spaghetti for all I care" (Henderson, 2006). Mr. Sayre continued his argument stating that it is difficult to compose purely performance-based building codes for straw bale construction without the use of prescriptive requirements, grounded in rigorous testing. Building officials and advocates of this practice have been working on it for over fifty years, and to this day, have failed to produce anything exhaustive to the level of wood or steel frame construction.

The difficulty in this process is exemplified with the building codes currently in existence in Arizona and New Mexico. While Arizona code language leans prescriptive in nature and New Mexico performance, most experienced building professionals would suggest that both are actually mixes of both. The point here is that even though the codes in Arizona and New Mexico were intended to be purely prescriptive and performance-based, respectively, such purity is almost impossible to achieve with alternative building techniques (Henderson, 2007). At the same time, the cultural ramifications and the negotiated nature of the code establishing process, the mixed result of standards is to be expected.

To this day, Arizona, California, Colorado, Nebraska, New Mexico, Nevada, Oregon, and Texas are the only states with local jurisdictions that have adopted straw bale building codes. Although, almost all the other states will allow permits to be purchased that are experimental in nature. Even with all the advancement, many county and city building offices will request additional information specific to safety and structure before issuing any permit at all. In these cases, there is independent testing data, in addition to engineer stamped house plans, that will increase the chances of obtaining a permit and therefore, provide a legitimate straw bale home (Morrison, 2008).

Concerns

At this time, it is necessary to address the other concerns that are often associated with straw bale construction. As mentioned previously, the concerns are the consequences of a lack of proven building codes. Upon further review, many of the concerns would be alleviated, if not completely dispelled altogether, if proper codes were established.

Fire Resistance

When the concept of building with straw is presented, it is often met with a concern about its resistance to fire. Contrary to popular belief, tightly and densely packed bales of straw are surprisingly fire resistant. There are many factors that attribute to this fact, but the most important to note is the relatively high levels of silica (3-14%) contained in a bale of straw (Straw Bale Registry, 2008). The Straw Bale Registry (2008) went on to describe how the silica will allow for outer layers to char when burned, but leaves a well insulated, inner core. ASTM E-119 fire testing in New Mexico provided supporting data to this argument when it found that a plastered, 18-inch straw bale wall survived fire penetration in excess of two hours. The same testing found that walls that had not been plastered survived approximately 34 minutes, which only strengthens the case for this building technique.

Additional Testing performed by the National Research Council of Canada determined that plastered straw bale walls performed better than conventional building materials. Upon further review, the plastered surface withstood over 1800 degrees Fahrenheit of heat for two hours before any cracks appeared (U.S. Department of Energy, 1995). Straw bales are compacted to such a degree that they lack enough air to permit combustion while holding just enough to provide an efficient insulation value. An example of this principle is that of attempting to burn a telephone directory. Loose pages will burn fairly easily, but the book as a whole won’t catch fire. Besides, even if straw bales weren’t resistant enough themselves, a half an inch or more of plaster on any type of wall structure or partition will satisfy any building regulation related to fire protection (Benge, 1999).

Moisture Problems and Rot

Another common argument against using bales of straw in construction is moisture problems and rot. Without proper and adequate safeguards in construction and design, straw can become saturated with water, which would be an ideal home for fungi and mites. Because of this fact, it is vitally important to not only purchase dry bales, but to keep them dry until they have been properly sealed within the wall with plaster (U.S. Department of Energy, 1995). In addition to keeping the bales dry, the foundation upon which the bales rest must be elevated at least six inches above the outside ground level. This proper precaution will help protect the bales from inevitable rain water from splashing off the roof.

According to *The Last Straw* (1994), few organisms are able to decompose straw, which is the leading reason why a vast majority is burned instead of attempting to turn it back into soil. It is true that high moisture levels in straw bales can provide an opportunity for fungi to invade the walls and lead to decomposition. The same can be said for many building products, especially if the moisture content is directly related to poor design and proper precautions during installation (Piepkorn, 2008). Several articles from *The Last Straw* (1994) have focused specifically on this issue of moisture problems. Three common practices were stressed to prevent moisture from gathering around the walls including: (1) constructing wide overhangs, (2) installing good capillary breaks between the foundation and the straw walls and (3) calculating the necessary slope of the ground protruding away from the house.

Mice and other pests

Once straw bale walls are plastered, any chance of entry for vermin and other rodents is eliminated. At the same time, within straw bale walls, there exist fewer havens for pests than conventional wood or stick framing (U.S. Department of Energy, 1995). Contrary to many people's beliefs, hay and straw are not interchangeable. While hay is leafy and easily eaten by many creatures, straw is fibrous and tough and it also lasts longer. On the other hand, straw is the empty stem of a baled grain crop, which means no food to attract any rodents. Any home, whether straw bale or otherwise, that has food left out or easily accessible will be an ideal attraction for vermin. Either way, mice or other furry creatures are not attracted to the straw, but the gaps and crevices often associated with bales of straw. As long as the straw walls have been properly sealed and plastered, a mouse will not be able to tell a difference between it and any other plastered wall (Steen, Steen, and Brainbridge, 1994).

Structural Stability

If fairy tales have taught us anything about civil engineering, it could be referred to as the *First Little Pig's Law of Construction*, which would state that under no circumstances should you build anything out of dried-out stalks of grain (Fahrenthold, 2007). As creative as this Law of Construction may be, many simply refer to this structural fear of straw bale construction as the *Big Bad Wolf Theory*. In other words, there still remains a great deal of reservation for this building technique, specifically pertaining to its structural stability. Opponents believe, or at least claim, that a storm with large gusts of wind will have no problem leaving a home owner with nothing more than a slab. These arguments are not only unfounded, but simply illogical in nature.

Though structural testing of straw bale walls have been limited, load-bearing and non-load bearing walls were tested at the University of Arizona and a certified testing laboratory in Albuquerque, NM, in 1993 (Straw Bale Registry, 2008). Compression, transverse lateral loading, and in-plane lateral loading were conducted on the load-bearing and non-load-bearing walls, at which time the examiners verified the structural integrity of each wall. As one might guess, straw bales do not have much structural resilience, but must be tied together at the top of walls in order to resist any significant lateral load. This can be accomplished with a timber (bond) beam, which is connected to rods extruding up from the top layer of bales. To ensure structural stability, a common practice has consisted of using the straw bales to serve as infill panels to a timber post and beam structure (Benge, 1999). Either way, structural stability, let alone longevity, should not be a concern considering the 200 year old straw bale houses scattered across the Sand Hills of Nebraska.

Cost Effectiveness

On average, straw bale construction tends to be a cost effective, alternative, building practice. For example, construction costs for low end houses (approx. 120-1000 sf.) range from $5-20/sf. At the same time, the high end houses (approx. 2500-4000 sf.) will usually cost around $80-120/sf. Costs will vary depending upon a myriad of variables including the size of the building, the cost of materials, the design of the house, and the amount of 'sweat-equity' contributed, to name a few (U.S. Department of Energy, 1995). The real point to be made here is that upon completion of the actual construction, straw bale homes run more efficiently, which results in less expensive energy costs. Due to the high insulation, energy savings have been recorded as high as 75% compared with conventional building techniques (Wilson, 2008).

When discussing the cost effective and efficient nature of straw bale construction, financing is important to mention. When it comes to obtaining financing with reputable mortgage companies, straw bale construction has been officially recognized by FNMA (FannieMae) as well as other secondary market buyers. Currently, there are a number of additional lending institutions and insurance companies in the Austin, TX city limits that have succeeded in their approvals of straw bale construction. As a result, there are numerous examples of straw bale building in their regulatory jurisdiction, which will aid any owner or advocate in pursuing test data to validate future claims (Straw Bale Registry, 2008).

Conclusions

The main hindrance facing straw bale construction can be summed up in two words: building codes. Though its history and background is found in grassroots, this building technique has found itself firmly entrenched in the 'green building' industry found all over the world today. If new and useful building techniques are to be used in effort towards energy efficiency and environmental responsibility, then the use of straw bales must be at or near the front of the line. Currently, straw bale construction is believed to be in a pivotal point in its development process. In terms of its cost-effectiveness, ease of installation, energy-efficiency, and sustainability, this building technique is not only ready to be accepted in the industry, it may be needed in the near future as difficult times approach. Natural building resources are becoming scarce and the world's population is rapidly increasing, so alternative building techniques must be necessary consequences of these truths.

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