

Eco-Architecture and Alternative Building

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The state of New Mexico and the Southwest offers a prime location for the building of alternative housing. The abundance of solar power and warm climatic conditions enable the use of a variety of indigenous building materials the standard wood frame construction, typical of most of the United States, diminishes in comparison to the benefits of Southwest architecture. The native people of the Southwest have used the earth as their primary building material for thousands of years.

A short drive around the state of New Mexico will show many examples of traditional adobe buildings and homes. The massive walls of these buildings are used as protection from the heat of summer and the cold of winter. When we look at the walls of these structures, we begin to explore the possibilities of varied building materials and specific advantages. Besides traditional adobe, these walls can be built using straw-bale or even recycled materials. Adobe construction has become almost a status symbol in New Mexico. The oldest and easiest way of building has a new look in the Southwest.

As we enter the new millenium, construction practices grow and change to support human need. As populations continue to grow, the environmental burden placed on housing needs creates a strong desire for alternative materials. In this paper I will explore three types of ecological construction. These are adobe building, straw-bale building and Earthships. For each type I will include the building process, building materials, and benefits. This information should be taught in an active learning environment for students and as an Eco-curriculum for students who will be future consumers of resources.

The student design studio will enable each individual to create his or her design and bring it into a three-dimensional reality. The studio layout will offer a new experience for students in the architectural and building fields. They will use light tables, projectors, trace boxes, and drafting equipment to create visual ideas for their portfolios. This portfolio will serve as an assessment tool and reference. After identification, sketching and design work, students will create scaled models of their work. An assortment of media, such as clay, chipboard, adobe and even found objects allow each student the experience of hands-on building and problem solving.

Section 1: ADOBE BUILDING

Adobe comes from the Arabic word *atobe*, which means sticky glob or muck. The architectural style of adobe migrated from North Africa to Spain to America. Adobe has been a main source of building material in the southwest and the world for many years, "earth is man's oldest building material" (1) There are numerous examples of this style of building all over the world. Some of the architectural styles in the Southwest include traditional pueblo and contemporary homes, (See Figures 1 and 2). The walls are made from mud dried in the form of bricks. Straw is sometimes added to strengthen the bricks, but it is not necessary. These brick may vary in size, from 4 x 4 x 8 inches to 4 x 12 x 18 inches. There are ready made bricks available in standard sizes and they are sometimes more economical, (See Figure 3). The insulation value of the adobe

will stabilize at about 12" thickness. After this thickness, the inside temperature will stabilize near the outside temperature (2). In the winter during the day, the adobe will retain the heat and dissipate that heat during the night. The opposite will happen in the summers. The heat will be kept out in the day and let in as the nights get cooler. This is natural insulation or the R-factor.

Adobe buildings will last for many years with minimal repairs necessary. It is not uncommon for mud plaster to last from 5 to 15 years without needing to be repaired. When repairs are needed, they are simple and cheap to make. Even in areas of substantial rainfall, vertical surfaces with rain up to 25 inches per year will only erode about 1 inch in 20 years (3). Cement stucco can be used instead of mud plaster with even longer periods before repairs are needed.

Adobe structures are not limited to residential housing. There are examples of warehouses, storage sheds, workshops and other common buildings. A typical 600-sq. ft., three room dwelling with 10 inch walls would require 3000 bricks, based on a 10 x 4 x 14 inch brick. Two people can make these bricks in 5 days. They will require no special equipment other than forms and a wheelbarrow. Another great feature of adobe is the little skill that is required (4).

The major benefits of using the adobe are thermal storage, low sound-transmission levels, and availability of material, manageability, fire protection and solidity. Many old and new adobe structures are visible in New Mexico and the Southwest. Construction practices are simple and basic and have not changed for thousands of years. The first step is to make the adobe bricks. Simple forms are used to size the mud. After the bricks have partially dried, the forms are removed and the bricks are stacked on edge to dry. The drying process takes a minimum of 6 days (5). The second step is to lay the bricks with mortar or mud. After the walls are completed, the exterior and interior surfaces are covered with stucco or plaster to produce a smooth finish.

Lesson Plan

Objective:

Students will be able to

Identify different examples of adobe structures

Discuss different construction practices and techniques for adobe building

Create sketches and drawings of adobe structures

Create 1/4" scale floor plan of adobe home

Construct adobe forms using Popsicle sticks and make scaled adobe bricks

Apply mud, plaster, or stucco finish to completed wall.

Activities:

A slide presentation will familiarize students with examples of old and new adobe buildings.

Students will sketch examples of the buildings for their portfolios from slides.

Students will also design a floor plan in one of the suggested styles.

Students will use Popsicle sticks to construct forms and make adobe bricks at 1/4" scale.

Students will use their bricks to create the exterior walls of their model floor plans.

Students will create a section of a portfolio for adobe structures that includes

Sketches

Articles and research material

Lecture notes

Pictures

Poster and Presentation Boards

Materials:

Slide projector and slides of old and new style adobe structures

Popsicle sticks

Glue

Mud and aggregate

Drafting equipment

Magazine articles and Internet research

Evaluation:

In class discussion with visual-verbal presentation of drawings and models

Verbal quizzes and discussion

Tests

Project design

Class and self-critique of the structure

Portfolio grade based on the following:

Fluency and clarity of communication

Imagination, innovation and creativity

Understanding process

Detail and overall aesthetics

Technical competence

Section 2: STRAW BALE BUILDING

Straw bale construction is not new although it may seem to be. It has been used for over 100 years, and it is recently making a comeback in the residential construction trade.

Before 1936 all known straw-bale structures in the United States used the walls to support the roof. This was known as the "Nebraska Style" (6). After 1936, strawbales were used as infill material. The bales are placed inside a roof support structure, such as post and beam, or concrete for their insulation values and not as support for the roof (7) .

Dr. William Henry Burritt built a two story mansion using straw bales in 1936, (See Figure 4). The first house, which used mostly wood for the structural support and the straw as in-fill material, burned the day Dr. Burritt moved in. He rebuilt his house this time mainly using concrete instead of wood for the structural parts. This house remains in good standing condition today.

Another straw bale process of building uses the bales by encasing them in mortar much like brick laying, (See Figure 5). There was a general store built in 1948 using this technique (8). Another technique for building non-load-bearing walls is to compress the bales. This is an example of typical construction practices of today, (See Figure 6 and 7).

Straw bale building slowed between the early 1950's and early 1980's, most likely due to the increased availability of mass-produced building materials. Straw bale building is not limited to dry areas. Straw bale homes have been built in Washington State, which receives 75" of rain annually. Until 1991 straw bale structures were given the lowest possible building permit and were generally not bank financed. In 1991, Virginia Carabelli of Tesuque, New Mexico built the first insured and bank financed straw bale home. In addition, around this time, Tony Perry organized the Straw Bale Construction Association, SBCA. The SBCA sponsored small-scale fire tests and transverse load tests to incorporate straw bale building practices into New Mexico building codes. A copy of New Mexico's straw-bale construction guidelines and codes located on the Internet at <http://www.earthbuilding.com/nm-straw-bale-code.html>.

Straw bale building uses building materials from a by-product of wheat and rice grain production. The straw can be grown in a short period in contrast to lumber, which takes years to produce usable material. Therefore, it is a fast, sustainable building material. This type of building does not require expensive tools or specialized laborers. Building with straw bales is less labor intensive than concrete block, adobe or stone. The straw is very forgiving and lends itself to the creativity of the builder.

A clear advantage of straw-bale construction is insulation. A straw bale has a better insulation value or R-Value, than the most modern well insulated homes.

Product	R-Value/per inch

Wood	1
Brick	.2
Fiberglass batt.	3.0
Straw with the grain	2.4
Straw against the grain	3.0

A 3-string bale stacked flat, which is 23" wide, has an R-Value of 54.7. If that bale were stacked on edge, 16" wide, the R-Value would be 49.5. These values are 2 to 3 times greater than an well-insulated modern framed house (9).

Each year grain farmers battle with the remains of their harvest, straw. Straw does not decompose very rapidly and becomes a burden for the farmers. The burning of straw in California produced more Carbon Monoxide or CO than all the electrical power generating plants in the state combined produced. There is 1 million tons of rice straw burned, which produces 56,000 tons of CO. Burning 97,000 tons of wheat straw produces 5,000 tons of CO. The straw does not decompose very rapidly and becomes a burden for the farmers. It is estimated that if all the straw left after harvest was baled instead of burned, 5 million 2,000-sq. ft. homes could be built every year. This would help the farmers and help the homeless while reducing the amount of CO in the air (10).

The affordability of straw bale homes is cheaper or at most comparable to modern building practices. If the owner becomes the builder, the structure can cost between \$5 to \$20 per sq. ft.; \$20 to \$50 if the owner sub contracts part of the work out. Expect to pay \$50 to \$80 for a contractor to build the entire house. Today a typical two by four framed house will cost \$75 to \$100 per sq. ft. Another benefit of straw bale is fire safety.

In the mid 1980's the National Research Council of Canada carried out fire rating tests on plastered straw bales and found them more resistant than conventional building materials. A mortar encased bale passed the test with a maximum temperature rise of only 110 degrees F. for 4 hours. The plaster coating withstood 1850 degrees F. for 2 hours before a small crack appeared. In 1993, the state of New Mexico found similar results in their tests. The first test on an unplastered wall section met the standard requirements by exposing the face panel to 1000 degrees F. within 5 minutes and increasing the temperature to 1500 degrees after 30 minutes. The temperature rise on the unheated side was 1.97 degrees F. It took 30 minutes to burn through the center of the test wall, not the middle of the exposed bale. It burned through at a joint where 2 bales met; the rest of the bale was only charred half way through. The second test was exposing 1942 degrees F. to a plastered wall section. The temperature rise on the unheated side was only 10 degrees F. Neither flames nor gases penetrated the wall (11). Straw-bale construction has recently made a great comeback in the residential sector. All the research and testing is really stacking up to support straw-bale construction. Self-sustaining building practices are becoming more of a necessity.

Lesson Plan

Objective:

Students will be able to:

Comprehend terminology

Identify the processes needed to construct a straw bale home.

Evaluate the benefits of straw bale built structures.

Create a floor plan and section view of a straw bale structure.

Incorporate New Mexico Standard Straw-bale Codes into their house designs.

Complete a model replica of straw bale construction.

Activities:

The students will build wall sections using clay or another medium to signify the straw bales and tooth picks to represent the rebar.

They will finish the walls with a mud plaster finish.

Students will design a straw-bale structure using straw-bale-building codes.

Students will create a section of a portfolio for straw-bale construction that includes
Sketches

Articles and research Material

Lecture notes

Pictures

Poster and Presentation Boards

Materials:

Slide projector

Articles and Internet information and sources.

Guest speakers from straw bale construction companies and SBCA, if available.

Straw-bale model medium such as marshmallows or clay

Toothpicks to represent the rebar

Mud and aggregate

Evaluation:

In class discussion with visual-verbal presentation of drawings and models

Verbal quizzes

Project design

Class and self-critique of structures

Test taking

Identification of materials and practices

Wall building project evaluation

Portfolio grade based on the following:

Fluency and clarity of communication

Imagination, innovation and creativity

Understanding process

Detail and overall aesthetics

Technical competence

Section 3: EARTHSHIP BUILDING

The Earthship was the creation of Michael Reynolds. Reynolds has been revising his designs of the Earthship for over 20 years, but the core remains the same. Earthships are designed to be completely self-sustained living environments. Builders use recycled materials such as tires, bottles and cans for their walls. The structures are heated and cooled using passive solar design. The homes are designed to operate as a unit. From the catching of the rainwater on the roof, to the recycling of the wastewater through a garden filtration system, to the photovoltaic panels catching the sun, the Earthship is an entity within itself.

The building process is rather simple and does not require any complicated machinery or skills. The supporting walls are built using recycled tires. These tires are filled with dirt, packed and tied together, much like straw bale homes, using rebar (See Figure 8).

After the main exterior walls are constructed, interior walls are built with cans and bottles. Each wall is plastered to help in the insulation and protection of the wall.

The materials needed to construct Earthships can easily be collected, which helps to reduce the amount of materials in the landfills. There are over 194 million vehicles on the road in America. Used tires are very cheap if not absolutely free (12).

The first process is to build the load bearing walls, that will support the roof system. The walls are built using recycled 15" or larger tires. They are set in place and filled with dirt, is then compacted either by a jackhammer or with a home made tamper. Once the first layer is in place, the second layer is staggered over the first layer and tied together with rebar (See Figure 9). The walls are built in a U-shape; this is the basis of Reynolds design. After the exterior walls are built, the interior walls can be built. Most of the interior walls are constructed using cans and

bottles. These walls are partition walls and will not have any weight on them. This process is similar to the exterior walls, but instead of using dirt and rebar, they are held together using cement. After all the walls are complete, they are covered using adobe or stucco. The entire South wall is reserved for the windows and solar panels. The windows allow light into the structure. The light and heat are stored in the flagstone flooring and the massive walls.

The Earthships rely on the sun for power, which is referred to as going "off grid." These homes also rely on catch water and cisterns for their water collection and storage. The roof is used to collect the water, which is then stored inside the house in a large cistern for later use. The entire south wall is used to grow food and recycle water. The greywater is recycled through the garden system and comes out 99.5% pure. The sun is used for heat and power.

The entire house and systems are self reliant and independent. The owner/builder can collect recycled materials and build their home for a cost of anywhere from \$5 to \$100 per sq. ft. Personal involvement can greatly reduce the cost of building- as the owner becomes also the laborer.

Lesson Plan

Objective:

Students will be able to

Identify and understand components of the Earthship concept:

- Wall Building

- Power, Water

- Heating

Understand the building processes of Earthships

Understand environmental conditions needed for constructing an Earthship.

Create 1/4" scale floor plan

Construct a wall section using recycled materials

Activities:

Slide presentations

Discussion and research of information

They will design all aspects of the house:

- Floor plan

- Electrical system

- Rains catch system

- Filtration system (greywater)

Students will create a section of a portfolio for Earthship construction that includes:

- Sketches
- Articles and research Material
- Lecture notes
- Pictures
- Poster and Presentation Boards

Materials:

- Internet for research material
- Recycled cans
- Mortar, mud and plaster
- Drafting equipment
- Earthship Volume I, II, III.

Evaluation:

- In class discussion with visual-verbal presentation of drawings and models
- Verbal quizzes
- Project design
- Class and self-Critique of structures
- Test taking
- Identification of materials and practices
- Wall building project evaluation

Portfolio grade based on the following:

- Fluency and clarity of communication
- Imagination, innovation and creativity
- Understanding process
- Detail and overall aesthetics
- Technical competence

Section 4: TYPICAL DESIGN STUDIO SETTING

The design studio is the best approach for students to experiment with hands-on learning. The studio layout (See Figure 10) allows students to engage in many activities at their own pace. Not all students will be working at the same stations at the same time. This gives the students more responsibility and invites their creativity into the learning process.

The design studio is organized to incorporate many processes into the same space. Students will be exposed to manual drafting, CADD drafting, light table tracing, projector tracing, slide tracing and model building. Some students will finish a task earlier than other students and can move on to the next station. A design studio learning environment is excellent for students to learn other skills, such as independent work, team work, applied learning, and problem solving.

Students will begin by sketching and tracing images at the light table, tracing boxes, and projector stations. Next, they will use the manual and CADD drafting stations to finalize their ideas by incorporating measuring and dimension skills. After the design process is complete, students will build a model of their design. This can be done in clay, adobe, chipboard, or found

objects. These processes guides the students through the steps needed to complete an actual project. They will have a better understanding of the actual building processes, as well as, great senses of accomplishment in seeing their design go from thoughts to designs to models.

Notes and Bibliography

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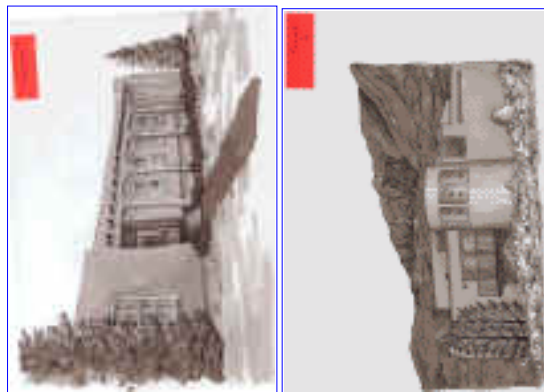


Figure 1 Figure 2

Figure 3

Type of adobe	Dimensions (in)	Weight (lb)
Egyptian brick	3 x 5 x 10	8

Veneer brick	4 x 4 x 16	26
half adobe	4 x 4 x 8	23
Burnt adobe (Las Palomas, Mexico)	8 x 3.5 x 16	30
New Mexico standard adobe	4 x 10 x 14	30
Adobe (old style)	4 x 5.5 x 16	28
Adobe (old style)	4 x 12 x 18	50
Mexico (standard Las Palomas adobe)	3.5 x 10 x 16	35
Taos standard adobe	4 x 8 x 12	26
Hydra Brikcrete pressed adobe	3.625 x 10 x 14	30
Porta Press pressed adobe	3 x 10 x 14	35
Terron (Isleta Pueblo)	7 x 7 x 14	35
Dome brick (mosque)	2 x 10 x 6	8
CINVA-Ram pressed adobe	3.75 x 5.5 x 11.5	20

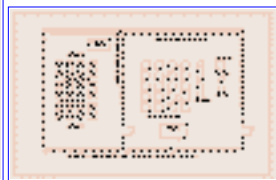


Figure 4
Figure 9

Figure 5
Figure 10

Figure 6

Figure 7

Figure 8