Designation: E2392 – 05

Standard Guide for Design of Earthen Wall Building Systems[1]

This standard is issued under the fixed designation E2392; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This standard provides guidance for earthen building systems that address both technical requirements and considerations for sustainable development. Earthen building systems include adobe, rammed earth, cob, cast earth and other earth technologies used as structural and non-structural wall systems.

1.1.1 There are many decisions in the design and construction of a building that can contribute to the maintenance of ecosystem components and functions for future generations, that is, sustainability. One such decision is the selection of products for use in the building. This standard addresses sustainability issues related to the use of earthen wall building systems.

1.1.2 The considerations for sustainable development relative to earthen wall building systems are categorized as follows: materials (product feedstock); manufacturing process; operational performance (product installed); and indoor environmental quality (IEQ).

1.1.3 The technical requirements for earthen building systems are categorized as follows: design criteria, structural and non-structural systems, and structural and non-structural components.

1.2 This standard does not provide guidance for structural support of roofs made of earthen material.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C66/C66M Specification for Specification for Sand for Use in Lime Plaster[3]

D559 Test Methods for Wetting and Drying Compacted Soil-Cement Mixtures

D560 Test Methods for Freezing and Thawing Compacted Soil-Cement Mixtures

D698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft^3(600 kN-m/m^3))

D5860 Test Method for Evaluation of the Effect of Water Repellent Treatments on Freeze-Thaw Resistance of Hydraulic Cement Mortar Specimens

E631 Terminology of Building Constructions

E2114 Terminology for Sustainability Relative to the Performance of Buildings

2.2 *ASCE Standards:*[4]

ANSI/ASCE 7 Minimum Design Loads for Buildings and Other Structures

3. Terminology

3.1 *Definitions:*

3.1.1 For terms related to building construction, refer to Terminology E631.

3.1.2 For terms related to sustainability relative to the performance of buildings, refer to Terminology E2114. Some of these terms are reprinted here for ease of use.

3.1.3 *alternative agricultural products*, *n*—bio-based industrial products (non-food, non-feed) manufactured from agricultural materials and animal by-products.

3.1.4 *biodegradable*, *adj*—capable of decomposing under natural conditions into elements found in nature.

3.1.5 *biodiversity*, *n*—the variability among living organisms from all sources including: terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems.

[1] This guide is under the jurisdiction of ASTM Committee E60 on Sustainability and is the direct responsibility of Subcommittee E60.01 on Buildings and Construction.

Current edition approved March 1, 2005. Published March 2005. DOI: 10.1520/E2392-05.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from American Society of Civil Engineers (ASCE), 1801 Alexander Bell Dr., Reston, VA 20191, http://www.asce.org.

3.1.6 *ecosystem*, *n*—community of plants, animals (including humans), and their physical environment, functioning together as an interdependent unit within a defined area.

3.1.7 *embodied energy*, *n*—the energy used through the life cycle of a material or product to extract, refine, process, fabricate, transport, install, commission, utilize, maintain, remove, and ultimately recycle or dispose of the substances comprising the item.

3.1.7.1 *Discussion*—The total energy which a product may be said to "contain" including all energy used in, inter alia, growing, extracting, transporting and manufacturing. The embodied energy of a structure or system includes the embodied energy of its components plus the energy used in construction.

3.1.8 *renewable resource*, *n*—a resource that is grown, naturally replenished, or cleansed, at a rate which exceeds depletion of the usable supply of that resource.

3.1.8.1 *Discussion*—A renewable resource can be exhausted if improperly managed. However, a renewable resource can last indefinitely with proper stewardship. Examples include: trees in forests, grasses in grasslands, and fertile soil.

3.1.9 *sustainability*, *n*—the maintenance of ecosystem components and functions for future generations.

3.1.10 *sustainable development*, *n*—development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

3.1.11 *toxicity*, *n*—the property of a material, or combination of materials, to adversely affect organisms.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *adobe*, *n*—*(1)* unfired masonry units made of soil, water, and straw with or without various admixtures; *(2)* the soil/straw or soil/straw/admixtures mix that is used to make them; *(3)* the mud plaster used for covering walls or ceilings, or both; *(4)* the building that is built of adobe and; *(5)* the architectural style.

3.2.1.1 *Discussion*—The word itself is believed to come from an Arabic word *atob*, which means muck or sticky glob or *atubah* "the brick." The adobe style of architecture migrated from North Africa to Spain, so the name adobe is likely to have come with it. In many other countries, the word adobe is meaningless, and it is more accurate to say "earthen-brick." Other forms of the same material with different details and names, such as rammed earth, Pisé, Jacal, Barjareque, cob, or puddled mud are sometimes referred to as adobe.

3.2.2 *adobe construction*, *n*—construction in which the exterior load-bearing and the non-load-bearing walls and partitions are of unfired clay masonry units while the floors, roofs and interior framing may be wholly or partly of wood or other approved materials.

3.2.3 *adobe, stabilized*, *n*—unfired clay masonry units to which admixtures, such as emulsified asphalt or cement, are added during the manufacturing process to help limit water absorption and increase durability.

3.2.4 *adobe, unstabilized*, *n*—unfired clay masonry units that do not meet the definition of stabilized adobe.

3.2.5 *carbon sink*, *n*—a reservoir that absorbs or takes up released carbon from another part of the carbon cycle.

3.2.5.1 *Discussion*—For example, if the net exchange between the biosphere and the atmosphere is toward the atmosphere, the biosphere is the source, and the atmosphere is the sink

3.2.6 *cast earth*, *n*—a construction system utilizing a slurry containing soil, calcined gypsum and water, which is poured into forms similar to those used for cast-in-place concrete.

3.2.7 *clay*, *n*—inorganic soil with particle sizes less than 0.005 mm (0.0002 in.) having the characteristics of high to very high dry strength, medium to high plasticity and slow to no dilatancy.

3.2.8 *cob*, *n*—a construction system utilizing moist earthen material balls stacked on top of one another and lightly tapped into place to form monolithic walls. Reinforcing is often provided with organic fibrous materials such as straw and twigs.

3.2.9 *earthen building systems*, *n*—building systems that utilize soil as the principal structural material.

3.2.10 *energy efficient*, *adj*—refers to a product that requires less energy to manufacture or uses less energy when operating in comparison with a benchmark for energy use, or both.

3.2.10.1 *Discussion*—For example, the product may meet a recognized benchmark, such as the EPA's Energy Star Program standards.

3.2.11 *gravel*, *n*— inorganic soil with particle sizes greater than 2 mm (0.079 in.).

3.2.12 *horizon*, *n*—distinctive layer of in situ soil having uniform qualities of color, texture, organic material, obliteration of original rock material, and more.

3.2.12.1 *Discussion*—In *World Reference Base for Soil Resources*, by the Food and Agriculture Organization of the United Nations, seven master horizons are recognized – H, O, A, E, B, C, and R.

3.2.13 *indoor environmental quality (IEQ)*, *n*—refers to the condition or state of the indoor built environment in which the building product is installed. Aspects of IEQ include: light quality, acoustic quality, and air quality.

3.2.14 *loam*, *n*—soil with a high percentage of organic material, particles are predominately silt size but range from clay size to sand size.

3.2.14.1 *Discussion*—Loams are usually good agricultural soils due to their nutritional organic content and their ability to hold water.

3.2.15 *manufacturing process*, *n*—refers to the process of creating a building product and includes manufacturing, fabrication and distribution procedures.

3.2.16 *materials (product feedstock)*, *n*—refers to the material resources that are required for the manufacture or fabrication, or both, of a building product.

3.2.16.1 *Discussion*—Material resources include raw materials and recycled content materials.

3.2.17 *moisture wicking*—the capillary uptake of water from foundation soil, ambient humidity or precipitation. Moisture wicking can result in saturation of adobe with an accompanying decrease in strength and durability.

3.2.18 *operational performance (product installed)*, *n*—refers to the functioning of a product during its service life.

Specific measures of operational performance will vary depending upon the product. Aspects of operational performance include: durability, maintainability, energy efficiency, and water efficiency.

3.2.19 *pressed-block*, *n*—a construction system that consists of walls made from earthen materials formed in a block mold by the compacting of lightly moistened earth into a hardened mass.

3.2.20 *rammed earth*, *n*—a construction system that consists of walls made from moist, sandy soil, or stabilized soil, which is tamped into forms.

3.2.20.1 *Discussion*—Walls of unstabilized soil are usually a minimum of 300 mm (12 in.) thick for load bearing purposes. Soils for rammed earth construction usually contain about 30 % clay and 70 % sand.

3.2.21 *sand*, *n*—inorganic soil with particle sizes ranging from 0.05 to 2.0 mm (0.002 to 0.079 in.).

3.2.22 *silt*, *n*—inorganic soil with particle sizes ranging from 0.005 to 0.05 mm (0.0002 to 0.002 in.) having the characteristics of low dry strength, low plasticity, and rapid dilatancy.

3.2.23 *straw*, *n*—an agricultural waste product that is the dry stems of cereal grains after the seed heads have been removed.

3.2.24 *straw-clay*, *n*—a construction system that consists of clay slip and straw, of which straw makes up a high percentage by volume.

3.2.24.1 *Discussion*—This system is well suited for manufacturing bricks, floor blocks, and insulating panels

4. Summary of Practice

4.1 This guide identifies the principles of sustainability associated with earthen building systems. Additionally, it outlines technical issues associated with earthen building systems, identifying those that are similar to construction that is commonly used in the marketplace.

4.2 This guide is intended for use in framing decisions for individual projects.

4.3 This guide is intended for use in framing decisions for development of standards and building codes for earthen building systems.

5. Significance and Use

5.1 *Historical Overview:* Earthen building systems have been used throughout the world for thousands of years. Adobe construction dates back to the walls of Jericho (now located in Israel) which was built around 8300 B.C. Many other earthen structures have been functioning for hundreds of years. However, with the development of newer building materials, earthen building systems have been largely abandoned in part of the world where they were once commonly used.

5.2 *Sustainability:* As world population continues to rise and people continue to address basic shelter requirements, it becomes increasingly necessary to promote construction techniques with less life cycle impact on the earth. Earthen building systems are one type of technique that may have a favorable life cycle impact.

5.3 *Building Code Impact:* Earthen building systems have historically not been engineered. The first written standards for adobe were developed in the United States in the 1930s and were based on common construction practices. Only during the last 20 years have architects and engineers attempted to engineer adobe and rammed earth for use and compliance with contemporary building codes. Standards for the use of adobe were initially limited to local and state codes, predominantly in the southwestern United States. However, over time regional and national model building codes adopted provisions for adobe construction. For example, the International Building Code (IBC)[5] provides empirical requirements allowing the use of adobe when the applicant follows specific procedures. New Mexico building code provides empirical requirements for the use of both adobe and rammed earth building systems. Where the building code does not specifically address earthen building systems, governing agencies frequently classify the construction as an alternative material, design, or method of construction. An alternative material, design, or method of construction will be approved when the code official finds that the proposed design is satisfactory and complies with the intent of the provisions of the code and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in the code in quality, strength, effectiveness, fire resistance, durability and safety. However, development of standards such as this can aid in the appropriate recognition and adoption of earthen building systems materials and methods by building codes and code enforcement agencies.

5.4 *Audience:* There are existing markets in the United States and internationally using adobe, rammed earth, and other earthen building systems. It is estimated that 40 % of the world's population lives in earthen dwellings[6]. Safety, functionality, and sustainability of earthen building systems can greatly be improved through establishment of an international design standard. Intended users of this standard guide include: planners, developers, architects, engineers, interior designers, general contractors, subcontractors, owners, financial organizations related to building industry, building materials and product manufacturers, government agencies including building officials, and other building professionals.

6. Considerations for Sustainable Development

6.1 *Materials (Product Feedstock):* Materials of earthen building systems include a binder soil, typically clay, clay-silt mixture or loam; and inorganic or organic tempering materials, or both. Sand and gravel are commonly used inorganic tempers and straw, hair, and chaff are commonly used organic tempers. Soils may be stabilized, using such materials as cement, asphalt emulsion, calcined gypsum or cactus juice, or may be unstabilized. Adobe bricks may be held together by a variety of mortars. Systems may be finished with plaster or pigments, or both, or left unfinished.

6.1.1 *Soil:* Soils for earthen building systems are a mixture of a binder soil, for example, clay, silt, clay-silt combination or loam, and temper soils of sand and gravel. These mixtures may

[5] Available from International Code Council (ICC), 500 New Jersey Ave., NW, 6th Floor, Washington, DC 20001-2070, http://www.iccsafe.org.

[6] Information from ICBO Vol 1, published 2/2000. Available from International Code Council (ICC), 500 New Jersey Ave., NW, 6th Floor, Washington, DC 20001-2070, http://www.iccsafe.org.