Cast Earth: A Revolutionary Building Concept

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As the cost of quality wood continues to increase and cement is being linked to global warming by some researchers (one study estimates that it contributes as much as 8 percent at present), the need to develop sustainable alternatives—particularly those that use local resources—is emerging as a primary force driving the building market into the future. The mix and delivery systems of cast earth differentiate it from its forerunners—adobe, rammed earth and pise—and, in so doing, offers a viable and economical building alternative. In the U.S., the perception of adobe and rammed earth is that they are not cost-effective. The reasons for this belief are that both technologies are highly labor-intensive, demanding either a large budget or sweat equity, and both require walls 16 to 24 inches (406 mm to 610 mm) thick to achieve structural soundness, which results in added materials costs. Cast earth technology could reduce the amount of labor and wall thickness required, thereby lowering labor and building costs while remaining a sound and sustainable alternative to both wood and concrete.

A BRIEF HISTORY OF CAST EARTH

Cast earth was invented in 1993 by metallurgist Harris Lowenhaupt. After two years of experimenting with retarders, Lowenhaupt built the first cast earth wall in Boulder City, Nevada. Over the next two years, he continued testing retarders and monitored the test wall for resistance to weathering and structural integrity.

The test wall passed initial trials so successfully that, in 1995, Harris contacted Living Systems' Michael Frerking, a Prescott, Arizona, architect and general contractor of earthen buildings for over 20 years, to help him construct a small commercial test building in a Boulder City sand and gravel yard. A 20-foot by 30-foot (6096 mm by 9144 mm) building was fully formed, and cast earth was batched and delivered like concrete in a redi-mixer and pumped into the forms with a grout pump. Stripping the forms revealed strong walls without cracks.

Citing this building as proof of its efficacy, Frerking was able to convince a client to use cast earth rather than rammed earth. Construction of the first cast earth home, the Cottle Residence, began construction in April of 1996 in Prescott, Arizona. It took more than two weeks to form the walls of the 4,000 square foot (371.6 m^2) custom home and 900 square foot (83.6 m^2) garage, but only two days to pour the over 140 yards (128 m) of required material: using an onsite mobile mixer, a crane and a bucket, the Living Systems construction team achieved production rates of 10 to 40 yards (9 m to 37 m) per hour. The second cast earth home, the McKean residence, was constructed in 1997. Since then, five other homes have been built in the Southwestern U.S., with plans for several more currently on the drawing board.

THE CAST EARTH MIX

There are several basic differences between the cast earth mix and other earthen mixes. The primary difference between cast earth and adobe, rammed earth and pise is the use of calcined gypsum as a binder. Mixing soil with gypsum is not a new idea, but outcomes prior to the development of cast earth were likely very unfavorable. The problem was that gypsum acts as an accelerator when mixed with earth, resulting in set times of five to ten minutes or less—an "open time" too short for most practical applications. What is revolutionary about the cast earth mix is that it contains a retarder invented by metallurgist Harris Lowenhaupt, the addition of which allows the product to remain "open" anywhere from 15 minutes to eight hours without any reduction in strength. Further, unlike cement, gypsum is totally compatible with clay, so cast earth walls are free of shrinkage and cracking, are stronger than adobe, and are generally stronger than rammed earth or pise (unless the latter employs large amounts of cement and much less or no clay, and is thereby effectively not an unburned clay product).

Cast earth is a patent-pending product that requires training and licensing for use.

Because cast earth is compatible with clay, it can "tolerate" more kinds of soil, especially those with a higher clay content. Unlike adobe (which is naturally weaker because clay is a less effective binder) or rammed earth and pise (where clay is optional at lower strengths and detrimental at higher strengths), a cast earth can contain up to 20 percent clay without a reduction in strength, thus making the use of site soil a real possibility in its mix design.

Depending upon the soil used, a mix of 15 percent (by weight) gypsum to 85 percent soil yields a compressive strength of 500 to 1,000 pounds per square inch (3445 kPa to 6890 kPa) and a 20 percent to 80 percent ratio yields a compressive strength of over 1,000 pounds per square inch (6890 kPa)—three times that required for adobe or rammed earth. Again, comparatively speaking, the modulus of rupture for cast earth starts at 150 pounds per square inch (1033.5 kPa), versus 50 pounds per square inch (344.5 kPa) for adobe and rammed earth. In terms of shrinking and cracking, a mix of anything more than 15 percent clay in adobe, rammed earth or pise will likely result in severe shrinking and cracking, but a cast earth mix with that percentage (or higher) of clay produces walls that are smooth and free of cracks because, chemically, gypsum and soil work together to expand rather than contract.

There are other advantages to the cast earth mix over other earthen mixes. Gypsum is a common, earth-friendly material that is used, among other things, as a soil conditioner. Although most calcined gypsum is obtained through mining, synthetic gypsum (a by-product of coal burning power plants) is also available for use in cast earth, and recent research suggests that wall board may prove a viable source for recycled gypsum. In addition, while it is always best to reduce moisture contact with any earthen structure, cast earth is a stabilized material. Although it loses some strength when fully saturated, it retains its structural soundness and integrity.

THE CAST EARTH DELIVERY SYSTEM

Another remarkable difference between cast earth and adobe, rammed earth and pise is the fact that it can be poured at very high volumes. As such, cast earth can effectively employ the same technologies that the concrete industry uses to mix and place material. Concrete batch plants, redi-mix trucks, mobile mixers, cranes and buckets, and concrete pumps have all been used successfully. Used as a companion material to concrete, cast earth can easily be delivered by concrete suppliers. Moreover, because cast earth is pourable and uses retarder-controlled gypsum instead of concrete as a binder, walls can be poured quickly and forms stripped almost immediately. This, in turn, opens up the possibility of employing alternative forming methods, such as the use of "gang" forms, "slip" forms or, ideally, no forms, which would contribute to further reductions of labor and production costs.

Because cast earth is poured and not layered or sprayed, additions to the forming structure itself can be employed. For example, a thermal break is created by using a product called "Insteel" that comes in 4-foot by 8-foot (1219 mm to 2438 mm) styrofoam panels that are 2-inches to 4-inches (51 mm to 102 mm) thick and have a 2-inch to 4-inch (51 mm to 102 mm) wire mesh grid on both faces that are cross-tied through the panel. The resulting configuration—a 5-inch (127 mm) exterior cast earth veneer, a 2 to 4-inch (51 mm to 102 mm) rigid foam thermal break and a 15 to 16-inch (381 mm to 406 mm) interior cast earth structural wall—is a 24-inch (610 mm) thick finished wall strong enough to be used in Seismic Zone 3 areas. It also has an effective *R*-value in the 25 to 40 range, depending on the climate of the building location.

A final difference between cast earth and other forms of earth construction has to do with aesthetics. Unlike those of adobe or rammed earth (which must be stuccoed) or pise (which, due to the process used to produce them, remain homogenous in look), the walls of a cast earth building can be manipulated during the mixing and pouring processes to produce variations in texture and color. If poured in a wave-like manner, a finished wall will take on a layered, natural look reminiscent of sedimentary rock formations. Oxides can be added during the mixing or pouring process (i.e., in the mixing auger, the bucket, the pump). Moreover, through the use of high-grade architectural forms, aspects of a finished wall can be made to take on a range of texture through a very smooth marble look. Through careful forming, walls are 90 percent complete when the forms are stripped.

THE CAST EARTH LICENSING PROCESS

Cast earth is a patent-pending product that requires training and licensing for use. Although concrete technologies are employed in its delivery system, its mix is nothing like that of cement. Due to its radically different properties, the mixing and placing of cast earth requires specific training, and strict standards have been established to prevent the material from being used in an unprofessional manner. Moreover, through proper development and structuring of the licensing process, a cash flow could be created to support a cast earth trade association. Unlike some other fields of earth technology, in which innovation has been slow and closely guarded, the aim of a cast earth trade association would be to further its advancement in a professional and collegial manner.

WHERE IS IT GOING?

The EPIcenter is a private sector/government partnership for the development and display of innovative green technologies. Frerking is currently a consultant to the EPIcenter project at Montana State University, which is featuring cast earth as part of a national green (environmentally safe) building program. A $7 million cast earth lab and student union pilot building will be built on the campus in the spring of 2000, serving as the forerunner to a $60 million green building planned for later construction.

Cast earth is presently confronted with a "chicken or the egg" paradox regarding cost and use. At present, the cost per square foot of wall area of cast earth construction is comparable to that of adobe and rammed earth—about twice the cost per square foot of wall as standard frame construction. The wall thickness necessary when building with earthen materials typically increases construction costs by about 10 to 25 percent. To make cast earth more affordable, designers and builders must exploit its two main advantages; the possibility of extraordinarily high production rates and the potential for thinner [12-inch (305 mm) high] walls that have an *R* value of 25 to 40. With regard to the former, licensed cast earth contractors have been able to reach rates upwards of 35 yards (32 m) per hour. Compared to the time needed to produce rammed earth walls, this production rate is astounding. Further, it is well within the realm of possibility that the production rate could as much as double once cast earth moves from the "one off" custom home arena to the development arena, in which buildings can be formed and poured more efficiently. The fact that cast earth is not approved by the International Conference of Building Officials (ICBO) necessarily impedes its entry into the development arena, as the tests and inspections required of structures made of materials not recognized by the building code can increase costs substantially.

Although cast earth has to this point been used exclusively in the southwestern U.S., its application is not limited to that area. There has been growing interest in all parts of the U.S. for energy-efficient earth construction, and inquiries about cast earth have been received from the northeast United States and Canada, as well as Africa and Australia. Because one of the most common concerns has to do with moisture and its effects upon cast earth, further testing is planned in order to correlate the relationship of humidity and moisture to the material's strength. With the help of the Build America Program, thermal testing will soon be done at the Oak Ridge Tennessee National Testing Laboratory to establish "effective" *R* values. Also, through the EPICenter Project in Bozeman, Montana, Frerking expects to soon initiate seismic testing for 12-inch (305 mm) thick reinforced cast earth walls. The results of these tests will help determine the appropriate wall configurations for different geographic locations in the U.S. Frerking would like to coordinate these efforts with ICBO so that the testing is consistent with tests that are necessary for the ICBO approval process. ■