Use of Bottom Ash and Fly Ash in Rammed-Earth Construction

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ABSTRACT

A demonstration of rammed-earth building construction incorporating coal combustion bottom ash and fly ash has been proposed in North Dakota, but several issues related to the environmental and engineering performance of the rammed-earth–ash product are under laboratory-scale evaluation at the Energy & Environmental Research Center prior to full-scale demonstration.

The work reported was designed specifically to evaluate North Dakota materials, but the procedures used are applicable to materials from any location. Results of a review of the rammed-earth technology and an evaluation of market potential for rammed-earth buildings in North Dakota and the region are presented.

The procedures for development of a rammed-earth–ash mix design are detailed. Results of the laboratory-scale assessment of the durability are reported. A comparison of insulating properties of normal rammed earth and rammed earth–ash are presented. Results of an environmental assessment include information on trace element constituents and radon emanation.

INTRODUCTION

A demonstration of rammed-earth (RE), also referred to as plisé or tamped-earth, building construction has been proposed in North Dakota. RE construction is an historical method of construction using earth compressed into a form, similar to adobe. Although RE is typically associated with buildings in the southeastern United States, structures also exist throughout the eastern and midwestern United States, constructed primarily during the middle of this century. There has been a renewed interest in RE construction worldwide, due in part to the rising cost of traditional wood building materials and increased awareness of energy-efficient materials. Australia, the European Community, and the United States have all developed strong organizations to foster interest and growth in this new industry. The soil used in RE construction must fall within a certain range of characteristics to perform well. In North Dakota, some soils are appropriate for RE construction without the use of additives as stabilizers; however, more frequently, North Dakota soils need some amendment to meet performance requirements for RE construction for durability and strength.

Modern RE construction frequently uses stabilizers to enhance engineering performance and durability. Coal combustion fly ash and bottom ash have excellent potential for use in RE construction as a low-cost alternative to portland cement and other stabilizers because of its cementitious properties. The Energy & Environmental Research Center (EERC) is currently investigating the use of fly ash and bottom ash from a North Dakota lignite-fired power plant. The EERC has performed extensive evaluations of North Dakota lignite ash for environmental suitability, physical properties, and engineering performance. These studies indicate that lignite fly ash is environmentally benign and offers advantageous cementitious performance. Lignite bottom ash is also environmentally benign and has properties similar to the aggregate used in numerous applications.

PROJECT PLAN

Several issues need to be evaluated prior to the demonstration of the RE building technology in North Dakota: 1) the appropriateness of the local soils, 2) the use of coal combustion bottom ash and fly ash as well as other additives such as portland cement, and 3) the performance of rammed earth in the North Dakota climate. The laboratory study is currently using a single source for North Dakota soil and fly ash and bottom ash from one North Dakota power plant. Soils and coal combustion by-products (CCBs) from other sources may need to be evaluated on a laboratory scale on a case-by-case basis. A review of the RE technology for practicality and an evaluation of market potential for RE buildings in North Dakota and the region are also under way as part of the EERC effort. The work is being funded jointly by the North Dakota Industrial Commission on recommendation of the Lignite Research Council and the U.S. Department of Energy through the EERC Coal Ash Resources Research Consortium.

The overall goal of this work is to evaluate the end product of the RE process for performance and durability. Specific objectives are:

- To determine a mix design based on local materials.
- To perform tests to ensure environmental acceptability.
- To perform tests to verify the long-term durability of the RE block.
- To perform a preliminary evaluation of the RE technology proposed and the market potential for RE construction in North Dakota.
- To investigate CCBs as a low-cost alternative to current stabilizers commonly used.
- To compare R-values of RE blocks with those of unamended soil mixtures.

A mix design is being developed based on a matrix of trial combinations. The trial combinations include various combinations of soil, bottom ash, fly ash, cement and lime. Strength is being used as a measure of performance in the first round of mix design. The many different clay minerals and clay mixtures each have unique properties. Blocks made from the mix designs will also be

evaluated by scanning electron microscopy (SEM) to determine the degree of stabilization of the clay minerals. They will also be sent to an independent laboratory for thermal R-value testing according to the American Society for Testing and Materials (ASTM) C 518 procedure.

The environmental properties will be addressed to ensure that the RE blocks do not pose a health threat from runoff and ultimate disposal. All of the materials, soils, clays, and ashes will be tested for their major, minor, and trace element chemistry. It will be important to determine the trace element composition of the materials used to produce the RE products. If the concentrations are very low, then leachate from runoff or ultimate disposal will be of little concern. The blocks produced will be tested for leachability as well as their potential for radon emanation.

Final products will need to be tested for durability. Durability testing will include freeze–thaw tests following ASTM procedures for soil stabilization. Wet/dry cycles will also be used to help determine durability. A modified Proctor test will be used to determine compaction properties.

A brief feasibility study will be performed in two steps. The first will be an evaluation of the product and building design by a qualified builder who can evaluate the RE technology as a competitive technology to stick buildings. The second step will be to survey the building community in North Dakota for a history of alternative building technologies such as concrete buildings, block, or any other nontraditional stick-built homes and buildings.

Preliminary results of the laboratory investigations will be available in fall 1999. Further results will follow in spring 2000. If results indicate good performance of ash-modified soil for RE construction, a full-scale demonstration will be performed in 2000. The EERC will report all of these activities on its Web site.