THESIS

ASSESSING THE PERCEPTION OF COMPRESSED EARTH BLOCK (CEB) AMONG CONTRACTORS IN THE PIEDMONT REGION OF NORTH CAROLINA

Submitted by

Evan G. Hughes

Department of Construction Management

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Advisor: Rodolfo Valdes-Vasquez

Jerry Vaske
Jonathan Elliott

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ABSTRACT

ASSESSING THE PERCEPTION OF COMPRESSED EARTH BLOCK (CEB) AMONG CONTRACTORS IN THE PIEDMONT REGION OF NORTH CAROLINA

The earliest earthen dwellings in the U.S were made by manually pressing a mixture of moist earth and straw into roughhewn blocks. This method, known as adobe, is durable and environmentally benign but requires more time and manual labor than most conventional materials, and as a result has been largely ignored by U.S. contractors with the exception of those working in New Mexico. This is true of most earthen building techniques, including compressed earth block (CEB). CEB retains many of the environmental benefits of adobe and can be produced with automated machinery, allowing for rapid and consistent block production in large volumes. With the advent of labor and time-saving technology, the practical barriers presented by traditional earth building methods have been greatly reduced, necessitating an exploration of the non-technical barriers to CEB acceptance and adoption in the U.S.

Studies conducted in Africa and Southeast Asia have shown that home-buyers often associate earthen structures with poverty, transience, and poor performance. Research performed in Midwestern states have indicated similar results. The current study seeks to determine what, if any, perception barriers to CEB acceptance and adoption exist among contractors in the North Carolina Piedmont region, which lies between the Appalachian Mountains and the Atlantic coastal plain and possesses ideal soil for earth building. Despite these favorable conditions, the North Carolina Piedmont has yet to develop a significant market for earthen architecture and virtually no research has been conducted to investigate this phenomenon.

To address this gap in the research, a survey instrument was designed and piloted in New Mexico. Pilot data and feedback were used to refine the survey instrument, which was then distributed to general contractors in the Piedmont. A third survey was distributed to select contacts in the researcher's professional network. These surveys aimed to assess contractors' awareness of CEB, their experience with CEB, and their perception of CEB's practical merits and drawbacks. Two telephone interviews were also conducted, one with a North Carolina contractor who specializes in CEB construction and another with a Texas-based manufacturer of automated CEB block presses.

Quantitative data gathered from the two survey distributions revealed disparate opinions of CEB's cost-effectiveness, aesthetic value, and structural worth. Respondents with no CEB experience provided largely neutral opinions in these areas, indicating that they may have been unable or unwilling to provide definitive positive or negative opinions due to their lack of experience with the material. Respondents who had used CEB were either neutral or positive. Qualitative data gathered from these two survey distributions indicated a similar divergence of opinion between the two respondent groups. Both phone interview subjects recommended increased education and exposure to CEB to overcome skepticism and lack of knowledge among the construction industry and the general public.

The results of this study assist building professionals and their clients in understanding how non-technical barriers (i.e. barriers not related to time, infrastructure, technology, or capital) may impede the acceptance and adoption of CEB and other non-conventional materials. Identifying and addressing these barriers is a necessary step for increased market penetration of CEB in the North Carolina Piedmont and elsewhere.

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DEFINITION OF TERMS

The following terms and definitions are referenced in this study:

Compressed Earth Block (CEB): Blocks produced using a mixture of clay soil and coarse sand that is fed into either a manually operated or automated block press.

Compressed Stabilized Earth Block (CSCEB): CEB that have been produced using a mixture of clay soil, coarse sand, and one or more strengthening additives such as lime or Portland cement.

Conventional Materials: For the purposes of this study, these are defined as concrete, concrete masonry units (CMU), fired masonry, timber framing, or steel framing.

Earth Architecture: A style of architecture characterized by the use of soil or soil mixed with various additives to form the major structural elements of a building.

Embodied Energy/Embodied Carbon: The total amount of energy required and carbon dioxide created to produce a good or service. This can be expressed as mega-joules per kilogram (MJ/kg) and tons of carbon dioxide per kilogram of the item or material produced (tCO_2/kg)

Hygroscopic Buffering: The ability of a material to absorb or release moisture in response to ambient humidity.

Non-Conventional Materials: Any material other than concrete, concrete masonry units (CMU) fired masonry, and timber or steel framing

Non-Expansive Clay: Clay that does not swell and shrink when exposed to moisture.

Non-Technical Barriers: Barriers to the acceptance and adoption of a building material that are unrelated to the material's physical, chemical, or structural properties.

Perception Barriers: Barriers to the acceptance and adoption of a building material that are directly related to the perception of the material's efficacy and value.

Thermal Mass: The ability of a material to absorb and store thermal energy (heat).

CHAPTER I: SCOPE OF THE RESEARCH

The construction industry is a tremendous consumer of energy and natural resources (Ortiz et al, 2007). Most of these resources and energy are consumed in the creation and use of what are considered conventional building materials. Alternatives that require less material and energy expenditures exist, including compressed earth blocks (CEB) (Huberman and Pearlmutter, 2007). CEB are composed of a mixture of clay-rich soil and coarse sand. They are produced using either manual or automated hydraulic block presses rather than being pressed by hand as is the case with traditional adobe, and can be produced locally if on-site soil meets certain criteria (see Appendix I). Table 1 offers a short comparison of the physical properties and manufacturing requirements of CEB and traditional adobe.

Table 1: ***Comparison of Technical Properties of CEB and Adobe***

Technical Property	CEB	Traditional Adobe
Compressive Strength[1]	652.6 psi	464.1 psi
Flexural Strength (stabilized)	145 psi[2]	98.6 psi[3]
Block production rate[4] (single person only)	750-850 blocks/hour	100-300 blocks/day
Can be mechanically pressed (automated)	•	
Can be hand-pressed	•	•
Requires drying in sun or firing in kiln		•
Requires manual mixing of soil		•
Does not require cementitious additives	•	•
Can be produced locally	•	•
Lower embodied energy than concrete and fired masonry.	•	•

1. Kouakou and Morel, 2009; 2. Garg et al, 2014; 3. Vega et al, 2011; 4. Smith and Austin (1989).

The soil of the North Carolina Piedmont (hereafter "Piedmont") possesses unique properties that make CEB construction a potentially viable alternative for contractors and owner-builders. Piedmont soil contains a great deal of kaolinite (Calvert et al, 1980), a type of clay that does not expand and contract dramatically when exposed to moisture. Yet CEB has not caught

on among either contractors or their clients despite the presence of optimal soil and modern machinery that makes block production faster and simpler than earlier methods. To understand why CEB has been largely ignored in this region, an electronic survey was developed to assess contractors' familiarity with CEB and their perception of its efficacy, practicality, and applicability. At the outset of this study, the researcher hypothesized that contractors surveyed in North Carolina would have little to no experience with CEB or awareness of its strengths and weaknesses. It is also hypothesized that a minority of survey respondents would actively oppose CEB and other non-conventional materials due to preconceived notions of their cost-effectiveness and relevance in modern construction.

The purpose of this chapter is to: (1) investigate the problem at the heart of this research and (2) identify the impacts of this study.

Research Context

Adobe construction has a noticeable presence in California, Texas, Arizona, and New Mexico (Gerbrandt and May, 1980). New Mexico has historically been the largest producer of adobe in the United States and contains one third of all adobe structures in the U.S (Smith and Austin, 1989), most of which are found in and around the cities of Santa Fe, Albuquerque, and Taos. Beyond these areas, adobe and other forms of earth block construction including CEB have been mostly ignored in the United States.

The Piedmont, which possesses ideal soil for earthen construction, has yet to develop a substantial earth building tradition. This is not a unique situation in the Southeastern U.S. The Georgia and Virginia Piedmont contains ultisols (Markewich et al, 1991) like kaolinitic clay, known for their load-bearing strength and low swell-shrink characteristics. For regions that do

not possess ideal soil, stabilizers like Portland cement or lime may be added to enhance the strength of the blocks. These cement-stabilized compressed earth blocks (CS-CEB), while having higher embodied energy than unstabilized CEB, nevertheless offer an embodied energy savings of 86% over fired masonry and 25% over concrete (Maskell et. al., 2014). Nevertheless, these energy savings and performance charactaristics have not allowed CEB to gain a foothold in North Carolina or elsewhere.

Problem Statement

The perception of CEB and other earthen materials has been studied in Africa, Asia, and the Middle East, but it has not been thoroughly explored in Europe or the United States (Kraus, 2012; Thorpe, 2011; Smith and Austin, 1989). Given CEB's advantages over traditional earth building methods, it is necessary to explore building professionals' perception and awareness of this material, particularly in regions like the Piedmont where the soil is ideal but earth architecture has no substantive market share. To understand the limitations to broader acceptance of earth as a building material in general, and CEB specifically, it is important to understand contractors' perceptions of earth as a building material.

Goals and Objectives

The purpose of this study was to assess the perception of CEB among contractors in the North Carolina Piedmont and determine whether their perception of the material is acting as a barrier to its acceptance and adoption. The following objectives were identified and addressed in pursuit of this goal:

Objective 1: Collect and analyze previous research conducted in the United States and abroad to highlight non-technical barriers to the acceptance of earthen materials. A variety of

earth-building techniques are covered in the existing literature, though research on the perception of these materials among stakeholders in the construction industry is limited. Research on the perception of CEB in the United States is virtually non-existent.

Objective 2: Develop a survey that assesses the perception of CEB among general contractors. The survey draws on the studies performed by Kraus (2012) and Francis and Prosser (2012). The research undertaken by Kraus provided the inspiration for the structure of the survey and the decision to target contractors rather than the general public. The use of a word-association question in the survey was taken from Francis and Prosser**.** This item was included in the survey to provide respondents with an avenue of expression that was less restrictive than multiple-choice or Likert-Scale questions. Survey questions were designed to assess respondents' perception CEB in in order to determine whether their perception of CEB differed substantively from their perception of non-conventional materials in general.

Objective 3: Pilot the survey from Objective 2 in New Mexico, and use the resulting data to refine the survey's content and structure. The survey was sent out to thirty nine contractors in Santa Fe, Albuquerque, and Taos. Additionally, the survey was distributed to the staff at the Associated Contractors of New Mexico, with the request that they forward it to any and all members of their organization that were willing to participate. Due to a low response rate the data resulting from this pilot could not be used to draw any meaningful conclusion, but was a necessary step in the development of the survey itself.

Objective 4: Distribute the survey to general contractors working in the North Carolina Piedmont and elsewhere. The survey was created using Qualtrics, an online survey development platform, and distributed electronically via a link emailed directly to

contractors. Follow up with a second distribution to building professionals in the researcher's network who are familiar with CEB, having worked with it in professional practice.

Objective 5: Collect and analyze survey results using a variety of statistical analyses. Identify any patterns among responses that indicate the presence of shared opinions on the efficacy, cost-effectiveness, and applicability of CEB in residential construction. Identify any relationships between familiarity with the material and perception of its efficacy and value.

Objective 6: Supplement the quantitative data from survey distributions with short telephone interviews conducted with construction professionals who are familiar with CEB and have experience with the material and the equipment required to produce it, and who have used it as a building material in one or more projects.

Due to the lack of earthen architecture in the Piedmont, and the absence of any real earth building tradition in North Carolina, it was hypothesized that the majority of respondents would have little to no experience with CEB or any other earth-building technique. The researcher also predicted that the same majority would not harbor any active opposition to non-conventional materials, but that their willingness to adopt such materials would be contingent on the demand of their clients.

Research Questions

The following questions guided the development and execution of this study:

Q1. Is the perception of CEB among contractors in the North Carolina Piedmont region limiting its adoption in the residential construction market?

Q2. Does the perception of CEB among contractors in the North Carolina Piedmont correlate with their perception of other non-conventional materials?

Q3. Is there a relationship between contractors' experience with CEB, or their awareness of CEB, and their perception of its efficacy, cost-effectiveness, and applicability in residential construction?

Delimitations

The study was limited to participants currently working in the U.S. This study focuses on general contractors and, with the exception of one telephone interview with a CEB press manufacturer, does not substantively address the perceptions of architects, construction managers, owner's representatives, engineers, specialty consultants, and other non-contractor professions in the construction industry.

Limitations

The first e-survey was distributed to contractors in the North Carolina Piedmont, many of whom perform the majority of their work in that region. As such, the applicability of the resulting data is somewhat limited, as it does not provide an accurate picture of the perception of CEB among contractors in other regions of the state. The second e-survey distribution was sent to building professionals within the researcher's network, who were encouraged to forward the survey throughout their own networks. These initial contacts' academic and professional pursuits revolve around CEB. As a result, responses from the second round of survey distribution are not representative of the perceptions of general contractors who are unfamiliar with the material. The survey was also distributed electronically via email, excluding contractors who do not publish their email addresses online.

Assumptions

It is assumed that all participants accurately and honestly self-reported information related to their experience in construction, their experience with CEB, and the geographic areas where they performed the majority of their work.

Researcher's Perspective

The built environment in the United States produces roughly 43 percent of all CO2 emissions in the country (Brown, 2006). Educational facilities alone use approximately 14 percent of all energy consumed in U.S buildings, excluding shopping malls (Hesterman, et.al, 2014). One path to reducing these impacts is the adoption of alternative construction materials like CEB that require less energy to produce and result in spaces that can be heated and cooled more efficiently. CEB retains many of the environmental advantages of traditional adobe, namely low embodied energy, potential for local production, and high thermal mass, without the time and physical effort adobe requires. Moreover, if CEB is stabilized with Portland cement or a similar additive, it offers the same vertical and lateral load and flexural bond strength as conventional masonry (Tennant et al, 2013). I believe that, if the construction industry wishes to reduce its environmental impact, alternatives to conventional materials must be explored.

Reader's Guide

This study assesses the perception of compressed earth block (CEB) among contractors in the North Carolina Piedmont region to determine if their perception of CEB, and their experience with it, is acting as a barrier to its acceptance and adoption. The following chapters detail how this assessment was carried out. Chapter II offers a summary of research performed to date on barriers to the adoption of materials similar to CEB in other countries, provides an explanation of

the gap in this research, and justifies the need for this study. Chapter III discusses the methodology used to carry out the study, and details the creation of the survey instrument, the preliminary survey pilot, and the subsequent collection of survey data and telephone interviews. Chapter IV provides an analysis and discussion of this data, and Chapter V serves as a conclusion and point of departure for future studies investigating the barriers to the adoption of CEB and other non-conventional materials.

CHAPTER II: A REVIEW OF RESEARCH CONDUCTED TO DATE

In order to understand how contractors' perception of CEB can help or hinder its acceptance and adoption, a literature review was performed to determine if CEB and related materials have faced perception barriers to adoption either domestically and internationally. This literature review revealed a lack of structured research to date on the perception of CEB and other earthen materials in the United States, though it did yield noticeable perception patterns among contractors and their clients in Africa and Asia. This gap in current research is significant and justifies the need for this study. Furthermore, this literature review helped provide further context for understanding the role that perception barriers play in the adoption of non-conventional materials.

Research in Africa and Southeast Asia.

Research conducted in Africa and Southeast Asia has shown that social perception of earthen construction plays a significant role in its adoption. Hadjri et al. (2007) surveyed residents of both traditional rural homesteads and urban dwellers in Zambia to assess their perception of the durability and livability of earth-walled buildings. Questionnaires were also randomly distributed to architects, engineers, and contractors, and an inspector from the Zambian Bureau of Standards (ZABS) was interviewed. The authors found that a third of the rural residents would, given financial resources, continue living in an earth home if construction methods were improved. All of the urban residents indicated the opposite, stating that earth houses were a symbol of low social status. Seventy three percent of the contractors surveyed had never built with earth, and most were reluctant to build with earth due to perceived performance limitations and societal pressure to pursue more "upmarket" projects. The ZABS official

lamented the lack of both an earth building code and vocational training programs in earth building in the nation's universities. This study was limited by participant response rate and sample size: only 22 of 60 contractors invited to participate responded, and only 20 Zambian citizens were surveyed. Despite these limitations, the majority of participants demonstrated a clear bias against earthen construction.

This phenomenon has been studied and discussed elsewhere in Africa. Sameh (2013) conducted a literature review and performed case studies of earth buildings in Egypt. She concluded that earth buildings are bound by low social status in the residential sector, and that the end-user perspective of earth homes has been shaped by the assumption that they are unsafe (Sameh, 2013, p. 5). The applicability of Sameh's research is limited by the inherent subjectivity of her methodology and the context in which her recommendations are given. She bases her conclusions on a review of extant literature, rather than original research. She argues that earth structures are durable because ancient civilizations built their fortresses out of mud. That may be true, but only because mud is what ancient builders had at their disposal. Her solutions for overcoming social stigmas against earthen homes rely heavily on government subsidies and new regulation. In a country like Egypt, currently in turmoil, expecting the government to sponsor sustainability interventions is unrealistic. Nevertheless, her assertion that exceptional earth architecture can be used to promote earth homes may offer a way for contractors in developed countries to engage potential homeowners in greater numbers.

UNESCO, in a CEB production best-practices manual for Sudan, shared several of Sameh's (2013) recommendations. In Sudan, earth-block construction is regarded with skepticism and mistrust and is not recognized by the public as an "acceptable, durable building material" (Adam and Agib, 2001, p. 65). A lack of earth building standards and codes, fueled by

skepticism among government authorities, is also cited as a major barrier to earth building efforts. This lack of standards, the authors pointed out, leads to poorly built structures that inevitably fail in poor weather, confirming negative stereotypes about CEB's performance. The authors also noted that while earth structures in Sudan are typically used by the poor, in developing countries earthen architecture is often associated with middle to high income housing (p. 66), in the same way that a bicycle might be used by the poor for basic transportation and by the upper class as a way to demonstrate their commitment to sustainability. Like Sameh, Adam and Agib recommend constructing high-quality public-use buildings, using CEB with stabilizing additives that increase the blocks' durability, to convince public officials and the general public of the potential of earth construction.

Public skepticism and associations with poverty have been recorded elsewhere in Africa as significant obstacles. Ballerino (2002), during her Master thesis research, interviewed urban and rural homeowners in Port Elizabeth, South Africa, and found that urban residents almost universally avoided raw, natural materials, particularly earth. Social pressure to emulate the middle and upper classes had led low-income urbanites to view earth buildings as structurally unsafe and a social step backward. This issue was compounded by owners who only trusted conventional building materials, particularly concrete masonry (p. 35). In addition to public skepticism and associations with poverty, researchers have identified the lack of earth architecture awareness and education in most countries as a barrier to its acceptance and adoption. Zami and Lee (2011) constructed a questionnaire, based on barriers they identified in a literature review, and administered it to a panel of ten stabilized earth construction experts. The panel indicated that a lack of modules of earthen architecture in most universities has

become a major inhibitor of CS-CEB adoption, and that polarization among earth construction professionals has not helped.

The panel urged earth architecture practitioners to avoid thinking of earth as either perfect or worthless, and instead objectively analyze the weaknesses of earth as a building material in order to improve its efficacy (Zami and Lee, 2011, p. 238). These experts also stressed the value of fostering exemplar earth architecture projects to help market earth construction as a material for all classes, not just the poor. Zami and Lee's research is limited by such a small participant pool. However, there are a limited number of earth construction specialists in the world, which the authors acknowledge. Furthermore, the authors' methodology relied on each member of the panel arriving at a consensus independent of one another, which lends validity to their conclusions.

A lack of knowledge among stakeholders was also noted by Niroumand et al. (2013), who surveyed members of the International Council on Monuments and Sites (ICOMOS)—considered experts in earth architecture history and earth building education—working in Malaysia, Iran, India, Australia, Britain, and the United States. A total of 763 responses were recorded from all six countries, 150 of which came from Malaysia, Iran and India. Participants from Iran and Malaysia believed a lack of earthen construction education was a major obstacle, and those from India indicated a lack of knowledge and awareness among builders and end-users. Responses from all experts surveyed showed that earth architecture is pursued in developing countries in order to achieve lower life cycle costs, whereas experts of earth architecture in developed countries are motivated by a desire to work in an industry that values the environment (p. 156). This study offers a window into the minds of a large number of experts in both developing and developed countries. In the current body of research, this is rare.

Most research on social and cultural barriers to earth architecture implementation focuses on developing nations, particularly those in Africa, and does not involve such a large pool of participants.

A majority of the barriers mentioned thus far were cited almost 20 years ago by Gooding and Thomas (1995). They studied production methods of cement-stabilized CEB (CS-CEB) in Africa, Sri Lanka, and Mexico. Using surveys distributed to urban and rural residents, government agencies, and compressed earth block manufacturers in seven African countries, they found that, while CS-CEB had potential as an economically and structurally viable building material, several barriers were hindering its acceptance throughout Africa. These included a lack of structured research on earth-block production best practices and a lack of earth-block building codes. Both had led to the production of poor quality blocks for buildings that were technically illegal.

The structures built with these inferior blocks inevitably failed, perpetuating negative stereotypes about the material's durability. Over time, CEB became associated with poor quality, poverty, and transience. According to the authors, average homeowners "[were] prepared to spend ten years building a house rather than use 'low cost' building materials" (p. 18). To counteract this negative perception, the authors recommend that CS-CEB be treated like any other commercial building product and undergo rigorous testing and quality control checks. They also recommend that CS-CEB be subjected to a coordinated marketing campaign.

Gooding and Thomas's work remains relevant because their surveys covered all major stakeholders in the construction industry, and provided a glimpse of the social perception of CEB in a broad swath of the developing world. Their study focused on CEB and its advantages over traditional earthen construction and their prime aim was the destigmatization of earth blocks,

which is wiser than simply improving current methods and waiting for the general public to catch on.

Research in Australia, Europe, and the United States

Studies conducted in wealthy nations have revealed social and cultural barriers that mirror those in developing countries. In their aforementioned survey of ICOMOS members, Niroumand et al. (2013) found that experts in Australia, Great Britain, and the United States saw a lack of knowledge and awareness of modern earth building methods as the greatest obstacles to their efforts. Kraus (2012) had similar results. Using a survey distributed to architects and architecture students in Kansas and New Mexico, he found that the perception of rammed earth among Kansans was shaped by three major assumptions, or "fallacies": Rammed earth is antiquated, unsafe, and suitable only in arid climates (p. 158-159). Durability was cited as both a positive and negative attribute among respondents, indicating confusion and a lack of technical knowledge of the capabilities and limitations of rammed earth. Based on this and other findings, he concludes that the greatest barrier to widespread adoption of rammed earth in Kansas is a lack of education among public officials, architects, construction professionals, and the general public (p. 162).

Due to unequal response rates Kraus was forced to aggregate all data into one set, heavily concentrated on students in Kansas. Additionally, the scope of the study is unknown, since he does not provide the number of surveys distributed or the number of responses collected. These limitations, combined with the differences in appearance, structural performance, and cost between rammed earth and CEB/CS-CEB, make it difficult to derive assumptions about the public perception of CEB from the results of his research.

Nevertheless, Kraus's findings correlate with the barriers discussed in previous research conducted in Africa and Asia. Such obstacles have also been observed in the U.K. Williams et al. (2010) studied the environmental, economic, and structural properties of CEB, to determine if it was a viable method of construction in Britain. Although their results indicated that it was, interviews with earth building professionals from Germany, France, and the United States revealed that a skeptical public, a lack of knowledge within the construction industry, and reluctant insurance companies had inhibited CEB's adoption (p. 102-103). Earth builders in these countries also incurred higher costs compared to conventional timber-framed houses, due in part to a lack of national earthen construction standards and low availability of block producers. Thorpe (2011), in his dissertation on the factors inhibiting cob construction in the U.K, shed more light on the negative influence of public perception. Thorpe distributed a survey to 382 residents of Taunton, a small town in southwestern England. Participants were presented with pictures of six houses and asked which one they would rather live in. Three were built with conventional methods and three with alternative techniques, including cob. Samples of various building materials were also shown, ranging from concrete block and fired brick to cob and recycled tires.

Thorpe found that, while the appearance of cob was not a limiting factor, over 60% of survey respondents expected their homes to be built of either brick or stone. The remaining materials were not considered "worthy" (p. 51). He noted that large contractors, who have the power to influence the way the U.K approaches mass housing, have probably avoided cob because it does not appeal to their clientele. British building regulations are also cited as a barrier, since they require walls with a lower U-value (thermal conductivity) than most cob

structures can attain. Thorpe concluded, based on these results, that the majority of people want "concrete and brick, strong, dependable materials which will last several lifetimes" (p. 57).

Gap in Current Research

Research conducted in Africa and Asia has shown that the opinions of stakeholders in the construction industry, contractors and building officials among them, can influence the adoption of earthen materials. Studies undertaken in Europe and the British Commonwealth have identified barriers that correlate with those found in developing countries. These include a lack of earth building codes, lack of knowledge and awareness among building professionals, and a skeptical public. Research on these barriers in the United States remains limited, and research that focuses on North Carolina, or any of the Southeastern states, is virtually non-existent.

CHAPTER III: RESEARCH METHODOLOGY

Very little research has been performed in the United States that identifies perception barriers to the adoption of CEB, or any other earthen material, in residential and commercial construction. Little to no research has been performed on this subject in the southeastern U.S., where soil properties and economic conditions offer an attractive environment for CEB construction. This study explored why CEB has not been adopted by contractors in the Southeast, specifically in the Piedmont, and sought to determine if contractors' perception of the material and experience with it, or lack thereof, has somehow fueled this phenomenon. To explore this question, an electronic survey was developed that measures contractors' perception of non-conventional materials in general, their experience with CEB, and their perception of CEB's structural properties, aesthetic qualities, and cost-effectiveness.

Research Approach

Data Collection

The survey was distributed via Qualtrics, an internet-based survey development and distribution platform. The survey assessed contractors' perception of non-conventional materials broadly and CEB specifically, and included a section that gathers the following demographic data: Experience building with CEB, number of CEB projects completed and duties performed on said projects, length of career in construction, primary area of construction expertise, number of projects completed annually, average number of people employed annually, and geographic area where majority of work is performed annually.

Sample

Responses were collected from contractors affiliated with home-building associations (HBAs) in the North Carolina Piedmont. Other stakeholders in the construction industry, such as architects, engineers, consultants, or members of the general public, were not considered. The researcher contacted administrative staff at HBAs in the Piedmont, who sent the survey along to their members. Individual contractors were not contacted directly, but instead received the survey either as a forwarded email or as part of a regularly distributed HBA newsletter. Ten HBAs were contacted in the following ten cities: Charlotte, Raleigh, Durham, Winston Salem, Cary, High Point, Greensboro, Concord, Gastonia, and Chapel Hill. These are the ten largest cities within the Piedmont region, not the ten largest cities in the state. Contractors in counties located outside of the Piedmont were ignored to ensure that only contractors located in the Piedmont received the survey. As many of these contractors are small businesses and thus may not have had ample time to respond to survey requests, a relatively low response rate of 10%, or between forty and sixty respondents, was expected.

A survey was also sent to construction professionals in the researcher's professional network in Oklahoma, Texas, and New Mexico. Questions tailored to contractors in North Carolina and New Mexico were excluded from this survey, though apart from these exclusions the content of this survey was nearly identical to the survey distributed in the North Carolina Piedmont. Participants in this distribution were encouraged to forward the survey to members of their respective networks. The intent of this snowball sample was to gather responses from construction professionals who had experience with CEB in order to determine if respondents' perception of it changed with increased exposure to the material in professional practice.

Finally, two telephone interviews were conducted. One was with a North Carolina residential contractor who builds CEB homes as well as conventional residences. The other interview was conducted with the president of a company, headquartered in San Antonio, Texas, that builds automated CEB presses.

Survey Development

The survey instrument was developed with input from Colorado State University faculty, as well as survey instruments developed in the literature outlined in Chapter II. Please see Appendix C for a copy of the survey.

Pilot Survey

After passing through several rounds of editing and revision, the survey was distributed to contractors located in Albuquerque, Taos, and Santa Fe, New Mexico as part of a pilot study. These cities were deliberately chosen for their connection to New Mexico's earth architecture tradition. Albuquerque is the largest city in New Mexico, and the soil of the Albuquerque Basin is ideal for earth construction; Santa Fe is New Mexico's capital and home to a famously strict building code mandating "Pueblo-Revival" architecture; and Taos is home to some of the oldest continuously inhabited earth structures in the world (Smith and Austin, 1989).

Survey participants were chosen at random using publicly available search engines, such as Angie's List and Dexknows, both of which allow the public to locate general contractors in their area. Thirty nine contractors were contacted: Thirteen in Taos, sixteen in Santa Fe, and ten in Albuquerque. The survey was also sent to the Associated Contractors of New Mexico (ACNM) with the request that they forward it to any and all ACNM members who may be interested in participating. It is unknown how many ACNM contractors received the survey.

A total of three complete survey responses and one incomplete response were received. No meaningful conclusions about the perception of CEB among contractors in New Mexico could be derived from such a small sample. However, the intent of this initial pilot was to develop and test the survey instrument, and in that regard it was a success.

Survey Sections

The survey (Appendix C) was divided into six sections: (1) An informed consent letter and explanation of the survey; (2) questions that assess participants' perception of non-conventional materials generally; (3) questions that assess participants' perception of CEB specifically; (4) questions that assess participants' prior experience with CEB; (5) general demographic questions; and (6) open-ended feedback questions.

General perception of non-conventional materials

This section consisted of nine questions that assess respondents' perception of non-conventional materials, specifically their opinion of these materials' cost-effectiveness, their future relevance, and their ease of use under local building codes. This section also assessed respondents' views on the role that contractors should play in directing the public toward or away from certain building materials; the relationship between contractors' interest in a building material and the interest level of their clients; contractors' willingness to invest in training in building with non-conventional materials; and whether or not that willingness is tied to the interest of their clients. All of the questions in this section are presented on a five-point scale. For each question, participants are asked to indicate their agreement with a statement, where 1=Strongly disagree, 2=Disagree, 3=Neutral, 4=Agree, and 5=Strongly Agree.

These questions are included in the survey because they allow the researcher to determine if contractors' perception of CEB is a reflection of their attitude toward non-conventional materials in general, or if they hold specific attitudes toward CEB that diverge from their opinion of other non-conventional materials. The questions dealing with contractors' willingness to invest in training were included to further determine if participants' behavior and material choices were entirely driven by their clients' wishes, or if they made these choices based on their perception of the materials themselves.

Perception of CEB

The next section deals with CEB specifically, and begins by asking respondents to provide the first three words they associate with the term "compressed earth block." This was included to assess respondents' perception of CEB in a way that is less structured than other question formats and provides a more freeform way to gather respondents' undigested opinion of the material. The remaining questions are presented on a five-point scale identical to the scale used in the previous section. These questions assess contractors' opinion of CEB's cost-effectiveness, environmental impact, attractiveness, structural integrity, and ease of use under local building codes. This section also assesses contractors' perception of the awareness of CEB among both their clients and other contractors, as well as other contractors' interest in building with CEB.

Prior Experience with CEB

This section begins with a skip logic question that asks whether the participant has any experience building with CEB in residential projects (the term "residential" was included because CEB, due to its weight, is largely unfit for structures over two stories and as a result is of limited use in commercial construction). Skip logic is incorporated so that, if the participant

responds "No," they are directed to the next section, thus streamlining the survey process. This section was included to gauge respondents' level of involvement in CEB projects relative to the rest of the projects they complete. In the North Carolina distribution, respondents with CEB experience were able to choose from the following positions: Company owner; laborer; mechanical, electrical, or plumbing subcontractor; CEB subcontractor; or project manager. In the second round of distribution, architect/designer and materials supplier were added as choices. The architect/designer position was not included in the North Carolina Piedmont distribution because the survey only targeted contractors. The materials supplier position was added based on feedback provided by North Carolina Piedmont respondents, who felt that materials suppliers should be added due to their close relationship with contractors. Prior to distributing the survey in North Carolina it was predicted that few contractors would be able to complete this section, due to the small number of CEB projects in the region.

General Demographics

This section contains multiple-choice questions that ask for the length of respondents' careers in construction, their primary area of construction expertise, number of projects completed annually, average number of people employed annually, and geographic region in which they perform the majority of their work. This last question is presented as a map of North Carolina with three regions: the Mountains, the Piedmont, and the Coastal Plain. Participants are asked to fill out a table with percentage values of work performed annually in each region, and are reminded that these values must add up to one hundred. For the survey distribution outside of North Carolina, this question was excluded. Instead, participants were asked where in they performed more than 50% of their work, and were given the following regions as choices: The Southeast (FL, AL, MS, LA, AR, SC, NC, TN, KY, WV), the Mid-Atlantic States (VA,

MD, DE, PA, DC), the Northeast (NJ, NY, CT, RI, MA, VT, ME, NH), the Upper Midwest (ND, SD, NE, MN, IO, WI, MI, IL, IN, OH), the Lower Midwest (MO, KS, OK), the Mountain West (CO, WY, MT, ID, UT), the Southwest (AZ, NM, TX), the West Coast (NV, CA, OR, WA, AK, HI), or anywhere outside of the continental U.S.

Institutional Review Board (IRB) Approval

The survey used in this study was sent to the Research Integrity and Compliance Review Office (RICRO) for approval before being piloted in New Mexico and was originally considered exempt from the regulations laid out in 45 CFR 46.101(b)(2). However, when the researcher decided to conduct phone interviews after two survey distributions, RICRO was contacted once again with a revised study protocol which was approved. This study maintains the confidentiality of all respondents and was perceived by the IRB as posing only a minimal risk.

Data Analysis

Frequencies, mean, median, and mode were examined. Mean values and response distribution from respondents with no CEB experience were examined to identify any differences in their perception between non-conventional materials and CEB. Independent samples t-tests were also performed to determine if any significant difference exists in perception of non-conventional materials and CEB between respondents with no CEB experience and those who had worked with the material. The researcher worked closely with select faculty in the Warner College of Natural Resources to ensure as thorough and complete an analysis of the data as possible.

In addition to collecting and analyzing quantitative data, two interviews were conducted with construction professionals who had worked with CEB to determine if their responses align

with the conclusions of researchers who have studied earthen materials and the barriers preventing their acceptance and adoption in the U.S and elsewhere.

Expected Outcomes

This study was intended to provide a stepping stone for further research into perception barriers hindering the adoption of CEB and other non-conventional materials in Southeastern states, and will shed light on the perception of CEB among contractors working the Piedmont. Additionally, it will help reveal potential biases against the material, if any exist. Researching these perception barriers will allow residential contractors throughout the Southeastern United States to understand and address the misgivings of customers and builders who are unfamiliar with earth building, or who doubt the safety and durability of earth construction.

CHAPTER IV: FINDINGS AND DISCUSSION

Data was gathered through the use of an electronic survey. The content of this survey was shaped entirely by the research questions posed in Chapter I, and was designed to determine if respondents' perception of non-conventional materials differed from their perception of CEB, or if any correlations exist between their experience with CEB and their perception of the efficacy and cost-effectiveness of non-conventional materials and CEB.

E-Survey Incentivization and Distribution

After experiencing a low response rate when piloting the survey in New Mexico, the researcher decided to incentivize participation in the study by giving participants in both survey distributions an opportunity to win one of three Amazon.com gift cards, valued at twenty dollars each (Appendix B). Once the e-survey was incentivized, it was distributed to ten home building associations (HBAs) in the ten largest cities in the North Carolina Piedmont region. These HBAs were instructed to forward the survey and survey instructions to their members and anyone in their HBA network in the Piedmont. This encouragement was provided in order to maximize the sample population.

This survey was then modified for a second distribution to four construction professionals in the researcher's network (please see the "Prior Experience with CEB" and "General Demographics" sections of Chapter III for more detail), who live and work in different parts of the United States and were selected for their experience building with CEB and studying it.

E-Survey Results

Response Rates

The North Carolina Piedmont e-survey was left open for five weeks and yielded 31 responses. Seven of these were incomplete and subsequently discarded, leaving a final Piedmont sample of 24. The second distribution was left open for four weeks and yielded six responses, all of which were complete and usable, rendering a final sample population of 30 respondents. The Piedmont e-survey was sent to HBAs and not directly to contractors. The second survey was a snowball sample. Thus, in both distributions it is difficult, if not impossible, to determine an exact response rate without entering into speculation.

The response rate for the second e-survey distribution was low in part because the four initial participants were the only people in the researcher's professional network with any experience working with CEB. Though they were strongly encouraged to forward the survey to their colleagues, an initial sample of four is small and may have limited the total number of viable responses received.

Several explanations for such low response rates among Piedmont contractors may lie in demographic data provided by respondents, one of which was company size by number of employees shown in Figure 1.

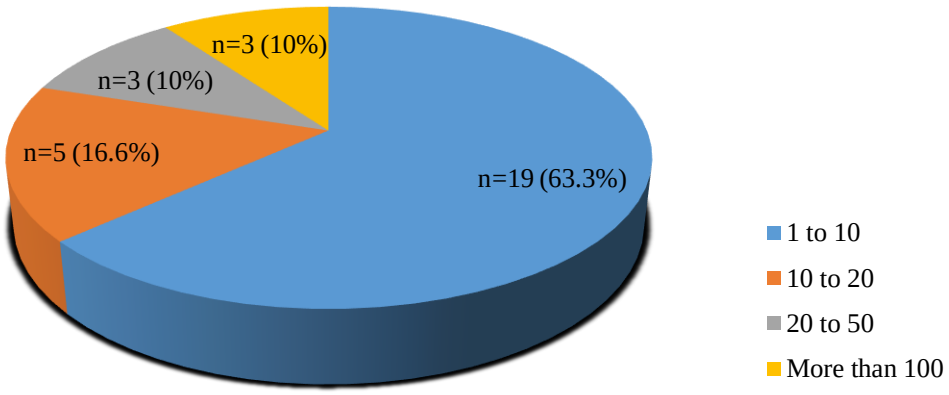

Figure 1: Size of Respondents' Businesses by Number of Employees (n=30)

The majority of respondents' reported either working for or owning construction companies with one to ten employees. Eighty percent, or 24 of 30 responses, came from contractors with 20 or fewer employees. While a contractor's employee roster is not the only measurement of its size, it can be assumed that construction companies with less labor power at their disposal may not have the same level of access to valuable resources, including time, that larger companies might enjoy. The small size reported by the majority of respondents may have also been compounded by poor timing on the part of the researcher. The e-survey was distributed in late winter, and according to the National Oceanic and Atmospheric Administration (NOAA, 2014) the winter of 2014-2015 was unusually harsh in the Eastern and Southeastern U.S., with record low temperatures recorded from New York to Houston (Erdman, 2014). Smaller construction companies have more difficulty absorbing unforeseen shocks, including delays due to inclement weather. This may have made it difficult for smaller contractors who received the survey to find the time to respond.

The size of these contractors is further revealed when their reported area of expertise, illustrated in Figure 2, is taken into account.

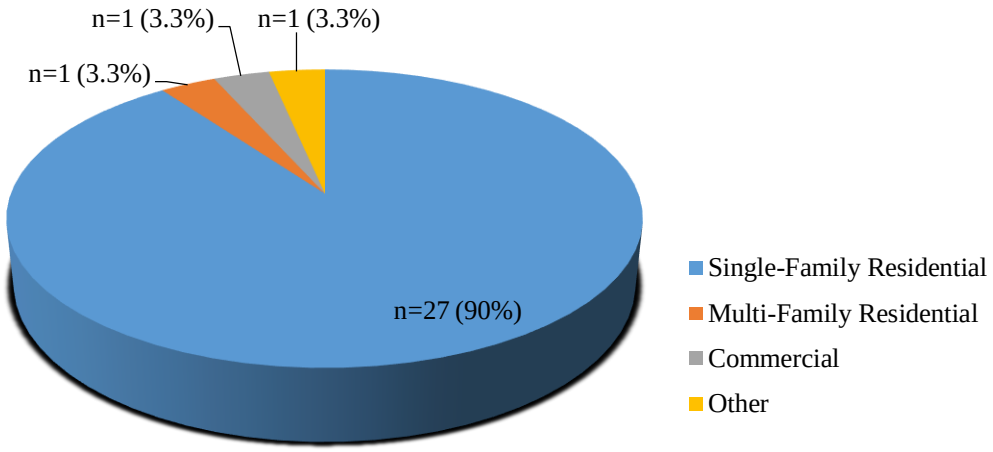

Figure 2: Respondents' Primary Area of Construction Expertise (n=30)

The majority of respondents specialized in single-family residential construction. The Piedmont survey distribution, which yielded 24 complete responses or 80% of the total sample, targeted contractors affiliated with HBAs, making this result fairly predictable. Given that 24 of 30 respondents came from contractors that employed 20 or fewer people and that 27 of 30 respondents specialized in single-family residential construction, the researcher assumed that the majority of respondents were smaller residential contractors with temporal and monetary margins that may have limited their ability to respond to the e-survey.

Other demographic data collected included the length of respondents' careers and average number of projects completed annually, illustrated respectively in Figures 3 and 4.

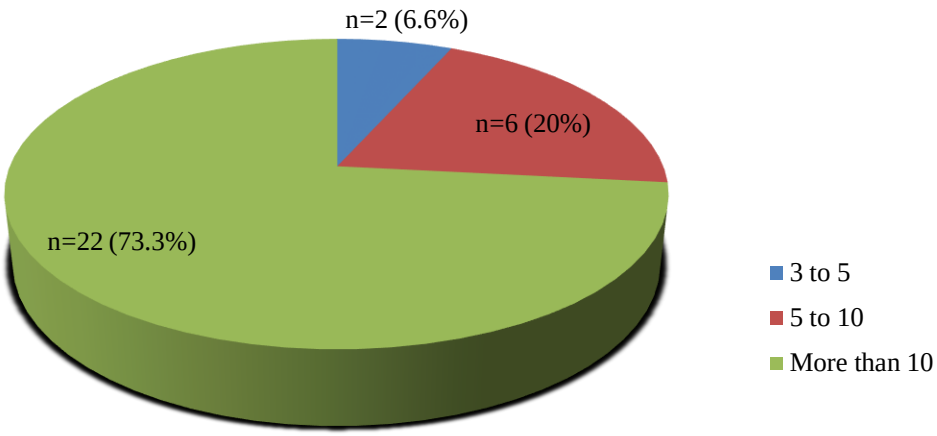

Figure 3: Length of Respondents' Careers as Licensed Contractors

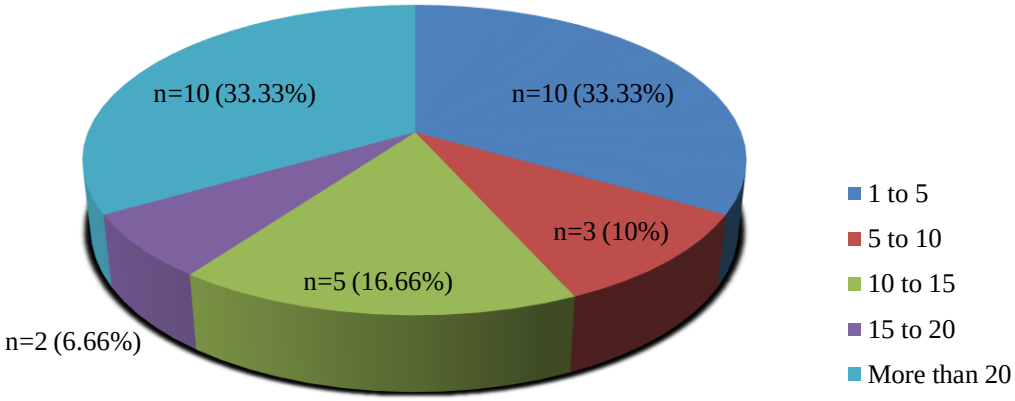

Figure 4: Average Number of Projects Completed Annually by Respondents

The majority of respondents (22 of 30) reported at least ten years of work as licensed contractors, with only two respondents reporting 5 years or fewer of licensed work. The distribution of contractors by number of projects completed was fairly lopsided, with ten

respondents completing 5 or fewer projects per year, ten respondents completing more than 20 projects per year, and the remaining respondents falling somewhere between these two extremes.

Piedmont Contractors' Perception of Non-Conventional Materials

The majority of the quantitative data collected with the survey instrument came from two sections, each with nine statements. The first section assessed contractors' perception of non-conventional materials, and the second section gauged their perception of CEB. For each question, participants were asked to indicate their agreement with a statement using a five-point scale. Table 2 summarizes responses from North Carolina Piedmont contractors.

It should be noted that, while 28 complete responses were recorded for this section of the survey, 24 respondents completed the survey in its entirety, including the second five-point scale section focusing on CEB. Data collected from the 4 respondents who did not complete the entire survey was discarded when survey responses from those with no exposure to CEB were compared with those with CEB experience.

Table 2: ***Perception of Non-Conventional Materials Among Piedmont Contractors*** **(*n*=28)**

Statement	1	2	3	4	5	Mean
Contractors should play a role in shaping their clients' perception of building materials.	0	0	1	15	12	4.39
I would invest training in building with non-conventional materials, given adequate client demand.	0	0	6	19	3	3.89
Most non-conventional building materials are not cost effective.	0	2	12	9	5	3.61
Non-conventional building materials are going to become more prevalent in the next decade.	0	3	11	12	2	3.46
Clients should play a role in shaping contractors' perception of building materials.	0	2	16	7	3	3.39
Existing building codes make non-conventional materials too difficult to use.	0	4	11	13	0	3.32
My interest in a building material is directly proportional to the interest of my clients.	2	11	4	9	2	2.93
I would invest training in building with non-conventional materials, regardless of client demand.	0	13	6	9	0	2.86
Regardless of client demand, I would not invest in training for building with non-conventional materials.	8	12	6	2	0	2.07

Note: Scores were measured on a 5-point scale: 1=Strongly Disagree, 2=Disagree, 3=Neither Agree Nor Disagree, 4=Agree, 5=Strongly Agree

The first statement, "Contractors should play a role in shaping their clients' perception of building materials," yielded a mean score of 4.39 among Piedmont contractors, with 15 respondents agreeing and 12 respondents strongly agreeing. This suggests that this respondent group shares the belief that contractors have a responsibility to promote certain materials or discourage their use, depending on their perception of the materials' value. The statement "I would invest training in building with non-conventional materials, given adequate client demand" yielded a mean score of 3.89, with 19 respondents agreeing and no respondents disagreeing or strongly disagreeing. This result suggests that these respondents do not actively oppose training in non-conventional materials. Finally, the statement "Regardless of client

demand, I would not invest in training for building with non-conventional materials" yielded a mean score of 2.07, with 12 respondents disagreeing and eight strongly disagreeing. Again, this demonstrates a lack of active opposition to training in non-conventional materials among contractors with no CEB experience. Beyond that, it would be difficult to draw any conclusions about their perception of non-conventional materials or the perception of these materials among all North Carolina Piedmont contractors.

Piedmont Contractors' Perception of CEB

The second section of scaled questions was designed to gauge respondents' perception of CEB to determine if contractors perceived it differently than other non-conventional materials. Table 3 shows the distribution of their responses.

Table 3: ***Perception of CEB Among North Carolina Piedmont Contractors*** **(*n*=24)**

Question	1	2	3	4	5	Mean
My clients are not aware of CEB.	0	0	6	7	11	4.25
There are very few, if any, CEB subcontractors in my state.	0	0	5	10	9	4.17
Contractors in my state are not aware of CEB.	0	0	9	8	7	3.96
Contractors in my state are not interested in building with CEB.	0	0	15	7	2	3.50
CEB is more environmentally friendly than conventional materials.	1	0	13	9	1	3.46
Existing building codes in my state make building with CEB too difficult.	0	1	18	4	1	3.21
CEB is visually attractive.	0	2	18	4	0	3.13
CEB is cheaper than conventional materials.	1	2	20	1	0	2.92
CEB buildings are structurally unsafe	0	7	17	0	0	2.79

Note: Mean scores are measured on a 5-point scale: 1=Strongly Disagree, 2=Disagree, 3=Neither Agree Nor Disagree, 4=Agree, 5=Strongly Agree

Slightly more than half of respondents either agreed or strongly agreed with the statement "Contractors in my state are not aware of CEB," with 18 respondents either agreeing or strongly

agreeing with the statement "My clients are not aware of CEB" and 19 respondents either agreeing or strongly agreeing that "There are very few, if any, CEB subcontractors in my state." Statements regarding CEB's cost-effectiveness, its visual attractiveness, its reputation among North Carolina contractors, its structural worthiness, and its ease of use under current building codes were met primarily with neutral responses. Taken together, these responses indicate that respondents did not harbor any active opposition to CEB, but rather that they may not have known enough about it to make definitive positive or negative statements. This is supported by the mean scores for statements related to CEB's physical properties and aesthetic appeal, all of which were very close to 3.00, "Neither Agree nor Disagree."

The Effect of Experience on the Perception of Non-Conventional Materials

One of the primary objectives of this study was to assess whether contractors' perception of non-conventional materials changes with exposure to CEB construction. An independent samples T-test was performed to determine any potential changes in perception between respondents with CEB experience and those with no exposure to the material. Results are shown in Table 4. Any differences in mean scores between Table 3 and Table 4 from respondents with no CEB experience are due to the removal of data from four respondents who did not complete the North Carolina Piedmont survey in its entirety.

Table 4: ***Effect of Experience on Respondents' Perception of Non-Conventional Materials (n=30)***[1]

Statement	Experience with CEB		*t*-Value	*p*-Value[2]	Eta[3]
	Yes (n=6) (M)	No (n=24) (M)			
Most non-conventional building materials are not cost effective.	1.83	3.63	-3.491	0.011	0.607
I would invest training in building with non-conventional materials, regardless of client demand.	3.83	2.75	2.495	0.019	0.427
Regardless of client demand, I would not invest in training for building with non-conventional materials	3	1.87	1.602	0.164	0.418
Clients should play a role in shaping contractors' perception of building materials.	4.33	3.42	2.427	0.022	0.417
Non-conventional building materials are going to become more prevalent in the next decade.	4.17	3.58	1.488	0.148	0.271
I would invest training in building with non-conventional materials, given adequate client demand.	4.33	4	0.954	0.377	0.232
Contractors should play a role in shaping their clients' perception of building materials.	4.33	4.46	-0.358	0.733	0.089
Existing building codes make non-conventional materials too difficult to use.	3.33	3.25	0.243	0.81	0.046
My interest in a building material is directly proportional to the interest of my clients.	3	2.88	0.227	0.822	0.043

1. Mean scores are measured on a 5-point scale: 1=Strongly Disagree, 2=Disagree, 3=Neither Agree Nor Disagree, 4=Agree, 5=Strongly Agree

2. *p*-value ≤ 0.05 is considered significant.

3. Eta $\leq .10$ is minimal; Eta = .243 is typical; Eta $\geq .371$ is considered substantial.

Several of these statements generated noticeable differences in perception of non-conventional materials, based on an examination of mean scores and Eta values, also known as the effect size (substantial at or above 0.371). The most striking difference in perception of non-conventional materials can be found in the in mean scores and effect size for the statement "Most non-conventional building materials are not cost-effective." Respondents with CEB experience provided a mean response of 1.83 while respondents with no CEB experience reported an average response of 3.63, with an effect size of .607. The statements "Clients should play a role

in shaping contractors' perception of building materials"; "I would invest in non-conventional materials regardless of client demand"; and "Regardless of client demand, I would not invest in training for building with non-conventional materials" also generated statistically substantial effect sizes of .417, .427, and .418 respectively.

The Effect of Experience on the Perception of CEB

Another objective of this study was to ascertain whether contractors' perception of CEB changes depending on their familiarity with the material. An independent samples t-test was performed to reveal differences in perception of CEB between respondents who had used it and respondents who had not. The results of this analysis are shown in Table 5 below.

Table 5: ***Effect of Experience on Respondents' Perception of Compressed Earth Block (n=30)***[1]

Statement	Experience with CEB		*t*-Value	*p*-Value[2]	Eta[3]
	Yes (n=6) (M)	No (n=24) (M)			
CEB buildings are structurally unsafe	1.50	2.79	-4.082	.000	.611
CEB is visually attractive.	4.00	3.13	3.112	.004	.507
My clients are not aware of CEB.	3.17	4.25	-3.017	.005	.495
Existing building codes make non-conventional materials too difficult to use.	2.67	3.21	-1.065	.331	.290
Contractors in my state are not interested in building with CEB.	3.00	3.50	-1.549	.133	.281
Contractors in my state are not aware of CEB.	3.50	3.96	-1.237	.226	.228
CEB is more environmentally friendly than conventional materials.	3.83	3.46	1.003	.325	.186
There are very few, if any, CEB subcontractors in my state.	4.33	4.17	.505	.618	.095
CEB is cheaper than conventional materials.	2.83	2.92	-.201	.848	.056

1. Mean scores are measured on a 5-point scale: 1=Strongly Disagree, 2=Disagree, 3=Neither Agree Nor Disagree, 4=Agree, 5=Strongly Agree

2. p-value ≤ 0.05 is considered significant.

3. Eta $\leq .10$ is minimal; Eta = .243 is typical; Eta $\geq .371$ is considered substantial

Several statistically significant differences in respondents' perception of CEB can be observed based on the results of this analysis. The statement "CEB is visually attractive" garnered a mean response of 4.00 from respondents with CEB experience and 3.13 from those with no exposure to it, with an effect size of .507. The more favorable perception of CEB's visual attractiveness from respondents with experience may be due to a preexisting bias for the material's physical appearance, or it may be have been shaped by their experience with the material. The statement "My clients are not aware of CEB" also produced an effect size of .495. There are several possible explanations for this difference in perception. One may be that respondents who have built with CEB maintain a client base that is more likely to self-educate and seek out non-conventional materials. Another potential explanation is that respondents with CEB experience have gone out of their way to educate their clients on the material's strengths and drawbacks.

The greatest difference in perception can be seen in responses to the statement "CEB buildings are structurally unsafe." Respondents with no CEB experience reported a mean score of 2.79, indicating neutrality to slight disagreement, while respondents with exposure to the material reported a mean score of 1.50, indicating disagreement to strong disagreement. This statement also produced an effect size .611. These results indicate that respondents with no CEB experience do not necessarily oppose its use based on safety or engineering concerns, but that they do not know enough about the material to make a definitive positive or negative statement. Conversely, these results indicate that experience building with CEB may have positively altered respondents' perception of its strength and structural integrity.

Word-Association Responses

In addition to collecting quantitative data through the use of scaled statements, respondents were asked to provide the first three words they associate with the term "compressed earth block." The use of word-association was inspired by the research of Francis and Prosser (2012) and was included to allow respondents to express their opinions without being constrained by a multiple-choice format. Responses are shown below in Table 6.

Table 6: ***Words Respondents Associated with the Term "compressed earth block" (n=30)***

Respondents with CEB Experience	Respondents with No CEB Experience
Masonry, labor-intensive, earth-friendly	Low-Impact, Localism, Niche
Warm, cool, healthy	CMU, green, future
Adobe, bricks, mud	Environmental, brick, mud
Fireproof, breathable, non-toxic	Adobe, Africa, mud
Slow, bugs, dirty	Soluble, temporary, mud
Dirt, non-cementitious, heavy	dirt, unknown, foundation
	Natural
	Never heard of it[1]
	Pressed, machine-made, strong
	Adobe, rural, untested
	Uncommon, new, trouble
	Natural, sustainable, unknown
	Have not used
	Unconventional building materials
	Dirt, water, compressed
	Green, costly, unproven
	Do not know
	Green, untested, costly
	Bricks, mud, third-world
	Mud, heavy, renewable
	Hippie, green, nonconventional
	Blocks made of dirt
	Dirt, clay, weight

1. Two respondents provided "never heard of it" as an answer. One of these responses was omitted from this table for brevity.

Responses to this question bolstered the quantitative trends and revealed a divergence in both knowledge and perception of CEB between the two respondent groups. Respondents with no CEB experience used words like "Never heard of it," "Have not used," and "Unknown."

These responses indicate a lack of knowledge of CEB. Some respondents used words that suggest a negative perception of the material, such as "trouble," "unproven," "untested," "temporary," and "costly." Other respondents in the same group used words like "green," "low-impact," "sustainable," "natural," "renewable," and "environmental." Others associated the material with "Adobe," "Africa," "third-world," and "rural."

Respondents who had worked with CEB associated the material with its technical and physical properties, using words like "fireproof," "breathable," "non-toxic," "non-cementitious," "heavy," and "labor-intensive." Positive words like "earth-friendly" "warm," and "healthy" were also recorded. "Dirt," "mud," "bricks," and "Adobe" were provided from respondents in both groups.

Interview Responses

Data collected from two survey distributions was augmented through two telephone interviews with construction professionals who have experience building with CEB. Both interview subjects were read a short script informing of their rights as interviewees (see Appendix E) prior to their respective interviews. Both subjects also consented to having their names and the names and geographical locations of their respective businesses published in this study. Both interview subjects were asked the same set of open-ended questions (see Appendix F), and their responses were transcribed by the researcher. For full transcripts of both interviews, please see Appendices G and H.

Jeff Gannon, Green Door Design-Build and DIG Southeast

The first telephone interview was with Jeff Gannon, owner of Green Door Design-Build, a residential contracting company located in Pittsboro, North Carolina, represented by the star-shaped mark in Figure 5 below.

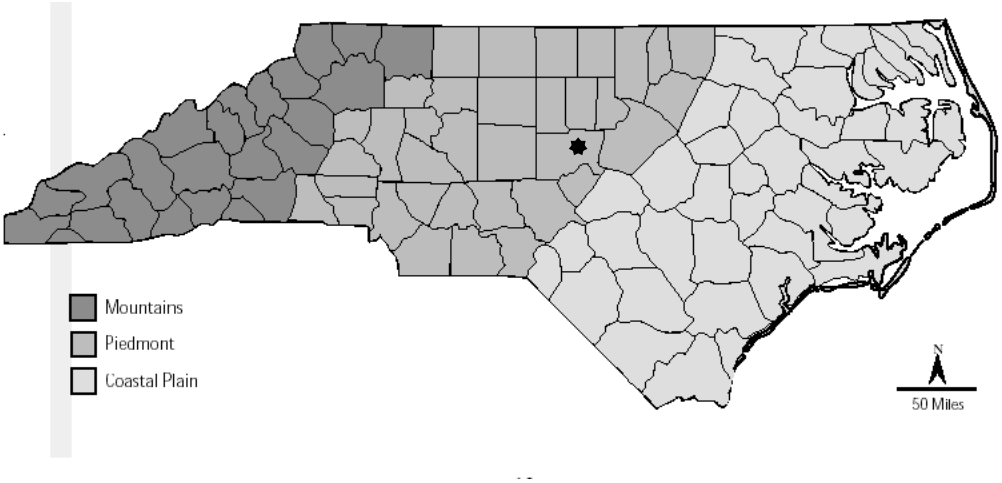

Figure 5: Location of Pittsboro, North Carolina

(Image taken from: http://www.secretary.state.nc.us/images/region1.gif)

Mr. Gannon, who has worked as a licensed general contractor for roughly seven years and currently employs three people, is also the owner of DIG Southeast, a subcontractor that manufactures CEB. At the time of the interview he had completed 2 CEB projects and was halfway through a third project. All of these projects are located in the North Carolina Piedmont and all were private residences.

After providing demographic data related to his businesses, Mr. Gannon was asked to describe his experience building with CEB. He mentioned three major obstacles to CEB construction that he had encountered: A limited number of subcontractors that are familiar with CEB construction; additional time required to educate laborers, subcontractors, and building inspectors; and inclement weather. He added that had encountered difficulty during various building inspections due to building inspectors' unfamiliarity with the material. "One visit from

an inspector would turn into two," as he put it. He also pointed out that he had generally been met with caution and curiosity from building inspectors and code officials, rather than open hostility, and that their caution abated considerably once they saw an engineer's stamp on the construction documents.

Mr. Gannon reported a positive response from his clients who have purchased CEB homes, with improved sound dampening and indoor air temperature regulation constituting the bulk of the positive feedback he has received. He pointed out that his interest in CEB was driven by both client demand and an independent interest in the material. "I could see the potential demand and absence of availability. Given those two factors, I thought it was worthy to jump in and provide a viable alternative to conventional construction." He also reported interest in the material from custom homebuilders who were curious about CEB but unfamiliar with its properties. Mr. Gannon noted, "It's funny because there's 800 years of quantifiable data on earth building. People don't always get that unless it's explained to them."

When asked what he perceived to be the biggest obstacles to the adoption of CEB in North Carolina and how those obstacles may be overcome, Mr. Gannon replied, "I think it's going to take education and exposure to catch on. That's all it's gonna take. The material will take care of itself. People just to learn about it and remove their misconceptions of what it is." He concluded the interview by pointing out that the simplicity of CEB is an asset to contractors who are teaching subcontractors or prospective homeowners how to build with the material. In his words, "It's not a complex material. You're able to teach someone how to build a house in half a day."

Lawrence Jetter, Advanced Earthen Construction Technologies

Lawrence Jetter is the President and CEO of Advanced Earthen Construction Technologies (AECT), a CEB press manufacturer located in San Antonio, Texas. Mr. Jetter has owned and operated AECT for 26 years and has worked as a builder, block manufacturer, and consultant for residential CEB projects. He has also sold his CEB presses to the U.S. military for use overseas, and is currently filling out orders for presses to be sent to Somalia and Sudan. He currently has five employees and works primarily in the San Antonio metro area, shown in Figure 6 below.

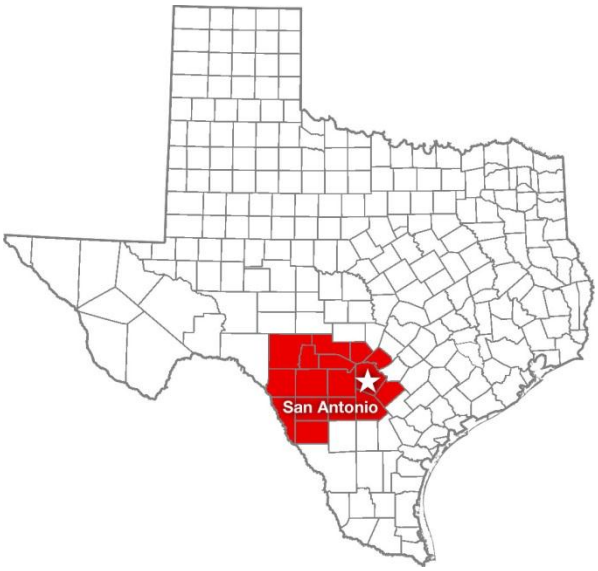

Figure 6: Location of San Antonio, Texas

(Image taken from: http://www.austinpump.com/images/sanantonio-full.jpg)

When asked to describe his experience working with CEB, Mr. Jetter said that he loved it but that the ability of contractors and homeowners to use it has been hampered by mistrust from architects and engineers. He observed that a fixation on concrete, steel, and wood has caused the construction industry to "[lose] sight of what's proven," referencing the long history of earth-building in the American Southwest. He added that CEB is a direct competitor with concrete, an

industry with a vested interest in maintaining its position as a major material supplier in both residential and commercial construction.

Mr. Jetter reported some initial mistrust from building inspectors but said that they, along with code officials, contractors, and architects who attended CEB training sessions offered by AECT, were "blown away" by the material. He reported a strong positive response from his clients, with home energy savings being the greatest source of positive feedback. Conversely, when asked how his peers have responded to his focus on CEB, he replied "Everybody thinks I'm crazy for doing this." He speculated that this may be because his peers in the construction industry do not understand the environmental and economic benefits of CEB dwellings to owners.

When asked what motivated his interest in CEB, Mr. Jetter responded that he initially pursued the material as a business decision, but that over time he "became a believer [and] a student of it." He went on to say that the biggest obstacle he had faced in his career were people who were skeptical of the material and that exposing them to CEB is the key to overcoming these negative perceptions:

> You go in there and build something. Let people touch it, feel it, experience it. People will go nuts for it. I should point out that building with CEB is a little slower than conventional construction, but if you build correctly it'll last. Training in how to build properly is important, too. Pay subcontractors by the block. That's why we require that, if you buy an AECT machine, you come to San Antonio and we train you, on building techniques, soils science and soil mixtures, etc. If you don't do the training, then we don't offer a warranty on the machine. That's how important the training is. The military sends 4-5 people for the machines they buy.

He concluded the interview by emphasizing the importance of training and education, particularly for engineers, architects, building inspectors, and contractors.

Chapter Summary

This study offers insight into the perception of non-conventional materials among a sample population of contractors, and how their perception of these materials differs from their perception of CEB. This study also illustrates how these perceptions are changed or altered with exposure to CEB in professional practice. Finally, this chapter sheds light on the experiences and perceptions of two construction professionals who have built with CEB and studied its properties. Chapter V offers a discussion of the results of these interviews, as well as relevant conclusions that can be drawn from the data collected from two survey distributions.

CHAPTER V: CONCLUSIONS AND RECOMMENDATIONS

The primary objective of this study was to study the perception of CEB among contractors in the Piedmont and determine whether their perception was acting as a non-technical barrier to CEB's acceptance and adoption in residential construction. A survey instrument was developed and piloted in New Mexico. This survey was further refined and distributed in North Carolina, and then to select contacts within the researcher's network who had experience working with CEB. Data gathered from both of these distributions were analyzed to determine Piedmont respondents' perception of CEB and what, if any, correlations existed between their experience with the material and their perception of its efficacy and value. This analysis of survey data was supplemented by two telephone interviews with building professionals who were familiar with CEB and had experience building with it.

The significance of this study, its limitations, and its implications for future research are discussed in this chapter. Final remarks are also included. This research is valuable in understanding the interaction between contractors' experience with non-conventional materials like CEB and their perception of their efficacy and value. Additionally, this study sheds light on how North Carolina contractors' perception of CEB impacts its acceptance among homebuilders and prospective homeowners in a particular region of the state.

Importance of the Study

Identifying non-technical barriers to the acceptance and adoption of CEB in the Piedmont allows contractors to better understand the strengths and weaknesses of the material, rather than relying on second-hand information and assumptions. Identifying these barriers also allows consumers to work with contractors and make building material decisions that are not driven by

bias, misperception, or lack of awareness. CEB possesses both strengths and weaknesses and is certainly not perfect for every project, client, or climate. Nevertheless, it may offer an alternative to conventional materials in residential construction. Further, the collection of factors in the Piedmont, primarily the soil profile and availability of labor and time-saving technology, make CEB a potentially viable choice for North Carolinians who wish to avoid energy-intensive materials like steel and concrete.

Addressing the Survey Results

This study was undertaken to determine what, if any, non-technical barriers were preventing the acceptance and adoption of CEB in the Piedmont region of North Carolina, and whether or not these barriers were related to contractors' perception of CEB as a viable building material. The results of two survey distributions show a divergence of opinion of the cost-effectiveness of non-conventional materials between respondents who had worked with CEB and those who were unfamiliar with the material.

An examination of the mean scores of the two respondent groups indicates that the surveyed contractors who had no experience building with CEB had a slightly negative perception of the cost-effectiveness of non-conventional materials and the value of non-conventional materials training. The statement "Most non-conventional materials are not cost-effective" generated an Eta value (effect size, substantial at 0.371 or greater) of 0.607. Respondents with CEB experience provided a mean response of 1.83 for this statement while respondents with no CEB experience reported a mean score of 3.63. These results indicate a sharp divergence in the perception between the two respondent groups, and would suggest that respondents with first-hand experience working with CEB have a more positive opinion of the

cost-effectiveness of non-conventional materials in general. This may be due to real-world exposure to construction schedules and estimates that take the cost of such materials into account. Similarly, respondents who had worked with CEB provided a mean score of 3.83 for the statement "I would invest in non-conventional materials regardless of client demand," with a mean score of 1.87 for respondents who had no CEB experience and an effect size between the two respondent groups of .427. This result suggests that respondents with CEB experience may have either sought out the material due to a preexisting independent interest and that this interest extends to other non-conventional materials, or that these respondents are more likely to seek out non-conventional materials after having worked with CEB.

An examination of the mean scores in Table 5 shows that respondents with no CEB experience did not share an overwhelming positive or negative perception of the material. The statement "CEB buildings are structurally unsafe" generated a mean score of 1.50 from respondents with professional experience working with CEB and 2.79 from respondents who had no CEB experience, with an effect size of .611 (the largest Eta value recorded in this study). A mean score of 2.79 is slightly below neutral and does not indicate a strong negative perception of CEB. However, the large effect size and the disparity in mean scores between the two respondent groups does indicate that respondents with CEB experience had a more positive perception of the material's safety and structural worthiness. Again this positive perception may have been preexisting or it may have been shaped by respondents' experience using the material in professional practice.

This absence of a shared perception of CEB among respondents with no experience using the material is reflected in the variation of words and phrases they associated with the term "compressed earth block" (Table 6). Some responses indicated a complete lack of knowledge of

the material, such as "do not know" and "never heard of it." Others provided words like "trouble" and "costly," indicating a negative perception of CEB. Some provided vague descriptors like "green," "environmental," and "hippie." Still others associated the term with "Africa," "rural," and "third-world," three responses suggesting an association with poverty and low social standing that is echoed in the research of Adam and Agib (2001), Ballerino (2002), and Hadjri et al (2007).

Responses from this word-association question and the two scaled statement sections do not show a shared positive or negative perception of CEB among this respondent group, confirming the researcher's hypothesis that the majority of surveyed contractors will not have a negative opinion of the material. Rather, they demonstrated that, with little or no first-hand knowledge of the material to rely on, respondents without CEB experience may not judge the material on its physical or technical properties and may have instead formed an opinion of its worth based on assumptions or viewed it through the lens of past experiences with other non-conventional materials. This becomes clearer when these responses are compared with those from respondents who have worked with the material. While limited conclusions can be drawn due to the low number of surveyed contractors with CEB experience (n=6), it is noteworthy that no one in this respondent group provided an overtly negative response. Additionally, their responses were either positive ("healthy," "earth-friendly," and "warm") or demonstrated an understanding of CEB's technical properties ("fireproof," "non-toxic," and "non-cementitious.")

Analysis of Telephone Interviews

Both interview subjects provided responses that reflect the conclusions of researchers who have studied barriers to the use of earthen materials in Africa, Asia, Europe, and the United

States. Both Mr. Gannon, a residential contractor and CEB subcontractor, and Mr. Jetter, a CEB press manufacturer, cited skepticism from their peers and lack of awareness in the construction industry and the general public as barriers to CEB uptake. Mr. Gannon and Mr. Jetter also repeatedly emphasized the importance of education and exposure to CEB in their efforts to overcome these non-technical barriers. These responses align with research conducted by Niroumond et al (2013), Kraus (2012), and Gooding and Thomas (1995), all of whom concluded that education and exposure are vital in promulgating earthen materials and dispelling misconceptions of their worth in the construction industry and among the general public. Furthermore, neither interview subject reported outright hostility from their peers, but rather caution and skepticism (both of which were abated when exposed to the material in either workshops or a jobsite setting). This further confirms the researcher's hypothesis that CEB may not face active hostility or opposition, but rather skepticism due to lack of awareness or exposure to the material.

Limitations

This cross-sectional study focused primarily on the perception of a niche material among members of a single profession in the construction industry. Moreover, the majority of respondents were located in one region of one state and specialized in residential construction. As such, their responses are not generalizable as the perception of CEB among contractors across the country, the perception of CEB among other construction industry professions, or the perception of CEB among commercial or industrial contractors. Additionally, the number of complete responses collected during both survey distributions was low (n=30), with six respondents having had any experience with CEB. This makes it very difficult to draw definitive

conclusions about the perception of the material among North Carolina contractors or building professionals elsewhere.

Future Research

This study was originally undertaken when the researcher discovered that the topic had not been examined in much of Europe, Asia, and the Americas, and was virtually unexplored in the Southeastern U.S. It is therefore necessary for other researchers to continue examining the effect of contractors' perception of CEB on its acceptance and adoption in southeastern states, where optimal soil exists and contractors have capital to invest in CEB equipment and training. These studies could target other professions to see if perceptions of CEB change depending on participants' roles in the construction industry. Architects and material suppliers, for instance, may have views that diverge from those held by contractors.

These future studies should be larger in both length and scope, perhaps covering all states with an identifiable piedmont region that lies directly east of the Appalachian Mountains. Future studies should also remain open for participation for several months, and should be distributed at the onset of warmer weather rather than the end of winter. This will help increase sample sizes and mitigate the effects of unforeseen inclement weather, schedule changes, dramatic increases or decreases in workload, and other unpredictable variables that make construction such a volatile profession.

Future research should also step outside of CEB and investigate whether the perceptions and opinions of contractors, architects, and engineers have helped or hindered acceptance and adoption of other non-conventional materials. Such studies could examine how these

perceptions change depending on the material, the market, building owners' income level, or the professions of study participants.

Final Remarks

Conventional building materials are flawed. Wood, for instance, is prone to moisture and termite damage. Steel and concrete are heavy, expensive, and require a tremendous amount of energy to manufacture. Yet these materials form the backbone of our commercial and residential building stock, while effective and environmentally benign non-conventional alternatives are marginalized, dismissed as impractical or costly, or simply ignored. In the face of rising global temperatures and precipitation levels (Mahlstein et al, 2013; Wentz et al, 2007; Hatzikiriakos and Englezos, 1993), it is imperative that alternatives to conventional materials be explored. However, it is equally important that these alternative materials be studied, subjected to testing, refined, and marketed like any other building material. It is this process that has allowed conventional materials to evolve over millennia, and it is the absence of this process that, in part, has hampered the widespread use of non-conventional materials like CEB.

For instance, had the construction industry focused only on the flaws of timber framing—its flammability, susceptibility to rot and termites, and limited service life—people may have been more likely to avoid it. Conversely, if advocates for CEB only focus on its strengths without addressing its shortcomings, then the material will not be able to evolve and gain widespread acceptance. As building professionals seek out information and educate themselves and their clients on the strengths and weaknesses of CEB and other non-conventional materials, more alternatives to energy-intensive materials and methods will become available and decisions will be made that do not rest on assumptions, second-hand testimony, or hearsay.

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APPENDICES

Appendix A: IRB Research Integrity & Compliance Review Office's Institutional Review Board Notice of Approval Form

Colorado State University
Knowledge to Go Places

Research Integrity & Compliance Review Office
Office of the Vice President for Research
321 General Services Building - Campus Delivery 2011 Fort Collins, CO
TEL: (970) 491-1553
FAX: (970) 491-2293

NOTICE OF APPROVAL FOR HUMAN RESEARCH

DATE:	May 22, 2015
TO:	Valdes Vasquez, Rodolfo, 1584 Cnstr Mgmt Hughes, Evan, 1584 Cnstr Mgmt, Khattab Mostafa, 1584 Cnstr Mgmt
FROM:	Swiss, Evelyn, Coordinator, CSU IRB 2
PROTOCOL TITLE:	Identifying Perception Barriers that are Preventing the Acceptance of Compressed Earth Block in Residential Construction
FUNDING SOURCE:	NONE
PROTOCOL NUMBER:	15-5868H
APPROVAL PERIOD:	Approval Date: May 22, 2015 Expiration Date: May 15, 2016

The CSU Institutional Review Board (IRB) for the protection of human subjects has reviewed the protocol entitled: Identifying Perception Barriers that are Preventing the
Acceptance of Compressed Earth Block in Residential Construction. The project has been approved for the procedures and subjects described in the protocol. This
protocol must be reviewed for renewal on a yearly basis for as long as the research remains active. Should the protocol not be renewed before expiration, all activities must cease until the protocol has been re-reviewed.

If approval did not accompany a proposal when it was submitted to a sponsor, it is the PI's responsibility to provide the sponsor with the approval notice.

This approval is issued under Colorado State University's Federal Wide Assurance 00000647 with the Office for Human Research Protections (OHRP). If you have any questions regarding your obligations under CSU's Assurance, please do not hesitate to contact us.

Please direct any questions about the

IRB's actions on this project to: IRB

Office - (970) 491-1553;

RICRO_IRB@mail.Colostate.edu
Evelyn Swiss, IRB Coordinator - (970) 491-1381; Evelyn.Swiss@Colostate.edu

Evelyn Swiss

Swiss, Evelyn

Approval is to recruit up to 10 participants with the approved verbal script. Because of the nature of this research, it will not be necessary to obtain a signed consent form. However, all subjects must be consented using the approved verbal script. The requirement of documentation of a consent form is waived under § _ _.117(c)(2).

Approval Period: May 22, 2015 through May 15, 2016

Review Type: EXPEDITED

IRB Number: 0000020

Appendix B: IRB Research Integrity & Compliance Review Office's Institutional Review Board Approval for Incentivization of Survey Instruments

Research Integrity & Compliance Review Office Office of Vice President for Research Fort Collins, CO 80523-2011
(970) 491-1553
FAX (970) 491-2293

DATE: February 19, 2015

TO: Rodolfo Valdes Vasquez, Construction Management
Evan G. Hughes, Construction Management

FROM: IRB Coordinator, Research Integrity & Compliance Review Office
(RICRO_IRB@mail.colostate.edu)

TITLE: Identifying Perception Barriers that are Preventing the Acceptance of Compressed Earth Block in Residential Construction in New Mexico and North Carolina

IRB ID: 144-15H **Review Date:** February 19, 2015

This project is valid for three years from the review date.

The Institutional Review Board (IRB) Coordinator has reviewed the following modifications of this project:

1. Addition of incentive (raffle of 3 $20 Amazon gift cards) for participants. Updated consent cover, survey and exemption request to reflect this change.

and has declared the study remains exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b). The IRB determination of exemption means that:

- You do not need to submit an application for annual continuing review.
- You must carry out the research as proposed in the IRB application, including obtaining and documenting (signed) informed consent if stated in your application or if required by the IRB.
- Any modification of this research should be submitted to the IRB through an email to the RICRO IRB Coordinator (RICRO_IRB@mail.colostate.edu), prior to making any changes, to determine
  if the project still meets the Federal criteria for exemption. If it is determined that exemption is no longer warranted, then an IRB proposal will need to be submitted and approved before proceeding with data collection.

- Please notify the IRB (RICRO_IRB@mail.colostate.edu) if any problems or complaints of the research occur.

Please note that you must submit all research involving human participants for review by the IRB. **Only the IRB may make the determination of exemption**, even if you conduct a similar study in the future.

Appendix C: Survey Instrument

(For further detail on survey development, see the "General Demographics" in Chapter III).

Compressed Earth Block Survey

This survey examines your views on Compressed Earth Block (CEB). Responses will be published in aggregate form and kept strictly anonymous. Thank you in advance for completing the survey.

1. To what extent do you agree or disagree with each of the following statements?
Please circle one number for each statement.

NOTE: The term "non-conventional" is defined as any building material other than timber-frame, steel stud, concrete, CMU, or fired brick.

Statement	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
Contractors should play a role in shaping their clients' perception of building materials.	1	2	3	4	5
Clients should play a role in shaping contractors' perception of building materials.	1	2	3	4	5
My interest in a building material is directly proportional to the interest of my clients.	1	2	3	4	5
Most non-conventional building materials are not cost effective.	1	2	3	4	5
I *would invest* training in building with non-conventional materials, *given adequate client demand*.	1	2	3	4	5
I *would invest* training in building with non-conventional materials, *regardless of client demand*.	1	2	3	4	5
Non-conventional building materials are going to become more prevalent in the next decade.	1	2	3	4	5
Regardless of client demand, I *would not invest* in training for building with non-conventional materials.	1	2	3	4	5
Existing building codes make non-conventional materials too difficult to use.	1	2	3	4	5

2. What are the first 3 words that you associate with the term "Compressed Earth Block (CEB)?"

_____ _____ _____

3. To what extent do you agree or disagree with the following statements?
Please circle one number for each statement.

***NOTE**: The term "conventional" refers to timber-frame, steel-stud, CMU, concrete, or fired brick construction.*

	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
CEB is cheaper than conventional materials.	1	2	3	4	5
CEB is more environmentally friendly than conventional materials.	1	2	3	4	5
CEB is visually attractive.	1	2	3	4	5
Contractors in my state are not interested in building with CEB.	1	2	3	4	5
My clients are not aware of CEB.	1	2	3	4	5
Contractors in my state are not aware of CEB.	1	2	3	4	5
There are very few, if any, CEB subcontractors in my state.	1	2	3	4	5
CEB buildings are structurally unsafe	1	2	3	4	5
Existing building codes in my state make building with CEB too difficult.	1	2	3	4	5

4. Do you have any experience building with compressed earth block in residential construction projects?

____ No

____ Yes

If yes, how many projects?

a). 1-3 b). 3-5 c). 5-10 d). More than 10

If yes, what positions best categorize your involvement on CEB projects?

a). Company owner b). Laborer c.) Mechanical, electrical, or plumbing subcontractor

d.) CEB subcontractor e.) Project manager

6. How long have you been a licensed contractor?

a). 1-3 years b). 3-5 years c). 5-10 years d). More than 10 years

6b. What is your primary area of construction expertise?

a). Single-family residential b.) Multi-family residential c.) Commercial d.) Other

7. How many projects, on average, do you complete annually?

a). 1-5 b). 5-10 c). 10-15 d). 15-20 e). More than 20

8. How many people, on average, do you employ?

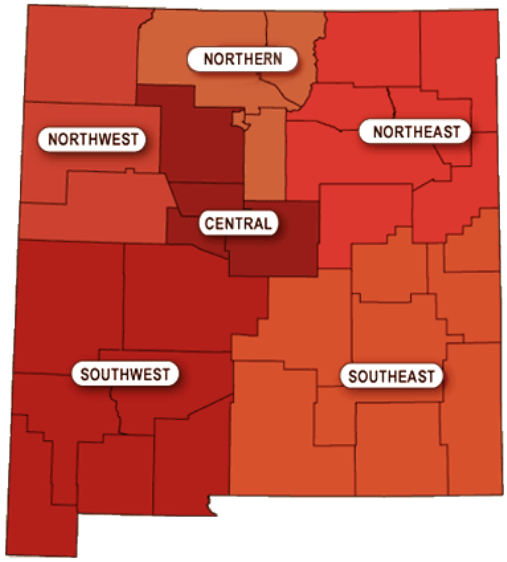
a). 1-10 b). 10-20 c). 20-50 d). 50-100 e). More than 100

9. Do you have comments about this survey that you would like to share? Please feel free to leave your feedback in the space provided below. Your response will be kept strictly anonymous.

10. Do you have any comments about CEB that you would like to share? Please feel free to leave your feedback in the space provided below. Your response will kept strictly anonymous.

Continued on next page…

11a. **For contractors in New Mexico:** Where do you perform the majority of your work? Please complete the table below, using the image provided below.

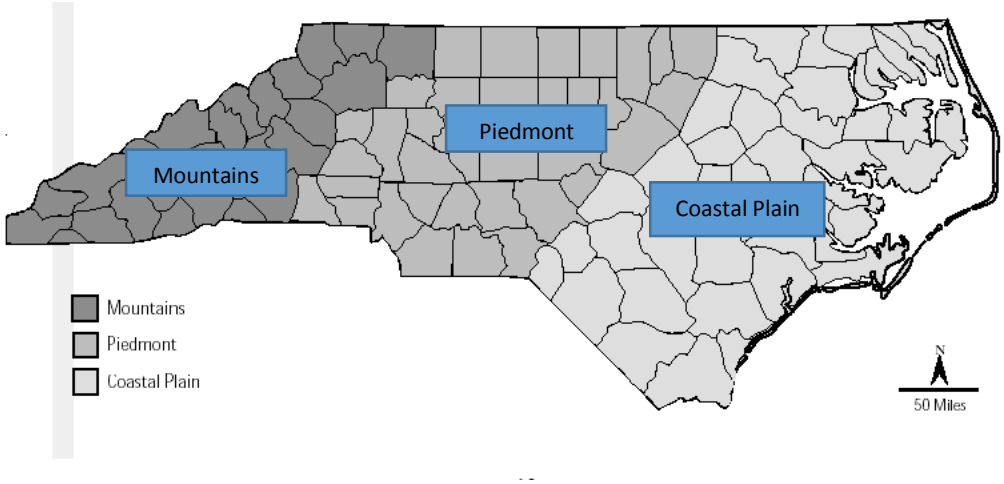


http://www.nmlandconservancy.org/~nmlandco/nmlc_img/img_map_lg.gif

Region	Percentage of Work Performed in Region
Northwest	
Northern	
Northeast	
Central	
Southwest	
Southeast	
	TOTAL: 100%

Continued on next page…

11b. **For contractors in North Carolina:** Where do you perform the majority of your work? Please complete the table below, using the image provided below.



http://www.secretary.state.nc.us/images/region1.gif

Region	Percentage of Work Performed in Region
Mountains	
Piedmont	
Coastal Plain	
	TOTAL: 100%

Thank you for completing the survey

Appendix D: Informed Consent Letter to Study Participants

Dear Participant,

My name is Evan Hughes. I am a researcher in the Department of Construction Management at Colorado State University. I am requesting your assistance with a survey to investigate the perception of compressed earth block (CEB) among residential contractors in partial fulfillment of my thesis requirements. The Principal Investigator for this study is Dr. Rodolfo Valdes-Vasquez from the CM Department at CSU, and I am the Co-PI.

We would like you to take an anonymous online survey. Participation will take approximately between 10 to 15 minutes to complete. Your participation in this research is voluntary. If you decide to participate in the study you may withdraw your consent and stop participation at any time without penalty. We will not collect your name or personal identifiers. When we report and share the data we will combine the data from all participants. While there are no direct benefits to you, we hope to gain more knowledge on the barriers preventing the wider acceptance and use of CEB in the U.S. residential construction market.

There are no known risks in participating in this study. It is not possible to identify all potential risks in research procedures, but the researchers have taken reasonable safeguards to minimize any known and potential, but unknown, risks.

At the end of the survey you will have an opportunity to enter a drawing to win one of three Amazon.com gift cards, valued at $20 each. Participation in this drawing will require you to provide an email address, which will not be connected in any way to your responses on this survey. Participants will be selected at random and notified using the email addresses they provide. All email addresses will be destroyed once the random drawing process has concluded and winners have been notified.

If you have any questions about the research, please contact Evan Hughes at Evan.Hughes@colostate.edu or Dr.Rodolfo Valdes-Vasquez at rvaldes@colostate.edu. If you have any questions about your rights as a volunteer in this research, contact the CSU IRB, at RICRO_IRB@mail.colostate.edu.

We appreciate your participation and help!

Best Regards,

Evan Hughes, LEED GA

Research Assistant

C: (919) 357-2465

E: Evan.Hughes@colostate.edu

Rodolfo Valdes-Vasquez, Ph.D.

Assistant Professor

P: (970) 491-0278

E: rvaldes@colostate.edu

Appendix E: Telephone Interview Consent Script

Telephone Consent
Colorado State University
(Assessing the Perception of Compressed Earth Block (CEB) Among Residential Contractors in the North Carolina Piedmont Region)

Hello,

My name is Evan Hughes. I am a graduate student in the Department of Construction Management at Colorado State University. I am requesting your assistance with a study to investigate the perception of compressed earth block (CEB) among residential contractors in partial fulfillment of my thesis requirements. The Principal Investigator for this study is Dr. Rodolfo Valdes-Vasquez from the CM Department at CSU, and I am the Co-PI.

This phone interview is will consist of questions pertaining to your CEB project experience. The interview will take approximately between 15 to 30 minutes of your time. Your participation in this survey is completely voluntary. This means you do not have to participate if you don't want to. If you agree to participate, you have the right to only answer the questions you choose to answer.

The potential risks of this research are minimal and confidentiality of private information that you share with us will be maintained to the highest level. You have the right to stop participation at any point during the interview if you choose. While there are no direct benefits to you, we hope to gain more knowledge on the barriers preventing the wider acceptance and use of CEB in the U.S. residential construction market.

If you have any questions about the research, please contact Dr. Rodolfo Valdes-Vasquez at rvaldes@colostate.edu. If you have any questions about your rights as a volunteer in this research, contact the CSU IRB, at RICRO_IRB@mail.colostate.edu.

"Do you have any questions?"

"Do you agree to voluntarily participate in this phone interview?"

[ ] No if No... Thanks for your time and have a great day. Good-Bye!

[ ] Yes if Yes... Now, we will continue with list of specific questions (please see next page).

Appendix F: Telephone Interview Questions

Demographic Questions

CEB projects completed:

Positions held on said projects:

Length of time as licensed contractor:

New single family residences:

Number of employees:

Where do you perform the majority (more than 50%) of your work?

Open-ended Interview Questions

What's the experience been like building with CEB, compared to conventional construction?

Did you encounter any mistrust or hostility from inspectors?

What's the response been like from your clients?

What's been the response from your peers?

What are the benefits of CEB projects?

Has your interest in CEB been driven primarily by client demand, or was it independent interest on your part?

Going forward, what do you see as being obstacles to adoption to CEB in this state, and what do you think it will take for it to catch on?

Anything else you want to add about the material, your experiences, etc.?

Thanks for your time and participation!

Appendix G: Telephone Interview Responses from Jeff Gannon

Demographic Questions

Business Name and Type: Green Door Design-Build and DIG Southeast. Green Door is a residential construction company and DIG Southeast is a CEB manufacturer and subcontractor.

CEB projects completed: "2.5 projects thus far"

Positions held on said projects: "Company owner and CEB subcontractor"

Length of time as licensed contractor: "Roughly 6 to 7 years"

New single family residences: "Usually 1-2 per year, depending on the year, with 6 or 7 other projects going on simultaneously (remodels, additions, etc.)"

Number of employees: "3 currently"

Where do you perform the majority (more than 50%) of your work? "100% of my work is performed in the Piedmont"

Open-ended Interview Questions

What's the experience been like building with CEB, compared to conventional construction?

"There's an obstacle of having a limited subcontractor base that is familiar with CEB construction. The number two obstacle is the weather! Also the additional time required to educate subs, laborers, and inspectors (one trip turns into two). One time an inspector brought a Director of Central Permitting and Inspections for Chatham County to help do the final inspection! This happened at the rough-in and final inspections."

Did you encounter any mistrust or hostility from inspectors?

"They had never seen it before, and were reluctant to put their name on the stamp. That's why they brought out the Director, who deferred to my engineer. No active opposition, just caution. Frankly I'm a little used to it, and they're a little used to it from me. I don't think I've ever built a straight-up stick frame house with conventional framing."

What's the response been like from your clients?

"One client really enjoys their house, I've gotten a lot of positive feedback, they've talked about it being comfortable and quiet. The other client has testified as to how quiet the house is. He said he can't hear his wife driving up. Even the dog can't hear it. I think that would make it a great product for an urban environment. During the construction process, we've able been to experience the benefits of working with CEB."

Continued on next page…

What are those benefits?

"The interior temperature was regulated really well by the material, which makes it easier to work on sheetrock, for instance. It makes painting easier, too. It makes tasks that are more temperature sensitive much easier."

What's been the response from your peers?

"I've gotten a lot of curiosity and interest from custom homebuilders. I haven't really talked to spec builders, companies of that sort, but I do think there are possibilities there, too. It's funny because there's 800 years of quantifiable data on earth building. People don't always get that unless it's explained to them."

Has your interest in CEB been driven primarily by client demand, or was it independent interest on your part?

"A combination of both. I could see the potential demand and absence of availability. Given those two factors, I thought it worthy to jump in and provide a viable alternative to conventional construction."

Going forward, what do you see as being obstacles to adoption to CEB in this state, and what do you think it will take for it to catch on?

"I think it's going to take education and exposure to catch on. That's all it's gonna take. The material will take care of itself. People just need to learn about it is and remove their misconceptions of what is."

Anything else you want to add about the material, your experiences, etc.?

"It's not a complex material, so you're able to teach someone how to build a house in a half a day."

Appendix H: Telephone Interview Responses from Lawrence Jetter

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Demographic Questions

Business Name and Type: Advanced Earthen Construction Technologies, a CEB press manufacturing company.

CEB projects completed: "6, but I manufacture the equipment. I'm not a builder."

Positions held on said projects: "I made the blocks, and also advised a little bit on it as we were going along."

Length of time as licensed contractor: "27 years as an equipment manufacturer, since 1989."

New single family residences: "I've run blocks for five single-family homes, but some of those mother gooses were big, 5,000-6,000 square feet."

Number of employees: "We've had 12, we're down to 5 right now."

Where do you perform the majority (more than 50%) of your work? "Right here in San Antonio."

Open-ended Interview Questions

What's the experience been like building with CEB, compared to conventional construction?

"I love it. If I had my way and I was 45-50 years old instead of 75, I'd be out there right now instead of manufacturing equipment. Because the biggest problem we have are with architects and engineers, who don't realize how good and effective it is. We know people in CO working with Crow Indians, designing CEB structures and acting as advisors."

"It's not new, but we've been so educated on concrete, steel, and wood, that we've lost sight of what's proven. We've got that concrete and steel mentality. Concrete people hate us."

> **Why do you think that is**?
>
> "We're direct competition with them. Cement is one of the biggest polluters in the world. Also, cement conducts heat and cold like a copper wire conducting electricity. It takes 21 inches of cement-stabilized block to get the same heating and cooling efficiency as 10 inches of pure dirt."

Did you encounter any mistrust or hostility from inspectors?

"Oh yeah, that's been a big thing, too. Most of the time, if I can get them settled down, they come around."

> **What do you mean by "settled down"?**

"I'll give you an example. We were out in OK, at Green Valley Farms in Cache, OK, back almost 20 years ago. Two trucks full of building inspectors came out for a training session on CEB. I trained them. They started out hostile, snickering under their breath. At the end of the day, every one of them came up and shook my hand and thanked me. They were saying things like "I can't believe this. Not in a hundred years." They were blown away. I've also done the same for architects in here in Texas. I'm really in the education business, not the manufacturing business."

What's the response been like from your clients?

"They are tickled pink. They can't believe it. For example, I built a 5,700 square foot house for a client. His old house was 340-380$ a month to condition, and it was about 3000ft. his new house is 140$-160."

What's been the response from your peers?

"I don't how to answer that. Everybody thinks I'm crazy because I keep doing this. What I can do for the poor people of the world is unbelievable. We're currently sending equipment to Mogadishu and Sudan. As far as comfort and safety, it's quiet, cool, comfortable, no radon, and so forth. They're even bullet-proof. You gotta leave the world better than when you arrived in it."

What are the benefits of CEB projects?

"No wood rot, they're cooler, and heating and cooling efficiency is tremendous. Cost of ownership is really low.

The use of fossil fuels is reduced compared to wooden clapboard houses. The cost to build is cheaper than brick-and-stick. But the problem is that everyone sees the adobe and goes crazy with design features that make it more expensive."

Has your interest in CEB been driven primarily by client demand, or was it independent interest on your part?

"It was a business decision initially. All of a sudden, as I got into it, I became a believer. My actual trade was as an auto mechanic, 35 years working as a service manager and foreman at Chevrolet dealerships. I got into it as a business decision to get away from the automobile business, and I became a student of it. I have learned so damn much from other people, and I've taught them stuff too."

Going forward, what do you see as being obstacles to adoption of CEB in a market like North Carolina, and what do you think it will take for it to catch on?

"People are the biggest obstacles. You've got to show them. Military bases have machines there now, and when they get out of military they ask about getting machines."

What do you mean by people being the biggest obstacles?

"Well, it's not an acceptable thing. Texas AM is building houses for poor folks in Texas, but Mexican immigrants didn't want them. They wanted brick and mortar houses. Education is a big problem."

In a place like North Carolina, with no earth building history, how do you overcome these obstacles that aren't related to the material's performance?

"You go in there and build something. Let people touch it, feel it, experience it. People will go nuts for it. I should point out that building with CEB is a little slower than conventional construction, but if you build correctly it'll last.

Training in how to build properly is important, too. Pay subcontractors by the block. That's why we require that, if you buy an AECT machine, you come to San Antonio and we train you, on building techniques, soils science and soil mixtures, etc. If you don't do the training, then we don't offer a warranty on the machine. That's how important the training is. The military sends 4-5 people for the machines they buy."

Anything else you want to add about the material, your experiences, etc.?

"The training and education is the most important thing. Once people see it, touch it, taste it, feel it, they're gung ho. We gotta educate engineers, architects, building inspectors, contractors, etc."

Appendix I: Photographs of Compressed Earth Block Manufacturing and Construction of CEB Homes

(all photographs displayed with permission from Green Door Design-Build)