AN ABSTRACT OF THE THESIS OF

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Abstract approved:

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Todd Scholz

Cob, similar to adobe, is an earthen building material made of soil, sand, and straw. Although cob was used to build homes in England centuries ago, it has reemerged as a sustainable and relatively inexpensive, alternative building material. A possible solution for housing in impoverished nations, cob needs to be studied more in order to provide reliable strength data so that the material can be codified. The purpose of this study was to determine if the use of chicken wire as reinforcement in a cob wall had an effect on the shear strength of the cob wall.

Using two types of soil (a plastic silt and a pure kaolinite), four cob wall panels were created, with one of each soil type being reinforced with chicken wire. The wall panels were tested in a shear box to simulate earthquake loading. The results of this study indicated that the kaolinite specimens showed a trend that the reinforced cob wall panel required a greater load than the unreinforced cob panel in order to deform the same amount. Reinforcement also appeared to increase the toughness of the cob panel. Trends regarding the reinforcement of the silt cob panel were unable to be determined due to the unknown orientation of the chicken wire reinforcement and incomplete data collection.

Key Words: Cob, Sustainable Building Materials, Reinforced Cob

Corresponding Email Address: britschk@onid.orst.edu

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Katy R. Britsch

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APPROVED:

Mentor, representing Construction Engineering Management

Committee Member, representing Construction Engineering Management

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Committee Member, representing Forestry

School Head, School of Civil & Construction Engineering

Dean, University Honors College

I understand that my project will become part of the permanent collection of Oregon State University, University Honors College. My signature below authorizes release of my project to any reader upon request.

Katy R. Britsch, Author

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Evaluation of Shear Resistance of Reinforced Cob

INTRODUCTION

Civilizations have been using earth as a building material to construct "permanent" dwellings for thousands of years. Cob, a mixture of clay, sand, straw, and water, is a relatively unknown earthen building material to the common individual, but is currently experiencing a revival in both Europe and the Pacific Northwest. Unfortunately, much is still unknown about how the engineering properties of cob support its ability to provide adequate housing. In current use, cob has shown that it has a great potential to benefit the poor of society and may be a great solution for providing them adequate housing that they lack. The seismic concerns regarding cob involve the soils inability to perform well under shear stress. Adding simple reinforcement that is readily available to impoverished citizens may aid in resisting rapid and catastrophic failure due to shear stresses induced by seismic events, thereby allowing time to escape a dwelling during such events.

The purpose of this study was to determine if the use of chicken wire as reinforcement in a cob wall has an effect on the shear strength of the wall. It was hypothesized that reinforcement will affect the deformation resisting properties of a wall made of cob. Specifically, using engineering properties of ductility, toughness, and stiffness as response variables, it was hypothesized that the inclusion of chicken wire reinforcement will increase the ductility, toughness, and stiffness of cob relative to cob without reinforcement.

This study constituted an initial investigation of the effect of reinforcement in two cob mixtures: a silt mixture and a pure kaolinite mixture. The findings provide evidence showing that further research has merit (e.g., broader range of soil types, other types of reinforcement, etc.). The outcome of this study may aid in the development of reinforced cob that citizens in impoverished nations could use to build houses with the confidence that they could safely escape them during a seismic event.

A History of Cob

The earliest cob dwellings have been traced back 10,000 years from present day (Evans, et al. 2002). Cob, coming from Old English meaning "lump" or "rounded mass," differs from other earthen building materials, such as adobe bricks, in that a cob structure is built monolithically (Bee, 1997). Cob homes are literally sculpted by hand, built upon a concrete stem wall or mortared stones as if they were a large piece of pottery. Cob has traditionally been a "built-by-feel" construction material. Cob builders know the mix of soil, sand and straw is correct when it "feels right" and stop building a wall when they feel that it "looks right." A large portion of cob experts come from England where cob homes appeared in the 13th century and became the standard of practice in the 15th century before dying out once other materials became more economical.

In the present day, the revival of cob homes began with the invention of "Oregon Cob," a mixture with considerably more straw and sand than its English predecessor. The addition of more straw and sand led to a greater strength of the cob material and therefore, thinner walls for cob homes and a more economical building material (see

Figure 1). Although cob has been in use for centuries, there are currently no building codes governing the material.

Figure 1: Modern Cob House in Oregon (Pino)

Relevant Research

Cob is still a largely unstudied material, with no previous studies completed regarding the possibility of reinforcing cob. The most recent study regarding the engineering properties of cob was completed in 2009 by fellow Oregon State University Honors College student, Quinn Pullen. In his thesis, Pullen conducted multiple experiments on various samples of cob produced in Oregon to determine engineering properties. Most applicable to the reinforcement of cob are Pullen's findings that the length of the straw fibers had an impact on the strength of the material. Cob panels with longer straw fibers had a slighter higher modulus of rupture.

Another noteworthy study is R. H. Saxton's 1995 publication of The performance of cob as a building material. Using a soil that was approximately 30% gravel, 35% sand,

and 35% silt and clay, Saxton found that a straw content of 1.0%-1.5% was optimal for compressive strength. The compressive strength of the cob samples decreased with increasing moisture contents over 12% (Saxton, 1995). Of the specimens with moisture contents less than 12%, compressive strengths varied between 600 to 1200 kPa (87 to174 psi).

Perhaps the most relevant research in regards to reinforced cob is that of Afsin Saritas and Lutfullah Turanli. They analyzed three different types of adobe walls regarding the effect of reinforcement with plaster mesh. One type of adobe had 1% straw content, making this wall similar to cob. The researchers used a fiberglass plaster mesh that is commonly used in supporting the plaster used both interiorly and exteriorly on walls in the construction industry. The mesh was placed between the horizontal mortar joints of the adobe block wall. The adobe wall panels were "subjected to a diagonal compressive load combined with a compressive edge load acting in the plane of the wall and normal to the direction of the mortar bed joints" (Saritas and Lutfullah, 2011). The variable diagonal load simulates a state of stress within the wall panel that is similar to the stresses produced within a wall due to the lateral loading of the wall during an earthquake. Saritas and Lutfullah found that the use of mesh increased the deformation capacity of the wall panels and allowed for an energy absorption that was approximately two and a half times that of the wall panel without reinforcing mesh.

Scope

This study focused on the effect of reinforcement in only two soil types: a plastic silt and a pure kaolinite. Chicken wire was the only reinforcement analyzed in this study. The experiment also utilized static loading, rather than dynamic loading.

MATERIALS

Two types of soil were used in producing the cob mixtures. The first soil was a silt collected from McDonald Research Forest in Corvallis, Oregon. The silt was harvested alongside a forest road and was red-brown in color. Previous study of the silt indicated that the soil is a high to medium plasticity silt (MH or ML) with approximately 20% gravel content (Pattison, 2008).

The second soil used was a pure kaolinite purchased in powdered form. The kaolinite was mixed with water in an industrial mixer until reaching a consistency that moist enough to be malleable, but not too moist that the clay would stick to a surface. Using this standard, the kaolinite had a moisture content of 35%, by weight, at the proper feel, which was slightly above the plastic limit (30%) and well below the liquid limit (47%) as determined in a separate study (Anantanasakul, 2010). The kaolinite was then placed in buckets and covered for use in the cob.

Straw for the cob mixtures was purchased at a local feed shop. This local grass seed straw was purchased in a bale with stalks of varying lengths. In practice, a cob home builder would use, as was for this study, a locally available straw that was abundant and economical.

Sand for the cob mixtures was purchased from an aggregate production plant near Corvallis, Oregon. Attempting to simulate sand that would be locally available to a person trying to build a cob home in an impoverished area, the sand chosen for the experiment was a natural, river run, washed sand.

Stainless steel chicken wire, commonly used for farming purposes, was purchased for this study. The chicken wire was a honeycomb structure, approximately an inch in diameter.

METHODS

Four specimens were created: two with the plastic silt cob mixture (one specimen containing chicken wire reinforcement) and two with the kaolinite cob mixture (one specimen containing chicken wire reinforcement). The two specimens of each type of cob mixture were created from the same batch of cob to control for the variables other than the reinforcement.

Mixing

The mix design for the two cob mixtures stemmed out of a desire to create a mix that could be easily replicated by people whose only access to a measuring tool may be a bucket. A test batch was created and evaluated based on the look and feel of the mixture, using Saxton's cob study as a guide (Saxton, 1995). Creating two identical cob mix designs for the two types of soils was ideal; however, due to the difficulty of mixing the sand into the kaolinite, less sand was used relative to the silt cob mixture. An overview of the two cob mix designs is shown in Table 1.

Table 1: Cob Mix Designs

Type of Cob	Quantity of Cob Component (Number of Five Gallon Bucket Loads)		
	Soil	Sand	Straw
Silt	3.0	3.0	3.5
Kaolinite	3.0	2.0	3.5

For the silt cob, the mixing process began by pouring soil and sand onto a tarp according to the "tarp method" developed by Becky Bee. The soil and sand were treaded upon and mixed using feet (see Figure 2).

Figure 2: Mixing Silt and Sand

Mixing the kaolinite cob began by creating fist-sized balls of kaolinite (in order to make mixing easier) and spreading them out on a tarp. Separating the kaolinite into smaller pieces helped evenly distribute the sand into the kaolinite. Sand was sprinkled over the kaolinite and then treaded into the clay (see Figure 3).

Figure 3: Mixing Kaolinite and Sand

Both the silt cob mixture and the kaolinite cob mixture were then rolled by picking up one edge of the tarp and pulling it over the sample to another edge of the tarp. This helped create a homogeneous mixture. An example of the kaolinite mixture can be seen in Figure 4.

Figure 4: Tarp Method for Mixing Kaolinite

Once the sand and soil were thoroughly mixed, water was added to the sample to help facilitate the addition of straw. Straw was sprinkled over the sample, treaded into the mixture, and then the sampled was rolled as previously described until a relatively homogeneous mixture resulted (see Figure 5).

Figure 5: Mixing Straw in Silt Cob

Compaction and Drying

Wooden molds for the specimens were placed on top of three layers of geotextiles, supported by a steel plate. The use of geotexiles allowed for moisture egress from both the top and bottom faces of the specimen during the drying process. This facilitated an even moisture profile throughout the specimen.

Cob was compacted into the molds directly onto the geotextile by the handful. The various lumps of cob were kneaded together to create a monolithic panel (see Figure 6).

Figure 6: Cob Compaction

The specimen was created in two lifts to allow for placement of the chicken wire, if the specimen was to be reinforced. For the reinforced specimens, a square of chicken wire was cut to fit snuggly within the mold and was pressed into the first lift of cob. More cob was then compacted by hand on top of the chicken wire and pressed through the chicken wire, as seen in Figure 7, to ensure that the panel acted as a monolithic structure.

Figure 7: Chicken Wire Reinforcement in Silt Cob

Once the mold was filled to the top , the cob was tamped with a wooden block to smooth the surface and provide further compaction. Cob homes are typically allowed to dry naturally in the sun before completion; however, in order to complete this study in a timely manner, the cob panel was then placed in a drying oven at 75°C for 72 hours (see Figure 8).

Figure 8: Drying the Cob in an Oven

Testing

A custom built, 32-in x 33-in simple shear box was used to test the cob material. The simple shear box was constructed using C-channel with hinges in all four corners. One side of the simple shear box was welded to the strong floor to allow for the load frame to deform into a parallelogram during loading, inducing pure shear stress in the specimen. A servo-hydraulic test system was used for the shear loading. A dual camera system with imaging software was used to collect load, deformation, and stress data. See Figure 9 for an overall view of the testing setup.

Figure 9: Cob Testing Equipment

Once the specimen was dried, it was removed from the oven and prepped to be placed in the load frame (see Figure 10).

Figure 10: Silt Cob Sample Before Testing

The geotextiles were removed from under the specimen and the specimen was transferred on top of plastic sheeting in the load frame. The plastic sheeting was used to approximate a frictionless surface, accounting for the fact that the wall panel would normally be oriented in a vertical position (turned 90 degrees from its position in the load frame). Due to shrinkage, the cob specimen was smaller than the load frame (see Figure 11).

Figure 11: Cob Sample in Load Frame

Therefore, in order to engage the specimen during loading, wooden shims were placed between the load frame and the specimen. Any gaps left between the shims and the load frame were filled with sand and compacted, facilitating full contact between the load frame and the specimen (see Figure 12). The specimen was then loaded at a constant shear rate of 0.3 in/min until failure, defined for the purposes of this thesis, as the point at which the load decreased abruptly and substantially without further increase in deformation.

Figure 12: Load Frame with Cob, Shims, and Sand

After data collection was complete, an approximately 6-in x 6-in sample of the cob panel was taken to determine the moisture content of the panel. The moisture content was determined in accordance with ASTM C 566 (ASTM 2008).

RESULTS

The results from the moisture content tests after shear testing are shown in Table 2. The silt cob specimens had a moisture content from 4%-5%; whereas, the kaolinite cob specimens had a moisture content from 0.9%-1.5%.

Table 2: Moisture Content of Cob Specimens

Cob Sample	Moisture Content (%)
Unreinforced Silt	4.3
Reinforced Silt	5.0
Unreinforced Kaolinite	0.9
Reinforced Kaolinite	1.5

The load-deformation curves resulting from the shearing of the silt cob panels are shown in Figure 13. For the unreinforced panel, peak load was approximately 1,110 pounds and occurred at a deformation of approximately 2.85 inches. The unreinforced panel failed at a deformation of 3.11 inches. For the reinforced panel, peak load was approximately 1,100 pounds and occurred at a deformation of approximately 2.03 inches. The reinforced panel failed at a deformation of 2.21 inches.

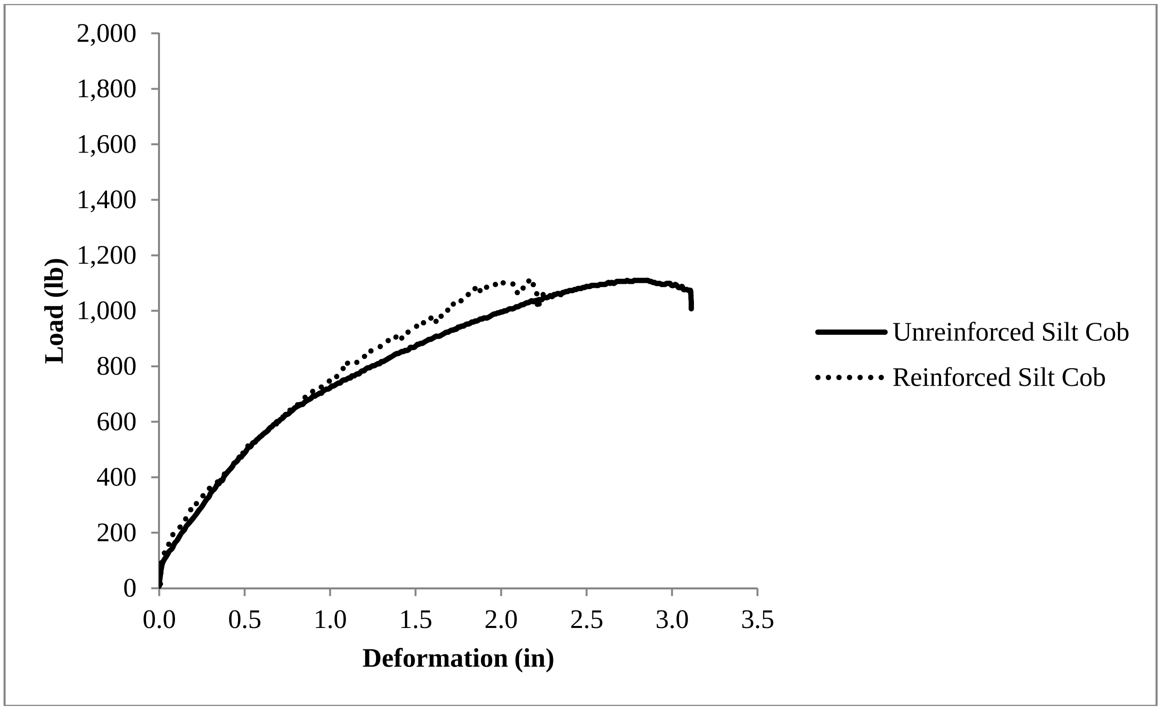

Figure 13: Shear Loading and Deformation of Silt Cob

The load-deformation curves resulting from the shearing of the kaolinite cob panels are shown in Figure 14. For the unreinforced panel, peak load was approximately 1,860 pounds and occurred at a deformation of approximately 1.10 inches. The unreinforced panel failed at a deformation of 1.63 inches. For the reinforced panel, peak load was approximately 1,760 pounds and occurred at a deformation of approximately 1.16 inches. The reinforced panel failed at a deformation of 2.30 inches.

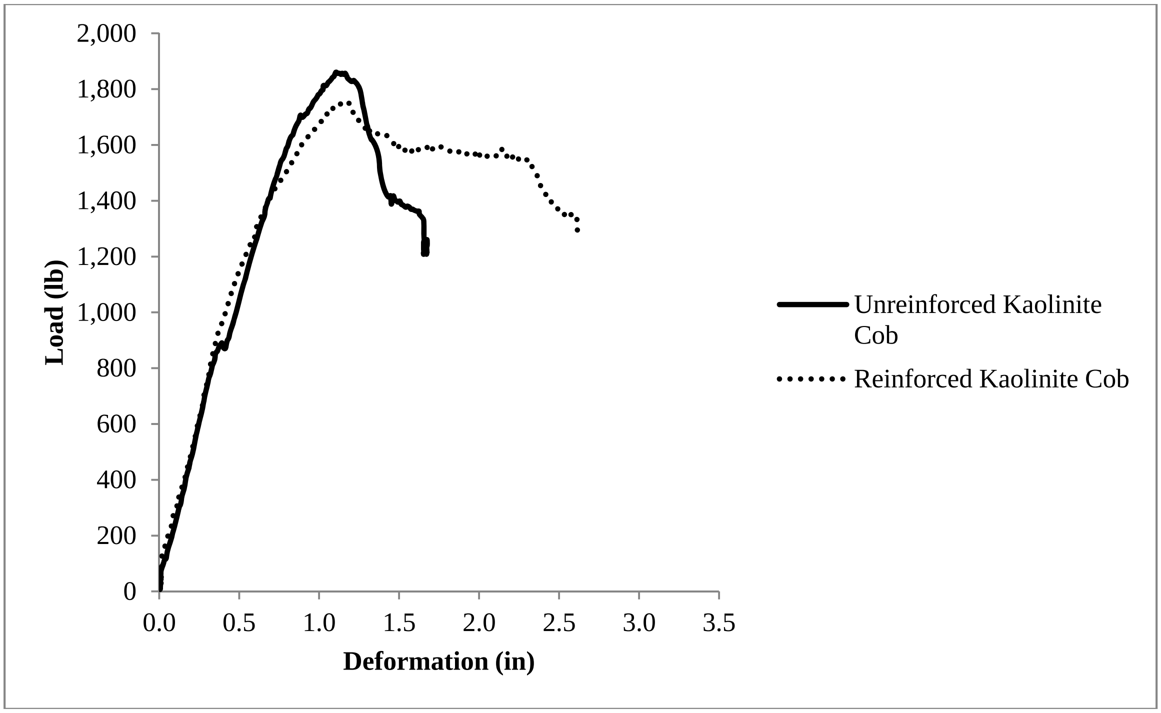

Figure 14: Shear Loading and Deformation of Kaolinite Cob

The stress-strain curves resulting from the shearing of the silt cob panels are shown in Figure 15. For the unreinforced panel, the ultimate stress was approximately 16.4 psi with a corresponding strain magnitude of 0.09. The stress at failure was approximately 15.9 psi with a corresponding strain magnitude of 0.10. For the reinforced panel, the ultimate stress was approximately 16.4 psi with a corresponding strain magnitude of 0.07. The stress at failure was approximately 16.1 psi with a corresponding strain magnitude of 0.08. Just beyond the knee in the curves immediately following initial loading, the specimens appeared to exhibit approximately elastic behavior up to a strain of about 0.02. At a strain of 0.02, the stress in the unreinforced panel was approximately 6.9 psi and the stress in the reinforced panel was approximately 8.0 psi.

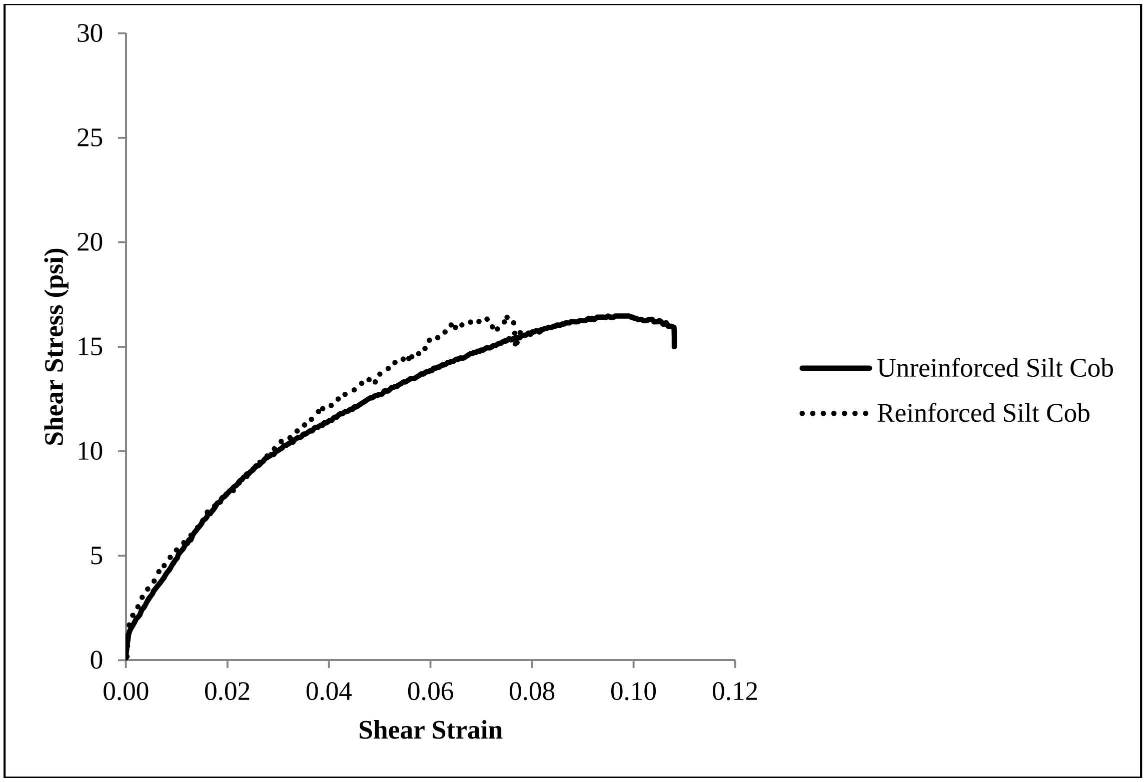

Figure 15: Shear Stress and Strain in Silt Cob

The stress-strain curves resulting from the shearing of the kaolinite cob panels are shown in Figure 16. For the unreinforced panel, the ultimate stress was approximately 27.9 psi with a corresponding strain magnitude of 0.04. The stress at failure was approximately 20.3 psi with a corresponding strain magnitude of 0.06. For the reinforced panel, the ultimate stress was approximately 26.4 psi with a corresponding strain magnitude of 0.04. The stress at failure was approximately 23.1 psi with a corresponding strain magnitude of 0.08. As with the silt cob panels, just beyond the knee in the curves immediately following initial loading, the specimens appeared to exhibit approximately elastic behavior up to a strain of about 0.02. At a strain of 0.02, the stress in the unreinforced panel was approximately 13.7 psi and the stress in the reinforced panel was approximately 18.9 psi.

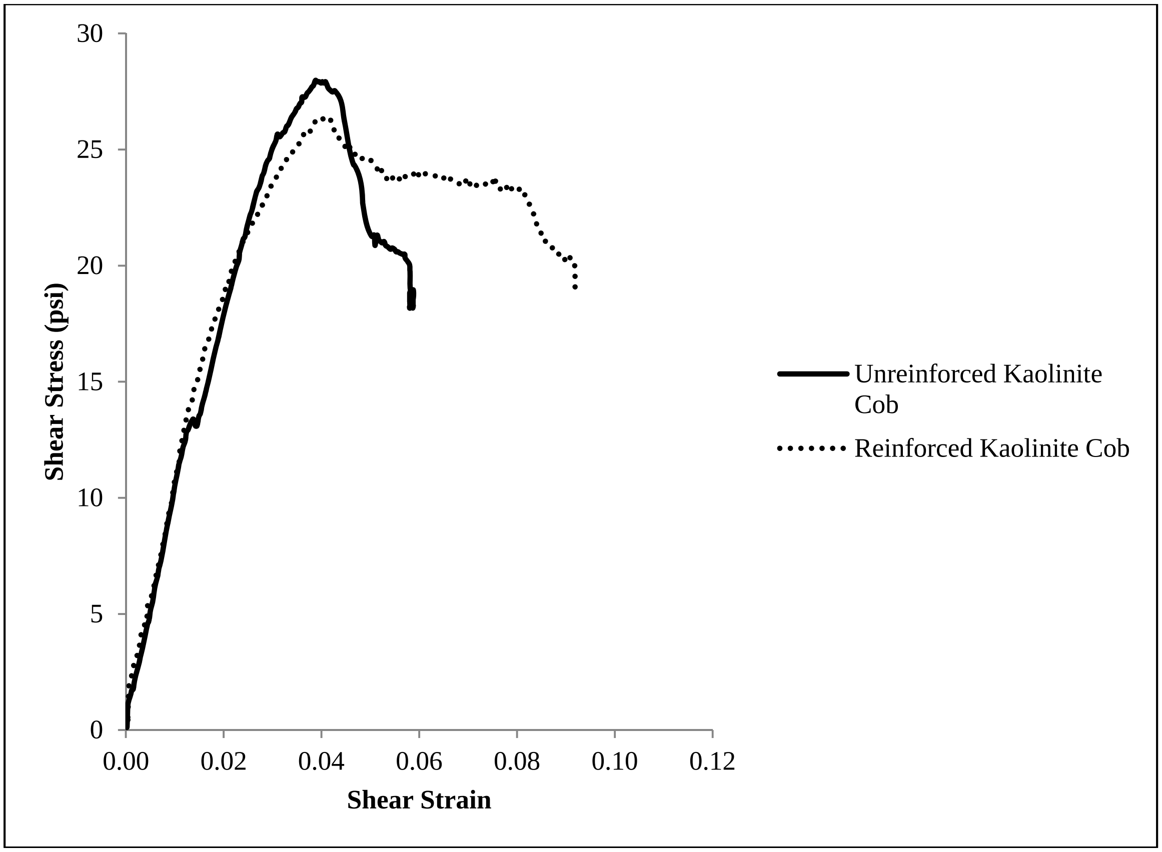

Figure 16: Shear Stress and Strain in Kaolinite Cob

ANALYSIS

Ductility

An approximation of ductility was used to determine the effect of the chicken wire reinforcement on the shear strength of the cob panel. Ductility, measured by percent elongation, was determined by dividing the deformation of the sample at failure by the length of the sample before loading and converting to a percent. The results of this analysis are shown below in Table 3.

Table 3: Ductility Analysis

Cob Sample	Length of Sample Before Loading (in)	Deformation at Failure (in)	Percent Elongation
Unreinforced Silt	28.9	3.11	10.8
Reinforced Silt	28.9	2.21	7.7
Unreinforced Kaolinite	28.5	1.63	5.7
Reinforced Kaolinite	28.5	2.30	8.1

Using Response Surface Methodology (RSM) to analyze the ductility data, an approximation of significance is determined. Values of -1 were assigned to the silt cob and the unreinforced cob results, while values of +1 were assigned to the kaolinite cob and reinforced results (see Table 4). From these data the reinforcement-soil type interaction plot was created (see Figure 17).

Table 4: Statistical Analysis Variables for Ductility Analysis

Soil Type	Reinforcement	Ductility (Percent Elongation)
-1 (Silt)	-1 (No)	10.8
1 (Kaolinite)	-1 (No)	5.7
-1 (Silt)	1 (Yes)	7.7
1 (Kaolinite)	1 (Yes)	8.1

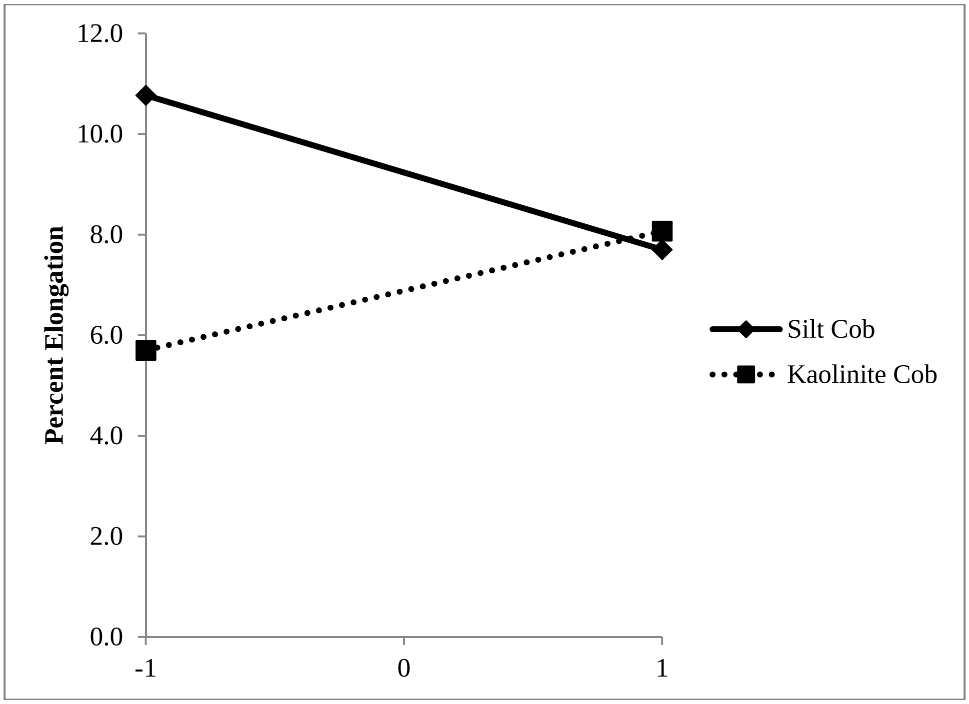

Figure 17: Reinforcement-Soil Type Interaction Plot for Ductility

From the interaction plot, the main effects of the two test variables (soil type and reinforcement) were calculated, along with the interaction factor, and an estimated regression coefficient for the effect of reinforcement on ductility (see Table 5).

Table 5: Main Effects and Interaction Factors for Ductility

Effect of Soil Type on Ductility	-2.35
Effect of Reinforcement on Ductility	-0.35
Interaction Between Soil Type and Reinforcement on Ductility	2.72
Estimated Regression Coefficient for Effect of Reinforcement on Ductility	-0.18

Toughness

Another RSM analysis was conducted to determine the effect of reinforcement on the toughness of the cob panel. Toughness is an indicator of both shear strength and ductility. The material toughness was calculated by determining the area under the shear stress-strain curves using the trapezoidal approximation method. Once again, values of -1 were assigned to the silt cob and the unreinforced cob results, while values of +1 were assigned to the kaolinite cob and reinforced results. The statistical analysis variables that were used for the toughness analysis are found in Table 6.

Table 6: Statistical Analysis Variables for Toughness Analysis

Soil Type	Reinforcement	Toughness (in-lb/in^3)
-1 (Silt)	-1 (No)	1.58
1 (Kaolinite)	-1 (No)	1.66
-1 (Silt)	1 (Yes)	1.49
1 (Kaolinite)	1 (Yes)	2.77

From the analysis variables, the reinforcement-soil type interaction plot was created (see Figure 18). The main effects of the two test variables (soil type and reinforcement) were calculated from the interaction plot, along with the interaction factor, and an estimated regression coefficient for the effect of reinforcement on toughness (see Table 7).

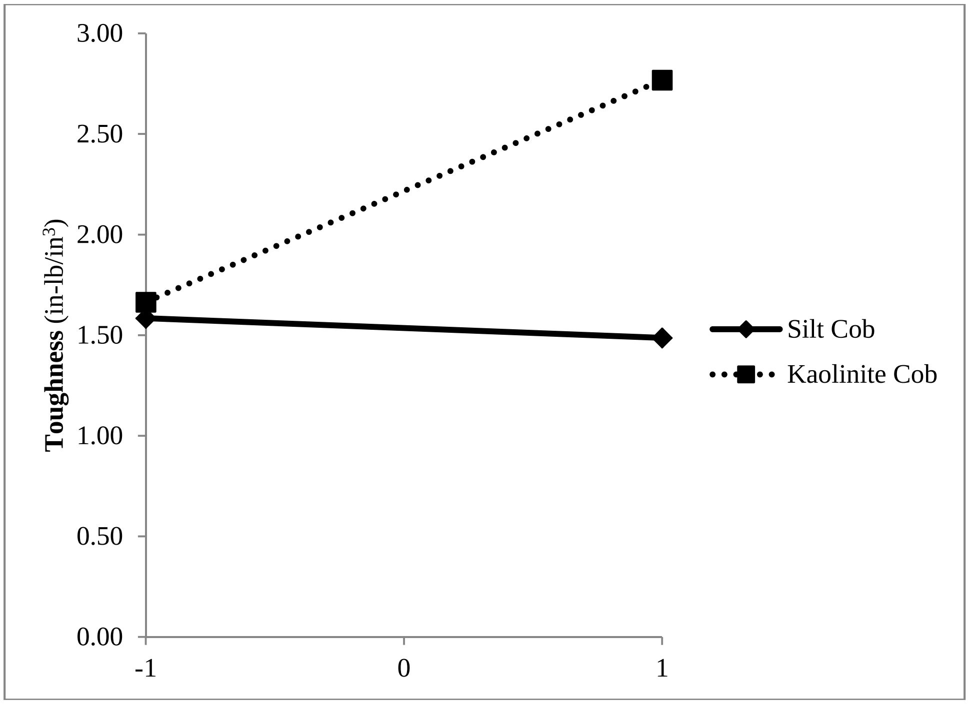

Figure 18: Reinforcement-Soil Type Interaction Plot for Toughness

Table 7: Main Effects and Interaction Factors for Toughness

Effect of Soil Type	0.68
Effect of Reinforcement	0.50
Interaction Between Soil Type and Reinforcement	0.60
Estimated Regression Coefficient for Effect of Reinforcement	0.25

Stiffness

A measure of stiffness, an elastic modulus gives the slope of the approximately elastic region of the stress-strain curves for the cob mixtures. The statistical analysis variables that were used for the stiffness analysis are found in Table 8.

Table 8: Statistical Analysis Variables for Stiffness Analysis

Soil Type	Reinforcement	Elastic Modulus (psi)
-1 (Silt)	-1 (No)	345
1 (Kaolinite)	-1 (No)	685
-1 (Silt)	1 (Yes)	400
1 (Kaolinite)	1 (Yes)	945

From the analysis variables, the reinforcement-soil type interaction plot was created (see Figure 19). The main effects of the two test variables (soil type and reinforcement) were calculated from the interaction plot, along with the interaction factor, and an estimated regression coefficient for the effect of reinforcement on stiffness (see Table 9).

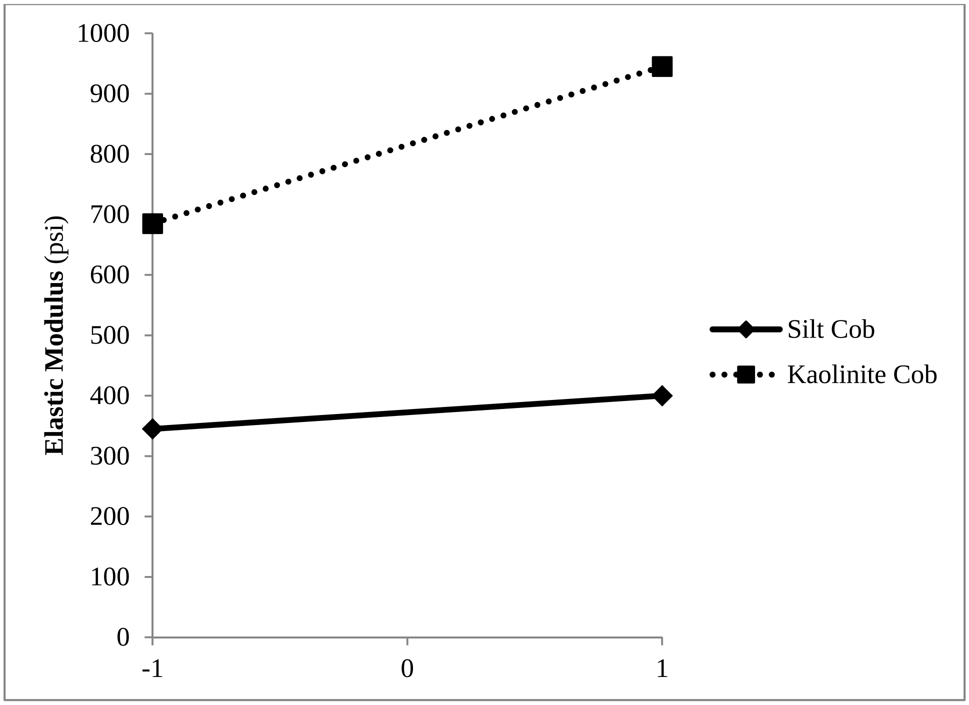

Figure 19: Reinforcement-Soil Type Interaction Plot for Stiffness

Table 9: Main Effects and Interaction Factors for Stiffness

Effect of Soil Type	442.50
Effect of Reinforcement	157.50
Interaction Between Soil Type and Reinforcement	102.50
Estimated Regression Coefficient for Effect of Reinforcement	78.75

DISCUSSION

The two kaolinite cob specimens showed very similar behavior in the approximately elastic region of the load-deformation curve (i.e., up to about 0.50 in. of deformation as shown in Figure 14); however, post-peak load behavior appears to have varied between the two specimens. The reinforced kaolinite cob specimen showed an ability to hold a greater load than the unreinforced specimen, while exhibiting the same deformation after peak load.

The observed behavior of the silt cob wall panel did not differ much between the reinforced and unreinforced specimens (Figure 15). A possible explanation for the lack of increase in shear strength in the reinforced cob sample may be that the chicken wire was not oriented correctly to take the shear stress induced by the load frame. The orientation of the chicken wire in the silt cob panel was unknown; however, for the kaolinite cob panel, the chicken wire was deliberately oriented so that the wires connecting the multiple strings of honeycombs were parallel to the direction of loading. As noted above, this orientation produced post ultimate stress behaviors that differed between the reinforced and unreinforced kaolinite specimens. It should also be noted that, for the silt cob, data were not collected long enough to fully determine the behavior of the material after peak load.

Overall, statistical approximation of the effect of reinforcement indicated a positive trend; however, analysis showed a negative trend for the ductility of the cob panels. This negative trend may be misleading because it was most likely due to the results of the silt cob with the unknown orientation of reinforcement lowering the overall ductility values for the reinforced cob. The main effect of reinforcement on ductility was nearly zero (-0.35), indicating that reinforcement had very little effect on the ductility of the cob panel. The estimated regression coefficient of -0.18 also showed that as reinforcement increased, ductility decreased. The positive interaction factor indicated that increasing the plasticity of a soil that is reinforced had a greater effect on ductility than the other extreme of a less plastic soil that has no reinforcement.

As mentioned previously, it is highly likely that the above results were skewed due to the unknown orientation of the chicken wire reinforcement in the silt cob. Setting aside the possibly skewed silt cob data and just observing the data for the kaolinite samples, it is clear that there was a positive correlation between increasing reinforcement and increasing ductility. To better determine this correlation, more trials of the kaolinite panel testing should be completed.

Analysis of the cob panels showed that the toughness for the silt cob panels was relatively constant (the difference between toughness values was only 0.09), regardless of reinforcement (Table 6). This lack of increase in toughness due to reinforcement can easily be explained by the unknown orientation of the chicken wire. However, in the kaolinite cob panels, the toughness increased by approximately 67% with the addition of reinforcement (Table 6). Although the regression coefficient is slightly low (0.25), it still shows that there was a positive correlation between adding reinforcement and increasing toughness.

From the approximate elastic moduli of the two types of cob mixtures (an average of 372.5 psi for the silt panels and an average of 815.0 psifor the kaolinite panels), it can be determined that the kaolinite cob panel had a greater stiffness than the silt cob panel.

The higher approximate elastic modulus for the kaolinite cob panel indicated that, at the same load, the kaolinite cob panel did not deform as much as the silt cob panel. In addition to the effect of the soil type on stiffness, the RSM analysis of the stiffness of the cob panels also showed that adding reinforcement increased the stiffness of the cob panels, as indicated by the large positive estimated regression coefficient for the effect of reinforcement on the elastic modulus of the material (Table 9). The elastic modulus of the kaolinite cob panel increased by approximately 40% with the addition of reinforcement (Table 8).

It should also be noted that the moisture contents of the reinforced cob panels were higher than those of the unreinforced panels (Table 2). A higher moisture content general decreases stiffness, so adjusting for moisture content, the increase in stiffness due to reinforcement may actually be even greater. The discovered increase in stiffness is significant in regards to the ability of a family to exit their cob home during an earthquake.

CONCLUSION

The kaolinite specimens showed a trend that the reinforced cob wall panel required a greater load than the unreinforced cob panel in order to deform the same amount; however, statistical approximation of significance, using RSM, did not support this trend when both types of cob were considered together. Analysis of the toughness of the cob panels showed that the toughness of the kaolinite panels increased with the reinforcement of the panel. RSM analysis of both types of cob mixtures showed that there was a positive correlation between reinforcement and toughness, indicating that reinforcement tended to increase the shear deformation resistance of the panel. Analysis also indicated that the stiffness of the panel increased with reinforcement.

Trends regarding the reinforcement of the silt cob panel were unable to be determined due to the unknown orientation of the chicken wire reinforcement and incomplete data collection. It is also likely that the results of the silt cob tests greatly lowered the significance of the kaolinite test results.

Further Research

Due to the discovered trends in the kaolinite panels that reinforcement may increase ductility, toughness, and stiffness of cob walls, further research regarding reinforcement should be conducted. Other relatively cheap and accessible materials may act as better reinforcement than chicken wire and are worth studying. Possible reinforcement options include the wire mesh used for reinforcing plaster, the plastic construction fencing used on construction sites, or other mesh-like materials. Different types of chicken wire (gauge and structure) could also be studied regarding their effects on the shear strength of cob walls. Different types of fibers, such as rope strands and tree branches, may also be effective types of reinforcement for cob walls.

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