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Proper Mixtures of Ellis County Soils for Adobe Construction, and Their Physical Properties

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INTRODUCTION

The word adobe used so commonly in the Southwest originated in Spanish and Moroccan roots which meant "to mix" or "puddle", and later came to be applied to sun-dried brick or to a structure of that material.

In the puddled state the soil grains are brought close together so that there is a mechanical locking between the angular soil particles, and so that the surfaces in contact can be cemented by the clay in the soil. Soil used in making adobe bricks should contain clay or other soil components in sufficient quantities to cause the particles to adhere strongly when dried from a moist and plastic condition, but not to a degree that will cause cracking. Soils which produce bricks with friable and erodable surfaces, because of a lack of binding components or an excessive amount of sand, should not be used.

Sun-dried or Adobe bricks are large mud bricks dried in the sun and then laid up in courses in the wall with mud mortar or regular mortar treated to make it water-proof. These bricks are probably more widely used than all the other methods of earth construction. Their popularity results from two characteristics: (1) The exact amount of shrinkage in the brick is relatively unimportant as long as the unit remains intact; and, (2) the labor requirement is extremely variable, as one man or a dozen may be put to work forming bricks with a minimum of equipment. A special kind of mixer is needed to mix adobe. With an ordinary mixer, the rolling barrel type, the mud has a tendency to form into a ball and roll around inside the barrel. If more water is added the mixture becomes too wet and slumps when the form is removed. A continuous cement mixer, a rotary bread mixer, or a plaster mixer is suitable.

Various sizes and shapes of bricks, to fit any odd places that may occur in construction, can be molded and laid up in the wall along with the standard size bricks. A rectangular brick four inches thick is the common size, though five and six inch thicknesses may be employed if the soil being used is of the proper type and greater attention is given to curing. The forms for shaping the bricks should be constructed from one inch lumber. The inside surfaces of the form should be lined

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with light sheet metal to keep the mud from adhering to the form. Standard size bricks are sometimes made with gang forms, where as high as three or four bricks are formed at one time. The form is removed immediately after the bricks are poured. If the form is not lifted straight up the brick will be deformed. Handles should be placed on the ends of the form to make removing easier. The standard-sized brick four by twelve by eighteen inches is a convenient size to handle. It weighs about fifty pounds; its volume is one half cubic foot and it has a wall face area of one half square foot when laid up in a wall. The computation of the quantity of brick required for any given wall is an easy matter. Smaller sized bricks are sometimes made to facilitate handling or because the soil is such that the larger sizes will crack badly.

The sun-dried brick method of adobe construction has been used successfully since the Civil War period (Long, 3). The use of stabilizers in the adobe bricks makes them water-proof and thus controls the erosion caused by hard driving rains. When a substance absorbs water and the water freezes, part of the material cracks off as the substance dries out. A typical example of this type of erosion can be found on buildings and even more noticeably on building foundations made from native limestone. This type of erosion in adobe construction causes the outside wall coverings, usually stucco, to crack off or pull away from the wall proper. Sometimes adobe bricks not treated with a stabilizer are painted on the outside to protect the bricks from erosion. Painting is not at all successful in localities that are subject to prolonged rain or damp weather or repeated freezing and thawing. Even though the wall erodes it may remain intact for many, many years, but it presents an unsightly appearance. With the use of a stabilizing substance the erosion due almost entirely to the absorption of water, can be completely avoided and the unsightly appearance of the outside of an adobe building does not occur.

Construction of buildings with stabilized soil has been used with much success in several sections of the United States. The purpose of this investigation was to determine whether the soils of Ellis County could be used to form waterproof soil blocks that might be used for construction. In the investigation eight soils found in the county were employed and several stabilizers were added to each in varying amounts to determine if the specific soils could be rendered waterproof. Several types of paint finishes were tested. The work was divided into three main parts: (1) Survey of Ellis County Soils; (2) Selection of soil material with respect to shrinkage; and (3) Treatment of soils with respect to waterproofing.

Collection of Soil Samples

Eight types of soil that appear in Ellis County, Kansas, were tested. Seven of the eight types were found on the Fort Hays Kansas State College Farm. The other sample was found two miles north and one mile east of Hays, Kansas. Each of the samples taken from the Fort Hays Kansas State College Farm was located with the aid of a Soil Map prepared by the United States Soil Conservation Bureau (Bass, 2). Samples were taken from the center of large areas known to be of a specific type. Owing to the poor cultivating properties of the soil north and east of town it was tested for useability in adobe construction.

The top soil was removed in each case to a depth where no grass roots or plant matter was found. This depth varied from ten inches to two feet. A seventy-five pound sample of each type was taken and the samples were stored in bushel baskets. A description of each sample and of the field conditions where they were collected follows:

Boyd clay loam

Even though the top soil was very dry, the subsoil was wet. The color of the sample was dark yellow and a few pieces of limestone were noticed in the sample. The sample was taken from a plowed field on which the last crop was wheat. The field sloped but it was not great enough to cause erosion by water.

Crete silty clay loam

The top soil was very dry but the subsoil was damp. The soil was black, sticky and adhered to the shovel. No limestone particles were noticed and when the sample dried the clods were not very hard. The sample was taken from a flat, plowed field.

Hall silt loam

The top soil was very dry and the subsoil was only damp at twenty inches; the color was very black. The soil crumbled into granules and no limestone particles were found in the sample. The field was under cultivation and was flat.

Hastings silty clay loam

The subsoil was wet and grayish-yellow in color and a few limestone particles were found. The sample was taken from a field that was under cultivation and located near a draw. Erosion by water was noticeable.

Rokeby silty clay loam

The top soil was dry while the subsoil was slightly damp. The soil was light-gray in color and contained no limestone particles. The field where the sample was taken was flat and under cultivation.

Colby silt loam

The subsoil was damp and gray with a slight yellow color and no limestone particles were noticeable. The sample was taken from a pasture of native grass, near a draw.

Colby silt loam (red)

This sample was found north and east of Hays and was taken from a pasture of native grass. The subsoil was damp and redish in color. There was a large quantity of limestone particles present which were extremely small; not pebbles as in the other sample where limestone occurred.

Tripp silt loam

Beneath the grass roots the soil was damp and contained a large amount of very fine sand. The soil sample was taken on the bottom land adjacent to Big Creek.

Determination of Soil Characteristics

One-hundred gram samples were taken from each of the eight seventy-five pound samples and dried in an oven. The oven was constructed from a wooden box approximately three feet long, two and one-half feet wide and two feet deep. One end of the box was used for a door. The box was lined with asbestos one-eighth of an inch thick. The heat was provided by two 300-watt light bulbs mounted in the top of the box. The temperature was kept at 140 degrees F. with a thermostat. The samples were dried for forty-eight hours. They were then pulverized in a mortar using a medium hard rubber pestle.

Ten grams of each of the dried samples were placed in test tubes to which forty grams of distilled water were added. After rubber stoppers were placed in the test tubes they were agitated by a shaking machine for two hours. The test tubes were then placed in an upright position and soil particles allowed to settle. After 24 hours the settling was complete and the liquid was siphoned off and given a hydrogen ion test.

A Beckman model G pH-meter with glass and calomel electrodes was used. The results of the test are shown in Table I.

Table I. Hydrogen Ion Concentration

Soil Type	pH
Boyd clay loam	7.18
Tripp silt loam	7.25
Rokeby silt clay loam	7.15
Colby silt loam	7.67
Crete silty clay	7.31
Hall silt loam	7.31
Hastings silty clay loam	7.34
Colby silt loam (red)	7.47

The residue of each sample was placed in the top sieve of a set of four sieves. The sieves were of the following sizes: 14 mesh, 24 mesh, 66 mesh, and 126 mesh. With the set of sieves in a vertical position each sample was shaken laterally for two hours and the percentage passing each was determined. The result of the analysis are shown in Table II.

Table II. Screen Analysis

Soil Type	Percentage Passing			
	14 mesh	24 mesh	66 mesh	126 mesh
Boyd clay loam	97	75	63	36
Tripp silt loam	95	91	74	51
Rokeby silt clay loam	96	81	70	68
Colby silt loam	99	96	88	76
Crete silty clay	100	91	67	53
Hall silt loam	100	97	79	64
Hastings silty clay loam	96	90	71	67
Cilby silt loam (red)	96	79	56	42

Selection of Soil Material With Respect to Shrinkage

To determine the effect of the addition of sand to the samples a form three inches by five inches by one inch was constructed of one inch lumber and lined with light sheet metal. Samples of each soil were mixed with sufficient water to give a consistency a little less than that of putty. A large piece of sheet rock was used for a pouring surface. The pouring surface was covered with a thin layer of very fine sand to prevent the bricks from sticking to it when dried. The form was dipped in water and placed on the pouring surface. The soil-water mixtures were poured into the form and worked well into the corners. The excess was struck off the top with a straightedge. The form was then lifted from the brick.

A tin trough twelve inches long, eight inches wide and six inches deep was used for a mixing vessel. The soil and water were mixed with a putty knife. The amount of water varied from twenty to forty per cent by weight. After the bricks had dried over night they were set on edge to allow equal curing from both sides.

Sample bricks were poured from pure soil and from mixtures containing 90% soil and 10% sand, 80% soil and 20% sand, 70% soil and 30% sand, and 60% soil and 40% sand. The sand used was standard concrete sand screened through a screen with a one-eighth inch mesh. A description of the sample bricks follows:

Crete silty clay

100% Crete silty clay

The cured bricks were very hard. All three of the samples developed surface cracks. The bricks did not break or crumble. The cracks were large but the samples remained in one piece.

90% Crete silty clay and 10% sand

The cured samples were hard and some warping was noticed. All of the samples broke.

80% Crete silty clay and 20% sand

The cured samples were very hard and some warping was noticed. Two of the three samples broke and the third cracked.

70% Crete silty clay and 30% sand

The cured sample bricks were very hard and none of the bricks broke. All three had medium cracks.

60% Crete silty clay and 40% sand

There were no cracks in the samples which were very hard. Warping was not noticeable and the texture was good.

Hastings silty clay loam

100% Hastings silty clay loam

A few small cracks were found in all of the three bricks. The bricks did not crumble but some warping was noticed.

90% Hastings silty clay loam and 10% sand

The cured samples were very hard with no cracks but some warping occurred.

80% Hastings silty clay loam and 20% sand

Two bricks had no cracks but the third one was cracked. The bricks were not very hard and no warping was noticed.

70% Hastings silty clay loam and 30% sand

There were no cracks and no warping occurred in the three samples. The texture of the bricks was good and they were hard.

60% Hastings silty clay loam and 40% sand

There were no cracks in the three bricks, the texture was sandy and the surface was easily rubbed off, the sample bricks having a tendency to crumble.

Boyd clay loam

100% Boyd clay loam

The cured bricks had large cracks, but were very hard. All of them had at least two cracks extending either along the length of the bricks or across them; never both ways.

90% Boyd clay loam and 10% sand

The cured bricks had large cracks, but were very hard; although they all broke.

80% Boyd clay loam and 20% sand

The bricks showed small cracks and were not very hard, but none of the samples broke. All were badly warped.

70% Boyd clay loam and 30% sand

The cured bricks had no cracks; were very hard. The texture was good and they did not warp.

60% Boyd clay loam and 40% sand

The bricks had no cracks, but were soft and crumbled when rubbed.

Hall silt loam

100% Hall silt loam

The bricks cured very well, no cracks being found in any of the samples. The bricks had a good texture, but were not very hard.

90% Hall silt loam and 20% sand

There were no cracks in the three samples, but the texture was sandy and the bricks had a tendency to crumble. A higher percentage of sand was not tried with Hall silt loam.

Rokeby silty clay loam

100% Rokeby silty clay loam

The bricks cured very well with no cracks or warping. The samples were hard and did not crumble.

90% Rokeby silty clay loam and 10% sand

No cracks were found in the samples, but they were soft and crumbled when handled.

80% Rokeby silty clay loam and 20% sand

The bricks were very soft and crumbled very easily and the texture was very sandy. No cracks were found in the samples.

A higher percentage of sand was not tried with Rokeby silty clay loam.

Colby silt loam

100% Colby silt loam

The samples cured very well with no warping. There were no cracks in the samples and the texture was good.

90% Colby silt loam and 10% sand

The sample bricks cured well; no cracks were found and the bricks did not warp.

80% Colby silt loam and 20% sand

There were no cracks in the bricks, but they were soft and crumbled easily.

A higher percentage of sand was not tried with Colby silt loam.

Colby silt loam (red)

100% Colby silt loam (red)

The samples cured very hard, but two broke and the other developed a large crack.

90% Colby silt loam (red) and 10% sand

All three of the samples had medium cracks, but none of them broke.

80% Colby silt loam (red) and 20% sand

The cured bricks were hard, but some small cracks were found.

70% Colby silt loam (red) and 30% sand

The samples cured very hard and no cracks were present.

60% Colby silt loam (red) and 40% sand

No cracks were found in the samples, but they had a tendency to crumble and had a sandy texture.

Tripp silt loam

100% Tripp silt loam

The bricks cured very well and were hard with no cracks.

A higher percentage of sand was not tried with Tripp silt loam.

When the sample bricks were cured they were measured and the percentage of shrinkage from their wet size was determined.

To determine the sand soil mixtures for standard size bricks that would not crack the following work was done.

A form was constructed of one inch lumber and lined with light sheet metal. The inside dimensions were eighteen inches by twelve inches by four inches. This size was chosen because a brick of this size is the largest standard brick. If a brick this size could be made without excess shrinkage, which causes cracking, the smaller sizes and specially-shaped bricks could be made without shrinkage cracks.

A sixty-pound sample of dry soil was dampened with water. After letting the mixture stand until the clods were softened, more water was added and mixed until the mixture was smooth and contained no lumps or clods of dry soil. The amount of water added was such, that the mixture was easily worked into the corners of the form, but not so large an amount that the brick slumped out of shape when the form was immediately removed after the brick was poured. The form was first dipped in water and then placed on a pallet which had been covered with a thin layer of sand to prevent the brick from sticking to it and to allow the brick to move as a whole as it dried. This not only prevented cracking because of sticking to the pallet, but made the brick much easier to remove from the pallet when dry. See Fig. 1.

The mixture was worked into the corners of the form with a trowel and the excess was struck off the top with a straightedge, then the form was removed. (In actual construction work, the upper and lower surfaces, that is the eighteen by twelve faces are sprinkled with sharp gravel to insure a good mortar bond.) The brick was then allowed to dry and cure. If the brick cracked upon drying, it was again mixed with water and more sand was added. The sand had been screened through an 8-mesh screen. When the mixture was again smooth and contained no lumps of dry soil it was poured as before and allowed to cure. This process was repeated until a mixture was found that when formed into a brick would cure or dry with no cracks.

The sand was added by volume, the first sand-soil mixture was five parts of soil and one part of sand; if that proved unsatisfactory,

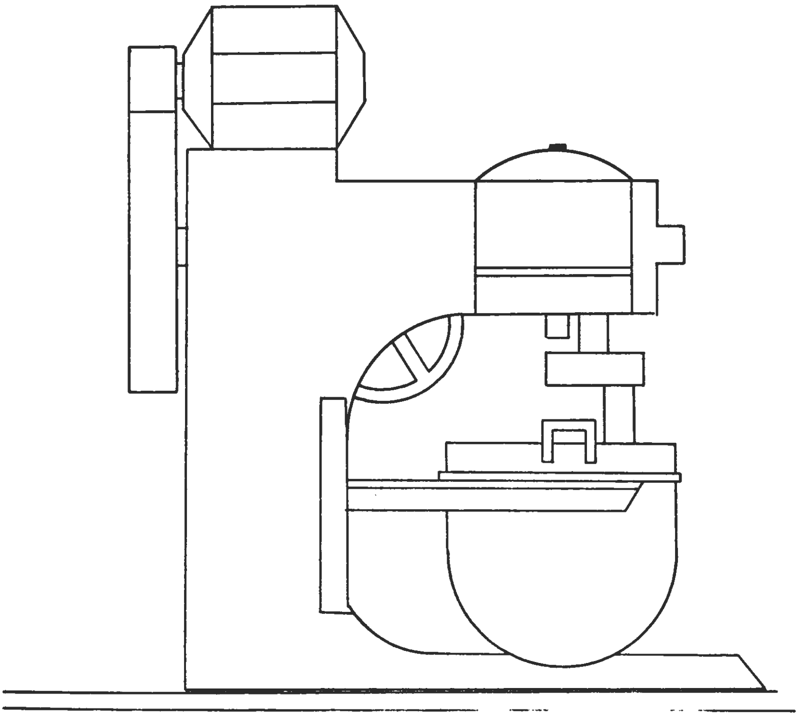

Fig. 1. Discarded bread mixer used to mix 60-pound samples of soil.

five parts of soil to two parts of sand were tried. This process was continued until a sand-soil mixture for each of the eight samples was found that when mixed with water and formed into a brick would dry without cracking. The mixtures are listed in Table III.

Table III. Sand Soil Mixtures Necessary for Bricks That Will Not Crack

Soil Type	Parts of Sand	Parts of Soil
Crete silty clay	3	1
Hastings silty clay loam	7	3
Boyd clay loam	3	1
Hall silt loam	7	3
Colby silt loam	7	3
Colby silt loam (red)	7	3
Rokeby silt clay loam	2	1
Tripp silt loam	0	1

The Effects of Adding Straw

Straw added to soil samples and then molded into sample bricks produced bricks of a quality no better than those containing no straw. The amount of shrinkage was reduced very slightly. The surface of the bricks containing straw was rough and coarse while those containing no straw was smooth. The addition of straw to soils containing the proper mixture of sand and soil apparently had no beneficial effect.

Stabilizers

Substances that are added to the soil-water mixture to produce a water-resistant soil block are called stabilizers. Six stabilizers were tested:

asphalt
road oil
reduced crude oil
residium*
colas G-104
bitudobe

The asphalt was of the type used as a roof coating. At room temperature is it a solid. The asphalt was heated until it was a liquid and kerosene was added. When the mixture cooled and the kerosene had evaporated the asphalt was in a very fine granular form. Asphalt in this form was tested.

The road oil was the type used in the surfacing of highways and was obtained from the Kansas State Highway Commission. It is a heavy black substance and is a liquid at room temperature.

Reduced crude oil was obtained at the Co-op Refinery located in Phillipsburg, Kansas. It is black in color, a liquid at room temperature and very heavy.

The residium was also obtained at the Co-op Refinery and is a heavy black liquid at room temperature.

Colas G-104 is a product manufactured by the Shell Oil Company for surfacing highways. It is dark brown in color and has the consistency of water at room temperature.

The bitudobe was purchased from the American Bitumuls Company. It is dark brown in color and has the consistency of water. Bitudobe is a product manufactured especially for stabilizing soil blocks.

Three of the stabilizers were discarded after preliminary tests which consisted of the following: Sample bricks three inches by five inches by one inch were poured. All of these samples were made from Tripp silt loam. Sample bricks were made containing 10% by weight of each of the six stabilizers. All of the bricks when cured were hard.

* See Riegels "Indus. Chem.," 3rd ed. (Reinhold Pub.), p. 404.

The samples were dipped in water and removed. Drops of water stood on the surfaces of all the sample bricks except the one containing asphalt. The sample containing the asphalt absorbed the water so asphalt was discarded.

The remaining samples were then placed on edge on a wet sponge. At the end of 12 hours the sample bricks were inspected. The sample bricks containing road oil and reduced crude oil developed very small cracks along the surface that was in contact with the sponge. When that surface was touched with the finger it crumbled away. Reduced crude oil and the road oil were discarded leaving residium, colas and bitudobe for more extensive tests.

Water Absorption Tests

Sample bricks, one and one-half inch cubes, were made to be used for the water absorption tests. The sand soil mixtures as given in Table III were used. Three different amounts of each of the three stabilizers were used:

1. One pound of stabilizer to fifty pounds of sand and soil.
2. Two pounds of stabilizer to fifty pounds of sand and soil.
3. Three pounds of stabilizer to fifty pounds of sand and soil.

Proper amounts of sand and soil were mixed dry. Then water was added and lastly the correct amount of stabilizer for the specific sample was added. The mixture was worked until its color was uniform. A form, three inches by five inches by one inch, was dipped in water and placed on a sand-covered level surface. The mixture was poured in, worked well into the corners and the top struck off smooth. The form was then removed. After the sample brick had stood for an hour a one-inch cube was cut from the corner with a knife which had first been dipped in water. The cubes were allowed to stand for 24 hours. At the end of that time the rough edges of the cubes were squared with

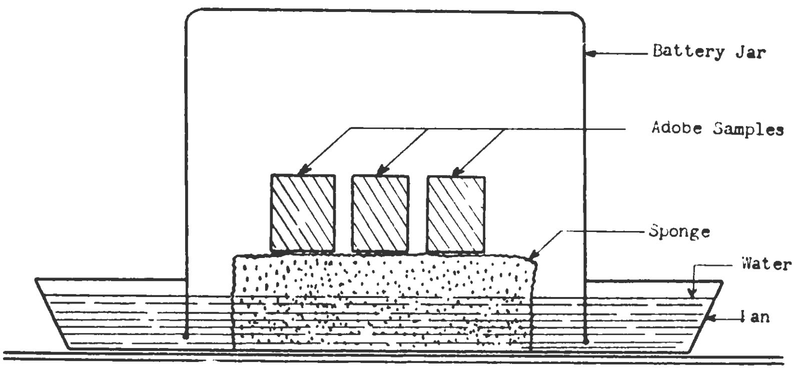

Fig. 2. Moist cabinet for absorption tests.

a knife. This was easily done because the sample bricks were not yet thoroughly dry. They were just dry enough to handle. They were allowed to cure for a week. At the end of that time they were placed in an oven kept at 140° F. until they attained a constant weight, which was recorded as the dry weight. The samples were placed upon a rectangular sponge one inch thick. The sponge with the sample bricks was placed in a pan three-fourths of an inch deep. A battery-jar was placed upside down over the sponge and the pan was filled with water. The lip of the battery-jar was kept under the surface of the water at all times. The jar and pan thus formed a moist cabinet as shown in Fig. 2. The battery-jar did not fit the bottom of the pan so tightly as to prevent the water from seeping under the jar as it was being absorbed by the sponge.

After seven days the sample bricks were weighed and the increase in weight from absorbed water determined. The results are given in Table IV.

Table IV. The Percentage Increase in Weight in Absorption Tests

Soil Type	Stabilizer	1 lb. to 50 lb.	2 lb. to 50 lb.	3 lb. to 50 lb.
	Bitudobe	14.70	13.50	5.82
Boyd clay loam	Colas	4.95	3.32	2.38
	Residium	3.38	3.24	2.39
	Bitudobe	24.00	11.40	3.97
Tripp silt loam	Colas	6.95	5.65	5.25
	Residium	3.11	2.28	1.70
	Bitudobe	6.80	2.20	1.97
Rokeby silt clay loam	Colas	3.39	2.20	1.55
	Residium	1.98	1.90	1.54
	Bitudobe	13.40	8.21	3.92
Colby silt loam	Colas	4.38	2.51	2.15
	Residium	4.08	2.40	2.21
	Bitudobe	9.90	6.23	3.80
Crete silty clay	Colas	4.45	3.35	2.80
	Residium	3.28	2.97	2.26
	Bitudobe	10.50	4.05	2.58
Hall silt loam	Colas	3.99	3.35	3.23
	Residium	1.83	1.22	1.05
	Bitudobe	9.30	6.41	3.72
Hastings silty clay loam	Colas	4.60	3.88	2.08
	Residium	2.84	1.92	1.42
	Bitudobe	10.30	10.20	2.94
Colby silt loam (red)	Colas	9.50	5.60	1.83
	Residium	5.00	3.29	1.28

Erosion Tests

A form four by three by one inch was constructed and lined with light sheet metal. The bricks were molded on a piece of sheet-rock sprinkled with fine sand. The mixture of sand and soil given in Table III was first mixed in a dry state. Water was then added until the mixture had the correct consistency. Lastly the stabilizers were added and the components mixed until the batch had a uniform color. The color was produced by the stabilizers, colas and bitudobe yielding brown, and residium giving black.

Three amounts of stabilizers were tried as follows:

1. One pound of stabilizer to fifty pounds of sand and soil.
2. Two pounds of stabilizer to fifty pounds of sand and soil.

3. Three pounds of stabilizer to fifty pounds of sand and oil.

Thus for each type of soil nine separate mixtures were tested, that is, three of each stabilizer.

The sample bricks were poured on the sand-covered surface and the mold removed immediately. After 48 hours the bricks were placed on edge to hasten the curing. Two bricks of each mixture were made, 144 bricks in all.

After the sample bricks had cured for approximately a week they were placed in an oven and kept at 140° F. until each brick had a

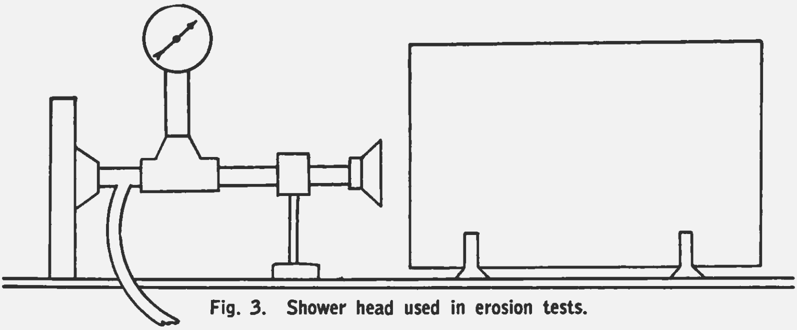

Fig. 3. Shower head used in erosion tests.

constant weight, assuring that the bricks were completely dry. The bricks were then piled in a dry place until given the test for erosion.

The erosion tests consisted of the following: dry sample bricks were blaced on edge and sprayed with water from a 2 inch shower

Table V. Table Showing the Result of Erosion Test
(One pound of stabilizer to fifty pounds of sand-soil mixture)

Soil Type	Stabilizer	Time	Maximum Depth of Erosion	Brick Condition	Extent of Erosion
Boyd clay loam	Bitudobe	3 m.*	¾ inch	very soft	very great
	Colas	5 m.	¾ inch	very soft	very great
	Residium	10 m.	½ inch	soft	medium
Tripp silt loam	Bitudobe	2 hr.**	¾ inch	soft	very great
	Colas	2 hr.	¼ inch	slightly soft	slight
	Residium	2 hr.	1/32 inch	hard	very slight
Rokeby silt clay loam	Bitudobe	35 m.	⅜ inch	soft	medium
	Colas	2 hr.	⅛ inch	hard	slight
	Residium	2 hr.	none	hard	none
Colby silt loam	Bitudobe	25 m.	¾ inch	very soft	very great
	Colas	2 hr.	⅜ inch	soft	medium
	Residium	2 hr.	⅜ inch	soft	medium
Crete silty clay	Bitudobe	3 m.	½ inch	very soft	great
	Colas	5 m.	¾ inch	soft	great
	Residium	34 m.	¾ inch	soft	great
Hall silt loam	Bitudobe	30 m.	¾ inch	soft	very great
	Colas	30 m.	7/16 inch	soft	great
	Residium	2 hr.	¼ inch	hard	slight
Hastings silty clay loam	Bitudobe	15 m.	⅜ inch	soft	medium
	Colas	15 m.	5/16 inch	soft	medium
	Residium	70 m.	5/16 inch	soft	medium
Colby silty loam (red)	Bitudobe	17 m.	¾ inch	soft	very great
	Colas	15 m.	½ inch	soft	great
	Residium	25 m.	⅜ inch	soft	medium

* minute
** hour

head. The pressure of the water was 10 pounds. The distance of the shower head from the bricks was seven inches. The time for spraying varied from three minutes to a maximum time of two hours. (The apparatus is shown in Figure 3.) If a brick became eroded within the time limit, the time was noted and the brick removed from the spray. A number of samples showed no erosion after two hours of continuous spraying. The results of the tests are given in Table V.

Table V. Table Showing the Result of Erosion Test (Continued)
(Two pounds of stabilizer to fifty pounds of sand-soil mixture)

Soil Type	Stabilizer	Time	Maximum Depth of Erosion	Brick Condition	Extent of Erosion
Boyd clay loam	Bitudobe	5 m.	½ inch	soft	great
	Colas	30 m.	¾ inch	very soft	very great
	Residium	30 m.	½ inch	soft	medium
Tripp silt loam	Bitudobe	2 hr.	¼ inch	slightly soft	medium
	Colas	2 hr.	⅛ inch	hard	very slight
	Residium	2 hr.	none	very hard	none
Rokeby silt clay loam	Bitudobe	2 hr.	none	very hard	none
	Colas	2 hr.	none	very hard	none
	Residium	2 hr.	none	very hard	none
Colby silt loam	Bitudobe	1 hr.	¼ inch	slightly soft	medium
	Colas	2 hr.	1/16 inch	hard	very slight
	Residium	2 hr.	none	hard	none
Crete silty clay	Bitudobe	16 m.	⅜ inch	soft	medium
	Colas	1 hr.	⅜ inch	soft	medium
	Residium	1½ hr.	¼ inch	soft	medium
Hall silt loam	Bitudobe	2 hr.	⅜ inch	soft	medium
	Colas	2 hr.	¼ inch	hard	slight
	Residium	2 hr.	none	hard	none
Hastings silty clay loam	Bitudobe	1¼ hr.	7/16 inch	soft	medium
	Colas	2 hr.	⅛ inch	hard	slight
	Residium	2 hr.	⅛ inch	hard	slight
Colby silty loam (red)	Bitudobe	17 m.	⅜ inch	soft	medium
	Colas	2 hr.	½ inch	soft	great
	Residium	2 hr.	⅛ inch	slightly soft	slight

Table V. Table Showing the Result of Erosion Test (Continued)
(Three pounds of stabilizer to fifty pounds of sand-soil mixture)

Soil Type	Stabilizer	Time	Maximum Depth of Erosion	Brick Condition	Extent of Erosion
Boyd clay loam	Bitudobe	5 m.	⅜ inch	slightly soft	medium
	Colas	1 hr.	½ inch	slightly soft	medium
	Residium	2 hr.	⅜ inch	slightly soft	medium
Tripp silt loam	Bitudobe	2 hr.	none	very hard	none
	Colas	2 hr.	1/16	very hard	very very slight
	Residium	2 hr.	none	very hard	none
Rokeby silt clay loam	Bitudobe	2 hr.	none	very hard	none
	Colas	2 hr.	none	very hard	none
	Residium	2 hr.	none	very hard	none
Colby silt loam	Bitudobe	2 hr.	none	hard	very very slight
	Colas	2 hr.	none	very hard	none
	Residium	2 hr.	none	very hard	none
Crete silty clay	Bitudobe	16 m.	¼ inch	soft	medium
	Colas	1 hr.	3/16 inch	hard	slight
	Residium	2 hr.	none	hard	very slight
Hall silt loam	Bitudobe	2 hr.	none	hard	very slight
	Colas	2 hr.	none	very hard	none
	Residium	2 hr.	none	very hard	none
Hastings silty clay loam	Bitudobe	1¼ hr.	⅛ inch	hard	slight
	Colas	2 hr.	none	hard	very slight
	Residium	2 hr.	none	very hard	none
Colby silty loam (red)	Bitudobe	2 hr.	¼ inch	soft	medium
	Colas	2 hr.	1/16 inch	hard	very slight
	Residium	2 hr.	none	very hard	none

Adaptability To Paint

A set of bricks the same size and having the same proportions of stabilizer as those used in the erosion tests was poured. The bricks were dried to constant weight. One-third of each sample brick was painted with aluminum paint, one-third was not painted and the other one-third was painted with asphalt base aluminum paint. The paint was allowed to dry for 48 hours. Then one-half of each of the three areas was given a coat of outside white house paint. After 48 hours a second coat of the white paint was given these surfaces. The paint was then allowed to dry for one week.

The aluminum paint used was Aluminum Du Pont Duco, made by E. I. Du Pont De Nemours and Co., Inc., Wilmington, Delaware. The asphalt-base aluminum used was Mayfair Asphalt Aluminum, Paint No. 2971 made by the Waggener Paint Company, Kansas City, Missouri. The outside house paint used was Pittsburgh Sun-Proof House Paint, 1-54v titanic outside white.

At the end of the drying period the paint was hard. All three of the strips given the two coats of white house paint were equally white. The bricks were laid flat and sprinkled with water. The amount of water was great enough to allow water to stand on the surface of the bricks. The temperature of the bricks was 70° F. The samples were then placed out-of-doors on a table, being careful not to spill the water from the surface of the bricks. Snow was falling and the temperature was 20° F. The samples were left out-of-doors for 48 hours. The lowest temperature during that period was —23° F. Owing to the location of the table, the sun of the following day, was warm enough to melt the snow that had fallen on the samples. That night the temperature dropped to 15°F. freezing the water and bricks again. The following morning the samples were moved indoors where the temperature was 80° F. The samples experienced a 103° change in temperature and were frozen twice. Upon careful examination no deterioration of exposed brick surface or of the painted surfaces was found.

The stabilizers did not show through the two coats of white paint on the bare brick, nor did they show after a period of 30 days. Using the Du Pont Aluminum or the Mayfair Asphalt Base Aluminum as a prime coat, made covering with white paint much easier. One coat of aluminum completely covered the black color of the samples made from soils stabilized with residium.

Conclusion

The soils of Ellis County are in general suitable for use in making abode bricks. All but one of the eight samples had to be blended with sand to prevent cracking. The amount of sand that had to be added could not be determined from the simple screen analysis nor from the hydrogen ion concentration. Pouring sample bricks with varying percentages of sand is the most dependable method of finding the admixture of sand necessary.

The requirements of the Federal Housing Administration for adobe brick construction is that the bricks be rendered water-resistant (Long, 3).

For a brick to be considered water-resistant the American Bitumuls Company requires that it absorb not more than 2.5% moisture by weight when exposed to a wet surface for seven days and should not be appreciably pitted or eroded in two hours of spraying with a fine spray (American Bitumuls Co., 1). It appears that all of the samples tested could be made to meet those requirements if a sufficient amount of stabilizer is used. The amount of residium needed to meet these requirements was less than that required of colas or bitudobe. In most cases less colas was required than bitudobe.

A prime coat of asphalt aluminum paint forms a very fine base for painting. The asphalt paint is also a water-proofing substance. The paint was applied with a brush. A better and more complete covering of the rough surface could have been made by spraying the paint on the surface. The tests given the painted surfaces were limited. To reproduce the climatic conditions of Ellis County for a span of five years was beyond the scope of the experimental work. From the tests given it appears that the surfaces will "take" paint and that the paint will retain its original color.

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