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Paints and Plasters for Rammed Earth Walls

R. L. Patty

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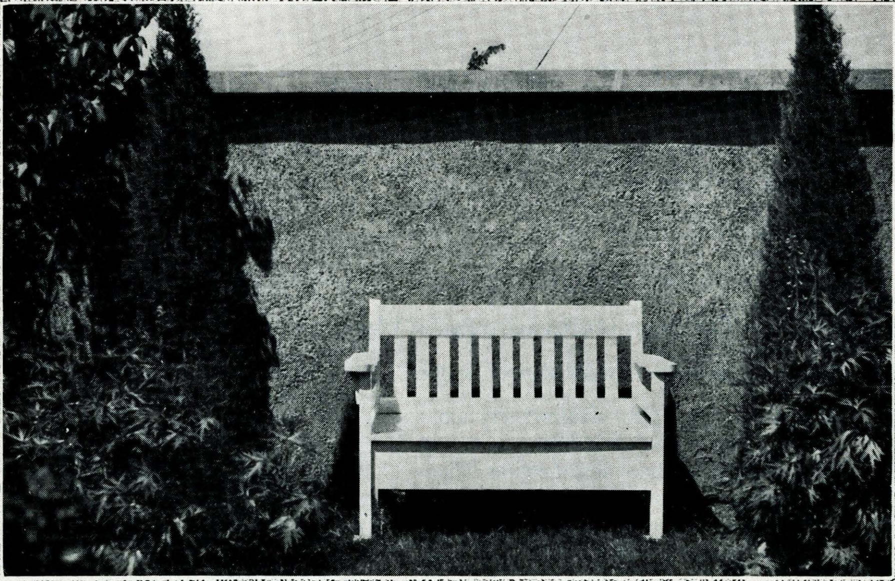

PAINTS AND PLASTERS FOR RAMMED EARTH WALLS

AGRICULTURAL EXPERIMENT STATION
South Dakota State College
BROOKINGS, S. D.

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Digest

Portland cement stuccoes, as used and proven satisfactory for ordinary stucco work in a community, will be satisfactory on rammed earth walls. The success of stucco work depends to a considerable extent on the sand that is used. For high quality work and for any except low walls, a bonding wire or mesh should be used the same as for stuccoing on frame walls.

For low walls of 8 feet or less the stucco has been nailed to the wall without the bonding mesh and with a saving in cost. Stucco should not be applied to a rammed earth wall until the wall has seasoned for several months.

Two inexpensive plasters have proven quite satisfactory on rammed earth walls. They are dagga-cement plaster and dagga plaster with an admixture of asphalt emulsion. Stuccoes and plasters will not be satisfactory on walls made from soil that is unfit to use.

The success of paints on exterior rammed earth walls has been generally disappointing. Only a comparatively small number of paint panels have proven satisfactory. Good quality lead-oil paints have shown satisfactorily on high quality walls only, for exterior work. Paints should be tried only after careful study of the paint panel results and with a thorough knowledge of the soil used in the construction of the wall.

Linseed oil and glue sizing have proven equally satisfactory for priming coats for lead-oil paints and possibly fish oil may be equally good. Priming coats that penetrate the wall have been found definitely unsatisfactory.

No transparent paint has been found satisfactory as yet. Linseed oil does little damage to the wall surface, but it has low durability. Other transparent paints except some extremely temporary ones damaged the wall deeply.

Most good quality paints have proven quite successful on interior walls. Cold water paints, with the exception of whitewash, have been satisfactory. Common wall plaster has proven quite successful on interior walls, and nailing the scratch coat to the wall has been satisfactory on all panels tried.

The most valuable and most practical admixture yet tried for rammed earth walls is ordinary sand. It may or may not contain a reasonable amount of coarse aggregate. Some coarse aggregate in the admixture will neither be an advantage nor disadvantage to the weathering quality of the wall nor to the success of the covering. A well graduated sand and aggregate will increase the strength of the wall, slightly, over an admixture of sand containing uniform sized particles.

ACKNOWLEDGEMENT. In this covering study the author wishes to acknowledge the assistance of L. W. Minium, H. H. DeLong, J. E. Cranston, W. D. Scoates, Edwin Townsend, J. M. Cranston, Moyne Kirby, Allen C. Henry, W. O. Eddy and many others who aided with the covering panels or with valuable suggestions.

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Introduction

According to historians of ancient times, pise' de terre (pronounced pee-say duh taire) or rammed earth walls have been known to stand in good condition for 250 years as bare walls or without any protective covering. In the first few years of this study there was some skepticism of this statement, but after 10 years there appears no doubt as to the truth of it. A few walls in our experimental yard made from natural soils will stand indefinitely as bare walls, and a larger number of walls in which sand was added to the natural soil will also stand indefinitely. During the first year or two a rammed earth wall is green and will be roughened more or less on the surface by violent driving rains, but after this period is over, a high quality wall will show little, if any weathering effect. Out of 29 walls built in the experimental yard 10 years ago, of distinctly different natural soils obtained from all parts of South Dakota, five would stand satisfactorily without any protective covering. They have stood unprotected and are still full dimension as checked by the concrete foundation under them. The walls are hard and sound, and the surfaces are roughened barely enough to give them an attractive appearance. No appreciable change has taken place in these walls since the end of the second year.

Six other walls in the yard will stand satisfactorily without any covering. These are of the 29 soils, but the walls were not built of the natural soil. Sand was added to the natural soil in building these walls to make the soil high quality. The corresponding wall made from the natural soils without the sand admixture are slowly weathering down and will not stand as bare walls. Such walls are only medium in quality and in order to be satisfactory, they must have a protective covering on the surface.

In view of the fact that the majority of walls will require a protective covering, the study of protective coverings began at this station very soon after the work on this type of construction began. The study has not been primarily a comparison of the quality of one brand of covering against another; it has been a test of all different types of coverings, methods of bonding and methods of application. High quality covering materials have been used throughout the study, and up to the present time no certain brand of any type of covering material has shown any advantage over another brand.

Owing to the large number of panels studied—approximately 240 to date—it did not seem desirable to show a more detailed record of inspections. Official inspections were made at 60-day intervals during the early life of the panel, and later reduced to two official inspections per year. Unofficial inspections were, of course, made more frequently.

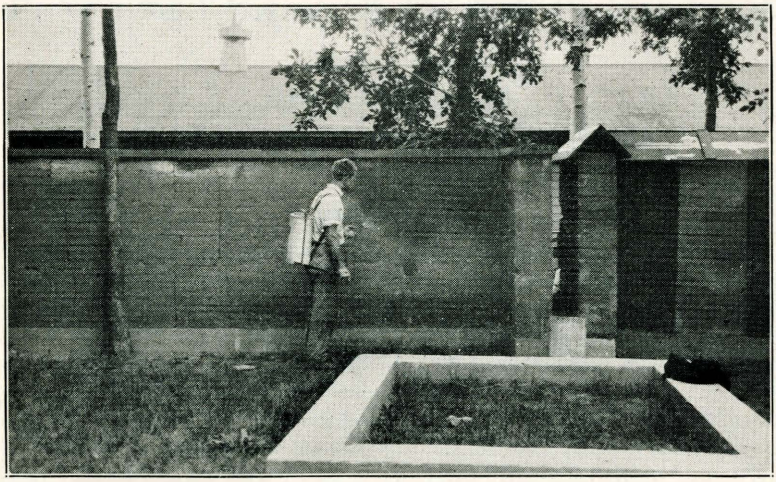

Fig. 2. Wetting Down a Rammed Earth Wall Before Plastering.

Before plastering the earth wall it is wet down so that the moisture will not be drawn from the plaster. A garden sprinkler or a hose can be used in place of this small spray machine.

Records of failures are as carefully recorded here as records of successful panels. The failure records will possibly be more valuable to prospective builders than the records of coverings that proved favorable.This statement is based on the many inquiries received from prospective builders indicating a desire to try out a great variety of materials for the purpose. A large number of materials were tested that were obviously unfavorable in order that a definite record of their failure would be recorded.

Second and third trials have been made with all covering materials that showed a promise of success or concerning which there might be a doubt as to normal control, fair conditions of application or fair conditions of exposure to the weather. Where second and third trials were made, large panels covering 10 to 15 square yards were usually used. This was true of both paints and plasters.

Paints have been tried persistently with the hope of finding a successful paint covering for earth walls, and especially with the hope of finding a successful transparent paint. Paints will protect the surface of earth walls from violent driving rains, and at the same time do not completely hide the identity of the material. This is of particular value in dwelling house construction, where the owner is not only interested in the high thermal efficiency and air conditioning value of this type of wall, but is also interested in having a wall that is unique and different.

Portland Cement Stuccoes are Satisfactory Exterior Coverings for Earth Walls

Portland cement stuccoes have proven dependable and satisfactory for rammed earth wall coverings over testing periods of six to eight years. Their disadvantage is that they cover the surface completely and hide the identity of the material. This disadvantage may be of economic as well as sentimental importance, because the exterior when stuccoed does not indicate the stability and high insulating value of the wall. Standard stucco mixtures and standard methods of bonding stucco to frame walls have been satisfactory for use on rammed earth walls. Experimental results also show that leaner mixtures may be used when economy demands it. A standard practice is to bond portland cement stucco to frame walls by metal lath or reinforcing wire mesh nailed to the wall. This practice is entirely satisfactory for earth walls and is advised in most cases. However, for economy in low wall construction the results show that the first or scratch coat of stucco can be nailed to the wall (see page 9) immediately after placing without the bonding wire and with satisfactory results. The nail heads will be covered by the second coat of stucco, and the stucco has stood successfully on walls up to eight feet in height. The nails used have been as large as could be driven into the wall. The size of nail that can be driven will depend largely on the age of the wall. The earliest that stucco should ever be applied to a wall after it is rammed is nine months. At this age 16d common nails can often be used. At one and one-half years, 12d

Fig. 3. Ordinary Stuccos Have Been Successful on Rammed Earth Walls.

The stucco on this poultry house has been on the walls for five years. The mixture used for the stucco was (1-4-⅕), 1 measure of portland cement, 4 measures of sand, and ⅕ measure of cem-mix. The sand was high quality. These walls were first painted. After two years the paint failed and this stucco was put on. The earth walls are slightly below average in quality.

nails can usually be driven and after that it is probable that 10d nails will be the longest that can be driven. Stuccoes and plasters are extremely heavy and the large nails are desirable for this reason.

Results have shown definitely that it is not practical to apply any stucco or plaster to rammed earth walls without some method of bonding it.

Mixtures For Portland Cement Stucco. Twelve experimental panels carrying slightly different mixtures have been studied. These stuccoes were applied during the years 1932-33-34. Since they were all satisfactory, reports will not be made on each separate panel in this bulletin. The panels varied in width and height but covered a total wall length of 160 feet. The cement-sand ratio in the stucco varied from 1 - 3 to 1 - 4 parts by volume; i.e., 1 measure of portland cement to 4 measures of sand. A commercial filler, cem-mix, was added in amounts ranging from 1/6 part cem-mix (1 part of cem-mix to 6 parts of portland cement) to 1/2 part cem-mix. Hydrated lime was substituted in place of the cem-mix in from "1/6 part lime" to "1/4 part lime" with no difference showing in the results as yet. The stucco men who did the work liked the mixture (1 - 3½ - 1/3) 1 measure of portland cement, 3½ measures of sand and 1/3 measure of cem-mix best. The results indicate that the sand-cement ratio should not be less than 3½ to 1 and that with well graduated sand a ratio of 4 to 1 is possibly better on good quality earth walls.

Methods of Bonding Cement Stucco. Forty-four experimental panels using different methods of bonding stucco were applied during the same period—1932 to 1934. These panels covered 526 lineal feet of wall. In general, the methods used included: No bonding (on bare surface); the use of light expanded metal or metal lath weighing 1.8 lbs. per square yard; the use of heavy metal lath weighing 3.6 lbs. per square yard; the use of 2-inch mesh stucco wire; the use of nails driven in holes that had been gouged in the wall with a special tool; and the use of nails driven directly through the fresh scratch-coat into the wall. In all cases the dry surface of the wall was sprayed with water but not thoroughly soaked. The entire surface of the wall was covered with the spray just before applying the first coat of stucco. The first coat of stucco was sprayed in a similar manner before applying the second coat.

Nailing The Bonding Wire. No advantage of one type of bonding wire over another has been shown as yet. If the heavier metal lath has an advantage over the lighter weight, it will probably be many years before the results will be evident. The bonding wire was nailed to the wall in two ways: with common wire nails, and with 16d wire nails with the heads bend over in the form of a hook or single-point fence staple. Two long panels were nailed with the hooked nails at random but at approximately 12 inch intervals each way. The result was satisfactory, but the nails were somewhat difficult to drive. A simple and satisfactory tool was devised for bending these nails very rapidly. The common nails proved quite satisfactory also. They were driven about 12 inches apart in the upper corners of the mesh, keeping the wire stretched. The nails are driven to carry weight, and they should be driven straight into the wall rather than having the point of the nail angle downward as it is driven. When the wall is too hard, nails smaller than 16d must be used.

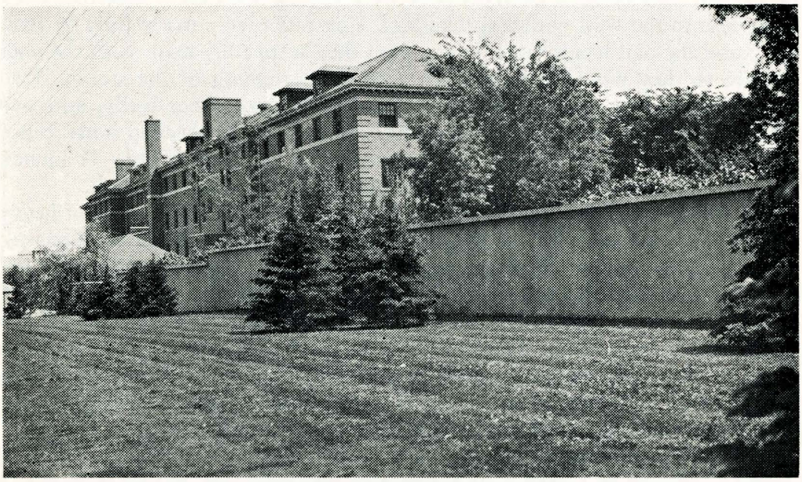

Fig. 4. A Section of Garden Wall Used For Trying Different Bonding Methods For Stucco on Rammed Earth Walls.

Twenty-eight bonding panels were used on this wall, including methods of nailing and joining bonding wire. Picture taken after four years.

Lapping Joints of Reinforcing Wire. Six stucco panels were bonded by lapping the metal lath and woven mesh reinforcing wire at the joints. Metal lath is bought in strips, and the strips must be fastened firmly together under stucco. The strips used in this study were all 99 inches long. The light-weight strips were 39 inches wide and the heavier weight strips were 48 inches wide. The strips were put on horizontally and were lapped from 2 to 3 inches where they joined. At the lap they were wired with two complete turns of No. 16 smooth wire with the ends well twisted. They were wired at intervals of 18 inches at both vertical and horizontal joints. Special care was given to the nailing along this lap. The results of this method were satisfactory. These panels were 50 feet long.

Butting Joints Of Reinforcing Wire. Two stucco panels were bonded by "butting" the metal lath reinforcing wire at the joints. Instead of lapping the mesh at the joints, the edges were placed so as to touch. They were wired together in exactly the same manner as the above panels and with the same spacing. They were also carefully nailed along the joints. Checks appeared in the stucco at more than one half of the vertical joints. The horizontal joints stood satisfactorily. Although the stucco may not fail due to these checks, this method of joining the bonding mesh is definitely unsatisfactory and careful lapping and wiring is advised. These panels were 50 feet long.

Nailing Through The Scratch Coat. Twenty small stucco panels approximately 7 x 6 feet were bonded by nails, only. Half of these panels were nailed directly through the first or scratch coat while it was soft. The other half was bonded by nails that were driven into holes that had been gouged into the wall with a special tool. The holes were made fully ½ inch deep and the nail heads were driven until they were fully flush with the wall surface so they would not interfere with the spreading of the stucco. Two panels bonded by driving the nails in holes checked rather badly, and two panels with the fresh scratch coat nailed to the wall also checked some. Since these panels were on shallow foundations with a depth of only 24 inches, it is possible that the checking was due to frost action under the wall.

A better test of this method of bonding was made on small walls of heavy clay soil that are unfit for use in pise' construction. Four walls were stuccoed; three were bonded by driving nails into holes gouged in the wall while the fourth was nailed through the scratch coat. All four stuccoes failed within two years' time as expected, since no covering has been found that would stay on a wall of heavy clay. The nails driven into holes did not prove to be as good as the nails driven through the green scratch coat. This study also showed that nails should be driven at random rather than in straight lines. One panel showed a definite crack straight down a row of nails.

Distances between nails have been varied on panels. Distances of 5, 7, 9 and 12 inches on center have been used, and nail sizes including 8, 10, 12 and 16 penny have been used. No apparent advantage has been shown in using smaller nails at closer intervals. Twelve or sixteen penny nails are no doubt desirable and at random intervals not to exceed 12 inches. This same nailing is desirable for bonding wire.

Wire Through Bolt Holes. Another method of bonding the reinforcing wire mesh to the wall was tried on two panels. This was supplementary to the regular nailing. In building the wall, bolt holes from the form were left through the earth wall at intervals of approximately 30 inches each way. A single strand of No. 16 smooth wire was cut to extend through these holes and about 3 inches on either side. These ends were twisted around the mesh reinforcing and the holes then tamped full of lean cement mortar. The idea worked satisfactorily but it is doubtful whether this extra fastener was necessary.

In applying stuccoes one practice that is well to avoid has been demonstrated. The stucco should not carry off the earth wall and onto the concrete foundation below as a continuous coat. Several failures or cracks in the stucco occurred at the point around the foundations. This is no doubt due to the difference in expansion and contraction of the two materials. If it is desired to stucco the wall over the foundation and to the ground, an expansion joint should be left at the top of the foundation and filled with an elastic filler such as "dum-dum."

Stucco And Foundation Depth: For successful stucco work on walls of any material the foundation should extend below the frost line to eliminate the heaving of the wall due to frost action. This practice should be followed in the use of stucco on pise' or rammed earth walls where absolute safety against failure is desired. The study of panels that has been carried on for six to eight years indicates, however, that on low walls, it might be practical to use stucco with foundations extending 24 to 36 inches below grade in

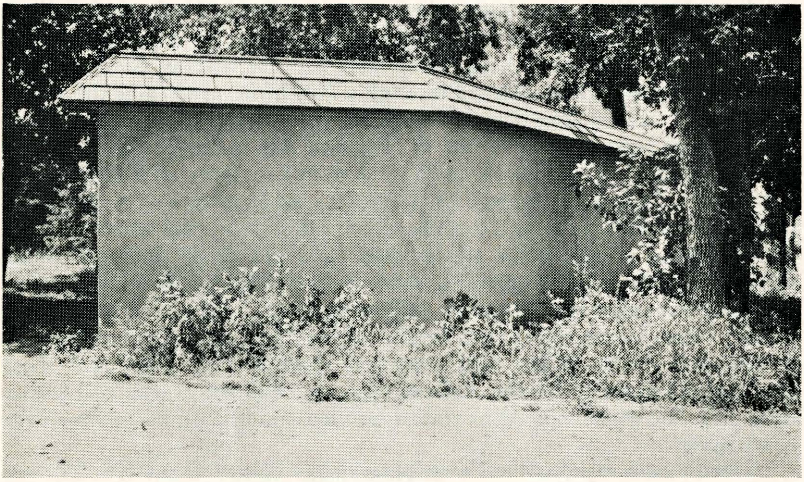

Fig. 5. Stucco Panels on a Section of Rammed Earth Wall.
The mixture used for the stucco panel in the foreground was (1-3½-⅓), 1 measure of portland cement, 3½ measures of sand and ⅓ measure of cem-mix. This was the mixture the plasterer liked best.

a South Dakota climate. The latitude of Brookings is 44 degrees north, with an average annual rainfall of 25 inches. A majority of the successful stucco panels are on shallow foundations and a half dozen panels have developed fine cracks that are obviously due to frost action under the foundations. No complete failures have resulted from it and the stucco on an experimental poultry house, having a foundation 30 inches below grade, is quite satisfactory after six years. In no case should shallow foundations (above the frost line) be used for any except low walls, and then only when economy requires it.

Care Of Stucco. Steel reinforcing rods were used at the bottom and top of the concrete foundations in most cases and the practice is a good safe-guard and especially where stucco is used on the walls. The steel rods are spaced 3 to 4 inches on center. The rods in the bottom of the foundation take the load of the wall from the top, and the reinforcing rods at the top take the thrust from below due to frost action. In the case of all stucco panels applied and of other plasters containing portland cement, care was taken to shade the fresh stucco or to spray it frequently for the first two days during the daylight hours. The best stucco jobs on any surface may check badly on a drying day if they are not protected or sprayed frequently.

Other Exterior Plasters and Stuccoes

A thorough study of inexpensive plasters and stuccoes has been made in an attempt to discover practical coverings that would be satisfactory on poultry houses and other low-walled farm buildings. Some plasters and lean stuccoes are showing very satisfactorily on the panels.

Dagga Plaster. Dagga plaster is a mud plaster that has been used through the centuries by the Spanish and Mexicans. A good quality dagga plaster will contain enough fine sand so that the plaster will dry without checking. The sand and clay should be screened through a No. 12 sieve which is the size of ordinary fly screen. The actual volume of sand and clay will be approximately three parts of sand to one of clay, and this mixture will usually be obtaind by mixing two measures of sand to one measure of average sandy clay subsoil. When the analysis of the clay is not known, a trial mixture is made, mixed with water to a slightly stiff mortar, and a trial smear or patch of it made on a wall. If the plaster does not check in 48 hours of drying weather and the bond is good, the mixture is satisfactory. If the trial patch checks, the mixture is adjusted by adding more sand. No admixture is used except water. When made with bright colored clay soils, an attractive soft plaster will result. When well protected from driving rains and sharp mechanical injury, on interior walls or under porches this plaster will last indefinitely, but when exposed to violent weather conditions, it is only a temporary cover.

Three panels were covered with plain dagga plaster. Panel No. 16Y was 3 x 5 feet in size. The cover was applied on August 12, 1931. It was plastered on the bare wall without any bonding agent. (All plaster coverings are applied after the surface of the wall has been sprayed with water.) After three years it began to fail and failed rapidly.

Panel No. 16YA was 3x5 feet in size. The cover was applied on August 13, 1931. It was plastered over a light metal lath, nailed to the wall. After eight years a slow wearing away of the surface is evident, but no part of the plaster has broken. This panel is partially protected from driving rains.

Panel No. 100Y was applied on August 5, 1932. Size of panel was 12 x 8 feet. It was plastered on the bare wall without any bonding agent. Failure sign after 21 months.

Dagga Plaster With Surface Painted. The results indicated that dagga plaster alone was too soft to resist driving rains, so painting the surface with lead-oil house paint was tried. Three large panels were treated in this way.

Panel No. 101Y was applied as follows: Priming coat of plaster was applied and nailed with 10d nails, 12 inches apart, at random on October 7, 1934; second coat of plaster on November 5, 1934. In May, 1935 this plaster was given a priming coat of thin oil paint, brushed; in June 1935 a second coat of good quality house paint was brushed on; in August 1935 a third coat of house paint was added. Size of panel was 12 x 8 feet. After four and one-half years this cover is in perfect condition.

Panel No. 33M was applied in the same manner as No. 101Y except the second coat of plaster followed in three days, on August 4, 1936. The size of the panel was 12 x 8 feet. A priming coat of glue sizing, 1 lb. of glue per gal. of water, was brushed on after 10 days. Three days later a coat of good quality house paint was brushed on, and five days later a second coat of house paint. After three and one-half years this panel is in perfect condition.

Panel No. 34M was applied on August 3, 1936, the day preceeding panel No. 33M. The size of the panel was 26 x 8 feet. This plaster panel was

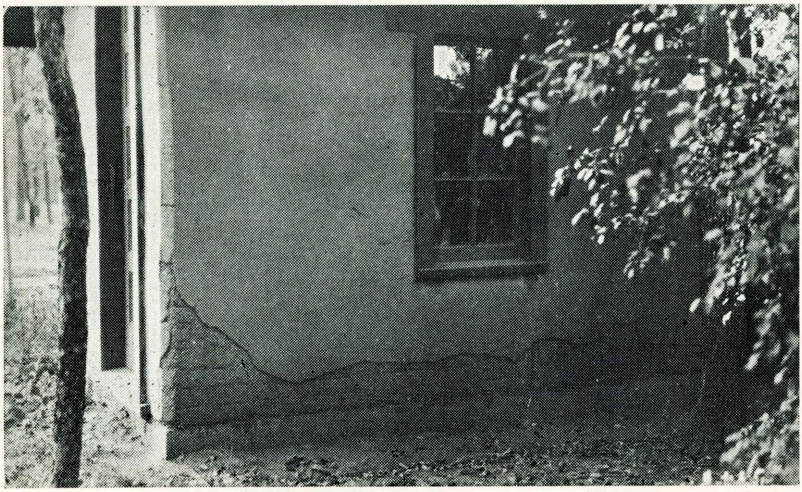

Fig. 6. Plain Dagga Plaster on Rammed Earth.

This plaster is made from sand and sandy clay mixed with water. It is a temporary covering, only. The picture was taken after two years. When painted with lead-oil paint, this dagga plaster is made quite durable. Panels are in excellent condition after five years.

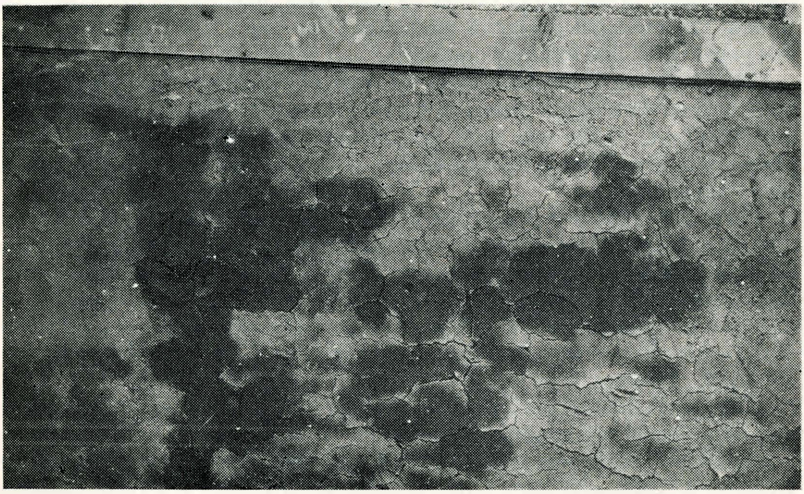

Fig. 7. An Example of Dagga Plaster Containing Too Much Clay and Not Enough Sand.

When dagga plaster checks like this, it must be removed and replaced with mortar containing more sand. Trial of a sample patch of plaster before using is advised.

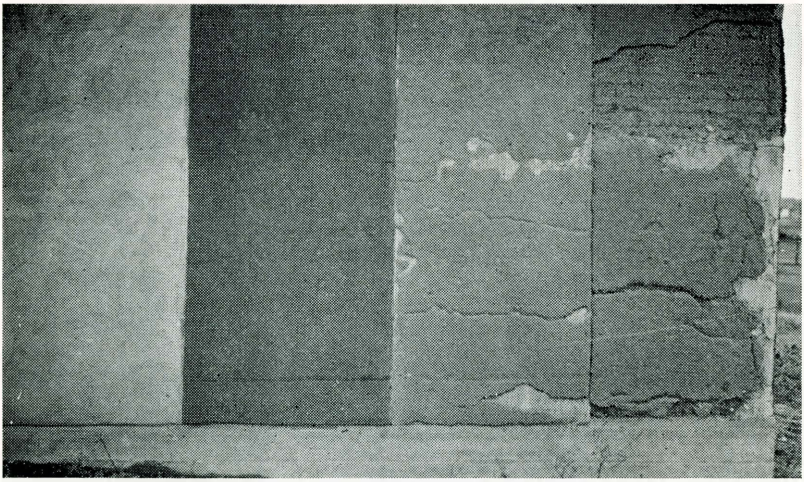

Fig. 8. Two Inexpensive Plasters Showing Excellent Results.

These plaster panels have been on for five years. The one at the left is dagga-cement plaster containing only 10 percent of portland cement. The dark panel is dagga plaster to which is added asphalt emulsion at the rate of ½ gal. per 100 lbs. of dry dagga plaster. The two panels at the right failed, although the plaster contained more cement than the dagga-cement panel.

painted in the same way and at the same periods as panel 33M. A different clay was used in the dagga plaster on this panel, and the plaster proved to contain too low a percentage of sand. After two years, two large patches on this panel failed due to heavy cracking.

Dagga Plaster With Admixture Of Asphalt Emulsion. Two panels have been covered with dagga plaster to which was added asphalt emulsion (Bitumul Stabilizer) at the rate of ½ gal. of emulsion to 100 lbs. of dry dagga plaster mixture. The asphalt emulsion, a thin liquid, was mixed in with the mixing water.

Panel No. 31M was 3 x 9 feet in size. The first coat was plastered on August 3, 1936 and nailed to the wall immediately with 10d common nails, 12 inches apart at random. The second coat was applied one day later. After three years and six months this panel is in perfect condition. The color is dark but the plaster promises to be a very durable one for the cost. The cost of the sand and clay was negligible, and asphalt used measured 1 ½ gals. per 100 sq. ft. of plaster. (See Fig. 8.)

This panel showed good promise, and according to our practice a second and larger panel was made of this plaster.

Panel No. 11Mb was 10 x 10 feet in size. The first coat was applied on October 8, 1938 over inch-mesh poultry wire, carefully nailed. Asphalt emulsion was mixed with the dagga plaster at the rate of 1 gallon per 100 pounds of dry plaster. This is double the amount used in panel No. 31M. The second coat was plastered on October 15. After 18 months this panel is in in perfect condition.

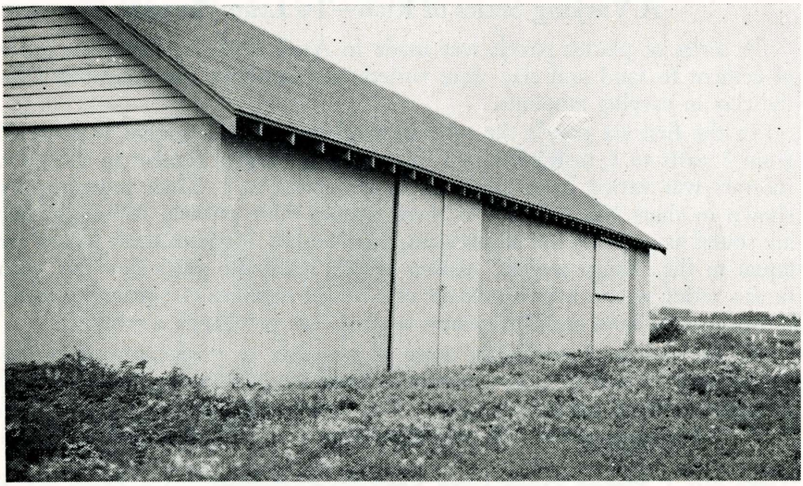

Fig. 9. Panels of Common Cement Stucco and of Dagga Plaster with the Surface Painted.
The section of wall between the doors of this machine shed is stuccoed with ordinary mixture of 1 measure of portland cement, 3½ measures of sand and ¼ measure of cem-mix. This section of wall was made of rammed earth blocks. The section close up is covered with dagga plaster with the surface painted.

Dagga-Cement Plaster. When laying up walls of rammed earth block, we found that when 10 percent of portland cement was added to dagga plaster, it made an excellent mortar. We tested this mortar for a period of four years and found it was extremely weather resistant. We call this plaster "dagga-cement plaster." Two panels have been covered with this plaster. The mortar was mixed in the proportions of 2 measures of sand, 1 measure of sandy clay and 3/10 measure of cement.

Panel No. 32M was 3 x 9 feet in size. The first coat was applied on August 3, 1936 and nailed to the wall immediately, with 10d nails, 12 inches apart. The second coat was applied one day later. After three years and six months this panel is in perfect condition. This plaster was made with yellow clay, and the color is lighter than the average stucco. One hundred square feet of this plaster required about one third of a bag of portland cement. A second and larger panel of this plaster was made.

Panel No. 12Mb was 10 x 10 feet in size. The first coat was applied on October 8, 1938 over inch-mesh poultry wire securely nailed to the wall. After seven days the second coat was applied. After 18 months this panel is in perfect condition. This particular mixture, which is made by adding 1 measure of cement to 10 measures of the dry dagga plaster mixture, seems to be quite definitely favorable. The series of plaster panels discussed in the following paragraph indicates that neither an increase in the cement nor in the clay is desirable. The trial of the ratio of sand to clay in the dagga plaster is definitely important.

A Varying Series of Rich—To Lean Plasters

A series of plaster panels was made in April 1938, in which the ratios of cement to sand and clay were varied, and cem-mix was substituted for the clay in varying amounts.

In the first six panels the ratio of sand to portland cement was varied from 3 parts to 1, to 6 parts to 1. The ratio of clay to cement in the same mortars was varied from 1 part to 1, to 3 parts to 1. These mixtures are shown in chart No. 1. None of these plasters were perfect. Although they are sound as yet, they are all checked, more or less. None of these panels are equal to the "dagga-cement" plaster which, with the particular clay used in this series, would have a mixture of 1-7-3, (1 measure of portland cement, 7 measures of sand and 3 measures of clay—see paragraph above).

In the last four panels the ratio of cem-mix to portland cement was varied from ¼ part to 1, to 1 part to 1. Panel No. 10Mb was plastered with a higher ratio of portland cement. This work was done largely for local benefit since these ratios will vary somewhat with the sand used.

Table No. 1. Plaster Panels From Lean To Rich Mortars On Earth Walls And Their Success

Panel No.	Size	Exposure	Date Applied	Plaster Mixture	Condition of Plaster 2 years later
1Mb	6' x 9'	south	Both Coats Apr. 30, 1938	Portland cement-Sand-Clay (1-3-1)	Sound but having few fine checks. Note: these checks were reported after 5 weeks.
5Mb	6' x 9'	south	Both Coats Apr. 30, 1938	Portland cement-Sand-Clay (1-4-1)	Sound, but not quite as good as 1Mb
4Mb	6' x 9'	south	Both Coats Apr. 30, 1938	Portland cement-Sand-Clay (1-4½-1½)	Sound, but not quite as good as 1Mb. Fully as good as 5Mb
3Mb	6' x 9'	south	Both Coats Apr. 30, 1938	Portland cement-Sand-Clay (1-5-2)	Sound, but not quite as good as 1Mb. About the same as 5Mb
2Mb	6' x 9'	south	Both Coats Apr. 30, 1938	Portland cement-Sand-Clay (1-5-2¾)	Sound as yet, but checks are larger. Too much clay for the amount of sand. Not as good as 3Mb
6Mb	6' x 9'	south	Both Coats Apr. 30, 1938	Portland cement-Sand-Clay (1-6-3)	Sound as yet, but not any better than 2Mb
7Mb	6' x 9'	south	Both Coats Apr. 30, 1938	Portl'd cement-Sand-Cem-mix (1-3½-¼)	Sound, but with slight hair checks
8Mb	6' x 9'	south	Both Coats Apr. 30, 1938	Portl'd cement-Sand-Cem-mix (1-3½-½)	Good. This panel is fine.
9Mb	6' x 9'	south	Both Coats Apr. 30, 1938	Portl'd cement-Sand-Cem-mix (1-3½-1)	Good. Same as panel 8Mb
10Mb	6' x 9'	south	Both Coats Apr. 30, 1938	Portl'd cement-Sand-Cem-mix (1-3-1)	Sound, but not quite as good as 9Mb. Mixture too rich.

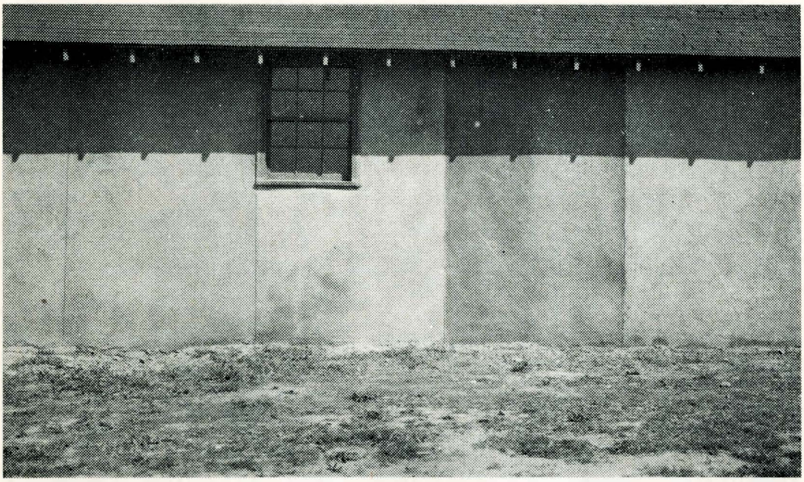

Fig. 10. Panels of Rich to Very Lean Cement Plasters Reported in Table No. 1.
Beginning at the right, these panels are No. 4Mb, 5Mb, 6Mb and 7Mb as shown in the table.

Relation of Success of Stuccoes to Quality of Wall

After a paint panel had failed on a small low quality test wall, it was given two coats of stucco. The stucco also failed after a short time indicating that stuccoes might not be satisfactory on low quality walls; i.e., walls made from heavy clay soils with high colloid content. Consequently, a series of small test walls, 36 inches wide by 30 inches high and made from soil of varying quality, were stuccoed. A standard stucco mixture was used. One end of each wall was left unplastered since a continuous coat around the wall might not show failure in a normal interval of time. It was applied in two coats under favorable conditions, and the first coat was nailed to the wall. The quality of the wall and success of the stucco panels were as follows:

Wall panel No. 65 is on a low quality wall containing 46.8 percent clay colloids. This wall was the first to be plastered, July 20, 1933, and it was an exception in that it was given only one coat, and this was not nailed. This plaster failed after two months. In October it was replastered with two coats of stucco in the regular way. After three month's time this plaster failed, the entire south side falling off. On July 2, 1934 this wall was given a coat of cold tar and the next week was given two coats of stucco. After nine months this plaster failed.

Wall panel No. 66 is on a low quality wall containing 61 percent clay colloids. This wall was given two coats of stucco with the scratch coat nailed. The stucco was applied during the first week in July 1934. After nine months this plaster failed.

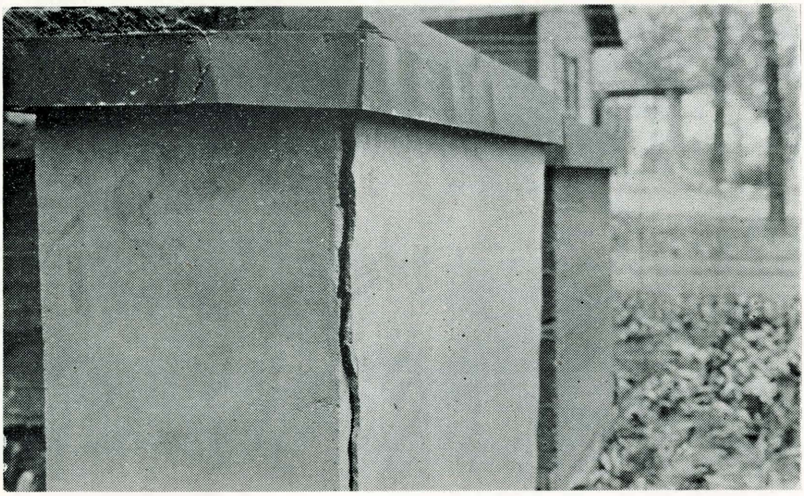

Fig. 11. Stuccos Will Fail on Heavy Clay Walls.

This stucco failed in less than a year's time. On a heavy clay soil that is unfit to use for rammed earth walls, even stucco will fail. It is not necessary to have high quality walls, however, as stucco will be satisfactory on average quality walls containing 30 percent or less total clay.

Wall panel No. 30 is on a fairly low quality wall containing 40.4[1] percent clay colloids. This wall was given two coats of stucco with the scratch coat nailed. The stucco was applied during July, 1934. After nine months this stucco showed a deep crack across the south side. After five years this stucco is deeply cracked on both sides and is nearly ready to fall off.

Wall panels No. 31, 32, 33 and 34 are medium quality soils, all of the same type and containing 37.2 percent clay colloids. These walls were given two coats of stucco with the scratch coat nailed in different ways. The stucco was applied during July 1934. After five years these stucco panels are all in perfect condition.

Wall panel No. 21 is a special wall of shale. This wall was built of shale taken from a highway cut along the banks of the Missouri River and was not a disintegrated soil. Metal lath was nailed around three sides of this wall with 16d nails. In August, 1935 this wall was given two coats of stucco. After four and one-half years this stucco is in excellent condition. Inspection indicates that there is no bond between the wall and stucco, but that the metal lath is holding the stucco intact.

1. A soil showing 40 percent or more of total clay colloids or containing 30 percent or more of conventional clay, according to the hydrometer method of soil analysis, is definitely unfit to use for rammed earth walls as indicated in South Dakota Agricultural Experiment Station Bulletin No. 298.

Paints for Exterior Use on Earth Walls

Paint coverings are attractive and especially desirable on exterior earth walls because they do not hide the identity of the material so completely, and a persistant effort has been made to determine the relative durability of various kinds of paints and painting practices for this purpose. Up to the present time 175 different paint panels have been used in the tests ranging in size from 8 to 100 sq. ft. After nine years of study, our report on the dependability of paints for this purpose is not very promising. A general statement would be that all paints are uncertain on outside earth walls and should be used only, when the complete analysis of the soil is known and after careful study of the subject. As discussed later in this bulletin the experimental work has shown a very definite relationship between the quality of the soil used in the wall and the success of paint coats. Temporary paints such as "cold water" paints have proven no better on earth surfaces than on other surfaces, and possibly not as good. So called moisture-proof paints have not proven to be moisture proof when used on earth walls, and the study so far has not shown any brand of paint or type of paint that is especially adapted for this purpose. The age of the earth wall at the time of painting has shown no effect upon the success of the paint coat. Wall sections have been painted one hour after the building forms were removed, and others were allowed to stand for four years before painting, with equal success.

Lead-Oil House Paints For Exterior Walls. Lead-oil paints or common o. s. (outside) house paint of good quality has proven to be the most satisfactory and durable paints yet tested. A few panels have proven satisfactory, while many others have failed. Another oil paint, a metallic zinc paint, has given about equal success. Some of the factors that may effect the success of oil paints are: the quality of the earth or dirt in the wall, the thickness of the coat of paint applied, the method of application, the outside temperature at the time of painting, the direction of exposure, the number of coats applied and the priming coat or first coat used on the surface.

It was decided not to use a standard lead-oil paint for test panels in this study, but to vary them as they would be selected and used by builders. In some preliminary work, cheap oil paints were found definitely unsatisfactory, and especially those paints containing mineral oils in place of linseed oil. Only good quality lead-oil paints have been used, therefore, and no paint has been used that contained less than 50 percent of white lead nor more than 30 per cent of zinc oxide in the pigment and not less than 88 per cent linseed oil in the vehicle.

Quality of the Wall and Success of Paint. The quality of the wall has a very definite effect upon the success or failure of the paint covering. This became evident early in the study and has been carefully checked and rechecked. Paints of any kind will be definitely unsatisfactory on low and medium quality walls. On high quality walls they are often successful. A high quality wall is one that will withstand weathering best. It will usually have a sand content of 70 percent or more, and it will always show a low

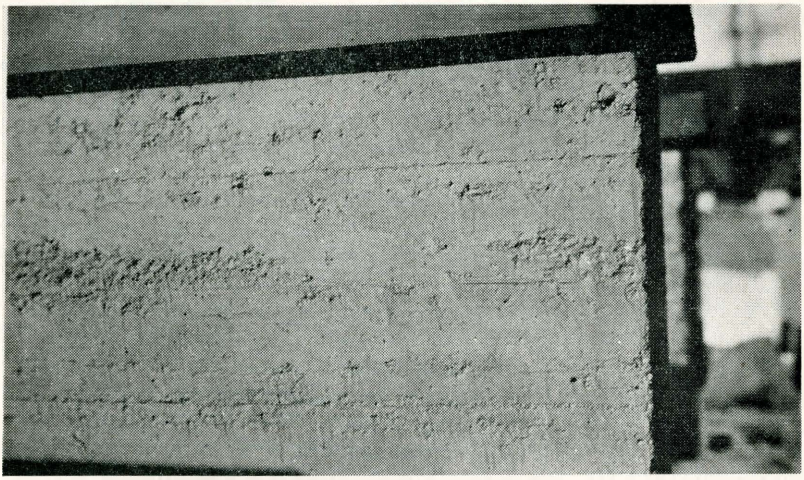

Fig. 12. Paints Are Satisfactory Only on the Highest Quality Walls.

This is wall panel No. 76, a high quality wall containing 77.2 percent sand on which lead-oil paint has been satisfactory. After four and one-half years the first coat of paint showed a trace of checking and the wall was repainted.

content of total clay colloids, around 20 percent or less. Paint panels on walls of this quality have proven fairly satisfactory for painting with lead-oil paint. Paint will appear to be satisfactory on walls of lower quality for periods ranging from eight months to three years before showing failure, depending on their quality. As discussed under stuccoing, walls of medium quality can be stuccoed satisfactorily, but paints will not be successful on them.

While the quality of a wall is better identified by the amount of clay colloids contained in the soil[2], the total sand content of the soil will indicate the quality of most soils. In the report on the following lead-oil paint panels the relation of the success of the paint to the sand content of the soil is shown. It will be noticed that the success of the paint varies directly with the amount of sand in the wall, with very little variation. All paint coats were brushed on after brushing the loose particles from the surface.

WALL PANEL NO. 66—lead-oil house paint; two coats of dark red paint over priming coat of linseed oil.

Date applied: Linseed oil July 20, 1933; first coat was applied after 4 days; second coat 20 days later; wall was 8 days old; both north and south exposures.

First failure sign appeared May 1, 1934 after 8 months; failed rapidly; total sand content in wall 19.8 percent.

WALL PANEL NO. 72—lead-oil house paint; two coats of dark brown paint over linseed oil.

Date applied: Linseed oil July 2, 1932; first coat was applied after 5 days; second coat 4 days later; wall was 4 days old; both north and south exposures.

First failure sign appeared after 12 months; failed rapidly; total sand content in wall 18.6 percent.

2. See South Dakota Agricultural Experiment Station Bulletin No. 298 "The Relation of Colloids . ."

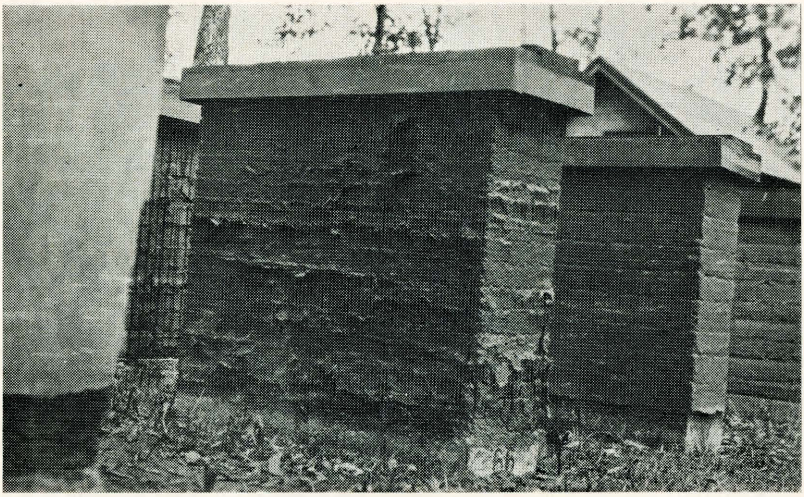

Fig. 13. A Failure of Paint on a Low Quality Wall.

This picture was taken one year after painting. The wall is of very low quality containing only 19.8 percent total sand and 51.5 percent total clay. The poorer the quality of the wall, the sooner the failure of paints on its surface.

Fig. 14. A Section of the Paint Failure on the Poultry House Shown in Fig. 2.

This paint was applied over linseed oil with a paint spray machine. The reason for the failure was the low quality wall. A paint spray machine is convenient for applying the priming coat for painting. Although brushing the priming coat on is quite satisfactory, it is somewhat tedious.

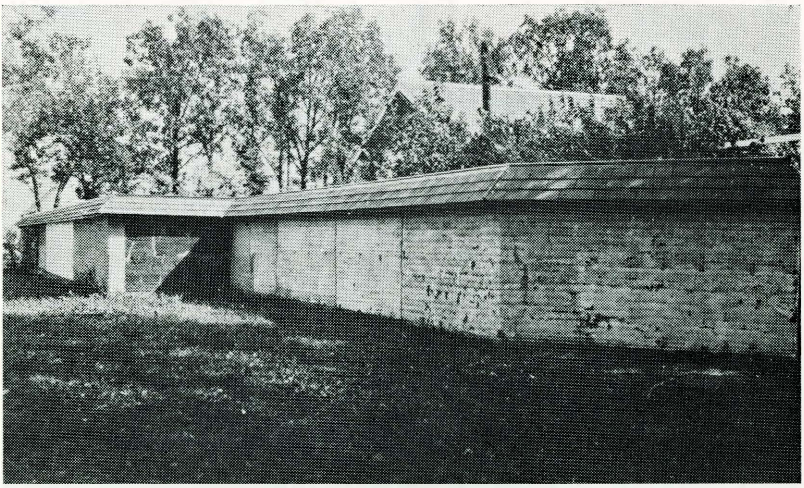

Fig. 15. One of the Paint Panel Walls Used In the Test.

On these wall sections paints were applied to panels from one hour after the section was finished up to one year later. Different weight priming coats were used and different qualities of soils were used in the wall sections.

WALL PANEL NO. 73—lead-oil house paint; two coats of dark brown over linseed oil.
Date applied: Linseed oil July 2, 1932; first coat was applied after 5 days; second coat 4 days later; wall was 4 days old; both north and south exposures.
First failure sign appeared after 1 year 9 months; failed slowly; total sand content in wall 45.8 percent.

PANEL NO. 1Y—lead-oil house paint; two coats of stone color over linseed oil.
Date applied: Linseed oil July 27, 1933; first coat was applied after 2 days; second coat 18 days later; west exposure.
First failure sign appeared 4 years later. Panel is not in bad condition after 6 years. Might be considered a satisfactory panel. Total sand content in wall 69 percent.

PANEL NO. 1AY—lead-oil house paint; two coats of yellow over linseed oil.
Date applied: Linseed oil August 10, 1931 (3.45 qts per 100 sq ft); first coat was applied after 3 days (2.9 qts per 100 sq ft); second coat 3 days later (1.45 qts per 100 sq ft); wall was 10 months old; east exposure.
First failure sign appeared 3 years 2 months later; failed very slowly; repainted October 1936; looked fine; second failure showing August 1939; total sand content in wall 69 percent.

PANELS NO. 22Y and 22AY (duplicate panels)—lead-oil house paint; one coat of stone color over thin paint priming coat (an equal amount of linseed oil added for thinning).
Date applied: Thin paint July 27, 1933; first coat was applied after 2 days; wall 2 years 8 months old; south exposure.
First failure sign appeared 3 years 1 month later; failed very slowly. A duplicate panel on the opposite side of wall—north exposure—showed first failure sign in August 1939 after 6 years. Total sand content of wall 69 percent.

PANEL NO. 23Y—lead-oil house paint; one coat of dark red paint over glue priming coat (1 lb of glue to 1 gal of water).
Date applied: Glue sizing coat July 27, 1933; first coat of paint 1 day later; wall 2 years 8 months old; south exposure.
First failure sign appeared 4 years later; failed slowly. A duplicate panel on the opposite side of wall—north exposure—showed first failure sign same date as above, after 4 years.

WALL PANEL NO. 76—lead-oil house paint; a single coat of cream color paint to which was added 25 percent linseed oil, making a rather thin coat.
Date applied: The one coat applied on January 20, 1933; wall 6 days old; both north and south exposures; (temperature 40°F.)
First failure sign after 4 years 6 months; wall given a second coat of dark brown; after 6 years and 9 months this panel is in perfect condition; total sand content of wall 77.2 percent.

WALL PANEL NO. 70—lead-oil house paint; one coat of white paint over linseed oil.
Date applied: Linseed oil April 8, 1933; coat of paint was applied after 14 days; wall was 1 hour old when linseed oil was applied; both north and south exposures.
First failure sign has not appeared after 7 years, and definitely satisfactory; total sand content in wall 83.8 percent.

A Special Sand-Paint Wall Series. A series of four walls were built from the same soil but with an addition of varying amounts of sand. These walls were painted with identical paints, at the same time, and left for observation on the success of the paint.

In wall panel No. 71 was a total sand content of 35 percent; in wall panel No. 79, 50 percent; in wall panel No. 84, 65 percent; and in wall panel No. 87, 80 percent. These four walls were given a coat of thin paint (2 volumes of standard paint to 1 volume of linseed oil) on November 25, 1935. A second coat of pale green lead-oil house paint was applied after 18 days. The weather was cool but above freezing, except at night, when they were protected with a tent. These panels were observed closely.

First failure signs appeared in these panels at the following intervals: panel 71 containing 35 percent sand, after 1 year and and 7 months; panel

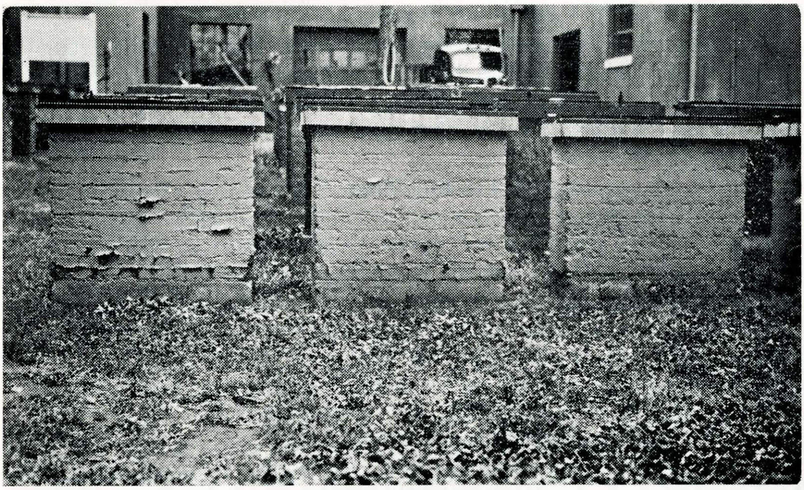

Fig. 16. The Success of Paint Coverings Varies Directly with the Sand Content in the Wall.

This picture was taken in November, 1939, just four years after the walls were painted. Wall No. 71 at the left has a sand content of 35 percent. Wall No. 79 in the center has a sand content of 50 percent. Wall No. 84 at the right has a sand content of 65 percent. Wall No. 87 with the end barely showing in the picture has a sand content of 80 percent.

79 containing 50 percent sand, after 3 years and 6 months; panel 84 containing 65 percent sand, after 3 years and 11 months; panel 87 containing 80 percent sand, after 3 years and 7 months. With the exception of panel 87 the periods before the first failure varied directly with the increased amount of sand in the wall. The paint on the south side of this wall, panel No. 87, is still in perfect condition after 4 years and 4 months, the one spot on the north side being the only failure on either surface, and the panel, as a whole, will outlast the others without question (see Fig. 16).

Thickness Of Paints And Number Of Paint Coats. Wall panels 76 and 70, described above, were two of the best paint panels. One was a single coat of thin paint and the other was a single coat of paint brushed rather thin and over a priming coat of linseed oil. Two other panels that were put on heavy and not well brushed out failed sooner than expected for the quality of the soil in the wall. A poultry house was painted by spraying, and the paint coat applied was heavy. This paint also failed too early. From these results it is safe to say that paint coats should be well brushed out and that heavy coats of paint are not desirable on earth walls. It is quite possible that a special-panel series on the question may prove that too many coats of paint are undesirable. Two series of three panels each were set up under well controlled conditions. The first panel of each series was given one coat of lead-oil paint; the second panel was given two coats; and the third panel was given three coats. These paints were all well brushed out. As this copy goes to press the first sign of failure has appeared in the three-coat panel; the one-coat and two-coat panels showing no failure as yet. In the second series, all three panels are in good condition as yet.

Methods Of Applying Paints On Earth Walls. Paints have been applied by both the brush and spray method. For applying the heavier paints, brushing has shown some advantage. This may be due to the fact that the sprayed coat is usually heavier. For thin priming coats, a paint spray equipment will save considerable time.

Outside Temperature At Painting Time. The fact that some of our most successful paint panels were put on in fairly cold weather indicates that cool weather will not affect the success of paint on earth walls any more than on lumber, and may possibly be advantageous for them.

Direction Of Exposure. As in the case of paint on wood, south exposures were more severe on most all coverings tried, than north exposures. This was especially true of oil paints. The panels on north exposures generally outlasted the identical panel on the south. No advantage could be noticed between east and west exposures, and there should be little, if any.

Age Of The Wall When Painted. The study indicates that the age of the wall, when painted, does not affect the success of the lead-oil paint. Twenty-eight large panels applied in duplicate on opposite sides of a wall showed no difference due to the age of the wall. The panels were applied at different intervals of time after the section of wall was completed and the forms removed, varying from one hour to one year. The priming coat brushed on the surface more easily when the wall was green and still con-

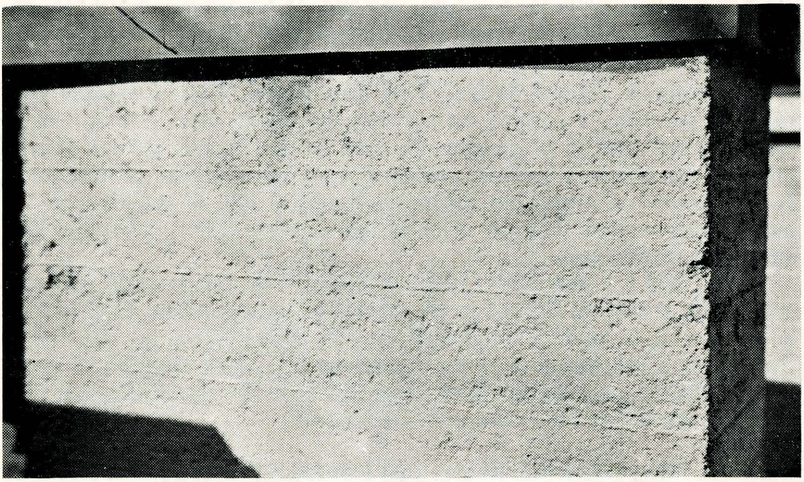

Fig. 17. An Admixture of Sand to the Soil Made This Wall Satisfactory for Painting.
This wall panel No. 70 had a coat of white lead-oil paint well brushed out over a priming coat of linseed oil just seven years ago. This is the best panel of the study. There is no check in the paint as yet. The wall has a sand content of 83.8 percent.

tained the moisture optimum for ramming. The surface was also smoother, if a smooth surface is desired. From the artistic standpoint, the rougher surface is more desirable. It will be noted that the best paint panel in the yard, wall panel No. 70, was brushed on the wall immediately after the forms were removed.

Penetration Of Paints On Earth Walls. Contrary to expectations, the penetration of paints was found undesirable. Paints and priming coats that penetrated the wall material caused deep failures on the surface and in no case did deep penetration of the material have any advantage. When a priming coat was used that penetrated deeply, this part of the surface weathered away very quickly when the paint on the surface gave way. Water glass was an example as used on panel 18M, described later.

Priming Coats Used For Lead-Oil Paints. The following materials were used for exterior priming coats under house paints: Linseed oil, very thin lead paint, glue sizing solution, soybean oil, fish oil, three commercial primers, whitewash and water glass. Linseed oil, thin paint and glue sizing have proven most satisfactory, and equally satisfactory as priming coats. They were checked time after time, side by side. Fish oil was used under a single panel only, and on this panel proved equal to the above three materials. It is now under further test as a priming coat. The other materials did not show satisfactory results, the water glass showing the poorest results. The thin paint priming coats were made by adding an equal amount of linseed oil and a small amount of drier to a paint of standard consistency. Glue sizing solution was made by dissolving cakes of a cheap grade of glue in warm water. A rate of ½ lb. of glue to 1 gal. of water, and of 1 lb. of glue to 1 gal. of water were both used with no noticeable difference in the success of the paint.

Repairing A Painted Surface That Has Failed. Two ways have been used for repairing a painted surface that has failed. One is to stucco the wall and the other is to roughen the wall so that it will have a mottled effect. If the wall is of medium quality it is useless to repaint it. Stucco will be satisfactory on a medium quality wall and it will, of course, make an entirely new surface. The use of metal lath or wire mesh is advisable for a stucco job in this case.

If the wall is a near high quality wall and if the first coat of paint has stood well, it may be desired to try another painting. When paint fails on an earth wall, it leaves a roughened spot. If, before repainting, the rest of the surface is roughened in spots, at random, a pleasing surface can be obtained. The exposed soil at these spots must, of course, be given a good priming coat before the entire wall is repainted.

Miscellaneous Paints and Coverings Tested

The following miscellaneous paint and covering panels were from 30 to 36 inches wide and 6 feet high. They were brushed on with a paint brush except where indicated. The quality of the two long walls used for these panels was fairly high, but not the highest in quality. The life of lead-oil house paint on these walls averaged about three and one half years. The loose dirt and dust on the surface was brushed away, and the priming or first coat applied to the dry wall.

PANELS NO. 2Y and 2AY (duplicate panels)—whitewash, two coats; contained slaked lime, salt, boiled-rice, spanish whiting and glue dissolved in water.
Date applied: first coat July 17, 1931; second coat immediately; both north and south exposures.
First failure sign on both panels appeared after 2 months' time; failed rapidly.

PANEL NO. 9Y—whitewash, two coats; same as above with yellow soap added.
Date applied: First coat August 15, 1931; second coat was applied after 2 days; east exposure.
First failure sign appeared September 28, after 6 weeks; failed rapidly by blistering.

PANELS NO. 3Y and 3AY (duplicate panels)—cold asphalt, "Liquid Asphalt," a commercial brand, single coat. Thinned with water by adding 1 volume of water to 2 of asphalt.
Date applied: The single coat on July 2, 1931; both north and south exposures.
First failure sign for both panels appeared November 7, 1931 after 4 months; failed slowly.

PANELS NO. 14Y and 14AY (duplicate panels)—cold asphalt, "Liquid Asphalt," two coats; same as on No. 4Y.
Date applied: First coat August 13, 1931; second coat after 7 days; both north and south exposures.
First failure signs, both panels appeared July 1, 1932 after 11 months; failed slowly.

PANELS NO. 4Y and 4AY (duplicate panels)—cement cream, two coats; portland cement was thinned with water until it was about as thick as average cream.
Date applied: First coat applied July 2, 1931; second coat applied 6 hours later; both north and south exposures.
First failure sign appeared on both panels Sept. 28, after 3 months; failed rather rapidly.

PANEL NO. 10—two coats of cement cream over glue priming coat. The cement cream was slightly thinner than average.

Date applied: Glue priming coat September 27, 1932; first coat of cement cream September 29, 1932; second coat was applied after 1 day; west exposure.

First failure sign appeared March 1, 1933 after 6 months; failed slowly; wall deeply damaged.

PANELS NO. 11Y and 11AY (duplicate panels)—cement cream, two coats of very heavy cement cream over a glue priming coat; cement as heavy as could possibly be brushed on.

Date applied: Glue priming coat September 22, 1932; both coats of cement cream were applied after 2 days; both north and south exposures.

First failure sign appeared in the form of checks immediately, but the surface was stiff and pieces did not loosen until 18 months later. Little damage to surface.

PANELS NO. 5BY and 5ABY (duplicate panels)—aluminum paint, single coat over linseed oil.

Date applied: Linseed oil, August 18,1933; first coat of paint applied after 6 days; both north and south exposures.

First failure sign appeared on both panels, April 25, 1935, after 1 year and 8 months; failed slowly.

PANEL NO. 6Y—cold tar "Pro-tec-tar," a commercial brand.

Date applied Single coat was applied September 8, 1938; south exposure.

First failure sign appeared August 7, 1939 after 11 months; failed slowly.

PANELS NO. 8Y and 8AY (duplicate panels)—cold asphalt, "Asphaltum," a commercial brand, medium weight asphalt.

Date applied: Single coat was applied July 8, 1931; both north and south exposures.

First failure sign both panels September 28, 1931 after 3 months; failed slowly; damaged surface very little.

PANELS NO. 13Y and 13AY (duplicate panels—cold asphalt, "Asphaltum," two coats; used as ready mixed.

Date applied: First coat August 13, 1931; second coat after 6 days; both north and south exposures.

First failure sign, both panels, appeared April 19, 1932 after 8 months; failed slowly; damaged wall some.

PANELS NO. 21Y and 21AY (duplicate panels)—aluminum paint over two coats of cold tar "Pro-tec-tar."

Date applied: First coat of cold tar, a thin priming coat, August 18, 1933; second coat of cold tar, normal consistency, after 1 day; coat of aluminum paint 6 days later; Both north and south exposures.

First failure sign appeared August 10, 1936 after 3 years; failed rapidly.

PANELS NO. 24Y and 24AY (duplicate panels)—cold water (masonry-wall) paint, mixed at the rate of 1¼ pts. of water to 1 lb. of powder "Bondex," a commercial paint, two coats.

Date applied: First coat, July 24, 1933; second coat after 3 days; both north and south exposures.

First failure sign both panels May 14, 1934 after 10 months; failed rapidly; no damage to surface.

PANELS NO. 25Y and 25AY (duplicate panels)—cold tar paint, two coats of "Pro-tec-tar," a commercial paint; the same as used under alumninum paint in panel 21Y.

Date applied: First coat August 5, 1933; second and heavier coat after 2 days; both north and south exposures.

First failure sign April 25, 1935 after 1 year and 9 months; failed rapidly and damaged surface heavily.

PANEL NO. 102Y—portland cement admixture to lead-oil paint, over a coat of linseed oil. One volume of portland cement was added to two volumes of house paint.

Date applied: First admixture August 29, 1934; second admixture after 2 days; south exposure.

First failure sign appeared May 20, 1936 after 1 year and 9 months. Damaged the wall surface badly.

PANEL NO. 23M—asphalt emulsion, a cold asphalt; single coat and no primer.
Date applied: July 21, 1936; west exposure.
First failure sign appeared July, 1937 after 1 year; failed rapidly; damage deep.

PANEL NO. 138T—asphalt emulsion, a cold asphalt; two coats, sprayed on.
Date applied: First coat, July 28, 1939; second coat after 1 day; south exposure.
First failure sign appeared after 90 days; failed rapidly.

PANEL NO. 139T—asphalt emulsion, a cold asphalt, single coat, sprayed on.
Date applied: Single coat, July 28, 1939; south exposure.
First failure sign appeared after 90 days; failed rapidly.

PANEL NO. 124T—a secret paint mixture for earth walls, a trade paint made on West Coast of United States for stucco and masonry walls, evidently containing lime as a base, a special oil and other ingredients, mixed with water to the proper brushing consistency. Single coat over water spray.
Date applied: June 29, 1939; south exposure.
First sign of failure occurred after 8 months; failed rapidly.

PANEL NO. 128T—secret formula "trade" cold water paint, same as Panel No. 124T except thinned out heavily with water; single coat over water spray.
Date applied; July 1, 1939; south exposure.
First sign of failure appeared after 8 months; failing rapidly.

PANEL NO. 101T—lead-oil paint over a special seal (primer) coat No. 2240. This seal coat was put up by a paint specialist for the particular purpose.
Date applied: July 29, 1937 for seal coat; second coat after 5 days; south exposure.
First failure sign after 2 years; failed rapidly.

PANEL NO. 102T—special pigment paint No. A95440 over a seal coat No. 2240 (same as above). This second coat contained portland cement at the rate of 1 lb. per gal.
Date applied: Seal coat July 29, 1937; second coat after 5 days.
First failure sign after 90 days; failed rapidly.

PANEL NO. 103T—special pigment paint No. A95440 over an alkali resistant priming coat No. 2235. Both of these paints were put up by a paint specialist for the particular purpose.
Date applied: Priming coat July 29, 1937; second coat after 5 days.
First failure sign after 90 days; failing rapidly.

Miscellaneous Transparent Coverings Tested

The following transparent paint covering panels were 3 feet wide by 9 feet high. They were brushed on a dry surface after brushing down the loose dirt. The wall was just slightly below a high quality soil.

PANEL NO. 1M—white shellac over a priming coat of glue sizing, two coats.
Date applied: Glue priming coat July 21, 1936; first coat of shellac after 1 day; second coat of shellac after 15 days; south exposure.
First sign of failure November 14, 1936 after 4 months; failed rapidly; wall damaged badly.

PANEL NO. 2M—spar varnish over a priming coat of glue sizing, two coats.
Date applied: Priming coat July 21, 1936; first coat of varnish after 1 day; second coat after 15 days; south exposure.
First failure sign appeared November 14, 1936 after 4 months; failed rapidly; wall damaged badly.

PANEL NO. 3M—glue primer, two coats.
Date applied: First coat of glue solution July 21, 1936; second coat after 6 days; south exposure.
First failure sign appeared November 14, 1936 after 4 months; failed rapidly; wall damage medium.

PANEL NO. 4M—linseed oil (boiled), two coats.
Date applied: First coat of linseed oil Aug. 10, 1936; second coat after 7 days; south exposure.
First failure sign appeared November 14, 1936 after 3 months; failed more slowly; wall damage slight.

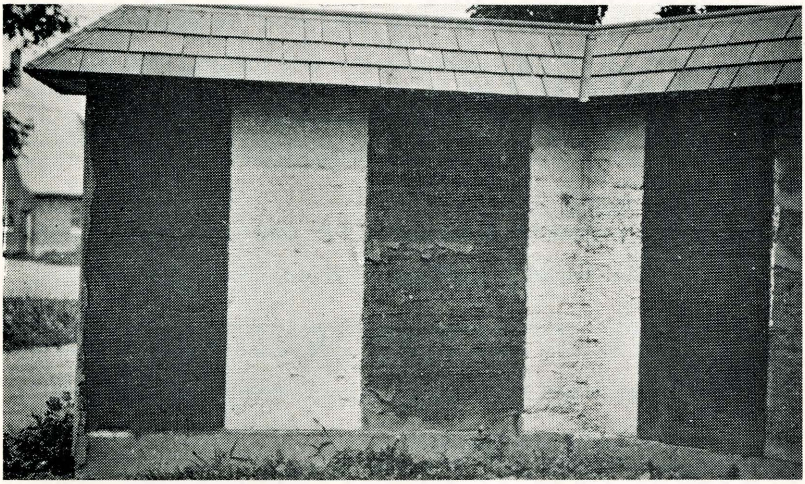

Fig. 18. Some Small Paint Panels For First-time Exposures.

When a paint covering indicated on the small panels that it might be successful, it was checked on larger panels, usually in duplicate. These are panels No. 101T, 102T, 103T, 104T, and 105T.

Fig. 19. A Typical Failure of a Transparent Paint.

This is a close-up of panel No. 103T, a transparent paint. No successful transparent covering has been found to date, and most of the transparent paints damage the wall surface severely. Stucco is the only covering that will correct a wall surface that has been damaged as shown here.

PANEL NO. 5M—white shellac, two coats.
Date applied: First coat of shellac July 22, 1936; second coat after 15 days; south exposure.
First failure sign appeared November 14, 1936 after 4 months; failed more slowly; better than 1M; wall damage medium.

PANEL NO. 6M—plaster filler, two coats; a commercial filler.
Date applied: First coat, July 22, 1936; second coat after 14 days; south exposure.
First failure sign appeared November 14, 1936 after 4 months; failed more slowly; wall damaged badly.

PANEL NO. 7M—tung oil, two coats.
Date applied: First coat of tung oil July 22, 1936; second coat applied 14 days later; south exposure.
First failue sign November 14, 1936 after 4 months; failed rapidly; wall damaged very deeply.

PANEL NO. 9M (Note: panel No. 8 was a check panel)—fish oil, two coats of sardine oil.
Date applied: First coat of fish oil July 21, 1936; second coat after 17 days; south exposure.
First failure sign August 19, 1937 after 1 year and 1 month; failed slowly; wall damage slight.

PANEL NO. 10M—soy bean oil, single coat.
Date applied: Single coat July 23, 1936; south exposure.
First failure sign November 14, 1936 after 4 months; failed slowly; wall damage deep.

PANEL NO. 11M—water glass (sodium silicate); two coats.
Date applied; First coat July 21, 1936; second coat after 2 days; south exposure.
First failure sign appeared September 21, 1936 after 2 months; failed rapidly; wall damage slight.

PANELS NO. 5Y AND 5AY—Linseed oil (raw), single coat.
Date applied: Single coat July 3, 1931; both north and south exposures. First failure sign, both panels, appeared April 19, 1932 after 9 months; failed slowly; wall damage slight.

PANELS NO. 6Y AND 6AY—"Used" crankcase oil, single coat.
Date applied: Single coat, July 3, 1931; both north and south exposures.
First failure sign both panels April 19, 1932 after 9 months; failed slowly; wall damage slight.

PANELS NO. 7Y AND 7AY—Paraffine-gasoline; 3 volumes of gasoline to 2 volumes of paraffine dissolved by heating; single coat.
Date applied: Single coat, July 3, 1931; both north and south exposures.
First failure sign November 7, 1931 after 4 months; failed slowly; wall damage very slight.

PANEL NO. 103T—Transparent paint No. 542A over a transparent sealer (priming) coat No. WP .0251. The paints were both made up by a California paint specialist for trial on earth walls.
Date applied: Sealer coat on July 29, 1937; first coat of 542A after 2 days; second coat 5 days later; south exposure.
First failure sign after 90 days; failed very rapidly by curling.

Paint Coverings Under Study With No Results Available As Yet. The following paint coverings have been applied to panels within the year, and reports will not be available for them until they fail or until they have stood successfully for four or more years: (a) casein paint, a commercial brand, red "Luminall" paint over a priming coat of linseed oil; (b) casein paint, a commercial brand, white "Luminall" over a priming coat of linseed oil; (c) casein paint, a commercial brand, red "Luminall" paint over a priming

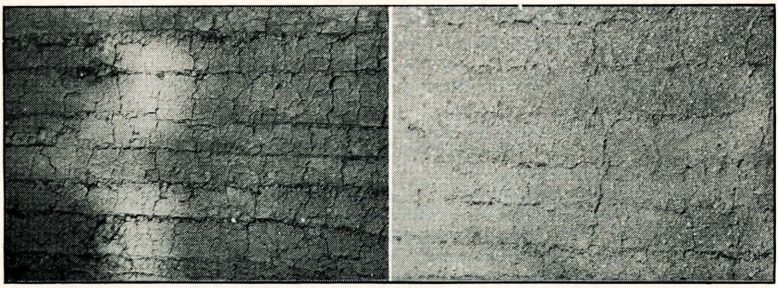

Fig. 21. Showing An Average Soil As It Is Improved By A Sand Admixture.

The wall at the left is not better than average soil with a sand content of 27.9 percent. The wall to the right is made from the same soil with sand added to bring the total sand content up to 59.6 percent. This increases the quality of the soil. If still more sand were added, bringing the total up to 75 to 80 percent, this wall might be painted successfully. If the soil is right, it might stand successfully as a bare earth wall.

coat of glue sizing; (d) lime-cement paint for stucco painting over light water spray, single coat. This paint was made up of 2 measures of hydrated lime, 1 measure of white cement, and 1/12 measure of common salt, thinned to brushing consistency with water; (e) lime-cement paint—same as above except two coats applied; lime-cement paint—same as above except that more water was used making a thinner paint; (f) a special moisture proof paint, a commercial brand, "Dobe-Kote," over a special priming coat for this brand of paint; (g) this same paint over a priming coat of boiled linseed oil; (h) the same paint over a priming coat of glue sizing; (i) casein paint, a commercial brand red "Luminall" paint—two coats applied to the earth panel without a priming coat.

Interior Coverings On Rammed Earth Walls

Different kinds of coverings were tried on interior surfaces of rammed earth walls with excellent success. Although the number of panels was not great, the coverings tried ranged from temporary cold-water paints to common plaster. With the exception of two whitewash panels, these covers are all in excellent condition after nearly four years. These panels were placed on the inside surface of the outer walls of a rammed earth machine shed. Since the building is not used for livestock or for human habitation, these paints have not been subjected to highly moist air on the inside.

The panels are large, and since we wished to try dagga plaster for an inside covering and with the different paint coverings, the lower half of the panels were plasered with dagga plaster. No dagga plaster was used on the panels that were used for other plasters, but it was used on all paint and check panels. This is the same dagga plaster as used on exterior walls and described on page 12. The panels were 6 feet wide by 9 feet high. The quality of the walls was just below a high quality wall. The plasters were put on by skilled labor, while the paints were brushed on by unskilled labor as has been the case with all exterior paint panels.

INTERIOR PANEL NO. 59M—Common plaster (commercial plaster plus sand)—two coats.
The first or scratch coat of plaster was nailed to the wall immediately after being applied. The same method of nailing was used as for exterior stuccoes. The wall surface was sprayed as for exterior work.
Date applied: First coat August 3, 1936; second coat August 4, 1936. First failure sign has not appeared. The plaster is in perfect condition.

INTERIOR PANEL NO. 60M—Common plaster, one coat over a single coat of wood-fiber plaster. The scratch coat of wood-fiber plaster was nailed and the wall sprayed as above. This scratch coat checked, so it was decided to finish with common plaster.
Date applied: First coat August 3, 1936; second coat of common sand plaster August 4, 1936.
First failure sign has not appeared. Plaster is in excellent condition.

INTERIOR PANEL NO. 51M—Dagga plaster without a cover; made as described on Page 12; two coats of dagga over sprayed surface; first coat nailed, 12 inches apart at random.
Date applied: First coat July 27, 1936; second coat after 2 days.
First failure sign has not appeared. This panel, as well as the dagga plaster on the paint panels, is excellent.

INTERIOR PANEL NO. 52M—Flat house paint, two coats over a commercial priming coat called a seal-coat for inside plaster surfaces. The priming coat was applied to the dry surface after dusting.
Date applied: Priming coat August 5, 1936 (used 1 gal per 100 sq ft); first paint coat after 2 days; second paint coat 5 days later.
First failure sign has not appeared; panel is excellent.

INTERIOR PANEL NO. 53M—Flat house paint, two coats over a priming coat of glue sizing solution on dry surface.
Date applied: Priming coat July 27, 1936; first coat of paint was applied after 11 days; second coat 3 days later.
First failure sign has not appeared; panel is excellent.

INTERIOR PANEL NO. 54M—Whitewash, same as panels No. 2Y and 2AY; three coats on soil, two coats on dagga plaster below.
Date applied: First coat August 5, 1936; second coat next day; third coat 7 days later.
First failure signs appeared June 1, 1937 after 10 months on earth surface. On the dagga plaster the first failure sign appeared August 11, 1939 after 2 years and 2 months; failed rapidly.

INTERIOR PANEL NO. 55M—Whitewash, two coats (same as 54M) over glue sizing priming coat.
Date applied: Priming coat of glue July 25, 1936; first coat of whitewash was applied after 2 days; second coat 1 day later.
First failure sign appeared on soil surface June 1, 1937 after 10 months, and on the dagga plaster after 3 years; failed rapidly.

INTERIOR PANEL NO. 56M—Muresco, two coats of light blue on dry wall surface.
Date applied: First coat August 7, 1936; second coat after 4 days.
First failure sign has not appeared. The panel is excellent after 4 years.

INTERIOR PANEL NO. 57M—Muresco, two coats of light blue over glue sizing priming coat.
Date applied: Priming coat of glue July 27, 1936; first muresco coat after 14 days; second coat 3 days later.
First failure sign has not appeared. The panel is excellent after 4 years.

INTERIOR PANEL NO. 58M—Buttermilk paint, two coats over glue sizing priming coat. The buttermilk paint was mixed at the rate of 4½ lbs. of white cement to 1 gal of buttermilk.
Date applied: Priming coat of glue July 27, 1936; first coat after 9 days; second coat 2 days later.
First failure sign has not appeared. The panel is in excellent condition after 4 years.

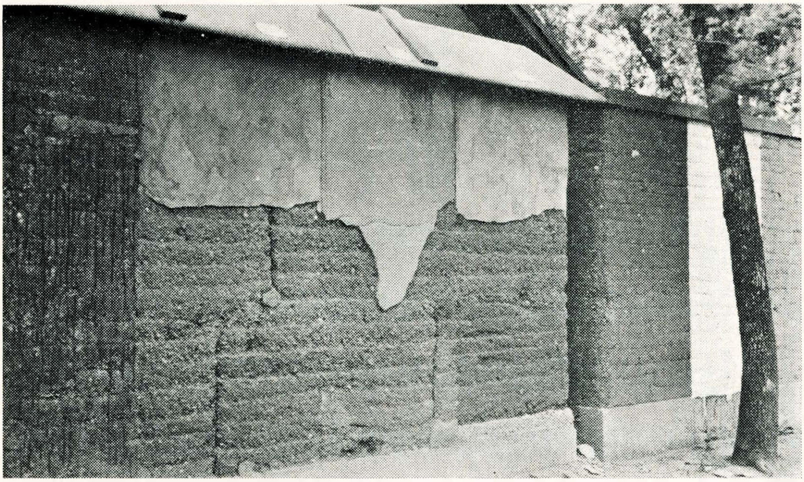

Fig. 21. Plaster Panels Applied Without Any Bond.
Plasters did not prove satisfactory on rammed earth walls without some method of bonding. These panels were intact for more than two years but failed completely, as shown.

Paints and Stucco Coverings are Not Moisture Proof

Early in the tests made with paint coverings on earth walls, it seemed that paints, when applied to new green walls, were just as successful as when applied to the walls after they had been thoroughly air dried. This fact was later quite definitely established. In view of this fact a study was made to find out if the high moisture content of the freshly rammed earth walls would come out through various coverings that might be used on those walls, and if so, at what rate. If the moisture did come through the coverings from the inside of the walls to the outside, it is logical to assume that moisture would also pass into the wall through the covering as the wall stands, and apparently without damage.

Forty-two typical rammed earth blocks were made from three base soils for this test.[3] One was a heavy clay soil, one a very light sandy soil and one intermediate soil. The test pieces were made in cubes of approximately nine inches, and the coverings were very carefully applied so as to thoroughly cover all six sides of these cubes. The following coverings were used: linseed oil, thin priming coat of lead-oil paint, standard o.s. house paint in one and two coat jobs, portland cement plaster (1 part cement to 3 parts sand), and check blocks left without any covering and weighed with the rest. As shown in table No. 2, a part of these blocks were painted or plastered immediately after they were rammed; a part of them were covered after two days, and a part of them were left for 10 days and then covered. Some were

3. See Table 1, Page 17 of South Dakota Agricultural Experiment Station Bulletin No. 277.

Table 2. Comparative Moisture Loss in Covered and Uncovered Blocks

Block No.	Date Made	How Treated	Kind of Soil (% Sand)	Moisture When Made	Loss in Percent: Loss in 6 da.	Loss in 12 da.	Loss in 18 da.	Loss in 24 da.	Loss in 30 da.	Loss in 36 da.	Loss in 42 da.	Loss in 48 da.	Remarks
1	Dec. 3	Painted at once	38.28	10.01	1.25	1.25	2.50	2.95	3.41	3.85	4.30	4.75	
29	Dec. 14	Painted immediately	38.28	9.61	1.32	2.68	3.14	3.60	3.60	3.60	4.07	4.55	
8	Dec. 6	Painted immediately	72.00	6.77	1.91	2.30	3.51	3.51	3.51	3.51	3.91	4.41	Painted 2nd coat in 3 da.
9	Dec. 6	Painted immediately	72.00	6.77	1.14	1.52	2.30	2.71	3.51	3.91	3.91	4.73	
2	Dec. 3	Linseed Oil at once	38.28	10.01	2.07	2.52	3.37	4.26	4.26	5.16	5.16	5.61	
30	Dec. 14	Linseed Oil at once	38.28	9.61	3.29	4.36	5.42	5.90	5.90	6.30	6.90	6.90	
6	Dec. 6	Linseed Oil at once	72.78	6.77	2.35	3.15	3.97	4.40	4.82	5.25	5.25	5.67	
7	Dec. 6	Linseed Oil at once	72.78	6.77	1.99	2.79	4.03	4.03	4.45	4.87	5.04	5.73	
3	Dec. 3	No cover	38.28	10.01	3.25	4.24	5.13	6.04	6.04	6.50	6.50	6.97	
16	Dec. 6	No cover	38.28	9.57	2.80	3.64	4.94	5.37	5.81	5.81	6.71	7.15	
5	Dec. 6	No cover	72.78	6.77	2.73	3.14	4.37	4.79	5.21	5.21	5.21	6.06	
4	Dec. 6	No cover	72.78	6.77	2.70	3.50	4.32	4.73	5.15	5.15	5.57	5.57	
10	Dec. 6	Linseed Oil 2 da. after made	72.78	6.77	1.55	1.94	2.74	3.95	3.95	4.37	5.21	5.21	
11	Dec. 6	Linseed Oil 2 da. after made	72.78	6.77	1.55	1.94	2.74	3.55	3.55	4.37	4.79	4.79	
12	Dec. 6	Painted in 2 da.	72.78	6.77	1.17	1.17	1.94	2.74	2.74	3.14	3.53	3.53	
13	Dec. 6	Painted in 2 da.	72.78	6.77	1.55	1.55	1.94	2.34	2.34	2.74	2.74	2.74	Painted 2nd coat 3 da. later
14	Dec. 6	Linseed Oil 10 da. after made	72.78	6.77	2.34	3.14	3.55	3.14	3.55	3.55	3.55	4.37	Painted 2 da. later
15	Dec. 6	Linseed Oil in 10 da.	72.78	6.77	1.52	1.92	2.31	1.51	2.31	2.31	2.31	2.71	Painted 3 da. later
25	Jan. 14	No cover	38.	9.61	3.51	5.02	5.51	5.51	5.70	5.99	5.99	5.99	
26	Jan. 14	No cover	38.	9.61	3.68	5.22	6.00	6.00	6.00	6.39	6.39	6.39	
27	Jan. 14	No cover	72.	6.88	3.46	4.73	5.23	5.23	5.23	5.23	5.23	5.77	
28	Jan. 14	No cover	72.	6.88	3.26	4.73	5.23	5.23	5.23	5.63	5.63	5.63	
17	Dec. 20	Linseed Oil at once	10.	15.42	3.52	5.09	6.75	7.88	8.00	9.40	10.24	10.24	
18	Dec. 20	Linseed Oil at once	10.	15.42	2.88	4.46	6.69	7.27	7.85	9.03	9.62	9.62	
20	Jan. 7	Painted at once	10.	14.47	1.94	2.93	4.46	4.98	5.51	6.05	6.05	6.58	
21	Jan. 7	Painted at once	10.	14.47	1.88	3.34	4.86	5.37	5.90	5.90	6.42	6.96	
19	Dec. 20	Linseed Oil 2 da. after made	10.	15.42	2.42	2.90	4.42	4.42	4.94	5.42	6.00	6.00	Painted after 15 da.
22	Jan. 7	Linseed Oil 2 da. after made	10.	14.47	2.34	3.80	5.32	6.89	6.89	6.89	7.42	7.42	
23	Jan. 7	No cover	10.	14.47	3.77	5.29	6.42	7.90	7.90	7.90	8.33	9.00	
24	Jan. 7	No cover	10.	14.47	2.68	4.30	5.84	6.89	6.89	6.89	7.31	7.96	
PLASTER SERIES													
P 1	Jan. 14	Plastered at once	74.7	6.88	1.08	2.29	2.78	3.15	3.15	3.24	3.24	3.72	
P 2	Jan. 14	Plastered at once	74.7	6.88	.65	2.52	3.00	3.00	3.00	3.00	3.00	3.77	
P 3	Jan. 14	Plastered at once	37.5	9.61	.17	2.50	2.68	3.15	3.15	3.61	3.61	4.47	
P 4	Jan. 14	Plastered at once	37.5	9.61	.51	2.68	3.61	3.90	3.90	4.09	4.56	5.24	Top of plaster broken
P 5	Jan. 14	Plastered 3 da. later	74.7	6.88	1.85	3.19	4.16	4.16	4.16	4.20	4.76	4.76	
P 6	Jan. 14	Plastered 3 da. later	74.7	6.88	2.03	2.40	2.88	2.88	3.26	3.75	3.75	3.75	
P 7	Jan. 14	Plastered 3 da. later	37.5	9.61	2.40	2.50	3.43	3.90	3.90	4.37	4.85	4.85	
P 8	Jan. 14	Plastered 3 da. later	37.5	9.61	2.21	2.31	3.25	4.18	4.18	4.18	5.14	5.14	
P 9	Jan. 14	Plastered 10 da. later	74.7	6.88	5.17	5.57	5.57	5.57	6.07	6.07	6.59	6.88	
P10	Jan. 14	Plastered 10 da. later	74.7	6.88	4.19	4.53	5.02	5.02	5.02	5.27	5.72	6.32	
P11	Jan. 14	Plastered 10 da. later	37.2	9.61	5.04	5.32	6.31	6.31	6.72	6.92	7.73	8.15	
P12	Jan. 14	Plastered 10 da. later	37.2	9.61	5.05	5.47	5.96	6.96	6.96	6.96	7.53	8.05	

given a second coat of paint. In order to correct for the loss of moisture in the plaster which was drying at the same time as the blocks, the weight of plaster applied to each block was taken and a sample "pat" of plaster was made. This "pat" was weighed along with the blocks, and the rate the plaster dried was determined. Corrections were made accordingly for the plastered test pieces. The blocks were carefully mounted on a wooden tray and placed on a long laboratory bench where they were kept under a laboratory temperature of approximately 70°F. and under normal air change. These blocks were weighed on a very sensitive scale every other day for a period of 48 days and the moisture loss recorded.

Table No. 2 shows that the moisture did come through all the coverings, although not at the same rate. The bare blocks lost moisture decidedly faster than the covered blocks. Paint and stucco retarded the drying-out at about the same rate. A second coat of paint retarded the drying-out over a single coat; and linseed oil retarded the passage of moisture much less than paints and stuccoes. Our results with paint panels lead us to believe that a thin coat of paint which allows the passage of moisture more freely may be better than a heavy coat that retards the passage of moisture to a greater extent.

A second study was made to measure the absorption and evaporation of moisture by outside walls and through a limited number of different types of paint coverings. A series of rammed earth building blocks were used for this study. These blocks had been air dried in the laboratory until the moisture in the blocks was equal to the moisture normal to an outside wall. One series of blocks was given a coat of lead-oil house paint over a priming coat of linseed oil; a second series was given a coat of casein paint over a priming coat of linseed oil; a third series was given a coat of "moisture proof" commercial paint over a priming coat of the same brand; a fourth series of blocks was left without any covering. The blocks were carefully mounted on wooden trays and stored in the open air but under a roof which protected them from rainfall but exposed them to air moisture. These blocks were exposed from July 10 to September 2, and each block was weighed on a sensitive scale every second day with two exceptions. They were given a total of 24 weighings during the period, and the fluctuation in weight due to absorption or evaporation of moisture through the surface coverings was recorded.

Although the amount was very small, the results did show that moisture does pass in and out through paint coverings. Some moisture change was recorded at more than 80 percent of the weighings, and during the period there was a trace or more of rainfall on 16 days. The sum of all the fluctuations for the 24 weighings as recorded for the "moisture proof" paint covering was an average of 2.068 lbs. per block; for the lead-oil house paint 2.434 lbs. per block; for the casein paint 2.624 lbs. per block; and for the bare blocks having no covering 5.535 lbs. per block. At the end of the weighings the blocks weighed within one-fourth pound of the first or original weight.

It was not in the purpose of the study to measure the percentage of moisture fluctuation in earth walls from day to day, but some idea of it may be seen from the results. The moisture fluctuation for a bare wall would be of most interest. The average moisture fluctuation for each weighing of each bare block was 0.23 pounds. The blocks averaged 82.34 pounds which would make the percentage just over one-fourth of 1 percent. Since the surface exposure of the blocks is approximately two and one-half times the surface exposure for the same volume of rammed earth in an average wall, the moisture fluctuation for a bare wall during this period would have averaged one-tenth of 1 percent.

Some Admixtures That Have Been Tried

No special study has as yet been devoted to admixtures for pise' or rammed earth walls. The following admixtures have been tried, however: sand and aggregates of different sizes and amounts, soft coal cinders, straw and grass fiber, portland cement, hydrated lime, sodium chloride (salt), tannic acid, and asphalt emulsion.

Sand and Aggregate admixtures in rammed earth walls increased the weather resistance very definitely for all soils except those that rate as unfit soils. The maximum percentage of sand in a soil for weather resistance will range between 75 and 85 percent, depending upon the soil. A high percentage of sand in a soil will reduce the strength in compression for that material slightly, but correction can be made for this by adding slightly to the thickness of the wall. This admixture is reported in more detail in South Dakota Experiment Station bulletins No. 298 and 277.

Soft Coal-Cinder admixtures in rammed earth walls increased the weather resistance in approximately the same manner as an admixture of sand. The cinders show more in the roughened surface of the wall, but the wall does not seem to weather away any faster for the cinders than for a sand admixture. Certainly, a cinder admixture would be excellent under a stucco covering. Cinders increased the transverse strength of the material somewhat, but no transverse strength should be recognized in design for rammed earth walls. As compared to an equal sand admixture the cinder test pieces showed a strength of only 5 percent or less than the sand test pieces. (See Page 38.)

Straw and Grass Fiber admixtures increased the strength of rammed earth test pieces when tested in compression at an early age. A detailed discussion of this is given on Page 42 of South Dakota Agricultural Experiment Station bulletin No. 277.

Portland Cement admixtures have been tried as to their effect on the compressive strength of rammed earth but not upon the weather resistance effect. Portland cement was added to four different soils having a sand content varying from 26 to 80 percent.

Portland cement was added to each soil at the rate of 15 percent based on the dry weight of the soil. For soil No. 1 containnig 26 percent of sand, no added strength was shown due to the admixture of portland cement. For soils 2, 3 and 4 with sand contents ranging from 48 percent to 80 percent, the compressive strength was doubled and almost tripled by the addition of the 15 percent of portland cement.

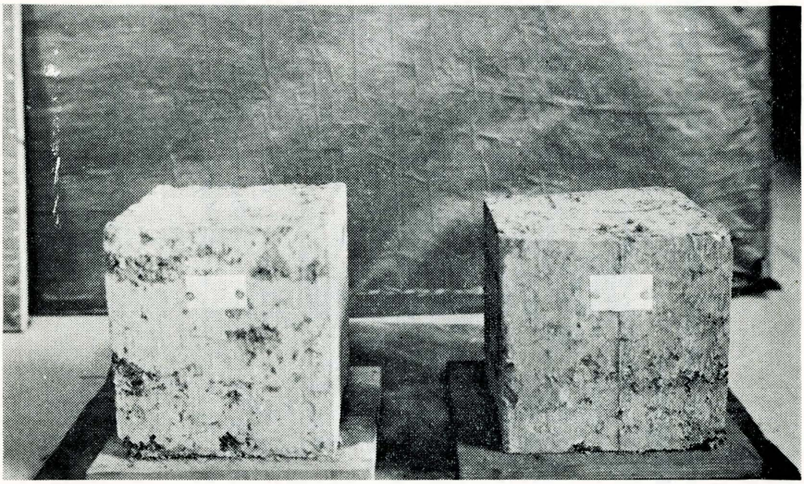

Fig. 22. Test Pieces Containing an Admixture of Cinders As Compared to Sand in Table No. 2.

The surface of these blocks are comparable to the surface of a wall in which cinders are used. The block at the right contains 1 volume of cinders to 2 of dirt; the one at the left contains 1 volume of cinders to 1 of dirt.

Hydrated Lime admixtures are reported in South Dakota Station Bulletin No. 277 on Page 41. Hydrated lime definitely decreased the compressive strength of concrete, although the strength curve was not uniform. When mixed in a weathering wall with a favorable soil and at the rate of 5 percent based on the dry weight of the soil, it has shown no advantage nor disadvantage from the standpoint of weather resistance.

Sodium Chloride (salt) admixture was tried in a weathering test only. It was mixed with the soil at the rate of 2 lbs. of salt per cu. ft. of wall. The admixture definitely reduced the weather resistance of the soil to which it was added. The wall failed rapidly.

Tannic Acid admixtures are under observation at the present time for weather resistance. No apparent advantage of this admixture has been shown as yet.

Asphalt Emulsion admixtures have been given a thorough test from the standpoint of weather resistance. This material was used in a weathering wall test at the rate of 1.2 gal. of oil to 100 lbs. of average sandy soil. The oil increased the weather resistance of the soil definitely. However, since it must be mixed with the soil in the condition of wet mud, it is entirely impractical to use with rammed earth. It lends itself well to stabilizing adobe brick in the Southwest and is being used quite extensively for this type of earth wall. Adobe brick are made from very soft mud, and the oil can be easily mixed with the brick for this reason. Asphalt emulsion has proven to

Table No. 3. The Effect of an Admixture of Cinders on the Strength of a Soil For Rammed Earth Walls As Compared to an Admixture of Sand—Strength in Compression

No. of like pcs. tested	Av. wt. of pcs. when made (in lbs.)	Av. wt. when broken (in lbs.)	Age when broken	Soil	Admixture	Av. ultimate load in compression	Strength as corrected for Height—(lbs./sq. in.)	Strength lbs./sq. in. compared: Cinders	Sand
3	51.29	45.36	1 yr 2 mo	No. 1 Black	None	42,703	507.6		
3	49.56	45.86	1 yr 2 mo	No. 1 Black plus	33⅓% Cinders	30,287	378.0	378.0	
3	55.92	52.0	1 yr 2 mo	No. 1 Black plus	33⅓% Sand	31,407	387.7		387.7
3	49.56	46.64	1 yr 2 mo	No. 1 Black plus	50% Cinders	25,340	338.5	338.5	
3	60.42	56.88	1 yr 2 mo	No. 1 Black plus	50% Sand	30,330	374.4		374.4
3	56.20	54.46	1 yr 2 mo	No. 2 Yellow	None	43,913	552.7		
3	55.71	53.47	1 yr 2 mo	No. 2 Yellow plus	33⅓% Cinders	39,697	505.9	505.9	
3	63.21	61.10	1 yr 2 mo	No. 2 Yellow plus	33⅓% Sand	40,098	526.8		526.8
3	51.75	49.23	1 yr 2 mo	No. 2 Yellow plus	50% Cinders	32,330	399.1	399.1	
3	61.25	59.54	1 yr 2 mo	No. 2 Yellow plus	50% Sand	29,390	362.8[1]		362.8

1 One block in this series dropped to 22,600 lbs. as compared to 32,000 lbs. for the other two, indicating a defect which upsets the curve slightly.

be a very valuable admixture to dagga plaster for plastering rammed earth walls (see Page 14).

From the practical standpoint, sand would seem to be about the only admixture worth giving much attention in rammed earth construction. If expensive admixtures are to be used, the cost of the material is apt to become too great for any except special cases. An admixture of sand to a medium quality soil will make a high quality wall—in many cases a wall that will stand without any covering.

A Comparison of Sand and Cinders as Admixtures for Rammed Earth Walls. In order that a comparison might be made of the strength of rammed earth walls when soft coal cinders are used as an admixture as compared to sand, 30 test blocks were made, using two distinctly different base soils, and varying the admixtures up to 50 percent which is in addition to the aggregate contained in the original base soils. Soil No. 1 is a heavy black soil containing 18.6 percent sand (33.2 percent clay and 48.2 percent silt), (hydrometer method of analysis). Soil No. 2 is an average or medium yellow subsoil containing 45.8 percent sand, (29.6 percent clay and 24.6 percent silt).

Three blocks of each were made for check blocks. Then three blocks of each soil were made with an admixture of 33⅓ percent cinders, and three blocks with an admixture of 33⅓ percent sand. Three more blocks of each soil were then made with an admixture of 50 percent cinders and another three blocks of each with an admixture of 50 percent sand. These test pieces made in the laboratory during the second week of January, 1938, were kept in the laboratory under normal temperatures until March 4, 1939 when they were tested to failure in a Riehl testing machine.

Although the test pieces containing the sand admixture showed a slightly greater strength in compression consistency, and for both soils, the difference was not great enough to be of material importance. As shown in the last two columns of table 2 the greatest difference was only slightly more than 5 percent. The analysis of the soft coal cinders used in the cinder admixture studies was as follows: particles larger than ¼ inch, 79.5 percent; from ⅛ to ¼ inch size, 7.5 percent; from 1/50 to ⅛ inch size, 9.4 percent; from 1/100 to 1/50 inch size, 3.5 percent.