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Rammed Earth Walls

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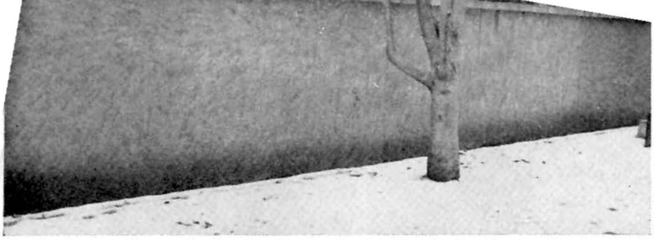

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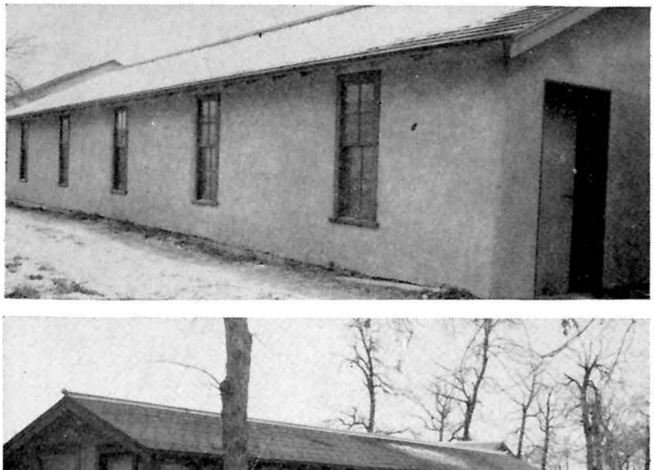
RAMMED EARTH WALLS



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The late Ralph Patty, shown here, was one of the pioneers in rammed earth construction. Most of the rammed earth research at South Dakota State College was done under his direction.

COVER PHOTOGRAPHS

Several rammed earth buildings and garden walls were constructed on the South Dakota State College campus 20 to 25 years ago. The photographs on the cover show the condition of some of the structures today.

(Top) Several hundred feet of garden or retaining wall were built from 1932 to 1940. Here one of the older walls with a cement cap and stuccoed sides stands firmly after 25 years of service.

(Second) Poultry house No. 1, built in 1932 and stuccoed in 1935, has been in continuous use. It is in good condition.

(Third) A 26- by 72-foot machine shed with 10-foot wall height was built in 1934-35. It still shows some of the sections of the experimental stucco panels. It is in excellent condition.

(Fourth) Poultry house No. 3, built in 1939-40, was stuccoed in the fall of 1940. It is a 20- by 60-foot structure. It has been used continuously for turkeys and is in excellent condition.

(Bottom) Poultry house No. 2, built in 1936, was stuccoed several years later, except the upper part of the south wall which shows 22 years of direct exposure.

RAMMED EARTH WALLS

H. H. DeLong[1]

INTRODUCTION

Rammed earth construction, as a building process, dates far back into history. The knowledge of how to build with this material was brought to America from Europe. There are records of homes and churches in the eastern United States which were built of rammed earth and have stood for more than 100 years.

Rammed earth construction is usually associated with a "build it yourself" program of construction in which earth, the building material, costs nothing, and in which the owner provides much of the labor of construction. Led by the Department of Agriculture, many of the state agricultural experiment stations of the Great Plains area constructed test walls and buildings in the 1930's. All stations concerned found that the material could be used, the buildings were substantial, and construction involved much labor. Most of the stations built only one or two small buildings.

The South Dakota Agricultural Experiment Station constructed five buildings and a number of test walls and protective walls and studied many soil mixtures and combinations. Work continued from 1929 to 1940. The structures have been in use from 20 to 25 years. Additional conclusions, which were not fully realized as early bulletins were published, can now be reported.

Inquires concerning rammed earth construction continue to come from various parts of the United States and foreign countries. This publication reviews briefly the various considerations in using rammed earth as a building material. It gives the physical properties of rammed earth, describes the construction procedures, reviews the characteristics of the finished buildings, and suggests some ways for further mechanizing the process. Favorable and questionable features are discussed to guide those who might consider rammed earth construction for their own building projects.

[1]Professor of Agricultural Engineering, South Dakota Agricultural Experiment Station.

USES AND CHARACTERISTICS OF RAMMED EARTH

Rammed earth is usually a subsoil, with perhaps additional sand, thoroughly tamped in layers within a form enclosure. The soil is placed within the form in a layer about 4 inches deep, leveled, and then tamped by heavy rammers until it has reached nearly maximum density. Succeeding layers are built above it until the form is full. The form can be taken off immediately and the wall section stands. With the form re-set, other wall sections can immediately be built adjacent to, or on top of, the first section. The form must always be accurately set in place and held there so that the wall is straight and true.

The layer of 4 inches of loose material can be tamped down to about 2 inches. Density attained will depend on soil and ramming and will range from 115 pounds per cubic foot to 140 pounds per cubic foot. The tamping procedure accomplishes its work in two ways; (1) by repeated vertical blows of the rammer; and (2) the rammer blows, which seldom strike the same place, tend to work the particles back and forth horizontally, thus working the material into the dense pattern.

Such a relocation of soil particles cannot be attained uniformly by a straight hydraulic press process. Even in rammed earth, the top of each layer is more dense than the bottom part, so 4 to 4½ inches is felt to be about maximum for the loose earth fill. The adobe, or mud brick process of earth building, attains its density by shrinkage of the soil as the water slowly leaves by evaporation. The adobe block must be reasonably small so that non-uniform drying and shrinking will not set up too many cracks.

Uses

Rammed earth is best adapted for use in side walls and major interior partitions. It cannot be used for below grade foundations, nor basement walls above underground footings. All but supporting interior partitions are more quickly made with wood or steel framing. Roof structures must be of wood or steel trusses with any of the conventional lighter weight coverings.

For certain farm buildings, such as shown on the cover, the side walls form a substantial part of the building. In homes where so many additional building parts are needed, such as basements, doors and windows, finished interior walls, insulation, attractive roof design, and built-in cabinets, the side wall construction is only a small share of the cost. Even if cost could be saved on the wall part, it is only a part of the total cost.

Rammed earth is a stable, permanent kind of building material. It should not be thought of as temporary construction. This material is never used where a tensile stress is developed, nor where a light-weight material is needed. The walls, if thick enough, have a fair measure of insulation, but in most cases the light-weight air-cell material, reflective material, or a combination of both, will give greater insulation with less space and less weight.

What buildings can be constructed of rammed earth? The South Dakota Agricultural Experiment Station, through its tests and observations, can recommend the following: poultry houses, machine sheds, garages, and barns where feed alleys are next to a major portion of the side wall. All such buildings should have stucco coatings on the exterior walls and on interior walls wherever there is danger of wear by contact with animals.

If rammed earth is used, it must be protected from water. Foundations should be 12 inches above grade, and the building site should be graded to drain away from the building. Substantial overhang of eaves should be used to prevent water running down the walls. Water should never be allowed to enter at the plate line and soak into the walls. The above precautions are usually adhered to for most other building materials.

Running water, in contact with a rammed earth wall, will soften and erode the wall. This should always be remembered in placing lawn sprinklers of any kind. Stuccoing will usually prevent most of these troubles, except the plate line drainage and this is safeguarded by a proper roof.

Physical Properties

Density. Various writers have reported densities for rammed earth from 115 pounds per cubic foot to 140 pounds per cubic foot. Obviously there was much variation of earthen mixtures used, of thoroughness of ramming, and some small differences in retained moisture. Table 1 gives the densities of three test soils at the South Dakota Agricultural Experiment Station.

Specific Heat. Rammed earth samples (75% sand content) varied in specific heat from .18 to .22 British Thermal Units per pound degree, as tested by South Dakota State College Physics Department.

Thermal Conductivity. Investigators' results vary widely and could well vary due to differences in density, material differences, and moisture content at testing time. In 1941 the Bureau of Standards (report BMS78) gives 11.3 Btus per square foot per hour per degree per inch of thickness for their test walls where density was 125 pounds per cubic foot.

Compressive Strength of Rammed Earth. Many tests were made on compressive strength of rammed earth. Most tests were made from special blocks that could be broken on the Riehle Tester. Most of the blocks were 9 inches by 9 inches by 9 inches. Due to column effect and combined stresses, it is quite meaningless to quote a compressive strength without specifying height of the test column and the area size.

(a) A 2¼-inch height of test block supported more than six times as

Table 1. Density of Rammed Earth with Relation to Sand Content

Soil	Sand Content of Soil, %	Unit Weight lbs./cu. ft.*	Specific Gravity
#1	10.36	119.4	1.92
#2	37.56	128.4	2.06
#3	74.82	138.9	2.27

much as a 9-inch test block of the same material.

(b) Age of the block and moisture content both affect the strength. Blocks increase in strength rapidly as the moisture dries out and gradually increase on up to 2 or more years of age.

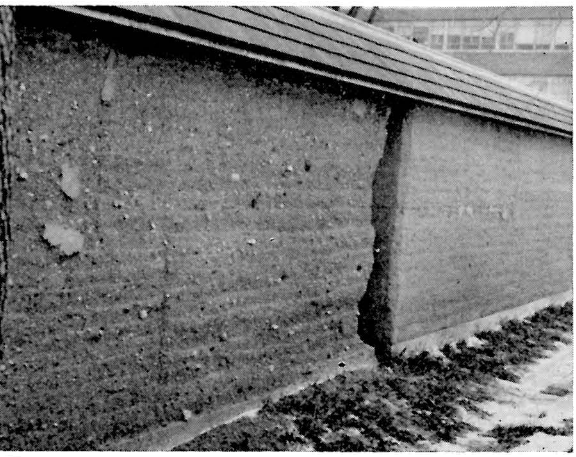
(c) Size of aggregate affects the strength only when the aggregate gets larger than the quarter-inch or above.

(d) When sand content gets up to 75%, the strenth is slightly lowered. A higher percentage of sand greatly reduces the strength.

(e) Moisture contents (at ramming time) of 9 to 13% have given the best strength in test blocks through a wide range of sand content variations.

(f) Heavy ramming (3 times over with 18 pound rammer) gave four times the strength of light ramming.

Figure 1. This shows bare, exposed walls of plain rammed earth(left) and "terracrete" (right) after 15 years of weathering.



Flat surfaced rammers proved superior to V-edged or rounded rammers.

(g) In admixtures, clean cinders proved to give as much strength as sand (see weathering quality below). Fifteen percent of portland cement adds little to a high clay soil, but doubles the strength of rammed earth when the sand content is from 50 to 75%, and improves the resistance to weathering (see figure 1). Adding lime decreased the strength.

(h) Addition of various fibers at different rates raised the compressive strength somewhat.

(i) For comparative test figures the following data will be quoted as a standard of comparison. A 9 inch by 9 inch by 9 inch test block made of soil of 75% sand content and 19% colloids[2] showed breaking strength of 353 pounds per square inch at 6 months, 446 at 1 year, and 497 at 2 years (average for 12 test blocks).

Durability, Weathering Resistance. More important that the compressive strength of rammed earth is the ability to resist deterioration through changes of weather and continued use. Mechanical abrasion or water erosion if allowed to continue would wear away the outer

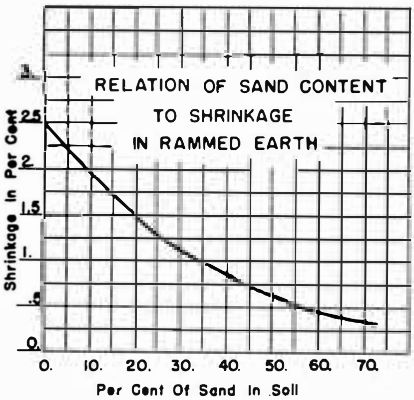
[2]Bureau of Roads standards of the early 1930's were used when this work was conducted. Therefore, colloids, as used in this publication, refers to the finer part of the silt plus all of the clay. The hydrometer method was used for sample analysis. All material in suspension after 15 minutes was called colloids. Other fraction standards used in this publication include—sand, 2,000 to 50 microns; silt, 50 to 5 microns; and clay, less than 5 microns.

surface. Five additional things enter in which may affect the entire wall rather than just the surface.

(1) Freezing and thawing when moisture content of the wall is high will definitely loosen the structure of the walls and allow them to crumble. Work done in December 1938 in sub-zero weather proved that newly rammed earth must go through its drying-out period before cold weather sets in.

(2) Shrinkage while drying out from its moisture content of 9 to 13% , which was necessary for the proper ramming, is the cause of a cracking and pulverizing action. Surface cracks appear soon after ramming, as the surface dries out first. Later these cracks lessen or even disappear for casual inspection, proving that the rest of the wall has internal shrinkage. Eventually a test block will attain a maximum shrinkage for a stable moisture content of near 3%. Two additional things appear to control shrinkage —sand content and percent of colloids in the soil used.

Figure 2. Shrinkage of rammed earth test blocks in relation to sand content.



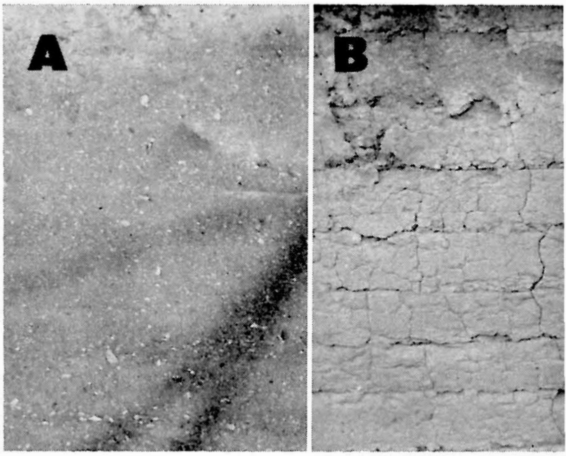


Figure 3. High sand content wall "A" shows little shrinkage while wall "B" with low sand content shows shrinkage and severe weathering.

(3) A high sand content prevents excessive wall shrinkage and cracking (see figure 2). Figure 3 shows the effect of sand content on shrinkage of uniformly made test walls. On actual test wall observation, the soil samples which have a 50 to 75% sand and otherwise suitable soil do not deteriorate due to the initial or continued effect of shrinkage.

(4) The percent of colloids in the soil used is a second cause of shrinkage variation. The colloids (by older Bureau of Roads designation) include all of the clay particles and the finer particles of silt. These fine particles have much more surface than their equivalent weight of sand particles. Therefore it takes more water to make the soil wet enough for semi-plastic conditions for proper ramming. Due to the need for add-

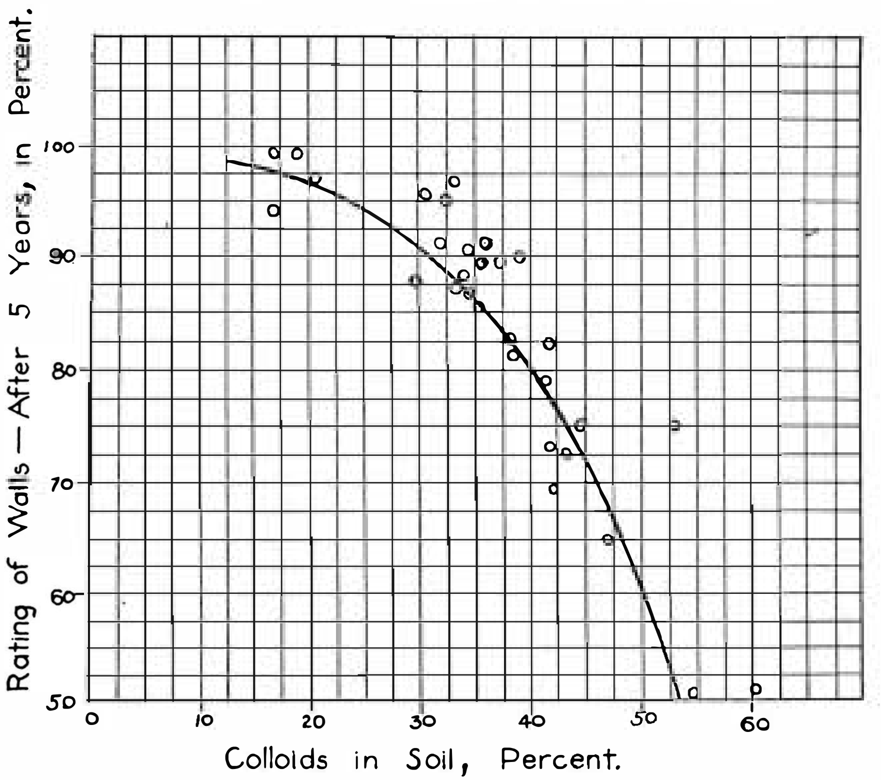
ing more water at ramming time, there is greater drying and greater shrinkage. Observation of test walls would indicate that a colloidal content of over 35 to 40% will produce an inferior wall (see figure 4), even though the sand content was above 50%. Here lies a second argument for insisting on a mixture that is 75% sand, as this automatically forces the colloid content down to 25% or less.

(5) Various admixtures may affect weathering ability. Cinders for aggregate are not as good as sand. Portland cement generally improves the wall, but lime has the opposite effect.

The only additional precaution is to see that the material is well mixed and that soil clods are not allowed to remain unmixed with sand. Figure 2 shows shrinkage of test block samples in relation to sand content. Figure 4 shows test wall ratings in relation to soil colloidal content.

Tensile stress. The tensile stress of rammed earth should probably be taken as zero in design work. Actually there is considerable tensile strength in a test piece, but as the

Figure 4. Test wall resistance to weathering in relation to colloid content.



test piece gets longer, the assurance of any reliable tensile strength would become less. Some tests were made with reinforced rammed earth beams with various types of reinforcing. Hooked rods in the lower portion of the beam improved the beam somewhat, but wood members or metal lath tended to separate the layers and were not as good as the beams with no reinforcing.

CONSTRUCTION TECHNIQUES

Many of the techniques of rammed earth construction have been developed in keeping with the ideas of manual labor, low-cost equipment, and the "build it yourself" approach. All of these were acceptable before the machine age and were reasonably acceptable during the 1920's and 1930's when labor costs and purchasing power were low. Highly mechanized procedures were never developed; but some suggestions can be made, in light of former experience, that would point the way to greater mechanization.

Foundations

Foundations for rammed earth must be strong and wide, since great weight is to be supported. The wall structure is wide, and any shifting of foundations results in cracking of the walls above it. It is recommended that the foundation extend 12 inches above the grade line to prevent undue moisture entering the wall from splashing and melting of drifted snow. This is especially important in northern climates where there is alternate freezing and thawing. Rammed earth, if soaked with water and then frozen, will start to crumble.

Rammed earth must not be used for basement walls below grade, even though a concrete footing is used. One building, a root cellar, was constructed this way just to verify the interactions of water and freezing. The walls were partially destroyed after 2 years and following that the building was torn down.

Figure 5a shows the cross-section of the foundations used in the South Dakota experimental buildings. Figure 5b gives a suggestion for a full width but hollow foundation, which might or might not be adapted to a full basement wall. Figure 5e shows a pier-type of foundation with continuous top, shaped for "pier-wall" construction. Such a foundation lends itself to machine digging and requires no forming lumber except for the top part. Vertical reinforcing in the piers should be bent horizontal to join in with the horizontal rods of the upper foundation. Foundation top could be narrowed by blocking at the time of pouring for sections at door or window and panel locations. Each major wall block of 5 to 7 foot length should have two piers.

Forms for Tamping

Forms for containing the earth while it is tamped must be rugged. The last form used in the experiment is an adaptation of the earlier and simpler ones, with a few extra conveniences (see figure 6). This form was large, being long enough for 15 feet of straight wall if used that way, or its equivalent length around a corner. The corner hinges

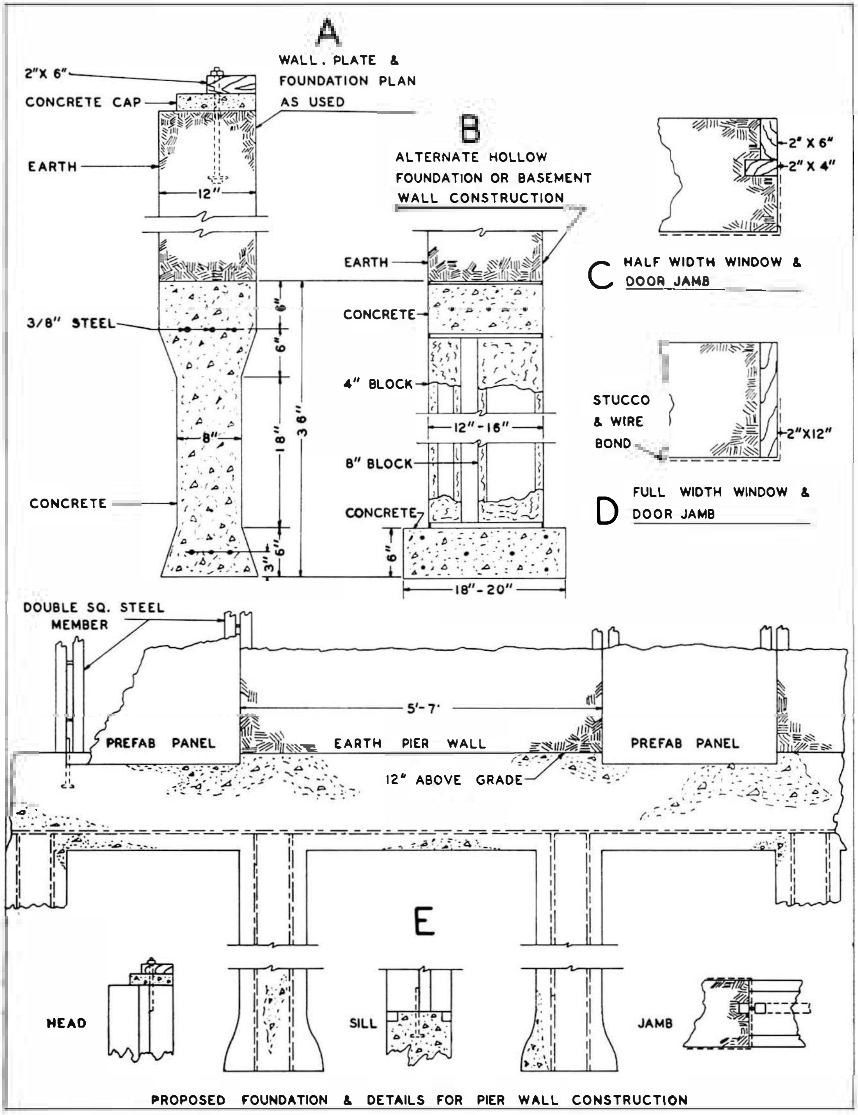
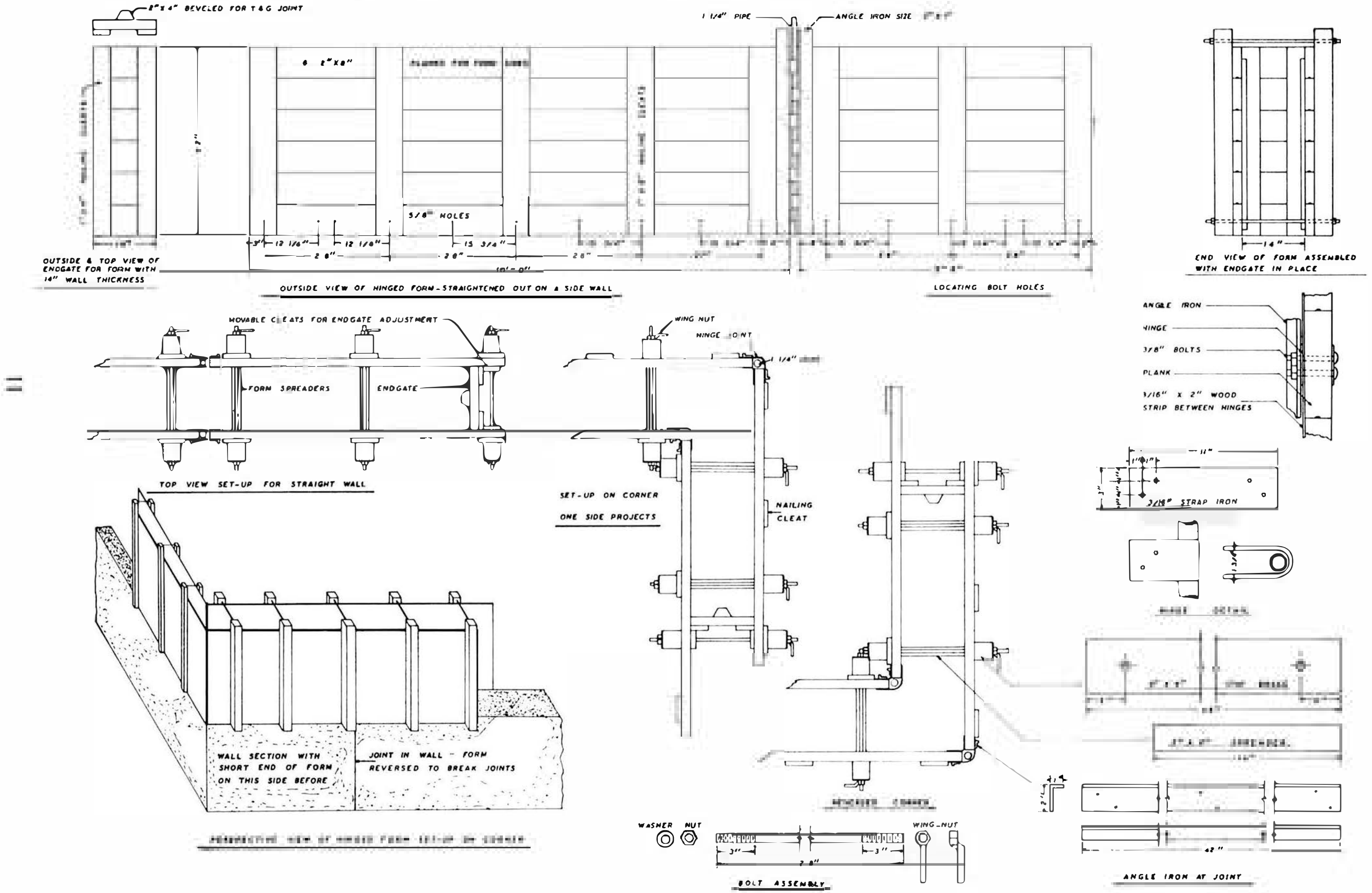


Figure 5. Foundation used in South Dakota buildings (a); a proposal for a hollow wall suitable for full basements (b); and a proposal for a "pier-wall" type of construction. (e).

Figure 6. A hinged type for construction of rammed earth walls and construction details.



with pipes for pins allowed a 90° angle, or if so desired a 60°, 120°, or any angle in between. If for any reason a shorter form were desired, the longer end or the shorter end could be used separately by pulling the pipe hinge pins. This was usually done at the time of form removal to make the separate parts easier to handle. Such a large form is hard to move, taking at least 3 or 4 men unless a derrick or hoist is used.

Following are some brief conclusions about forms:

(1) A large form that will hold a 2½ to 3½ foot depth and a 12-to 15-foot length of wall at one time is desirable.

(2) Small forms, though easy to move, cause too many joints, layers, and irregularities in the wall.

(3) Forms must be accurately made and must have the adjustments to be set straight and held straight.

(4) Bracing must be strong. The 4 by 4 inch stays as shown in figure 6, placed on 38-inch centers proved to be strong enough.

(5) The cross bolts which have been used in most previous form designs give some trouble in removal, and leave holes that need to be filled. In any new form developments, the designer should seek ways of eliminating these cross bolts through the wall.

(6) The form holds part of the answer to mechanization and should be part of the total design since it controls the filling operation and affects the use of all ramming tools.

(7) To date, most forms are designed to be set on a corner so that the corners can be rammed as a one-piece section. It is not good practice to try to make a wall section with open end form placed perpendicular to a finished wall section.

Mixing of Soil

Mixing of soil just before operations begin is almost a necessity. When sand is added, thorough mixing is always needed. Usually water will need to be added to arrive at the proper 8 to 11% moisture desirable forramming. Hand mixing with shovels is possible, but time consuming and laborious. Batch mixing in a concrete mixer is possible, but some hand work is still required. Machinery for one man to operate, which would convey soil and sand to mixer and then quickly deliver the next "layer batch" to form, would greatly aid construction work.

Ramming Tools

Ramming tools are shown in figure 7. When the loose dirt was first placed in the form, one man went over this with a large floor rammer like one pictured on the right. Three men then followed with 16 to 18 pound rammers such as those shown on the left. With experience, one can tell by the "feel" and "sound" when the tamping is complete. A pneumatic air hammer, shown between the other two types, when powered by a 5-horsepower motor and compressor, will enable one man to replace the three with the hand rammers.

Attachments and Joints

Rammed earth walls are massive and are called on to hold their load by compression. Due to the weight,

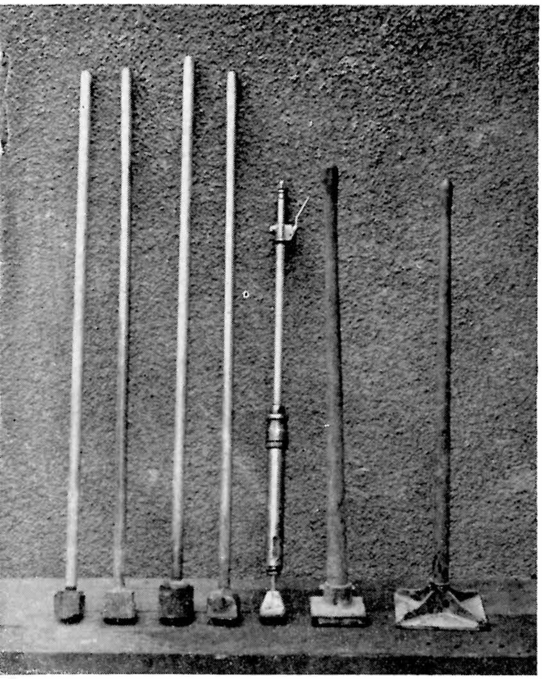


Figure 7. Four variations of hand rammers (left); a pneumatic rammer (center); and two floor tampers (right).

no attachment is needed at the foundation. A coating of asphaltum has sometimes been applied to the top of the concrete foundation before the wall is built. This precaution against moisture and vapor travel is worth consideration. A foundation that extends 12 inches above grade line is a better precaution.

It is good practice to sprinkle water on top of a dry wall layer before making a new rammed layer on top of it. Where one wall section is joined to another end to end, there should be a V-type lock joint. This is accomplished by a vertical member in the end piece on the forms.

At the plate line it is difficult to finish a rammed wall to a line exact enough to match a wood plate member on which the rafters or trusses are attached. A finish layer of poured concrete can be smoothed to an exact level. About two or three layers before the wall is completed, long anchor bolts should be embedded in the wall and rammed in place. These must have length enough to go through the concrete cap and at least the first wood member of the plate.

Door and Window Openings

One of the most difficult phases of making rammed earth walls is to provide openings that are accurate in dimension, with frames that are securely anchored in the earth wall. It is preferable to set the outer frames (rough-opening dimensions) inside the rammed earth forms, thoroughly brace these from the inside, and then ram on both sides of the opening. This will leave the wall joint at other locations than along one or the other of the vertical window margins.

Windows are usually placed at customary height in the wall with the full thickness of rammed earth wall below the opening. The wall section above the window calls for the insertion of a lintel to hold the weight of the section. These lintels can be made of 2-inch plank for small openings, or if larger, a box-type lintel or a reinforced concrete lintel.

It is always preferable to run door and window openings up to the plate and fill in the part above the rough opening with wood panels or other lightweight materials. Suggestions for window and door frames are shown in figure 5. Sketch "a" shows a flat frame and sketch "b" a half-width frame that has a notched infiltration barrier. Either of the rough - opening frames provides nailing anchorage for wire or metal lath for exterior stucco.

Construction Techniques of the Future

In view of all past experiences in construction, combined with the observation of how the buildings stand up under 20 to 25 years of use, it would seem advisable to predict some procedures and techniques that would make possible more convenient, more rapidly built, and more complete structures. These predictions are made in light of the conviction that if rammed earth construction is to survive in a highly mechanized industry, it too will have to be mechanized.

The pier-type wall construction, as shown in figure 5, should be the central idea. It would enable one to set a form reaching from foundation to plate line and firmly anchor it in exact position. Sides for the form could be added as the wall section was built. Door and window openings would be enclosed above and below with insert panels, thus avoiding all openings within the rammed earth itself. Corner panels could also be inserted, using doors or windows if desired. Such construction is not far diffierent from that used by Hibben at Gardendale, Alabama, as described in Merrill's book, *The Rammed Earth House.*

For foundation construction, the pier-type as shown in figure 5e would save both materials and forming labor. It would provide a full-width concrete foundation below the earth pier-wall sections and tie all foundation parts together.

A new and multiple use part is proposed in the doubled square steel tube member shown in figure 5e. This member could (1) be welded to the foundation bolt and the roof plate bolt to provide an excellent tension member, (2) provide the infiltration breaker notch in the earth wall, (3) provide the mounting frame for the panels, windows, and doors, (4) allow tie-through wires to secure outside stucco metal lath anchorage (perhaps interior plaster anchorage as well), and (5) the exposed square steel tube could further serve as electric conduit. It would not be impossible to build in or cut in electric conduit in earthen walls, but it would be time consuming to do it that way.

The form used should be adjustable to three or four lengths of pier-wall section, of one standard width, and high enough to form an approximate 8 foot wall. Machinery should be developed to fill the form with its new charge of loose earth within a few seconds so that the ramming process could be resumed without delay. The form should incorporate suitable scaffolding to make it safe and convenient for the workmen and to provide racks for necessary tools.

Figure 5e shows some of these ideas without developing the details.

PRACTICAL ASPECTS OF RAMMED EARTH

What is practical in building and what is not practical? Such a question leads to extended discussion on comparative durability, length of life, material costs, construction costs, appearance, adaptability and saleability. The conclusions may not be the same for every community or area, and such things as appearance depend somewhat on personal likes and dislikes, with preferences expressed for the common rather than the uncommon. Here are a few facts that may help answer the question in a given community as to whether rammed earth is a "practical" building material:

(1) The material is low cost if it can be taken from the building site. Its cost increases as it is transported, has sand added to it, or if anything involving labor is done to it.

(2) The rammed earth process lends itself to the "do it yourself" method, but the best results come where considerable skill and experience are involved. It certainly cannot be said that such work can be well done by workmen who are unsuited for other forms of construction. If done by hand labor, earth ramming will require some "brawn" and perseverance.

(3) Rammed earth construction has possibilities of mechanization, but when done, this requires capital and a volume of work to warrant the investment. In other words, a contractor must take over and build in quantity before mechanization is possible.

(4) Rammed earth, when properly made, is durable. In light of the 25 years of observation of the South Dakota State College buildings, it is predicted that they will stand for 100 years. Some of these buildings are obsolete in 25 years, but not worn out. This material is definitely not the "temporary" type; it is for permanent buildings which will not be moved.

(5) A good quality cement stucco has proved the best type of covering. Although stucco will adhere fairly well at first to the earthen surface, it is better to use a wire mesh nailed to the earthen wall with large nails (#10 penny, 12 inches on center) with the stucco applied over this in a two or three coat application.[3]

Stucco should not extend below the rammed wall on to the foundation below. Many kinds of paint have been tried on the test walls and at first were thought to be satisfactory. After longer observation, though, it is recommended that cement stucco is far better than paint. The bare, unprotected walls weather no faster uncovered than with painted surfaces that are allowed to crack and peel. Figure 8 shows test surfaces that were painted (gable end) and dagga plaster plus paint (side wall), both having failed after an extended test period.

(6) In appearance, rammed earth walls that are uncovered are not flashy; but most of the shades of soil, buff, brown, red, are pleasing in appearance. Black soil is less desirable, but usually a different colored subsoil is available. White pebbles in

[3] Bulletin 336, South Dakota Agricultural Experiment Station.

Figure 8. Test wall surfaces that have been painted (gable end) and covered with dagga plaster plus paint (side wall) have failed.

the sand make a contrasting color pattern when they show on the surface. When stucco is placed on an exterior surface, is can be left in natural color, have permanent pigment added, or be coated with any color of paint.

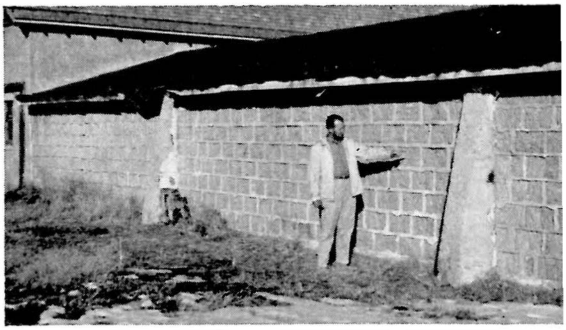
For interior walls, regular plaster may be used. Surfaces can also be touched up, brushed and painted. Even varnish or shellac leaves a pleasing surface with the natural soil color showing through. The major wall joints are the most noticeable defect, and it is believed that the pier-wall type of construction would eliminate all major wall cracks.

(7) Rammed earth construction is probably best used in one story (no basement) construction, but otherwise has few restrictions on size, shape, or type of roof structure. The roof trusses should not depend on the rammed earth wall for horizontal thrust. Shearing of the top layer may occur where anchor bolts hold plate to the wall if rafter members impose a horizontal stress.

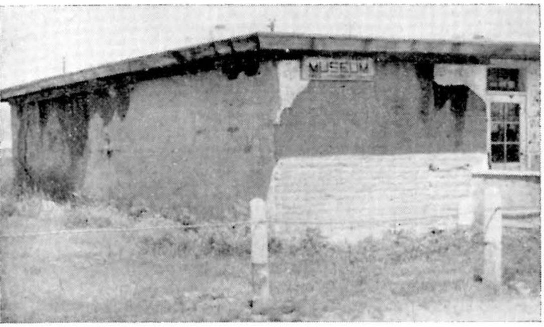
(8) Of the many additives used, portland cement added in proportions by volume of 10 to 15% proved to be the most practical. It increases the wall strength and improves the weathering ability, as shown in figure 1. However, the increase in strength is usually not needed and adding cement raises the materials cost.

(9) How good an insulator is a rammed earth wall? The South Dakota Agricultural Experiment Station buildings are warmer than a single layer of 1 inch wood boards, and when first built in the 1930's, made a favorable showing. Many of the barns, sheds, and poultry houses of that day were built of single boarded walls. Times have changed. Present day homes, poultry houses, and dairy barns are double wall construction with 1 to 4 inches of insulating material and perhaps reflective insulator material and vapor seals. A rammed earth wall, even though it is 12 to 16 inches thick, will not be so resistant to heat transfer as modern insulated walls. Placing insulation on the inside of rammed earth walls would be no harder than insulating masonry walls. Either would be more difficult to do than the insula-

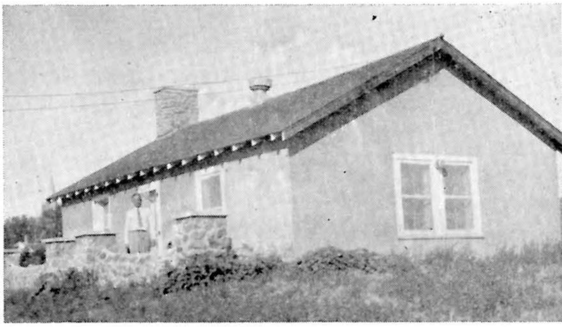
This photograph was taken in 1959 of a poultry house at Flandreau, South Dakota. It was built in 1939 and used as a residence until 1957.



Monolithic rammed earth barn with stucco cover and shed of uncovered block, built in 1936-37 at the Pine Ridge, South Dakota, Indian School, looks like this in 1959.

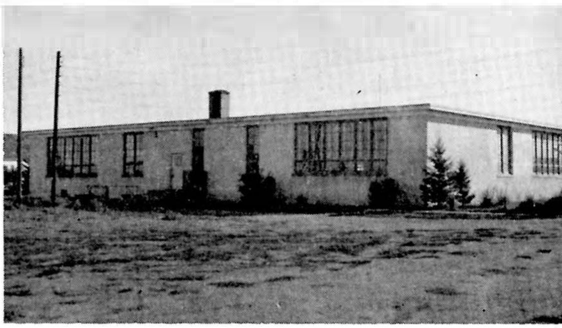


This museum at Bison, South Dakota, is not in use and is not maintained. The plate line is a cause of wall and stucco deterioration.



This is the Boy Scout house at Eureka, South Dakota.

Poultry house at Trent, South Dakota, built in 1938 and never stuccoed, is shown here in 1959.



The Indian school at Wamblee, South Dakota, was built in the 1930's. It is shown here in 1952.

tion of frame construction. It is recommended that dwelling houses for use in the northern part of the United States be insulated regardless of what construction is used.

(10) Farm people in most areas are free to build without building code restrictions. The South Dakota Agricultural Experiment Station research work has enjoyed this same freedom to build and experiment. Not all prospective builders have so much freedom. Cities and municipalities have building codes that are restrictive as to methods, materials, spacing, and perhaps additional zoning restrictions. These are all intended for the general good of the total community, and try to prohibit inferior building.

Some prospective builders have not been able to get a permit to build with rammed earth. Their local committees could find no statements relative to the use of this material. Not finding this positive permission, they may have interpreted this as prohibiting rammed earth. In such cases one can only show proof that rammed earth is durable, adequate in strength, non-combustible, and that there are many successful examples of this type of construction. In any event, in city home building, the prospective builder with rammed earth should secure his permit early in the planning stage, before going too far with the preparations to build.

BUILDING WITH EARTH IS WIDESPREAD

After reviewing the available literature, and after many years of correspondence with people from many foreign countries, one becomes aware of widespread interest in rammed earth construction. "Housing and Town and Country Planning," Bulletin #4 by the United Nations gives one of the most complete bibliographies of published material.

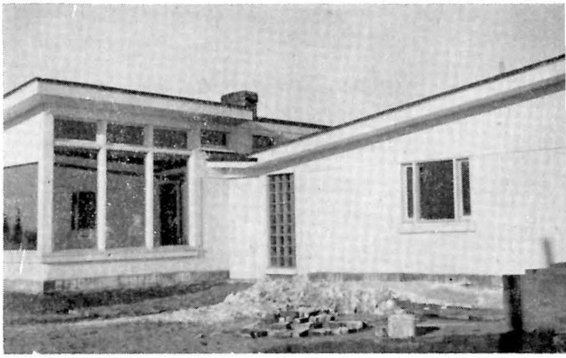
During the years of correspondence and soil sample testing, the South Dakota Agricultural Experiment Station has collected many pictures of rammed earth buildings that were built by other people, some which are in foreign countries. One group of pictures shows South Dakota buildings, all built in the 1930's but photographed in 1958-59 to show their present condition. These photographs with brief descriptions are shown on page 17.

Most people who have written for information have asked about rammed earth as a possible material for building homes. The South Dakota Agriculture Experiment Station did not build any homes. Many other people did, however, by using essentially the same methods as were used in the South Dakota building. Page 19 shows a group of these buildings.

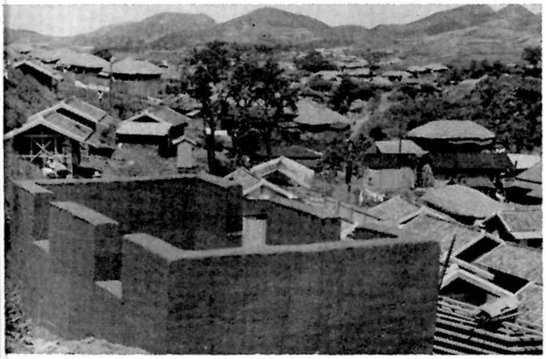
This is a rammed earth home built in the Netherlands.

This rammed earth home is located at Salem, Missouri.

A rammed earth home in Mexico is shown in this picture.



This home of rammed earth is located on Prince Edward Island.



Partially completed house, of a 50-unit project, in Korea.

Open house at a rammed earth home in Salmas, California.

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