

# Screenings

from the Soil Research Lab

IOWA ENGINEERING EXPERIMENT STATION  
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AMES, IOWA

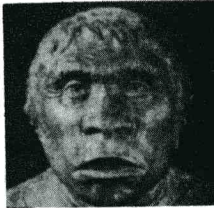
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SOIL: FOR BETTER HOMES AND GARDENS

## Plus Thunderation! Or, Who Rules the Roost

Gather 'round, do-it-yourselfers, and hear of the housing that very little jack built.<sup>1,2</sup>

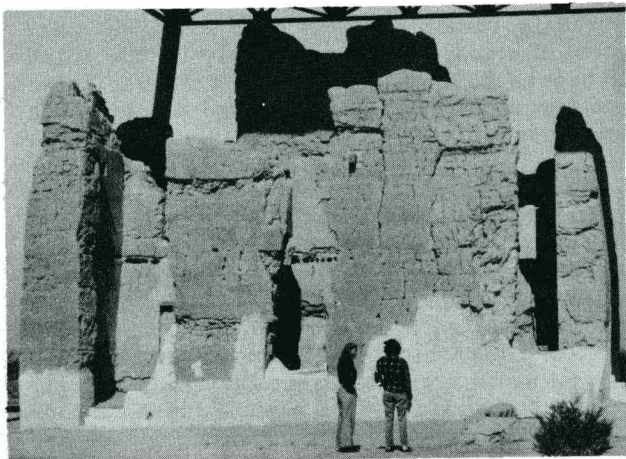
Prehistorically the cheapest housing was the cave, which is not unrelated to soil, being limestone weathered to its ultimate emptiness. The first grouchy landlord was probably the cave bear, who preferred caves because his growls echoed and reverberated in vibrant, stereophonic hi-fi. Even a belch could create terror.



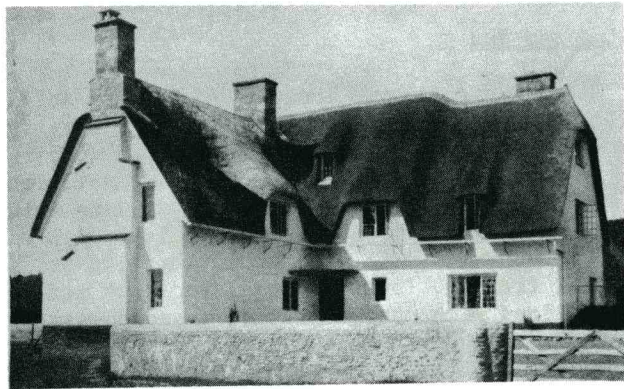
The author

Man was quick to perceive the acoustical advantages of the indoors, and after a few threats of peaceful coexistence he moved in and the bears moved out or had their heads bashed. Soon every cave in the valley had a man inside it, growling and singing and stoutly issuing commands, all for sport.

Unfortunately when wives heard the ruckus they also moved in. While true that a cave was a nice auditorium, it was an even nicer place to live.



The earliest adobe extant in the U.S. is this four-story watchtower built in Arizona for watchful Indians. It dates from about 1350, 140 years before Columbus or 600 years before now. That's a long time for anything to stand unaided.



A "cob" house built some 50 years ago in Merrie Olde Devonshire, SW England. For more about cob see par. 2 under "Stud and mud," next page. "Cob" contains no cobs.

This was woman's mistake, because men's voices, being lower than women's, are much better adapted to reverberating in caves. Masculine voices thundered authority, and women became submissive by the first echo. Thus from the hollow resonance of caverns was born our male dominated society. It was when man left the caves that his troubles began; without an echo he's been losing his voice in matters ever since. It's no accident that men sing in the bathtub, or that singers use electronic echoes. Gives them that virile, cave-man sound. Ugh.

## Castles of Sand, Plus Clay

Now everyone is suitably impressed that housing dictates society, we continue.

After caves came mud. Our evidence is that small boys smear mud, and things small boys do are fun for big boys, too; else why would we have baseball?

Early mud houses were built after the manner of the beaver, with sticks and twigs and generous

<sup>1</sup>In this issue we kick around another literary toy, the footnote. It is extensively used in scientific writing where it is necessarily set apart from other kinds of notes which are supposed to originate more from the head.

<sup>2</sup>This particular footnote has to do with the use of the word "jack." Foreign readers may not know that "jack" is slang for money. As here used it also alludes to a nursery rhyme, "Jack and Jill went up the hill to buy some things on credit; Jack fell down, and broke his crown," etc., etc.



amounts of mud plaster. In view of this, man could reasonably have been expected to evolve a large flat tail. Instead he broadened his palm. The broadened, upturned palm remained to become a dominant symbol of our urbane culture for example around the check-out desk in a large hotel. Future man will probably have hands the size of dinner plates, and fingers that mesh over and lock like a vault.

### Stud and Mud

Mud housing is used today in Africa and Asia, although it's something you would ordinarily prefer more for your in-laws than for members of your own family. The twig-and-mud construction is called wattle-and-daub,<sup>3</sup> wattle being the twig work and daub being as the name implies. A more formal approach still used in Europe is to erect timber framing, lace in twigs, and daub mud on both sides with the subjective thoroughness of an actress applying skin cream. The result has surprising longevity, but on close examination usually looks a little humdrum and certainly like nothing you would want to marry. Wattle-and-daub exists mostly in farm buildings, conveniently built during slack seasons.

Another style of building is to leave out the twigs and build walls from mixed straw and mud, called "cob." The cob was mixed on the job, usually by horse foot, then slapped on the wall in a continuous loaf about a foot high, packed into place and trimmed even on the two sides. By the time a building wall was thus circumnavigated the cob was usually dry enough to support another lift.

Cob construction was very common in France and drier parts of England up until the present century, and many cob houses a century or so old are holding up well today. They usually wear a protective camouflage of plaster, and look quite respectable and presentable. Increased cost of labor is what cooled the cob, and cob building is almost a lost art.



Wattle ready for the daub, Greece.

<sup>3</sup>Also stud and mud, daub and stower, rice and stower, raddle and daub, ham and eggs, ketchup and beans, or pickles and ice cream. Pardon us, we just ordered breakfast.



Stabilized adobe house, wall and double garage in Santa Barbara, California. Rather truly nice, N'est pas?

### IN MY ADOBE HOUSIENDA

Adobe, or mud brick, is such a lovable way to build, that enthusiasm is a popular hobby, like love or stamp collecting. Adobe differs from cob or wattle-and-daub in that whereas walls of the latter are built from soft mud, walls of adobe are built with dried adobe bricks laid up with mortar.

Adobe is especially common in the southwest United States and in Mexico, but is found the world over. It is a very ancient invention. The name is Spanish, but probably came from the Moorish word attûba, which probably came from the Egyptian tôbe and the hierglyph tb. It is rather characteristic of the British to ignore all this and call the same thing "clay lump." Unromantic British.

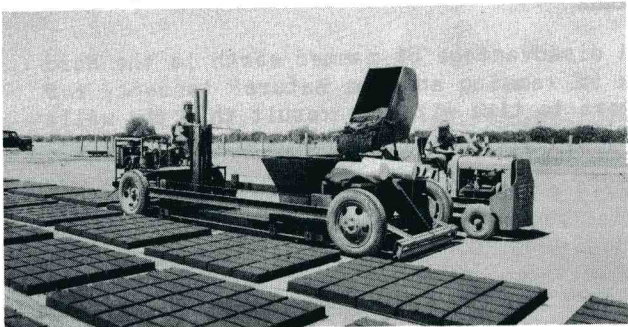
Traditional adobe is mixed much the same as cob, the fresh mix being a creamy sand-clay mud containing short cuts of straw. The mud is poured and worked into large molds laying on the ground, the top is struck off, the mold is lifted, and the brick allowed to dry. Usually by the third day bricks have gained enough strength to be tipped up on end to save space and promote more even drying.

The function of the straw is to give the bricks wet strength so the forms can be lifted with little damage, and also to provide capillary channels for more even drying. The bricks invariably shrink, and if they dry and shrink uniformly there is less cracking. There is a rather well documented historical instance of the need for straw in adobe brick manufacture (Exodus V, 7). About three short cracks per adobe brick is considered allowable. Too many shrinkage cracks means too much clay in the soil, but too little clay gives weak brick. Specifications are usually trial-and-error; to see if a soil is satisfactory you mold a few bricks and test them.



The dry brick should have an unconfined compressive strength of over 300 pounds per square inch.

Incidentally, there's a bit of the old erroneous in calling adobe "sun-baked;" even though it's



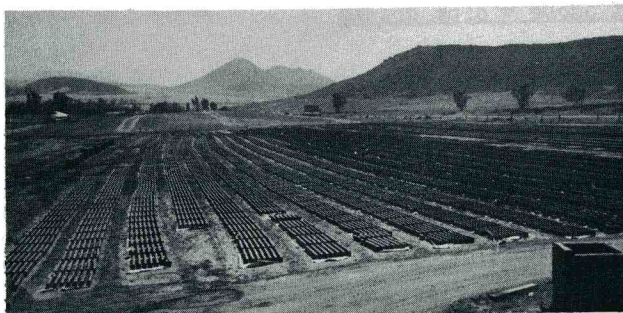
The Sumpf Molding Machine looks like the proverbial "Oo" bird, which lays square eggs and goes "Oo." Mud for the adobe eggs is prepared in a central mix plant, not shown. The nest is Kraft paper.

usually dried in the sunny outdoors. Adobe could dry just as well in the shade, if there were any shade. In fact, shading is sometimes attempted the first few days to reduce cracking. The reason adobe lasts is not that it's "baked," which it is not, but that it is forever kept reasonably dry or it contains a chemical stabilizer.

Instead of straw some writers suggest use of an equine byproduct commonly shovelled out from stables. It is called horse manure. There might be some advantages to using it in a guest house, or to give an authentic flavor to modern ranch-type dwellings, but from a purely personal prejudice, we would veto.

Adobe is now mainly used for one story construction because a second floor requires such thick bearing walls. Some of the adobe houses in California now over 100 years old have three-foot-thick first floor walls. Now the usual wall thickness is 12 to 18 inches, and about 8 inches for interior non-bearing walls. A convenient brick size is 4 x 12 x 18 inches, which when dry will weigh 50 to 60 pounds. Bricks are laid up with cement, lime, or mud mortar.

Adobe lasts well in climates of moderate rainfall, but like cob or other untreated soil walls it must be protected by a high and dry foundation plus wide overhanging eaves. The outside is protected by plaster or smoothed with mud plaster and given an annual whitewash. The abundance of white plaster gives south European towns a bright, clean look when seen from afar. Unfortunately the plaster does not stick well and is in constant need of repair, so the trim look dissolves on closer view.

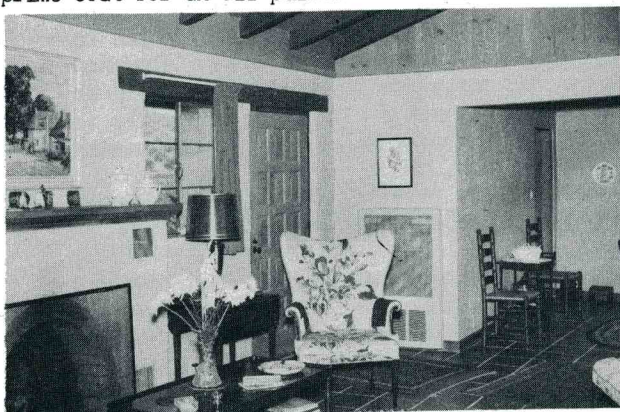


All-weather adobe brick

A latter-day development in adobe brick manufacture is to include a bit of asphalt in the mix-mud, a cheap capitalistic trick which not only makes the adobe waterproof, it makes it permanent. About 5 or 6 percent (a quart per brick) of a specially concocted asphaltic emulsion usually does the job. The asphalt only moderately darkens the natural soil color. Bricks are molded and dried the same way, but once dry and safely in the realm of high society they reject a further contact with shabbier hometown elements such as water. They are now in a class by themselves with trade names "Caladobe" or "Bitudobe."

Nowadays adobe is something more than just the dirt underneath an architect's fingernails. Some of the finest homes in our Southwest are built from treated adobe bricks. Advantages are that they are waterproof, fireproof, soundproof and insectproof, and the 12 to 15 inch walls are good heat insulation and, more important, they have a high heat capacity which evens out the thermal peaks and dips of day and night. In addition, treated adobe looks well and requires no paint. The majority of stabilized adobe houses are left natural on the outside, but some are painted.

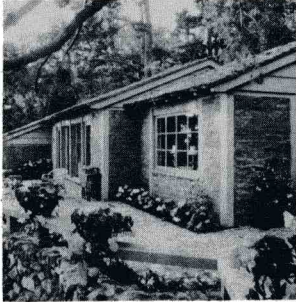
Insides are either painted for that rustic look or are lathed and plastered. Walls can be painted with a white portland cement-water slurry or an asphaltic base aluminum paint; either makes a good prime coat for an oil paint.



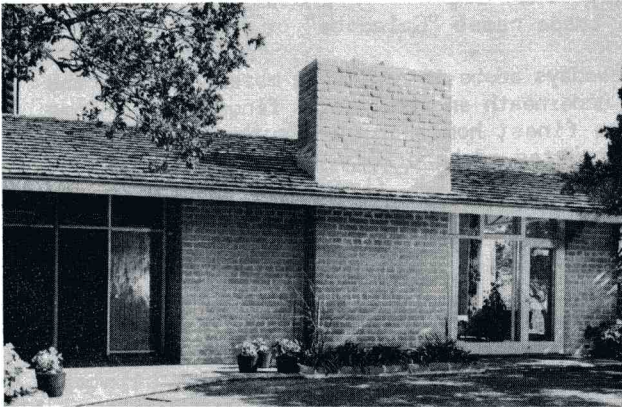


### Post adobe + pipe dreams

In this country adobe is no longer cheap unless one lays the walls himself or lets the little wife do it. A recent neat trick invented by a California architect is to support the roof on four-inch or eight-inch timber uprights, and use adobe to fill in the walls. Advantages are reduction in wall thickness and hence number of bricks, and after the frame is erected the walls can be laid by somebody without much skill or talent, which means, of course, the little woman.



An even neater trick is to support the roof on four-inch pipe and use special brick which fit around them. The wall appears to be solid brick, and there are no wood uprights to paint, and windows can run to the corners. Plumbing and electrical connections are run through the pipes.



### RAMMED EARTH

Unfortunately adobe, even stabilized adobe, probably will never invade moderate or wet climates. Not that the bricks won't last, which they will--they can't be manufactured. Drying of adobe bricks requires 20 to 30 days in a dry, sunny climate, and would unquestionably take longer in rain or snow or fog or freezing weather or some other such trick. Drying under a roof is not exceptionally practical. And interclimatory shipping would cost money.

An answer is "rammed earth," or as they say in France, "pisé de terre, oo la la!"<sup>4</sup> Whereas cob and adobe are made from mud, the counterpart rammed earth walls or bricks are made with relatively dry soil pounded or compacted in a form.

Advantages are immediate strength gain upon compaction, and higher density and greater final strength than are obtainable from merely drying a mud and watching it shrink.

### Tamping

A disadvantage of rammed earth is the hard work of ramming and the natural tendency for workers to tire with the result that the walls may get tired, too. One needs a good foreman.

Pisé walls are traditionally built on an initial course of stone, concrete, or brick, by erecting wood "shuttering" two or three feet high on both sides of the wall, spreading moistened soil in a four-inch layer inside the forms, and ramming until the tamper "rings," indicating thorough compactness. More layers are then spread and compacted.

Once the shutters are full, the tie bolts holding the shuttering are carefully removed and the bolt holes filled with soil, and the shutters are shifted to another location to continue the lift or begin another one. The rammed earth has enough strength that construction proceeds without delay. The soil gains more strength as it dries out.

Traditionally the ramming tool weighs about 15 to 18 pounds and has a semi-pointed heart-shaped head, but tests at South Dakota State College in 1945 showed a flat-faced rammer to be superior. The answer to the laborer's prayer is pneumatic, air-driven rammers, to save both time and back muscles. The main requirement is a compressor big and windy enough that ramming does not become weak-kneed.

### Proper water for ramming

Because the rammed earth method of compaction is similar to ways and means in highway engineering, much know-how has been borrowed. For example, we know that for any given compactive effort an optimum moisture content will give maximum strength and density. This can be predicted by laboratory test and aimed for in batch mixing by "feel." Usually the O.M.C. will make a soil damp enough to just hold a cast when molded by hand.

### Soil-cement

Anybody who goes to the trouble of ramming soil into a wall will probably look favorably upon addition of a bit of something to assure

<sup>4</sup>Rammed from earth, oo la la!





Pneumatic ramming of soil-cement walls in wood shuttering. Cameron Valley Project, Virginia

preservation. The most widely used chemical soil stabilizer in highway work is portland cement, and standard tests have been devised to determine needed percentages for a given soil (Screenings Vol. 2 No. 3). The mixed and hardened soil, or soil-cement, is strong, permanent and dandy for houses. Most readily stabilized are granular soils having a dash of clay; they usually require about 4 to 8 percent cement.

### Soil-cement blocks

Monolithic rammed wall construction is not the most versatile for houses with many corners, nooks and notches, although it is just the thing for simple, cheap little units that often look the price. More versatile and more costly, since it involves additional handling, are machine-produced rammed earth block. The block are usually soil-cement, although other soil stabilizers such as lime or lime-pozzolan should also work.

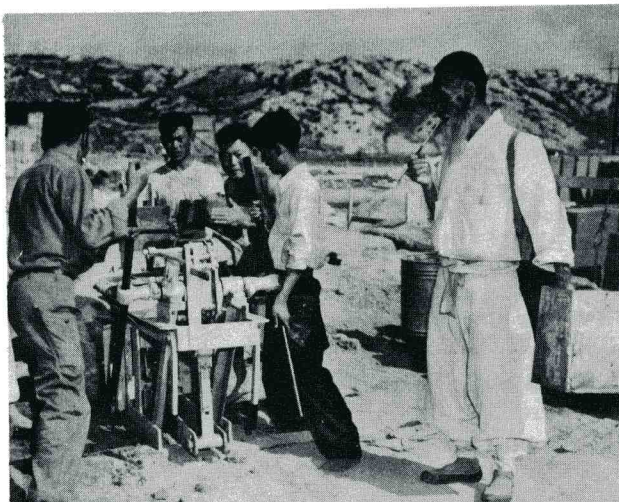
### HOW GOOD THE WALL?

Two questions regarding soil housing are to be answered: how good is it, and how much does it cost? In the early 1940's the U.S. National Bureau of Standards concerned itself with merit: test walls were constructed of soil-cement and plain rammed earth 14" thick, and of plain adobe block, asphalt-stabilized adobe block and soil-cement block, all with 12" wall thickness.<sup>5</sup>

Monolithic soil-cement came off very well, with no water through the wall, even without the recommended covering with white portland cement slurry. All of the stabilized soils satisfactorily resisted erosion. Block walls leaked at the mortar joints, giving some indication of the driving nature of the "rain." Bitudobe or Caladobe is now laid up with asphalt-treated cement mortar.

### Strength

Supporting strength of the soil walls ranged from a low of 5.6 T per ft for Bitudobe to a high of 117 T per ft for monolithic soil-cement. For comparison, frame walls will take about 5 T per ft, brick walls will take about 30.



The Landcrete hand-operated block machine, manufactured in Johannesburg, S.A., turns out soil-cement block for Korea. Production rate, 1000 per day. A similar power model will hatch block four times as fast.

Loads pushing laterally against the walls indicated the weakest walls withstand a 145 mph wind and are the equal of brick or concrete block masonry. Similarly, under impact loading from a swinging sand bag the soil walls fared better than brick or concrete block, but not so well as frame construction. In earthquake areas steel reinforcement is often used in earth block construction.

Racking loads applied longitudinally along the tops of the walls show the weakest earth walls to be about on a par with frame construction, with monolithic soil-cement having a strength much higher, about equalling brick construction.

It was concluded that earth walls are structurally adequate for one or two story buildings. Soil-cement strengths are especially high.

### Temperature

A big advantage of earth walls is a reputed high insulation value, but as usual you can't depend on a reputation to accurately describe anything. Measurements on 12-inch walls gave heat transfer coefficients of 0.646 for soil-cement and 0.54 for rammed earth, adobe, and Bitudobe. The 0.54 is about equal to that of an 8-inch concrete block wall with cores not filled. Twelve-inch brick or cinder block walls get heat transfer down in the neighborhood of 0.35. The earth construction still has a higher heat capacity which evens out temperature changes of day and night.

<sup>5</sup>National Bureau of Standards Report BMS78, 1941.

<sup>6</sup>B.T.U. per hour per square foot per degree Fahrenheit.



Type of wall	Compressive strength ton/foot	Transverse strength lb/sq ft	Racking strength ton/foot
14" soil-cement	53	104	3.1
14" rammed earth	7.0	59	0.9
12" soil-cem. block	58	112	2.8
12" adobe block	7.0	59	1.3
12" Bitudobe block	5.6	80	1.5
8" brick	30	50	3.2
8" concrete block	15	40	1.7
6" wood frame	5	270	1.0

Although dirt may be cheap, labor costs money, and before soil becomes a house it must be pulverized, mixed, and either rammed in place or laid up as bricks. Stabilized adobe is popular in our Southwest not so much because of the saving in dollars, although the cost is comparable with other types of masonry construction, but because adobe is very nice to live in and pleasant to look at and requires little upkeep.

Monolithic rammed earth construction probably could be made quite cheaply because of the reduced handling, particularly if a machine could be devised to exploit its peculiar construction advantages. The mix could be transported to the wall by truck and bucket or belt, rammed in place, and the forms shifted immediately to continue construction along or up the wall. Window and door openings might be sawed out afterwards. With conventional concrete the walls must be completely formed and braced, and the forms left in place until the concrete hardens. Rammed earth has not had the benefit of widespread use, with accompanying trial and experiment.

In labor surplus areas such as India, Africa, or around steel mills, the earth house fever may be said to be spreading slowly. Often where labor is cheap the conventional fired brick are cheap, too, and are competitive. An educated estimate is that stabilized soil will cost 10 to 15 percent less than equivalent brickwork, depending on local conditions.



RLH

A final factor is psychological, with prejudice typically an inverse function of education, and strongly seasoned by personal history. Whereas California corporation presidents are enthusiastic over their adobe homes and don't hesitate to recite the advantages, Gold Coast natives regard any soil housing as substandard and but another device to exploit and advertise inferior social standing. On the other hand the Gold Coaster's ancestral mud hut was substandard. When the soil house is made better than any other he may accept it as just as good.

#### ACKNOWLEDGMENTS AND REFERENCES

Most of our photographs are through courtesy of American Bitumuls and Asphalt Co., 320 Market St., San Francisco. The Company will supply a list of adobe brick manufacturers on request but is not itself in the business of testing soils. Adobe do-it-yourselfers should see "Build Your Own Adobe" by Paul and Doris Aller,<sup>7</sup> Stanford University Press, 1946. A more recent summary of adobe, post-adobe, and steel-frame-adobe, plus references, appears in California Division of Mines Mineral Information Service Vol. 12 No. 7, July, 1959, "Adobe Brick." Address Division of Mines, Ferry Building, San Francisco.

For rammed earth and soil-cement see "Manual on Stabilized Soil Construction for Housing," by Robert Fitzmaurice, published by the United Nations Technical Assistance Programme, New York, 1958, Sales No. 56. II.H.4, \$1.25. U.S. soil-cement tests are fully described in "Soil-cement laboratory handbook," Portland Cement Association, 33 W. Grand Ave., Chicago 10, Illinois, 1959.

The Korean photo on p. 5 is by former student Capt. Charles B. Ewing, U.S. Army Corps of Engineers. Capt. Ewing's thesis, "Application of cement stabilized soil to one-story building construction," is on file at the Iowa State University Library at Ames.

<sup>7</sup>What did we tell you about wives helping?