Stabilized Earth Construction in Virginia

Limits and Potentials

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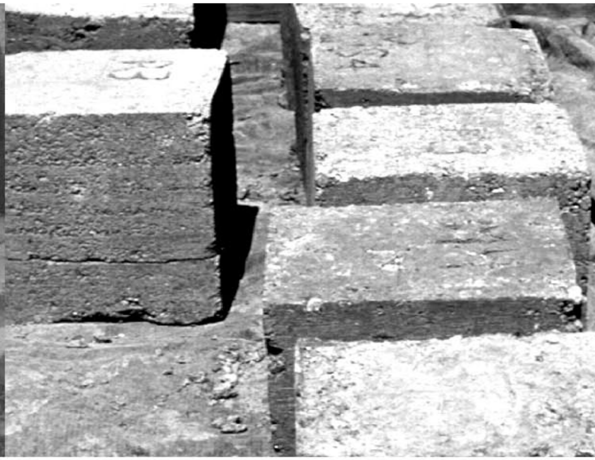
Rammed Earth Construction in the Southeast

Holy Cross Church
Stateburg, SC
1850

Dorchester Fort
near Charleston, SC
1696

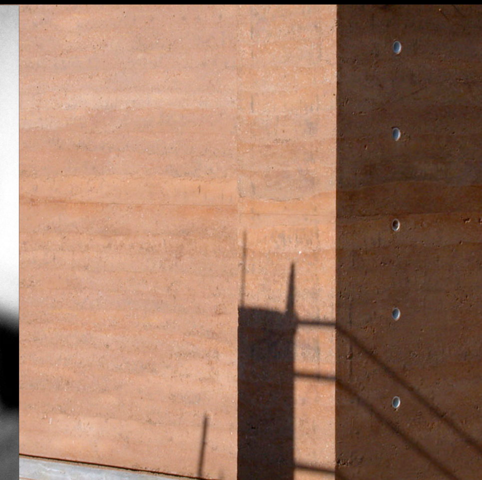
Stabilized Earth Terra Cruda Rammed Earth



Rules for wet climate

- Good Hat
- Good Boots

Setting rules for rammed earth wall construction



Soil Selection

Source of subsoil close proximity to building site

Subsoil testing

Subsoil: no organic matter, small to no amount of silt

Subsoil: variable mix of aggregates of fine sands to course sand, fine gravel to course gravel

Setting rules for rammed earth wall construction


No plumbing, mechanical, electrical in walls

No lateral thrust at top of walls

No upward thrust on walls from roof

Straight line tie down from roof to foundation

Structural ring beams at foundation and floor lines

No solid mechanical fasteners to door or window openings

Re-use form work

TERRA CRUDA SUMMER WORKSHOP 2002

VIRGINIA TECH
COLLEGE OF ARCHITECTURE AND URBAN STUDIES

A COMPILITAION OF TEST PROCESS AND RESULTS

SEDIMENT TESTS

THE FIRST STEP TAKEN DURING THE WORKSHOP WAS performing sediment tests on some of the subsoil from the site. This testing sought to determine if the composition of the soil would allow its use in terra cruda construction. The subsoil samples were taken from two pits near the proposed house site. The topsoil was removed to a depth of approximatley 18 inches and the subsoil samples were taken at approximatley 36 inches.

One-quart jars were used for the test.

- -1/3 of the jar was filled with soil
- -water was added to 2/3
- -the solution was shaken to an even consistency and allowed to settle
- -after 30 seconds a mark was made at the level of gravel
- -after 30 minutes another mark was made at the level of settling
- -after 24 hours another mark was made at the level of settling

The first mark designated the level of gravel.
The second mark designated the level of sand.
The third mark designated the level of clay/silt.

Due to the nature of the soil, the sand and clay did not settle out as distinct layers. The layers were distinct between gravel and sand/clay.

Four samples were taken from each pit:(ratio: gravel /sand;clay;silt)

Samples from Pit A	Samples from Pit B
5/9	4/11
4/7	1/2
4/10	1/2
6/9	1/3

5 + 6 JUNE

SIEVE TESTS

ONCE THE SEDIMENT TESTS HAD BEEN PERFORMED larger subsoil samples were sieved to determine the soil composition more accurately. Subsoil samples were taken from two locations: next to the barn and next to the proposed house site.

The samples were 768 cubic inches each.

These samples were passed through a series of sieves, with the amounts and grades of aggregate noted.

The results were:

	BARN TEST HOLE*	HOUSE TEST HOLE
course gravel	69 cu.in. (9%)	47 cu.in. (6%)
fine gravel	47 cu.in. (6%)	47 cu.in. (6%)
course sand#30sieve		30 cu.in. (4%)
fine sand#60sieve		69 cu.in. (9%)
clay/silt		576 cu.in.(75%)

*sand and clay/silt not tested

11 JUNE

TEST BLOCK FORM WORK

FORMWORK WAS NECESSARY TO COMPACT TEST cubes of rammed earth . This formwork was constructed with 3/4” AC plywood held in place with 1/4” diameter threaded rod. Their dimensions were 7 1/2” x 7 1/2” x 7 1/2”.

The surface of the plywood was coated with polyurethane sealant.

13 JUNE

USING THE FORMS, TEST BLOCKS WERE CREATED. Various combinations of earth, stabilizers, and aggregate were compacted into test blocks.

The stabilizers were lime and portland cement. Aggregates were separated from the local soil during the sieve process and sand was purchased from a local supplier.

Each block was first mixed by hand, to thoroughly combinet he dry elements. Water was then added slowly by sprinkling small amounts while mixing.

The correct combination of water and dry elements was determined by periodically performing the "drop test." This test consisted of compacting a fistful of mixture in one's hand and dropping it from an outstretched arm onto the ground. The number of pieces the handful of soil breaks into is noted. Three to four large clumps of soil is optimum. More pieces demonstrates that the mixture is too dry. Fewer pieces demonstrates that the mixture is too wet. Once a mixture had completed the drop test, compaction could commence.

Soil was added in lifts, or layers, each being compacted before the next was added.

Compacting was accomplished with wooden blocks struck with mallets. Compacting each lift to half its original depth was the goal. (i.e. 4 inches of soil mixture added as a lift was compacted to 2 inches)

Mixing & compacting process was analogous to larger scale production process.

Water was added to dry mix to desired consistency.

Drop test was employed to test consistency.

MATRIX

[1] Test conducted with 10 quart loose dry units compacted to 4.7 quarts

[2] M designates units comprised of 8 parts raw subsoil to 2 parts aggregate sieved from raw subsoil

[3] MS designates units comprised of 8 parts raw subsoil to 1 part aggregate to 1part sand

[4] % of stabilized earth stated as percentage of loose dry units

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[1] Test conducted with 9 quart loose dry units compacted to 4.7 quarts

[2] M designates units comprised of 7 parts raw subsoil to 2 parts aggregate sieved from raw subsoil

[3] MS designates units comprised of 7 parts raw subsoil to 1 part aggregate to 1 part sand

[4] % of stabilized earth stated as percentage of loose dry units

-"R" for raw soil or "M" for soil mixed with aggregate
- Number 1through 8 designating eight rounds of tests
- "L" for lime, "C" for cement

MIX	DATE	SUBSOIL[1]	AGGREGATE[2]	SAND[3]	CEMENT[4]	LIME[4]
R1	6/13	X				
M	16/13	X	X			
MS	16/13	X	X	X		
R2C	6/18	X			8%	
M2C	6/13	X	X		8%	
MS2C	6/18	X	X	X	8%	
R3L	6/13	X				8%
M3L	6/18	X	X	X		8%
MS3L	6/13	X	X		4%	4%
R4LC	6/13	X			4%	4%
M4LC	6/18	X	X		4%	4%
MS4LC	6/18	X	X		8%	
R5C	6/20	X			4%	4%
R5LC	6/20	X				8%
M5L	6/20	X	X		4%	4%
M5LC	6/20	X	X			8%
MSL5	6/27	X	X		4%	4%
MS5LC6	6/20	X	X			8%
R6L	6/25	X				8%
M6C	6/27	X	X			8%
MS6C	6/27	X	X		5%	
R7C	6/25	X			2.5%	2.5%
R7LC	6/25	X				5%
M7L	6/25	X	X		2.5%	2.5%
M7LC	6/27	X				5%
MS7L	7/2	X	X		2.5%	2.5%
MS7LC	7/2	X	X		5%	
R8L	6/25	X			5%	
M8C	7/2	X	X		5%	
MS8C	7/2	X	X			

SOIL MIX MATRIX

A VARIETY OF MIXTURES WERE TESTED DURING THE search for one that would work best with the soil from the site. This soil would eventually be extracted for the rammed earth construction.

The various combinations of soil, aggregates, and stabilizers making up these mixtures follow on the next two pages.

Each mix has a coded title. This title contains the following designations:

- an “R” for raw soil or “M” for soil mixed with aggregate
- a number 1 through 8 designating eight rounds of tests
- an ”L” for lime, “C” for cement

TEST BLOCK RESULTS

THE FORMWORK FOR THE MIXES WITH STABILIZERS was removed after 5 days. This allowed the portland and lime to sufficiently hydrate.

Needing no time for hydration, the formwork for the mixes without stabilizers was removed within one hour of compaction.

Test Blocks R1, M1, MS1, M2C, M3L: +5days

Observations:

R1: bottom corners loosing adhesion: minor surface dusting

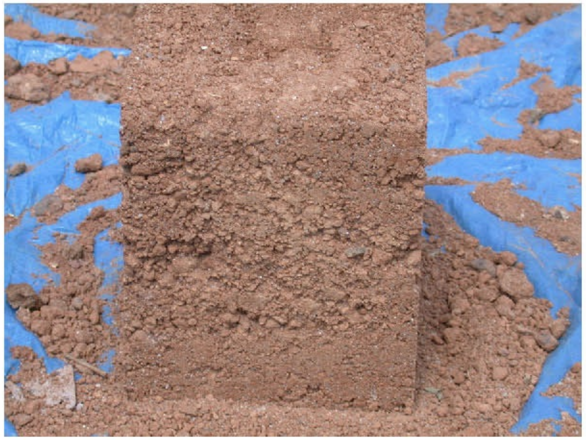
M1: minor surface spalling on sides and top

MS1: minor surface spalling on sides and top; sand aggregates adds to spalling

M2C: sample removed from formwork: very dense in comparison to non-stabilized blocks: corners stable; surfaces taut

M3L: Sample removed from formwork; very dense in comparison to non stabilized blocks; less dense than M2C; corners stable, surfaces smooth

M2C & MS1



Test Block M1 + 5 days

Left to right R3L, M2C, Ms1, R1

Test Blocks R1, M1, M2C, R3L: +7 days:

R3L

R1

M2 & MS1 + 14 days

Block M2 remains firm and surfaces smooth
Block MS1 softened, faces eroded and rough

MS1 & M1

Top, left to right: R2, R1, Ms4
Bottom, left to right: Ms2, R1, R3

20 JUNE

The test mixture that demonstrated high density, high resistance to weather, and best consistency was composed of

- 8 parts subsoil
- 2 parts aggregate sieved from raw subsoil
- 8% Portland cement

TEST WALL FORM WORK

ONCE A PRIME MIXTURE WAS IDENTIFIED WITH TEST blocks, a larger scale test form was constructed.

This test wall took the form of a garden bench.

Formwork for this bench was constructed of MDO plywood, 2X8 pine whalers, pipe clamps, and threaded rods.

3/4"X3/4" wood inserts were placed in the two front corners to test the possibilities of corner detailing.

SOIL MIXING

MIXING FOR THE TEST WALL OCCURRED ESSENTIALLY the same way as the test blocks.

A garden tiller replaced mixing by hand. The same method of combining dry elements first and adding water slowly was utilized.

Aggregate for the test wall was #10 crushed grey limestone, purchased from a local quarry.

The drop test was again the measure used to determine correct consistency and moisture content.

Stabilized soil mix
- 8 parts subsoil
- 2 parts #10 crushed limestone quarry sand
- 8% Portland cement

25 JULY

TEST WALL COMPACTION

SOIL WAS ADDED TO THE FORM ONE WHEEL BARROW at a time. The wheel barrow load was used as the measure for one lift.

One lift = 4 inches uncompacted
or
= 2 inches compacted

Compacting was done with two tamping devices.
One was a manufactured flat cast iron square at the end of a wooden handle. The other was a truncated pyramidical form with a cylindrical handle, constructed from a locust wood beam from the site.

The flat cast iron tamper worked well in compacting the center while the wooden one proved most effective in corners and along edges. To increase the mechanical bond between layers the wooden tool was used to create divits in the surface of a completed lift before the next was started.

CONCRETE CAP & FORM REMOVAL

A CONCRETE CAP TOPPED THE GARDEN BENCH. A key was created in the test wall to keep the concrete cap attached.

The test wall cured for a week before the cap was poured.

The purpose of the cap was to provide protection for the rammed earth, while creating a surface to sit on.

After seven days of curing, the formwork was removed.

The square corners of the earth work held their shapes fairly well. Crumbling occurred at layers where the mix was too dry.

The quark corner detail also held its shape, but the ninety degree knife edge varied from dull to sharp.

TEST WALL TWO

A SECOND BENCH WAS ALSO CONSTRUCTED.

The same form work was used, with different corner details. Soil mixing was done in one large batch, using a farm tiller. Lift height was increased to four inches compacted. A cap of concrete was also poured on this test wall.

CONCLUSIONS

A NUMBER OF CONCLUSIONS WERE DRAWN FROM the set of cubes and two test walls.

Test Mix:
The Soil tests indicate that there is a disproportionately large amount of clay in the existing soil to be useful as a satisfactory unaltered material for rammed earth construction. Athough there is a relativley broad range of round to roughly squared aggregate in the existing subsoil, it occurs in smaller quantities than is required for a good mix. Additional aggregate from a local quarry is required to bolster the aggregate in the subsoil.

Formwork:
The compaction of earth against the plywood skin and wood frame exerted forces that were difficult to predict. Corners were especially suseptible to bending and shearing.
Vertical corners resisted firm compaction and seemed to bridge over instead of conforming to the ninety-degree edge.
Horizontal right angles compacted better than vertical right angles except in the case where displacement trim was placed at the top of the formwork.
Complex trim work in the corners of the form made removal of formwork difficult and in some cases fractured the intricate corners of the earthwork.

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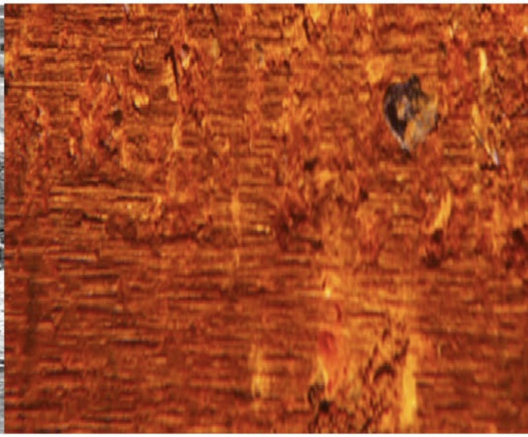


Test mix:
Disproportionately large amount of clay
Additional aggregate required

Formwork:
Compaction pressure forces difficult to Predict

Corners susceptible to bending & shearing

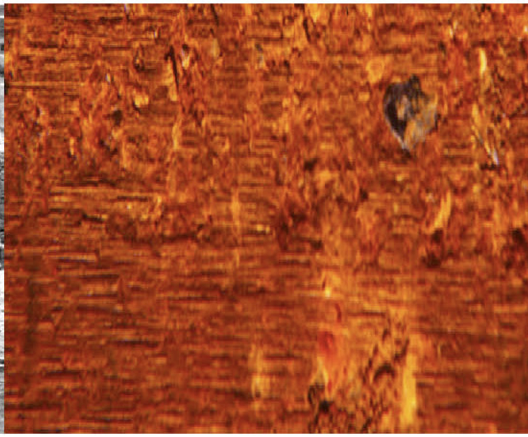
Complex trim work at the corners made removal difficult

CONCLUSIONS

Compaction and Durability:

Portland cement as a stabilizer appears essential, given the soil type and climate. Unstabilized rammed earth deteriorated quickly when exposed to rain when compared to stabilized rammed earth test blocks.
Compaction was the second determining factor in the durability of the test block. Poorly compacted test blocks, even with stabilizers, deteriorated more quickly than well-compacted blocks.
Moisture content was the most difficult factor to control. Determining the proper moisture content requires an experienced judgement faculty more similar to that of an artist than a labratory technician. The conventional drop test has to be combined with judging other qualities such as stiffness, smoothness, color, and texture. A labratory test can help in determining the percentage of moisture by weight.

More on-site tests and laboratory tests should be completed before and during the actual construction process.

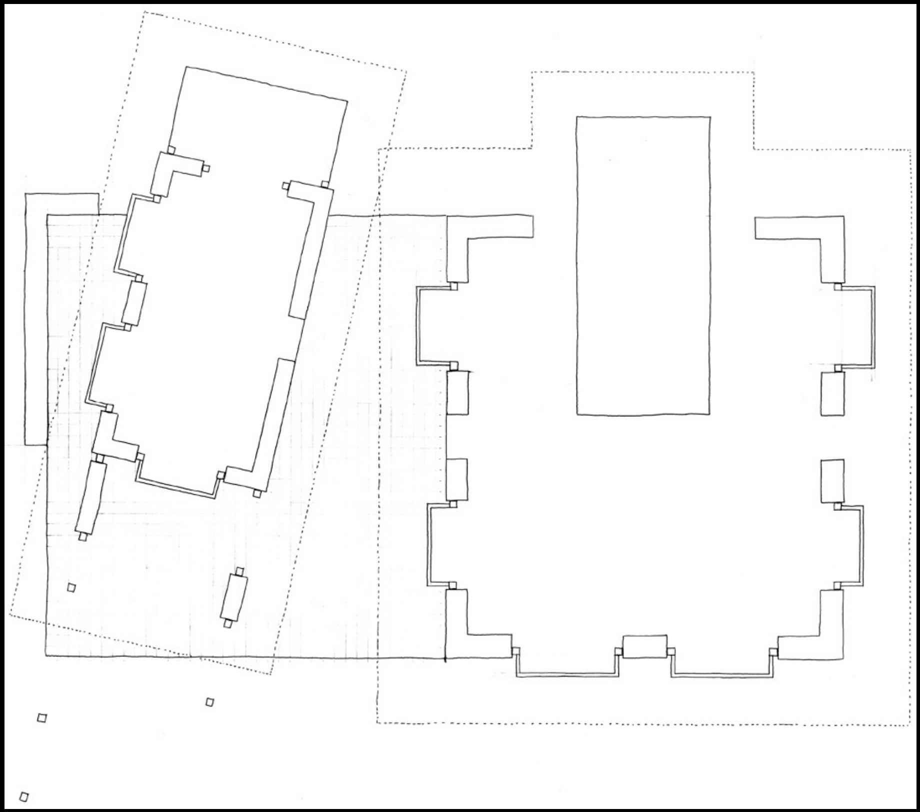


Portland cement as a stabilizer is essential. Non-stabilized rammed earth deteriorates quickly when exposed to rain.

Density of compaction was the second determining factor in durability.

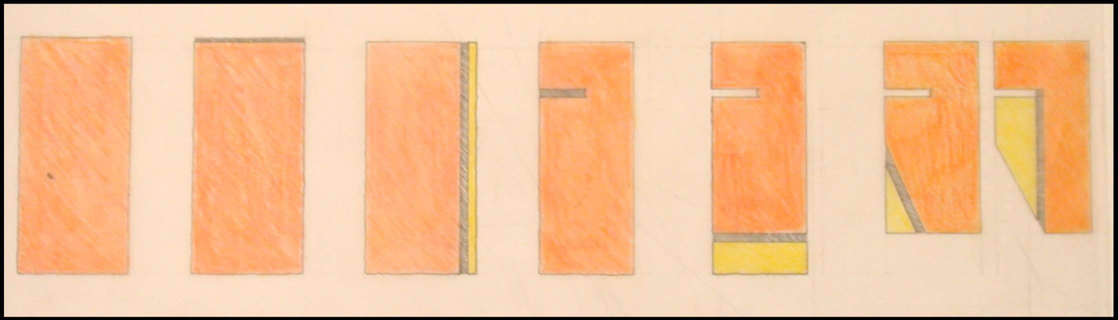
Moisture content is the most difficult factor to control.

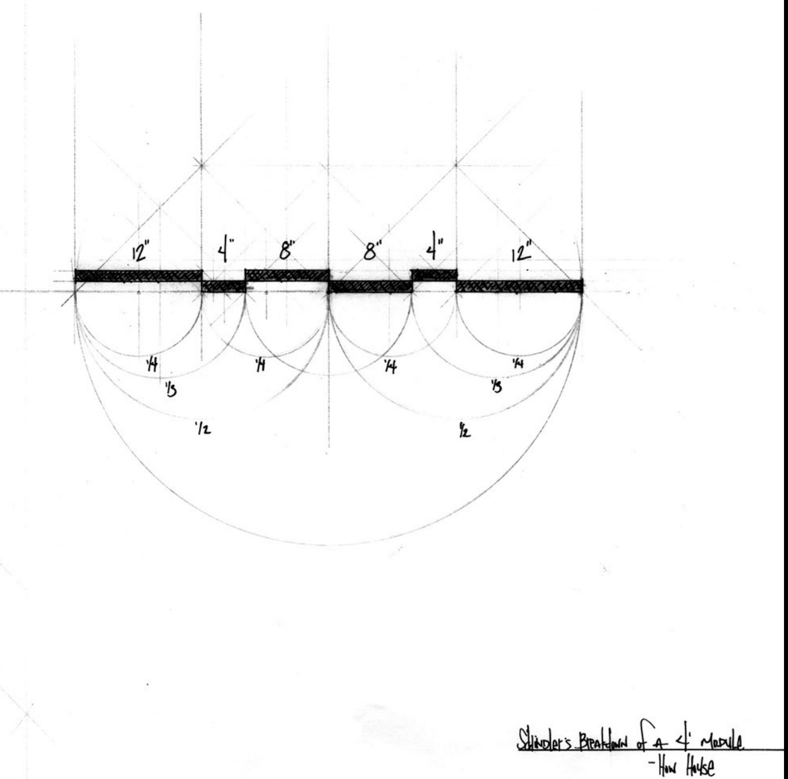
Setting rules for design



Symmetrical layout to maximize form re-use
4 foot module
House within a house
Vitrines in large openings
Baths and utilities in cabinets
Schindler frame vitrines and cabinets
Enjoy turning corners

Setting rules for design



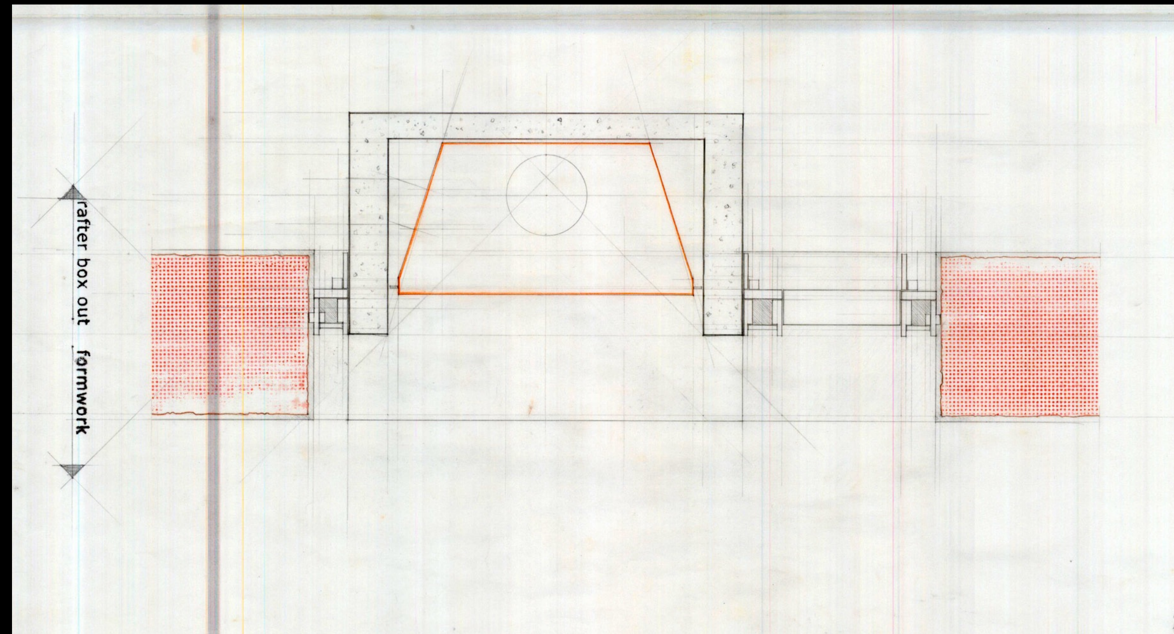


Set proportional rules

Schindler frame

Earth formwork

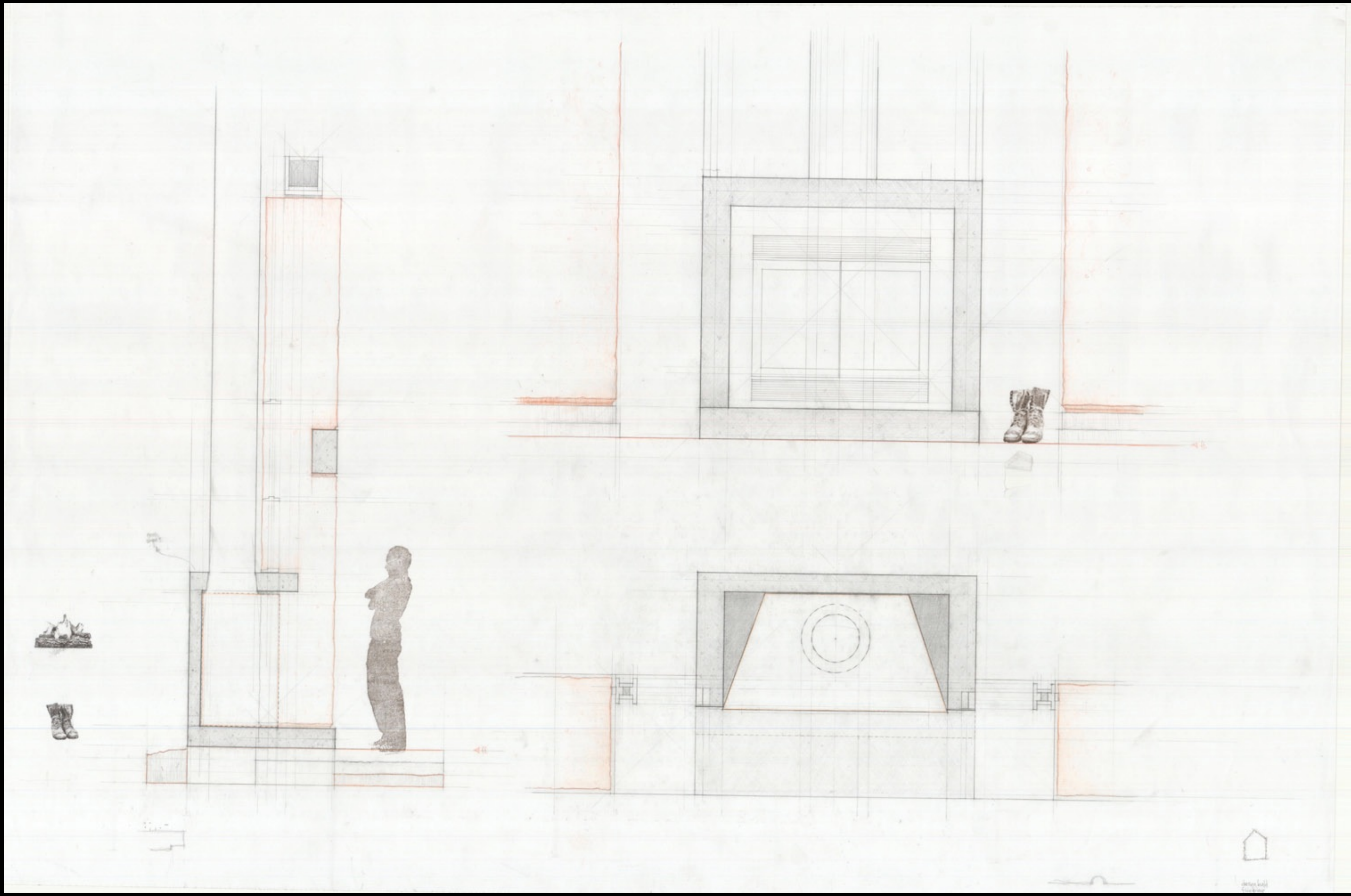
Setting rules for design



Run electrical wiring and devices in chases

Install fixtures within openings

Setting rules for design



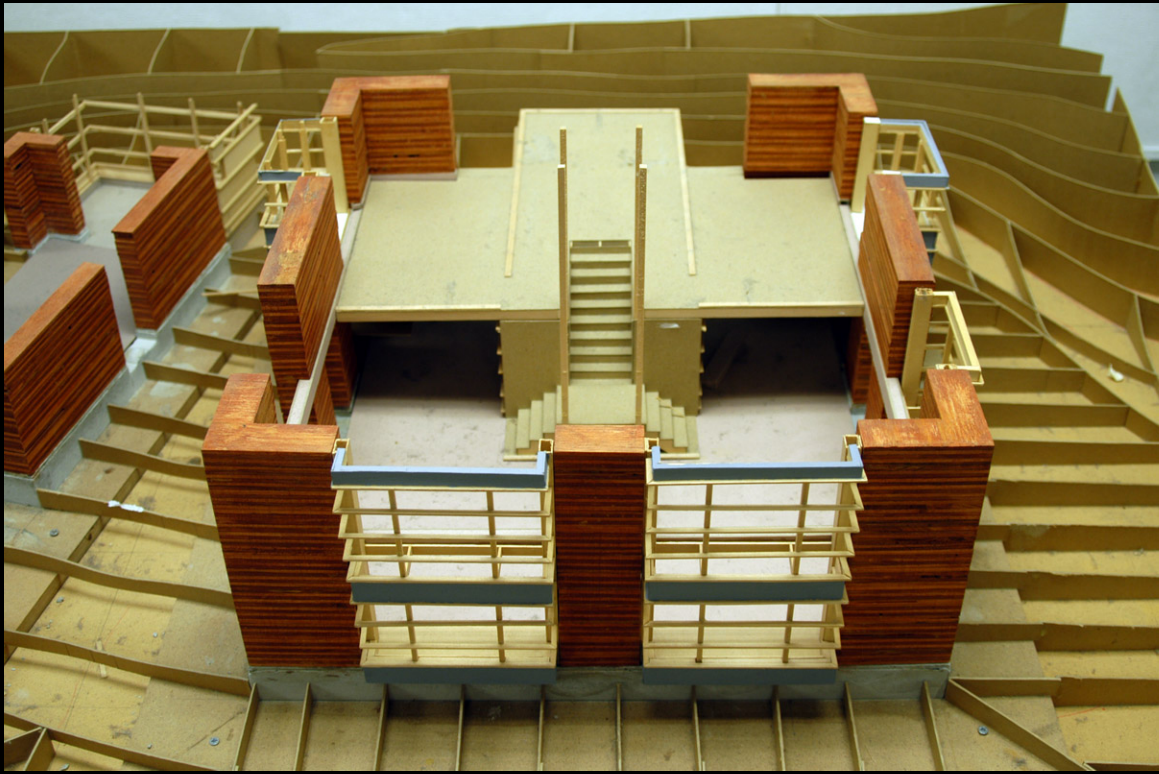
Base detail: foot shouldn't kick the wall

Setting rules for design

Adopt models

Adapt for situations

Setting rules for design



Floor system:

2x10 whalers and plywood sheathing reused from formwork
Flooring bears on concrete beams

Setting rules for design

Roof:

2x10 wood framing anchored to
12”x12” box beam


ARMY


Ingersoll

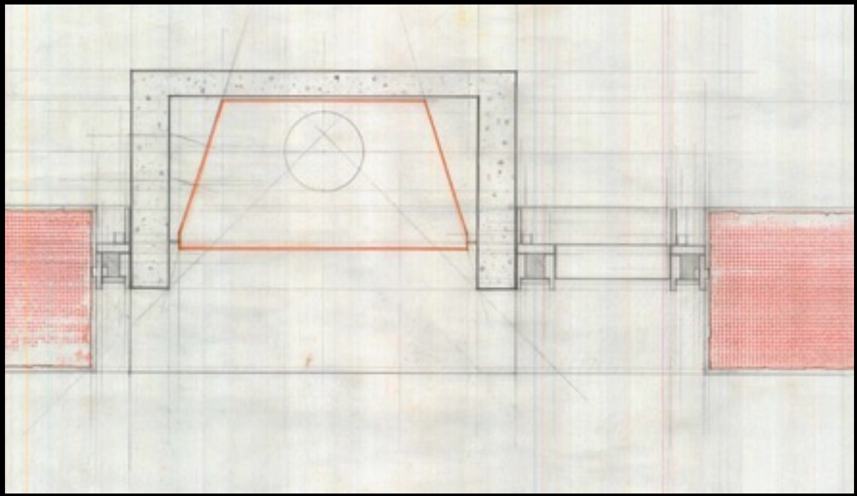

1050



Mustangs


bil-jax


bil-jax




Shelterwrap HD
"The Better Leveler"
Shelterwrap HD
"The Better Leveler"