CHAPTER 5

STEP-BY-STEP CONSTRUCTION

THE PRINCIPLE OF STEP-BY-STEP CONSTRUCTION

Imagine, now, that each family has laid out their own house for themselves, so that each one is marked out on the ground with stakes or stones or chalk marks.

How is it possible that all these houses, with their great diversity, can be produced in a simple and orderly manner which does not cost more than usual?

In the process we are defining, the different houses, laid out by different families, are not built from a system of "standard" drawings or from a system of standard "components," but are instead governed by a system of operations to be performed one after the other, step by step.

These individual steps or "operations" are so defined that they can be applied freely to each plan (provided that it follows certain minimal rules), and will, when properly executed, make a complete and structurally sound building from each plan, without the need for working drawings of each building.

The process is therefore capable of allowing mass production of large numbers of houses which are all different, without increasing cost.

Today's systems of housing production almost all rely, in one form or another, on standardized building components. These components may be very small (electrical boxes, for instance), or intermediate (2x4 studs), or very large (precast concrete rooms); but regardless of their size, buildings are understood to be *assembled* out of these components. In this sense, then, the actual construction phase of the housing production process has become an assembly phase: an occasion where prefabricated units are assembled, on site, to produce the complete houses.

It has been little understood how vast the effect of this has been on housing: how enormous the degree of control achieved, unintentionally, by these components and by the demands of their assembly. Yet, as anyone who has intimate knowledge of building knows, these components are merciless in their demands. They control the arrangement of details. They prohibit variation. They are inflexible with respect to ornament, or whimsy, or humor, or any little human touch a person might like to make.

It is said sometimes that, given our industrial age, these components are unavoidable, that they are the carriers of the wonders of industrialization. Yet, this is not true at all.

STEP-BY-STEP CONSTRUCTION

A house is an organic system, like a living creature. Its fabric cannot be properly adapted to its needs and functions unless the process of adapting goes all the way down to small details. In one house a certain shelf makes sense; in another it doesn't. In one house two columns make a basis for a seat; in another house these columns should be differently connected. In one house a front door is narrow; in another, wide. In one house the edge of the roof is higher, because that particular house has a place where people sleep on the roof; in another house steps make a place to sit and the base of the house, because the garden is so beautiful.

In short, the detailed adaptation of a house to its inhabitants must go all the way down to the details of construction; it cannot stop short, in the *plan*. Present methods of housing production make such adaptation impossible. Standard components, attached by standard connections, are assembled by workmen and crane operators who know nothing about the houses, have no feeling for what is going to happen in them, and cannot possibly adapt the details of construction to fit the needs of the inhabitants. And it is not only the process of construction that is at fault, but the techniques of construction, too: large panels, prefabricated components, dry assembly—none of them permit this ongoing daily adaptation of the building details to the building, which good design requires.

We therefore intend to replace the idea of a building system as a system of components to be assembled, with a step-by-step system of building *operations*, each one capable of making immediate, low-cost, high-speed, on-site adjustment to the emerging building as it is being built, so that detailed control over the building's shape and details passes into the hands of the builder and out of the hands of the designer of components or of the draftsman at the plant.

In this case we define the building system in terms of the actions that are needed to produce a building, not in terms of the physical components. This does not imply that there are no physical components. Of course there are. But the components are not standardized. Instead, only the actions, or the operations, are standardized. The components, which get created by the operations, take whatever size and shape they need to, to fit perfectly into the place where they will be.

We see at once that this is a much richer idea than the idea or a building system as a set of components. Even though the building process is considered standard, because its individual operations are all standard—still the buildings which can be made of these standard operations are much richer and show a much vaster range of possible variation than combinations of modular components can ever do. And at the same time, the buildings also have a beautiful simplicity. All igloos, for example, are made by the same process. No two are alike. But they have a much more organic unity, a much subtler adaptation of each one to its circumstances, than the arrangement of modular components could ever have.

Indeed, the twentieth century is the first period in history when building *has* been based on standard *components* rather than on a standardized set of *operations.* Even the construction of the traditional Japanese house, whose dimensions in plan are based on the standard $3' \times 6'$ tatami "module," is actually based on operations in which materials are crafted individually at the house, and allow great variety of actual plan and section. The stone houses of southern Europe, the brick houses of England and northern Europe, the wooden houses and churches of Scandinavia and Russia, all are built with a series of standard operations which allow the gradual development of the design from the initial layout on the ground. The largest module in a brick house is the brick—and even bricks are friable so that they can be cut; the wooden members are all cut to size; the plaster can cover any dimension of wall and ceiling. The materials can adapt to variations in the design, to slight curves in the wall, to the unforeseen need which arises in an organic construction process to move a door two inches this way, or a window three inches that way.

The full reasoning behind the idea that operations are more fundamental than components is given in *The Timeless Way of Building*—especially in Chapters 8, 19, and 23—so we shall not repeat the arguments here. Instead, we shall assume that the reader is familiar with those arguments, and go on to define certain additional points which it is necessary to understand in order to construct such a system of standard operations.

Above all, it is certainly not enough merely to conceive the building system as a set of *any* operations. In a weak sense, even the most tyrannical modular building system is *also* a set of operations—but this does very little good for the buildings it produces. The building system will produce organic buildings, good buildings, buildings whose parts are well adapted to the whole, only when the particular operations it contains meet certain very definite critiera. We have identified four of these criteria:

1. The operations do not impose dimensional constraints on the plan of the building. Instead, they create parts which are adapted in size to the place where they occur.
2. The sequence of operations *generates* the building from a rough layout designed directly on the ground; it does not merely fill in the physical reality of a previously detailed design.
3. The building operations are consistent with the patterns used to lay out the house plan.
4. Each operation is complete in itself, and is felt as a psychological fact of "accomplishment" when it is completed.

In the pages which follow, we shall explain the basis for these four criteria. Then, in the pages beyond that, we shall define the actual step-by-step operations we used to build the houses in Mexicali.

Criterion *1: The operations do not impose dimensional constraints on the plan of the building. Instead, they create parts which are adapted in size to the place where they occur.*

It is obvious from the foregoing discussion that this is the first and most essential requirement.

The great weakness of the modular components is that a plan gets distorted when it is rearranged to fit the modularity required by the components. For example, on a four-foot planning grid, a passage has to be four feet wide. But a passage that feels right in a particular place may be just 3′3″ or 2′11″ wide. If it has to be widened, it loses its feeling. Not only that. If the rest of the house has all been laid out, and the passage has to be widened to four feet, the rest of the plan will literally be torn apart: each space will have to have a slightly different proportion, and therefore a different feeling from the one that was originally laid out. In some cases, topological "tearing" will actually change basic adjacencies in the plan—and as we all know from experience laying out gridlike plans on paper, the grid will then ultimately control the plan entirely.

It is therefore essential that the plan's dimensions can be left exactly as they are—and that the building processes are fluid enough to make this possible.

(Incidentally, this is achieved, in part, merely by the sequence of patterns given in *A Pattern Language:* COLUMNS AT THE CORNERS, PERIMETER BEAMS, CEILING VAULTS, etc., which generate coherent structures without imposing distortions on the layout. See also, once again, *The Timeless Way of Building,* Chapter 23.)

Criterion 2: *The sequence of operations "generates" the building. It does not merely fill in the physical reality of a previously detailed design.*

In order to understand this criterion as clearly as possible, let us compare two rather different cases.

In one case, imagine a building which we have understood so perfectly before we begin construction that the actual process of construction is not creative at all. We merely fill in the details that have already been thought through in ultimate detail at the drawing board.

Compare this with a second case, in which, at the time we start construction, we only have a partial, imperfect picture of the building. In this case, as we complete the different building operations, each one sets down new details which open the door to some further understanding which we need in order to know exactly how to perform the next operation in the sequence.

In the second case, we may say that the building operations "generate" the building, because they are creative: they produce things which were not known before they were done; each one adds some extra dimension, some extra detail, to the conception of the building. On the other hand, in the first case, we cannot say that the building operations "generate" the building, because the operations are essentially passive, blind; they add nothing to the conception of the building, because that existed completely before construction began.

To a person who knows little about construction, it might seem that the first of these two alternatives is more desirable than the second. After all, if the building is perfectly understood from the moment that construction begins, it sounds as though there must be some kind of special perfection there—and this *seems* like a desirable thing.

In fact, however, this kind of rather mechanical perfection is very naive. It is, really, a mark of an unusual kind of simplicity—and not a good kind. Any builder who has long experience of construction knows that the most beautiful details, the most satisfying arrangements, cannot be predicted ahead of time, but arise as spontaneous, often ingenious reactions to the particulars which are encountered in the biilding site *during* construction.

But, of course, this ad hoc process of construction, which elaborates details as they are needed, according to their local circumstances in the building, only works when the process of construction itself has a certain natural grace or elegance. It cannot be done in just any building process, because it can far too easily lead to an endless series of mistakes, problems, and complications, which will increase cost, slow down construction, and even cause serious difficulties in the building.

This happens because, in a typical building process, the operations interlock in rather complicated ways. When doing one operation, it is usually necessary to be worrying about other future operations, to make "room" for them ahead of time. Thus, for instance, while building a foundation, it will typically be necessary to leave room for plumbing pipes, think through the exact location of drains, think ahead to variations in the thicknesses of walls that will be built much later, and so on.

The need for this kind of "looking ahead" has a very damaging effect on the construction process. For, since the possibility of mistakes produced by this complexity is a familiar fact of experience, people try to avoid the mistakes simply by building the same house over and over again, with all the details exactly the same as in a previously built house. If the way an electrical conduit fits neatly into the ceiling of a closet is to be useful in another house, then this other house must have exactly the same closet, and exactly the same electrical circuits—exactly the same—since even slight changes will create a new situation, with unpredictable and often unprecedented difficulties.

Thus, the prospect of this kind of difficulty exerts a powerful pressure towards standardization of plans. It strongly encourages builders to build the same houses or apartments over and over again, even in their details, so that mistakes will not occur.

Yet, we are committed, by the arguments of Chapters 3 and 4, to a process in which plans are different, in which each house, as it is built, is—in its plan—unlike any house that has been built before. If we are to avoid the mistakes which occur because of confusions among different operations, we must have a building system in which these mistakes just do not occur, even when houses all have different plans.

This requires a system of operations in which the operations have a certain very special property: *namely, that we can complete each operation by itself, paying attention only to it, secure in the knowledge that the operations which follow can always be done, because it is their nature to be able to adapt themselves to the results of the operation already performed.*

Consider an example: the formation of a vault over a room. In the construction system in Mexicali, each room has a vault. This vault is made of concrete hand trowelled over burlap, which has been stretched over a wooden basket woven to the configuration of the room. Now this series of operations has the property that we can lay the room out to whatever shape is dictated by its plan, without having to worry about the way the ceiling works, because no matter what exact shape the room takes, the ceiling can always be woven to fit it.

The same goes for the operation which fits the walls to the corners. When we place corner blocks to define the corners of a room, we are certain that we can always "stretch" a wall of wall blocks between the columns, because the blocks can be cut into the notches in the corner blocks. It is not, therefore, necessary to worry about the exact dimension of the wall, at the time we mark its corners—only about the corners themselves—because we are certain that the walls can be fitted to the corners afterward.

This is what we mean when we say that the sequence of operations "generates" the building. Each operation can be performed freely, to develop the products of the earlier operations, without complicated forethought.

And this kind of process is not only practical—or beautiful in a practical way. It is also a source of art and inspiration. A process which has this generative simplicity always allows a free building to be made, because the building grows slowly, step by step, the way a living organism grows—with no contortions having to be made along the way. And the result is simple and pure.

Criterion 3: The building operations are consistent with the patterns used to lay out the house plan.

When people use the pattern language to design their houses, the houses are different from most housing we know today, not only in the overall arrangements of plan, but also in the specific shape of rooms, the heights of ceilings, the existence of alcoves and thick walls, the finest details of construction—the windows, and trim, and ornament.

Many of these patterns, discussed at length in *A Pattern Language,* are impossible to achieve cheaply with the construction systems used nowadays. The cost of stud framing, for example, is increased greatly when ceiling heights are varied or if walls meet at angles different from right angles. The thin walls do not encourage the building of window seats or alcoves or deep window reveals. Indeed, almost everything about the construction systems that are used today promotes uniformity and flatness and antiseptic smoothness—while the goal of many of the patterns is greater richness, more indentations and projections, surfaces which are less mechanically "perfect" and more finely tuned to local circumstances.

A building process which is consistent with the pattern language must therefore allow for simple and cheap construction of all the patterns which a family may use in their house layout. For example, the building system must allow ceiling heights to vary from room to room—higher ceilings over bigger rooms, lower ceilings over smaller rooms (ceiling height variety). It must allow for the pattern THE SHAPE OF INDOOR SPACE, which states that room angles need to be roughly, but not exactly, ninety degrees. It must allow for alcoves, window places, and thick walls, all built into the original structure of the house. It must allow for the pattern STRUCTURE FOLLOWS SOCIAL SPACES, which requires that the load-bearing structure of a building be congruent with its social spaces—and therefore implies that a modular structural grid will most probably not be appropriate. It must allow for WINDOWS WHICH OPEN wide, and SMALL PANES of glass, and ornament. And it must allow for all these things easily—not as "extras," but as a normal part of the process.

Criterion 4: Each operation is complete in itself, and *is felt as a psychological fact of "accomplishment" when it is completed.*

These houses are not industrial products, in the normal sense, but human products. Whether the families themselves work on the houses or not, we intend the richness of the houses to be produced by the love and care with which they are made—either the love and care of the builders, or of the families, or both.

We have found out that this is affected very greatly by the psychological closure of the operations.

Compare, for example, the process of placing corner stones with the process of building the formwork for a foundation—both ways of starting the foundation of a house. In the literal sense, both are operations. But when the corner stones are placed, the person who does it has an immense feeling of accomplishment. A stage has been reached. The building has advanced another step. He feels complete when he has done it. By contrast, building the formwork for a foundation is a relatively shallow experience. The formwork can be finished, of course. But when it is finished, what has been accomplished? Something, certainly, but not quite so much. There is little exhilaration that goes with it.

Or compare a process in which walls and columns are all erected together, as one continuous structure, with a process in which there are two distinct operations: "erecting columns" and "placing the walls between the columns." Both processes can be equally practical. But there is an emotional crispness, a cognitive satisfaction, which comes more from the second than from the first, because distinct, attainable things have been done which contribute to the rhythm of the building process.

As far as possible, we believe it is important that the operations in a building process be conceived, defined, and cut apart in such a way that each one has this sense of completion, this exhilaration, this emotional crispness.

We should note, finally, that the operations which have this emotional crispness and integrity to the greatest degree are not only complete, integral, in themselves, but are also made up of smaller operations (suboperations) which have this same emotional completeness in *themselves*.

The process of making a slab is an operation of this kind. It is easy to understand and complete in itself, of course. There is a great sense of personal satisfaction when it is done. But, also, within this unitary operation, there are subsidiary units which, once again, have these same attributes. In our particular case, the slab operation consisted of the following smaller operations:

1. Placing tierra limo (fine sand) to the right level, and cutting beams in it.

2. Placing rebars and mesh.

3. Pouring the slab, screeding it to a rough level, and floating it.

4. Scattering the fine mixture of red oxide, cement, and sand on the still wet slab.

5. Trowelling to a hard finish, two hours later.

Each of these operations is itself a source of satisfaction when completed; it is itself a unit of accounting, a unit of time, and an element in the process. And the rhythm of the larger process is easily made up of these smaller units of rhythm, so complete within the larger units that they make the larger operation feel complete.

❀

In the next few pages, we present the construction operations that we used in our houses in Mexicali. As we shall see, these building operations meet our four criteria very well, and thus satisfy the principle of step-by-step construction very strongly.

However, we must make it clear that we in no way consider these *particular* operations to be of special importance. They *embody* the principle of step-by-step construction very well, and they conform to the criteria just discussed. But of course any other system of step-by-step construction which meets these criteria would do just as well; and, indeed, in other contexts (other countries, climates, etc.) it would be absolutely necessary to develop other, comparable steps.

STEP-BY-STEP CONSTRUCTION

Building Operations for Mexicali

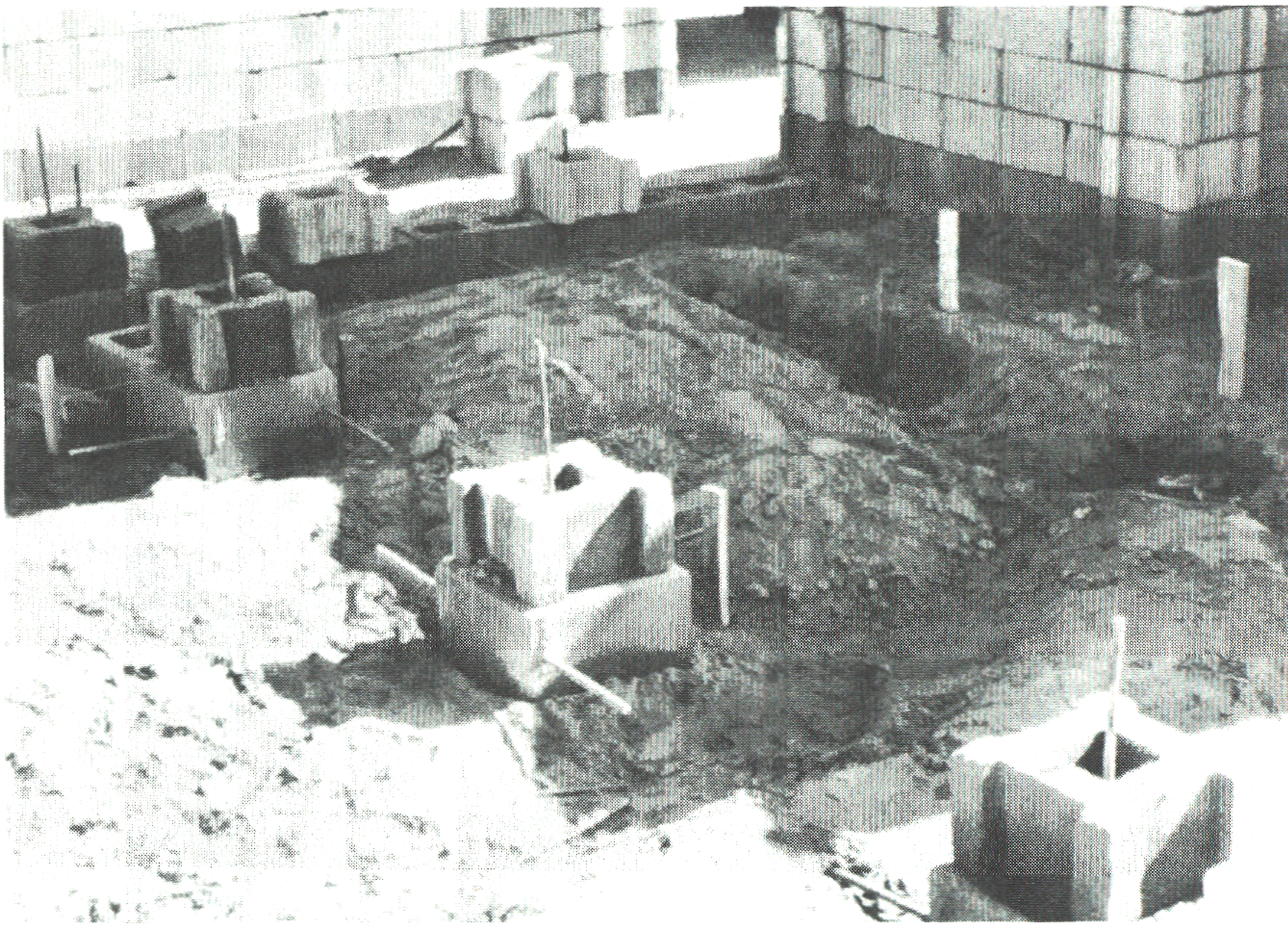
1. LAY OUT STAKES
2. EXCAVATE AND NEUTRALIZE SOIL
3. PLACE CORNER STONES
4. PLACE WALL FOUNDATIONS
5. PREPARE SLAB
6. PLACE UNDER-SLAB PLUMBING
7. POUR SLAB
8. ERECT COLUMNS
9. ERECT WALLS BETWEEN THE COLUMNS
10. INSTALL DOOR FRAMES
11. BUILD PERIMETER BEAMS
12. WEAVE ROOF BASKETS
13. ERECT GABLE ENDS
14. INSTALL ELECTRICAL CIRCUITS
15. PLACE ROOF FIRST COAT
16. PLACE ROOF TOP COAT
17. INSTALL WINDOW FRAMES
18. BUILD AND INSTALL WINDOWS
19. BUILD AND INSTALL DOORS
20. INSTALL PLUMBING
21. INSTALL ELECTRICAL
22. PAINT WALLS, ROOFS, AND TRIM
23. LAY BRICK FLOORS ON WALKS AND ARCADE FLOORS

1. LAY OUT STAKES

1. *Place column blocks.* Place a column block at each corner and on each side of doors.
2. *Place wall blocks.* Place wall blocks between column blocks, and adjust column block positions to allow each wall to be made of an integral number of whole and half blocks.
3. *Straighten lines and angles.* Adjust blocks until each wall is an integral number of blocks or half blocks, with the plan disturbed as little as possible. (This does *not* require right angles in all corners.)
4. *Place stakes.* Replace corner blocks with 18″ #3 rebars, hammered deep into ground so that excavation will not disturb them.

2. EXCAVATE AND NEUTRALIZE SOIL

1. *Excavate trenches.* Dig trenches, 8″ deep, along center lines, to form wall foundations, 12″ wide at top, 8″ wide at bottom.
2. *Pick earth.* Use pickaxes to loosen soil in center of slab area and at bottom of trenches, to a further depth of 8″; loosen soil, and prepare for flooding.
3. *Flood with lime.* Flood with a 5 percent lime solution.
4. *Wait five days.* Wait for the lime solution and mud to dry out.
5. *Compact.* Compact and reform approximate shape.



3. PLACE CORNER STONES

1. *Choose level.* Choose a finish floor level.
2. *Place tierra limo.* Place a base of tierra limo at each column position, to bring blocks to level of #1.
3. *Place blocks.* Place each block over a stake already in the ground.
4. *Level blocks.* As you place each block, use a line level to get it level with the previous block; then use carpenter's level to check the top of the block level in both directions.
5. *Check levels.*
6. *Place column block.* Once blocks are level, start putting a concrete column block over each foundation block.
7. *Place rebars.* Place an 18″ #5 rebar in each column, so that it projects at least 7″ above the top.
8. *Fill blocks.* Fill blocks with a 1:9 concrete.

4. PLACE WALL FOUNDATIONS

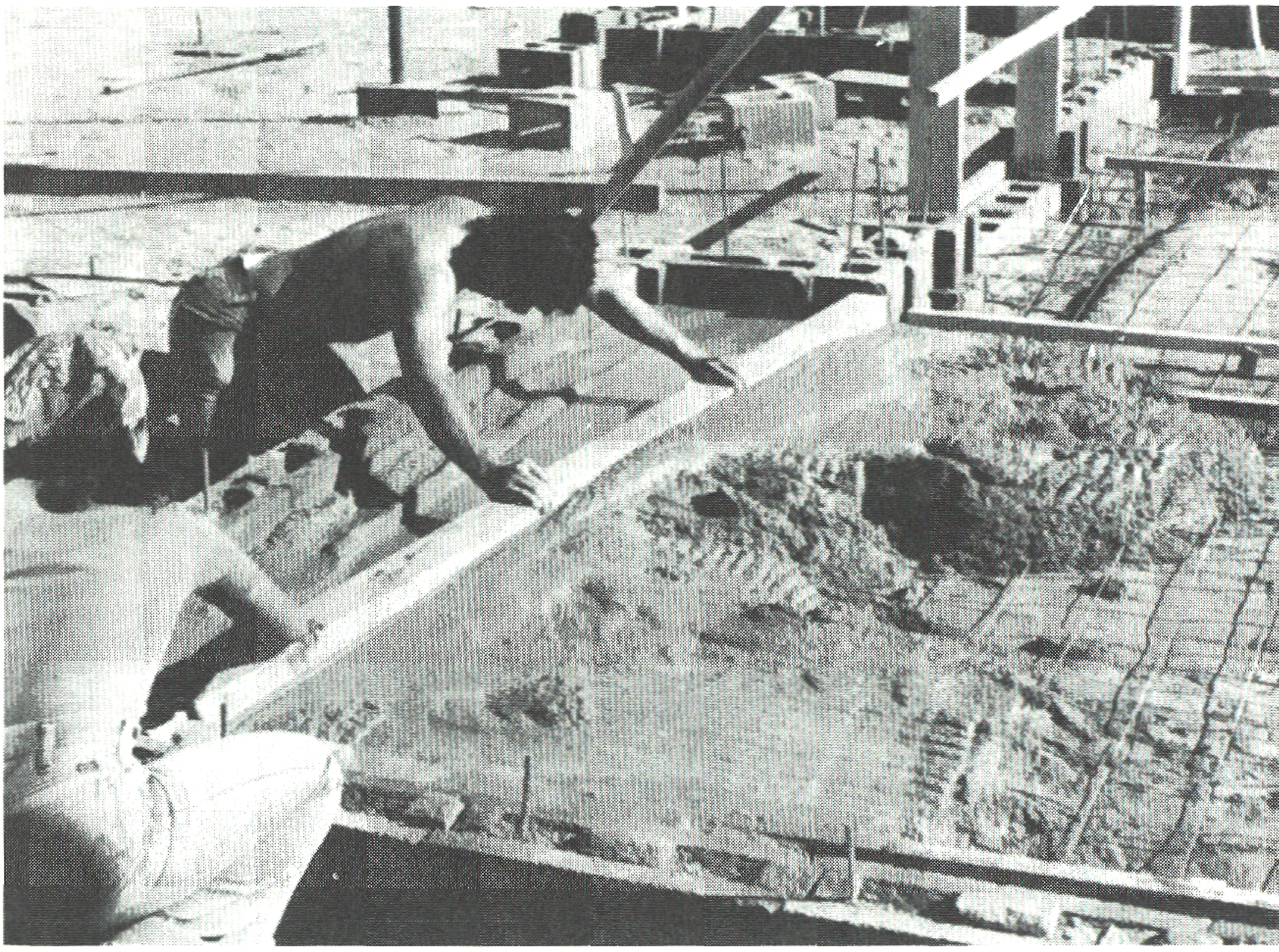
1. *Place foundation blocks,* to form a line along wall line, with rebars pointing inward.
2. *Level blocks.* Level with tierra limo to the level of the corner foundation blocks.
3. *Place red wall blocks.* Place one course of red wall blocks, interlocked with corner blocks.
4. *Insert rebars.* Place one #3 rebar in alternate cores.
5. *Fill cores.* Grout cores with 1:9 mix. Fill the core halfway up the upper block.

5. PREPARE SLAB

1. *Place lines.* Tie the lines across the foundation blocks to indicate a level that is 2″ below the top of the finished slab level.
2. *Fill with tierra limo.* Fill with tierra limo to the level of the lines.
3. *Compact well.* Compact and fill until the material is solid.
4. *Cut beams.* Use a steel trowel to cut ground beams out of the tierra limo.
5. *Cut extra beams.* Now, in any slab which has a length of more than 8′, cut extra beams to divide it into sections.
6. *Place rebars.* Cut and shape #3 rebars for the beams, and place them 4–5″ below the slab top.
7. *Place wire mesh.* Cut and place wire mesh. Tie the mesh to rebars at edges, and secure overlaps in the mesh.

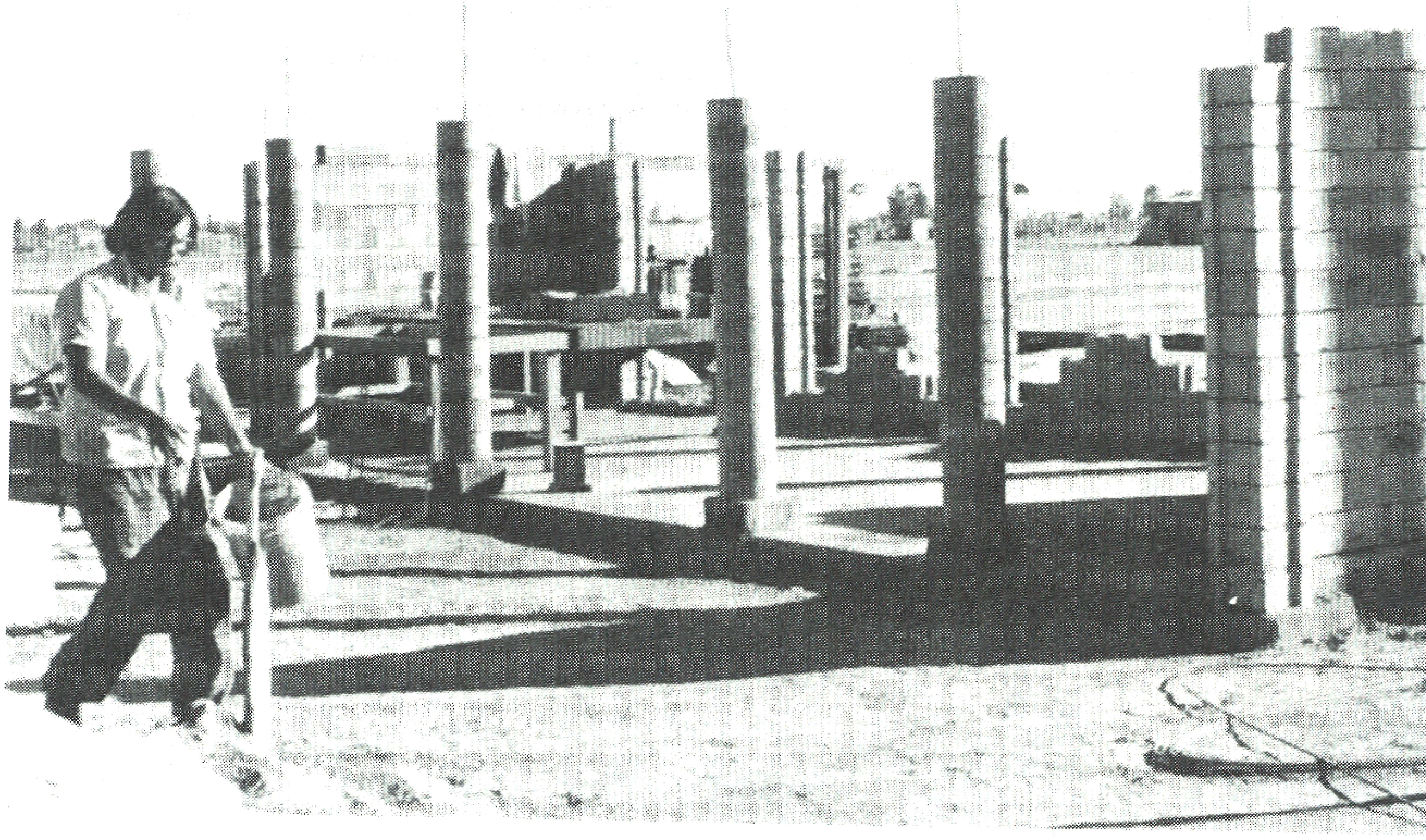
6. PLACE UNDER-SLAB PLUMBING

1. *Plot drain lines.* Get horizontal and vertical positions, with fall, elbow, and manhole positions.
2. *Buy pieces.* Buy lines, joints in ABS pipe.
3. *Assemble pieces.*
4. *Dig holes in positions.*
5. *Place pipes.* Prop them in position, using tierra limo fill to hold them steady.
6. *Backfill.* Fill holes with tierra limo.
7. *Cover tops.* Tie plastic over open tops, to prevent concrete from entering during the slab pour.



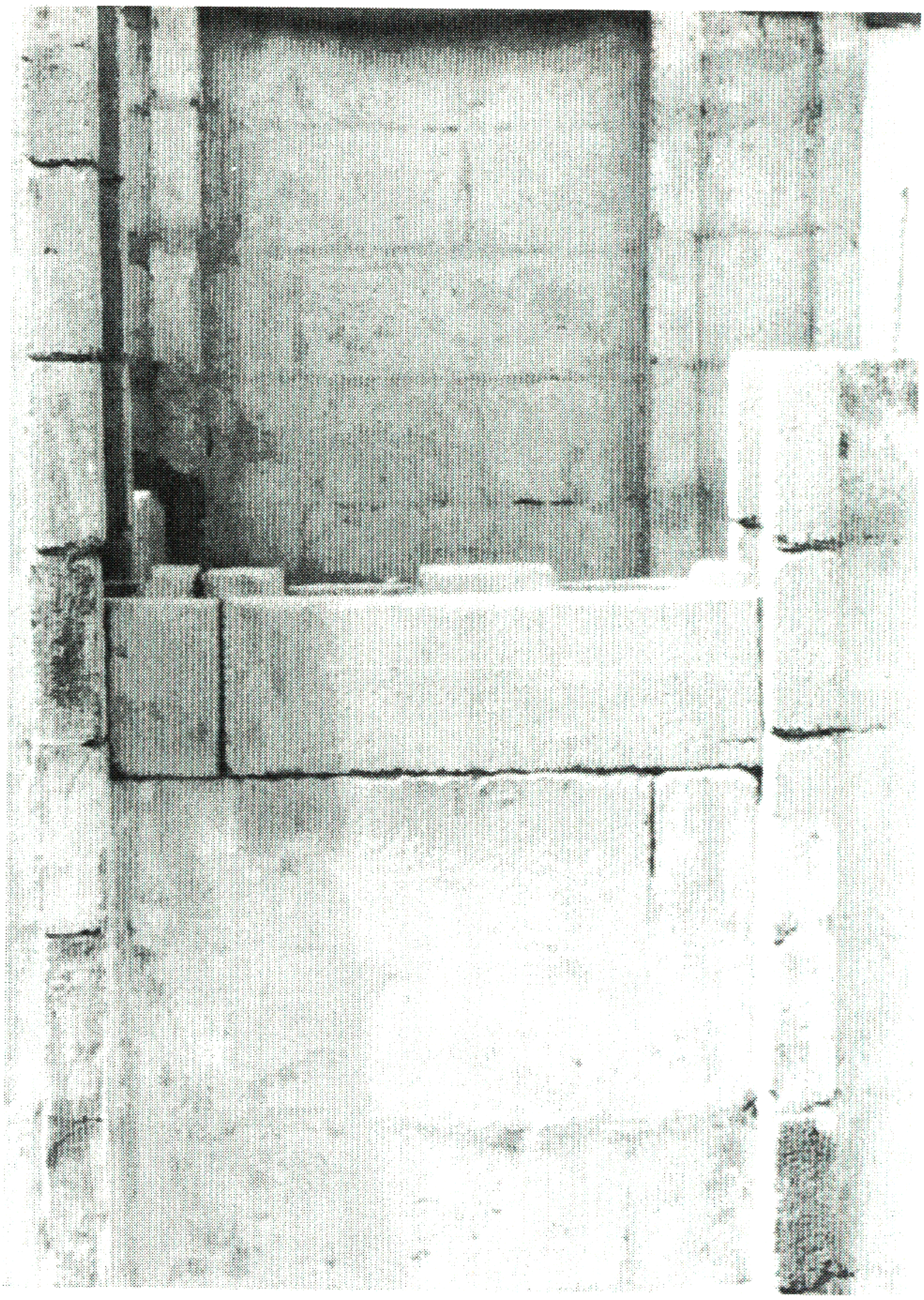
7. POUR SLAB

1. *Place mixers.*
2. *Prepare wheelbarrow runs.*
3. *Wet tierra limo.* Immediately before pouring each section of slab, wet it thoroughly until water stands on surface. This must be done immediately before the pour, so the tierra limo is still wet when concrete arrives.
4. *Pour concrete.*
5. *Screed concrete.* Using the top of wall blocks at edge, and special 2x4 screeds, level off the concrete.
6. *Float concrete.* With aluminum or wood floats.
7. *Scatter red oxide.* Use a sieve to scatter a mix of red oxide, cement, and sand, on the wet slab.
8. *Wait two hours.*
9. *Trowel surface.* With steel trowels, finish to a perfect surface.



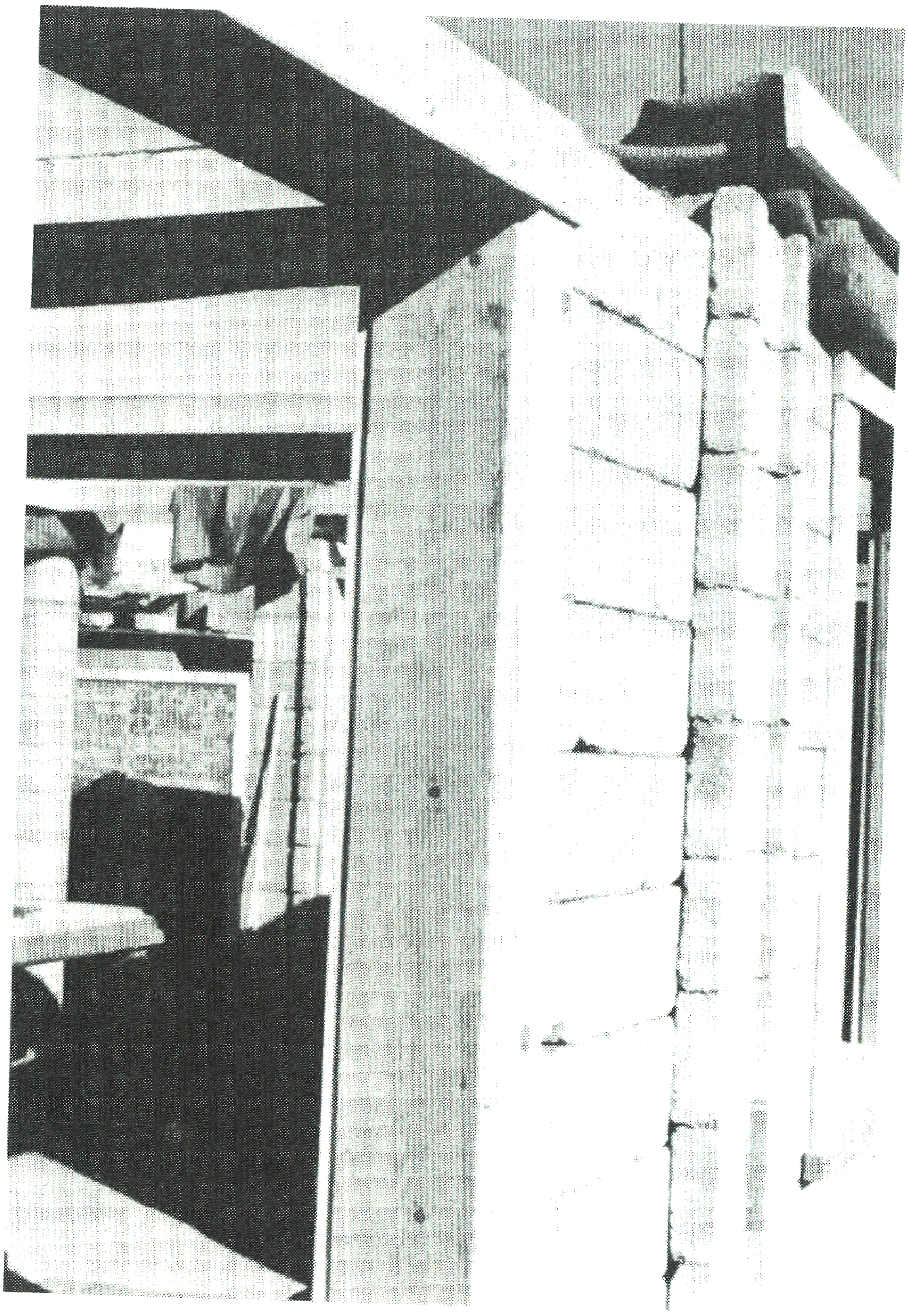
8. ERECT COLUMNS

1. *Clean bottom block.*
2. *Tie rebars.*
3. *Stack blocks.* Stack in groups of twelve, next to each column.
4. *Clean blocks.*
5. *Place blocks.* Check plumb and level of column, and of the top block at each stage. If not perfect, turn the block through 90, 180, or 270 degrees until it is perfect.
6. *Wet blocks.*
7. *Fill blocks.* After six blocks, fill with 1:9 concrete.
8. *Place blocks.* After 4 hours, continue placing the blocks on column.
9. *Wet blocks.*
10. *Fill blocks.* Fill the top six blocks.



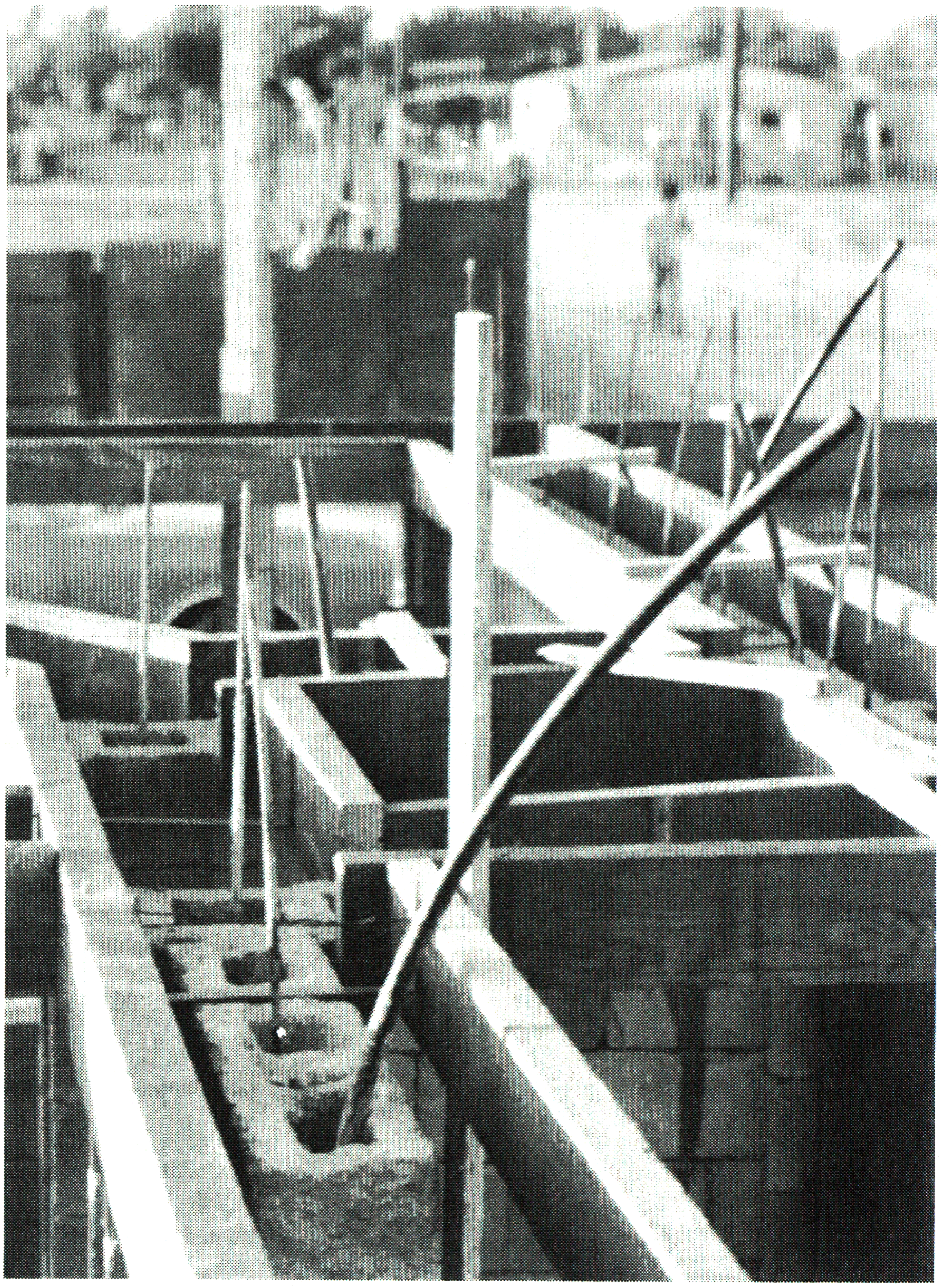
9. ERECT WALLS BETWEEN THE COLUMNS

1. *Chalk rebar positions.* Do this so that it is clear which holes to put rebars in when wall is built.
2. *Cut blocks.* Cut to size on cutter, and file smooth.
3. *Place blocks.* Place each block with a back-and-forth motion until it beds down.
4. *Fix windows.* After the fourth course, decide on window openings and variants in sill height.
5. *Place rebars.* In holes marked by chalk marks (see #1, above).
6. *Fill rebar cores.* Wet cores, and fill with a wet 1:9 mix, well compacted.



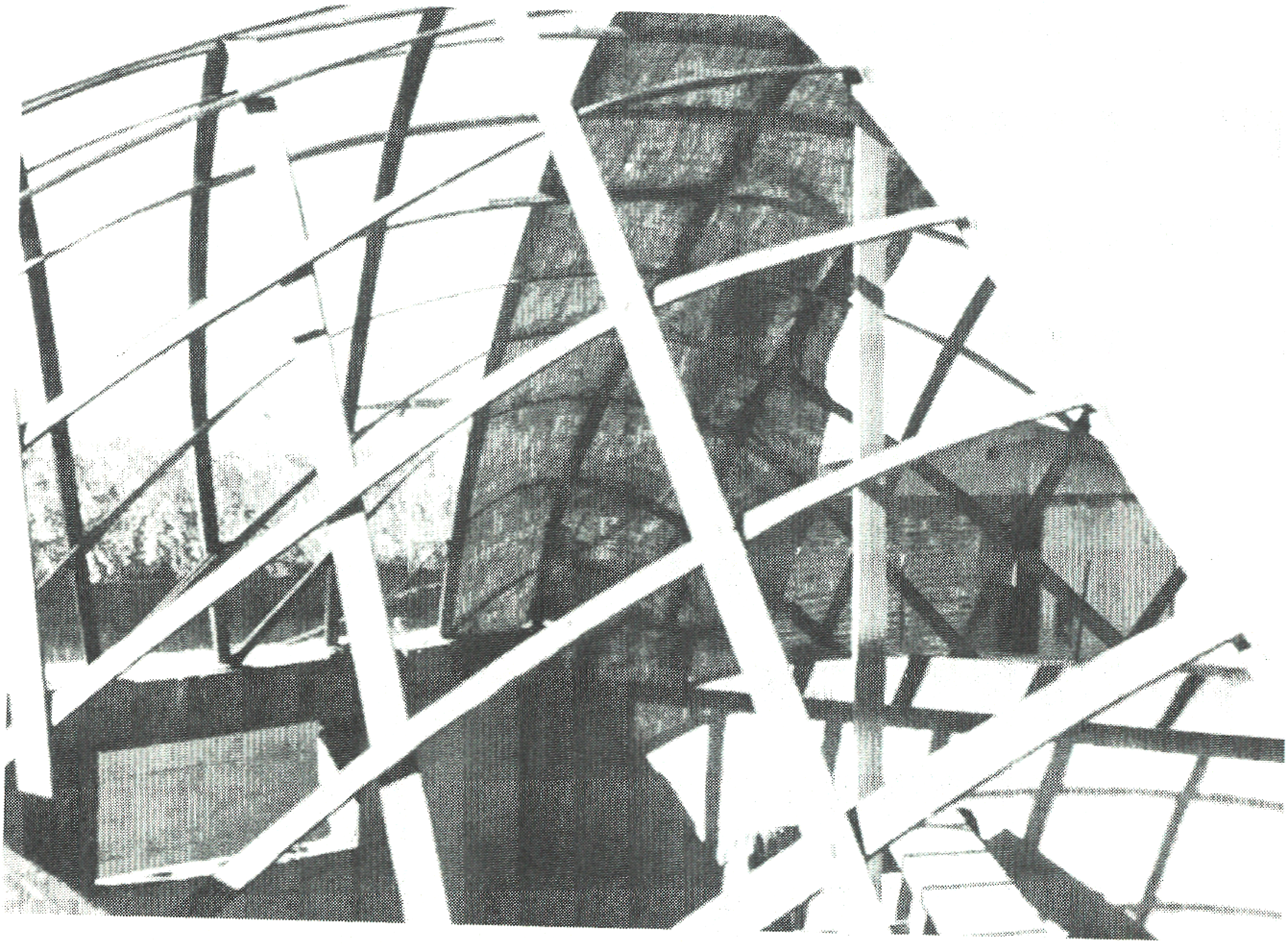
10. INSTALL DOOR FRAMES

1. *Calculate dimensions.*
2. *Cut lengths. Cut header.*
3. *Rout header.* Rout to fit vertical side pieces.
4. *Install expanders* (blocks of wood in column). Reposition frame and nail header.
5. *Drill for lag bolts.* Drill through side pieces with a ⅜ drill and countersink with 1″ drill.
6. *Attach lag bolts.* Install lead and lag screw, keeping frame vertical.



11. BUILD PERIMETER BEAMS

1. *Inventory beam lengths.*
2. *Cut 2x6's.*
3. *Nail 2x6's together at the tops with 1x2's.*
4. *Set beams in place.*
5. *Close ends together to close perimeter.*
6. *Nail U-frames* in place, moving around each room.
7. *Close underside.* Use pieces of scrap 1x4's over walls, and 1x10's over windows, and clear spans.

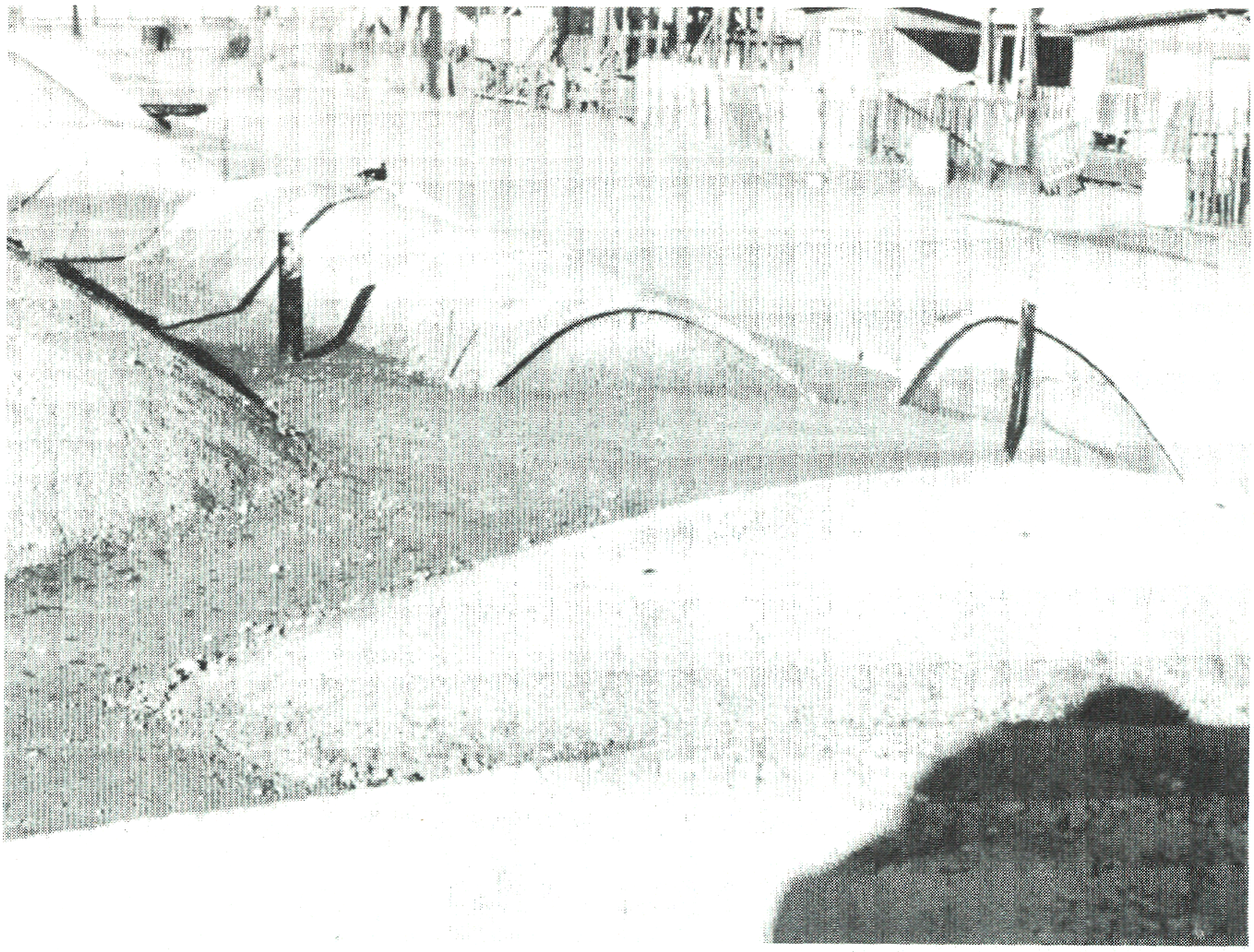


12. WEAVE ROOF BASKETS

1. *Set 1x2's.* Place a 1x2 along beam, 2 inches in from the inner edge, to form a trap for basket. Attach to U-rings with wire.
2. *Mark basket positions.* Make pencil marks at equal intervals, approximately 18″ apart.
3. *Soak strips.* Soak strips in water until they are soft enough to bend easily.
4. *Weave basket.* Weave a diamond lattice, with each alternate piece crossing under and over.
5. *Nail crossings.* Nail each crossing from above, using a second hammer underneath to steady. Start with center line and work toward the beams.
6. *Place reinforcing.* Place #3 rebars in every beam.
7. *Fill beam.* Fill the beam up to the top of the 2x6, so that it catches the bottom of all basket strips and holds them firmly.

13. ERECT GABLE ENDS

1. *Place blocks.* Place blocks over end beams to form a gable with the same profile as the basket. Cut blocks to be shorter than the curve.
2. *Fill angles.* Fill angles with stiff concrete/mortar to round blocks off to a correct curve.
3. *Leave vent holes.* Leave vent holes in the gable to allow air to escape. As high as possible.
4. *Place rebars.* Place extra rebars to come to the full height of the cells.
5. *Fill cells.*



16. PLACE ROOF TOP COAT

1. *Nail cornice.* Nail a 1x4 along outside top of beam, to form cornice.
2. *Nail drip formwork.* Nail a second piece outside cornice, to make formwork for an overlapping cap.
3. *Place rebars.* Place a #5 rebar towards the outside of the beam volume.
4. *Bend vertical bars.* Bend the vertical bars from the wall so that they lap the beam bar.
5. *Place lines.* Place lines to guarantee a straight and horizontal roof line.
6. *Mix concrete.* Make a lightweight mix, 3 parts sand, 6 parts pumice, and 1 part cement.
7. *Trowel concrete.* Place to a depth of about 1½ inches over the previous coat.
8. *Float to a smooth finish.*

17. INSTALL WINDOW FRAMES

1. *Check light.* Check the amount of light in each room.
2. *Enlarge window openings.* Break out blocks to enlarge windows wherever necessary.
3. *Measure openings.*
4. *Order materials.*
5. *Cut pieces.*
6. *Rout and plane sill.*
7. *Assemble frame.* Nail the frame together with diagonal brace to preserve perfect squareness.
8. *Place blocks and wedges.* Nail blocks to the underside of the perimeter beam.
9. *Fit frame.* Plumb sides and nail in place.

18. BUILD AND INSTALL WINDOWS

1. *Choose format.* For each window, decide on window format: cross pieces, vertical pieces, pane size.
2. *Measure window and compute components.* Use measurement sheet to compute components.
3. *Cut components.* Cut on a table jig, to exact lengths, out of stock sizes of 3/8, 1 1/8, and 1 1/2.
4. *Assemble edges.* Glue and nail top, bottom, and sides as four separate components.
5. *Glue and clamp.* Glue and clamp the four edges together with C-clamps, taking special care with right angles.
6. *Insert muntins.*
7. *Set nails.* Punch in nails, putty, and sand.
8. *Plane edges.* Plane edges to fit window frame.
9. *Hang windows.* Mark hinge positions, chisel out, drill and screw.

19. BUILD AND INSTALL DOORS

1. *Choose format.* Decide on format of door, size of lights, and the location of transom.
2. *Measure and cut.* Choose pieces of 1x6 for stiles, rails, and transom. Cut to length.
3. *Assemble.* Assemble, glue, and clamp these major pieces.
4. *Insert stops for inserts.* Make stops of 1x1 material.
5. *Cut and place plywood inserts.*

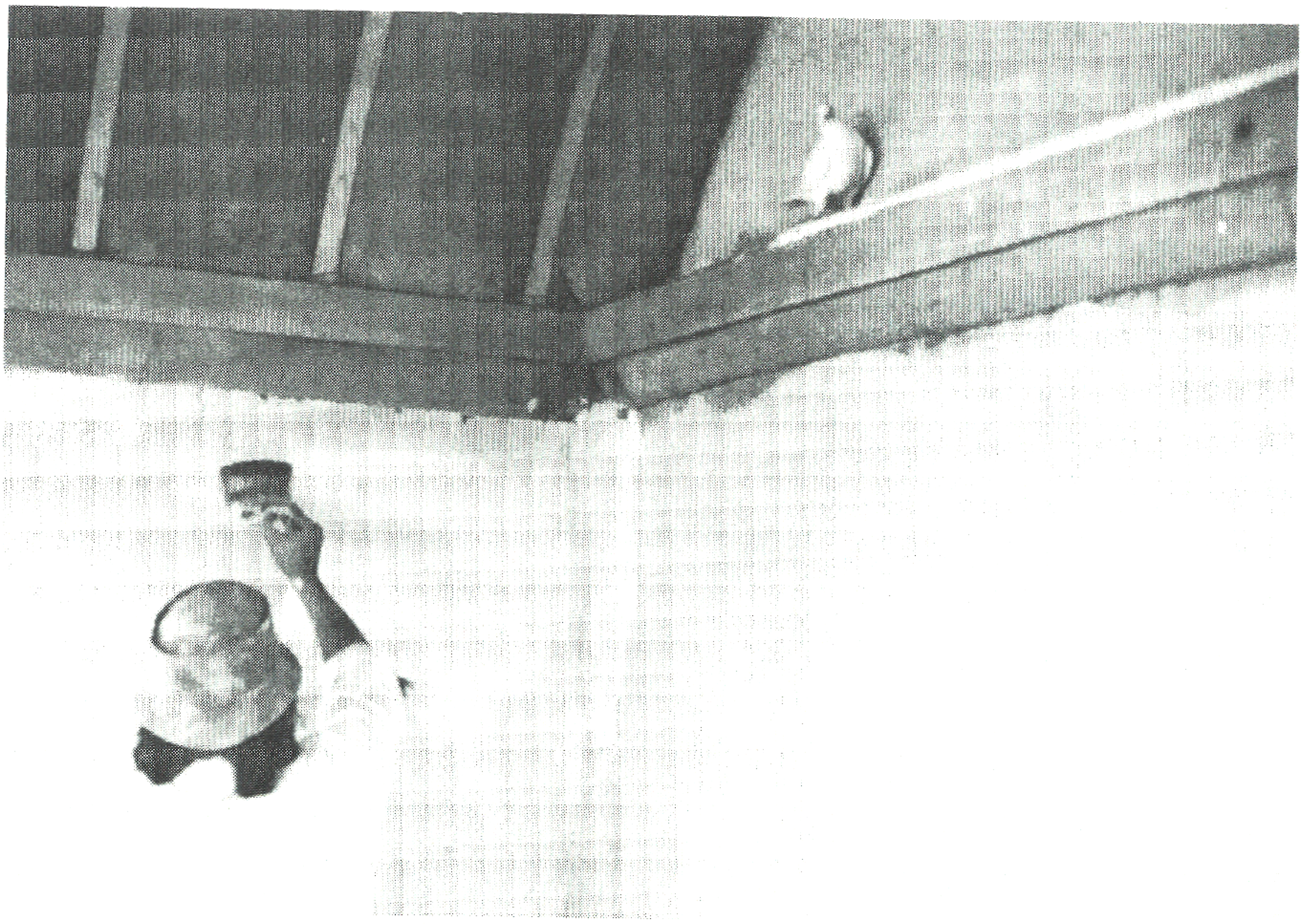
6. *Cut and place glass inserts.*
7. *Set hinges.* Mark 12 inches from each end; set them into the frame.
8. *Install lockset.* Drill out, install lock, attach handles.
9. *Hang the door.* Mark frame, attach hinges and place doorstops.

20. INSTALL PLUMBING

1. *Calculate pipe.* Calculate required lengths of pipe to use minimum amount, and minimize places where pipes have to cross hallways and doorways. For hot water, use ¾″ galvanized; for cold water, use ¾″ PVC.
2. *Place pipe.* Run the water pipe around the base of rooms; screw it flat against concrete wall blocks with metal straps.
3. *Install shutoff valves at fixture locations.*
4. *Hook up to main water supply.*

21. INSTALL ELECTRICAL

1. *Use #12 insulated copper wire.*
2. *Cut wire to length*, leaving 6″ at ends for connections in boxes.
3. *Pull wire.* Use steel wire already in tubes to pull the copper wire through.
4. *Make connections at junction boxes.*
5. *Install fixtures.* Connect and fix in place switches, outlets, and light fixtures.



22. PAINT WALLS, ROOFS, AND TRIM

1. *Prepare walls.* Use lime plaster to fill cracks in holes, repair broken blocks, and smooth surfaces. Only use where cracks are large and unsightly. Small cracks add to texture and are left as they are.
2. *Test colors.* Do experiments at full scale to determine the range of colors to be used on walls, cornices, and window trims. Make subtle color experiments on scrap until satisfied by beauty of colors.
3. *Whitewash exterior.* We whitewashed walls with a white that has green in it, to counteract glare and to go with the blue and green cornice colors.
4. *Paint inside.* Use white latex paint on inside walls.
5. *Paint cornices.* We used shades of blue, and a golden green tc paint cornice lines.
6. *Oil windows and frames.*

23. LAY BRICK FLOORS ON WALKS AND ARCADE FLOORS

1. *Lay out edges.* Mark the exact edges of all paved areas.
2. *Set floor height.* Place stakes to set floor height a few inches below slab height.
3. *Excavate.* Dig out earth to a level 4 inches below finish height.
4. *Place tierra limo base.* Place 2 inches of tierra limo, moisten, and compact and level.
5. *Place bricks.* Lay bricks in tierra limo, in regular patterns, herringbone, or alternating squares.
6. *Fill cracks.* Pour sand between cracks, wet down, pour sand, wet down, and repeat until the path surface is dense and compact.

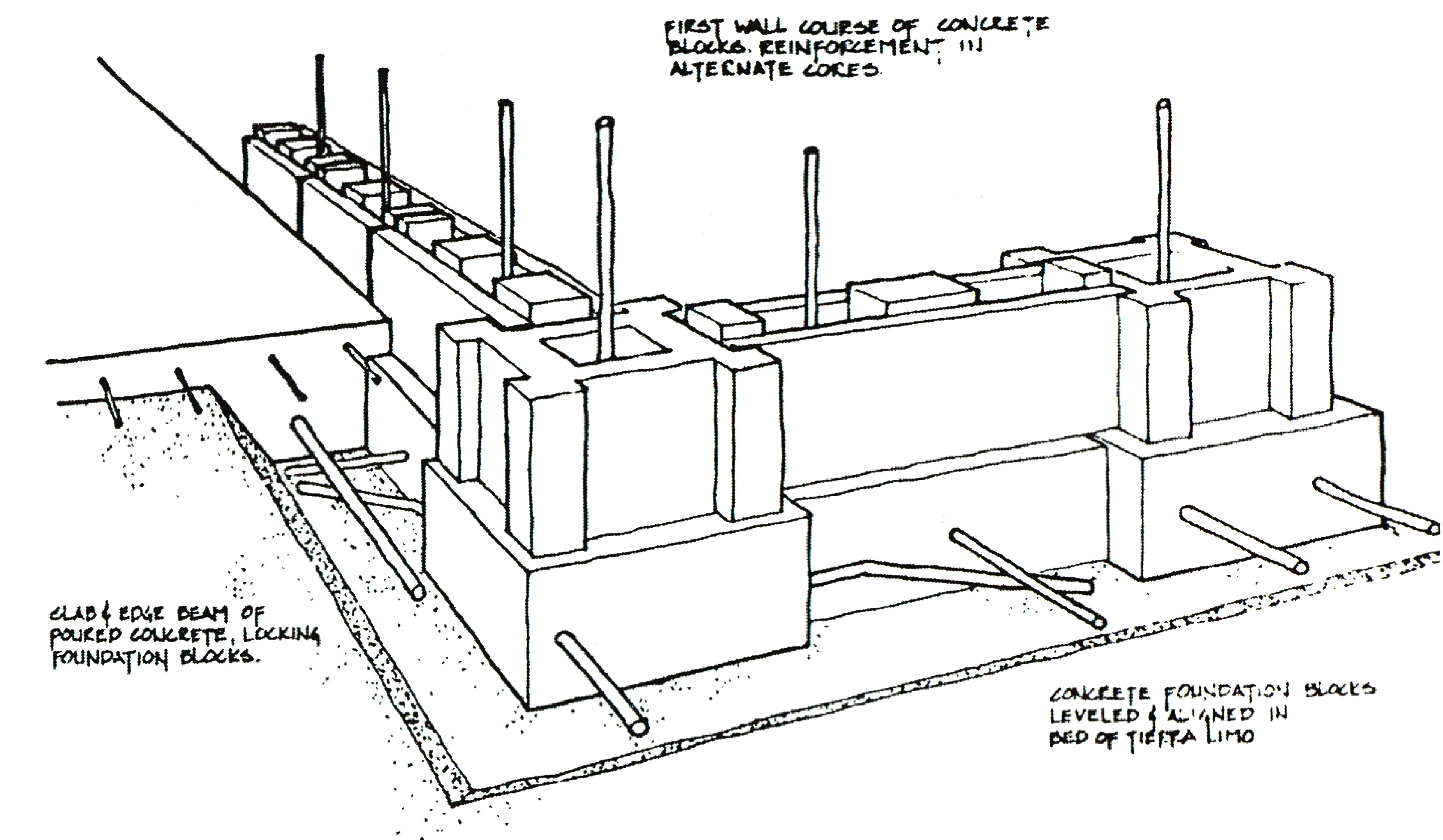
We finish this chapter with a discussion of the problem of permission. Under normal circumstances, the process by which a building receives a building permit requires a set of drawings for the building, complete with details and specifications.

Within the process we are describing here, such a procedure is, of course, impractical and self-defeating. Since each house is different, the production of architectural drawings for each one would greatly increase the cost of the houses. Furthermore, and perhaps more crucial, the need to make a set of drawings will inevitably encourage the draftsman to introduce all kinds of harmful changes in the drawings—straightening of lines, smoothing out of oddities, little injections of "style"—all of which are merely the result of the fact that the draftsman has to feel that he has put "something" into the buildings. All these "somethings" merely take the building further away from the original intention of the family who laid it out. They serve no useful purpose, but only make the building layout worse.

Nevertheless, most cities and local governments maintain the right to issue building permits, in order to protect the people who use the buildings from shoddy or dangerous workmanship. And it is certainly reasonable that a community should feel secure in the knowledge that every building meets certain reasonable standards of structural safety.

In order to meet the requirements of local building permission, but in a way which avoids the use of expensive and destructive working drawings for every building, we believe that it is quite possible for a government building inspection department to issue a per-

ORIGINAL FOUNDATION SYSTEM

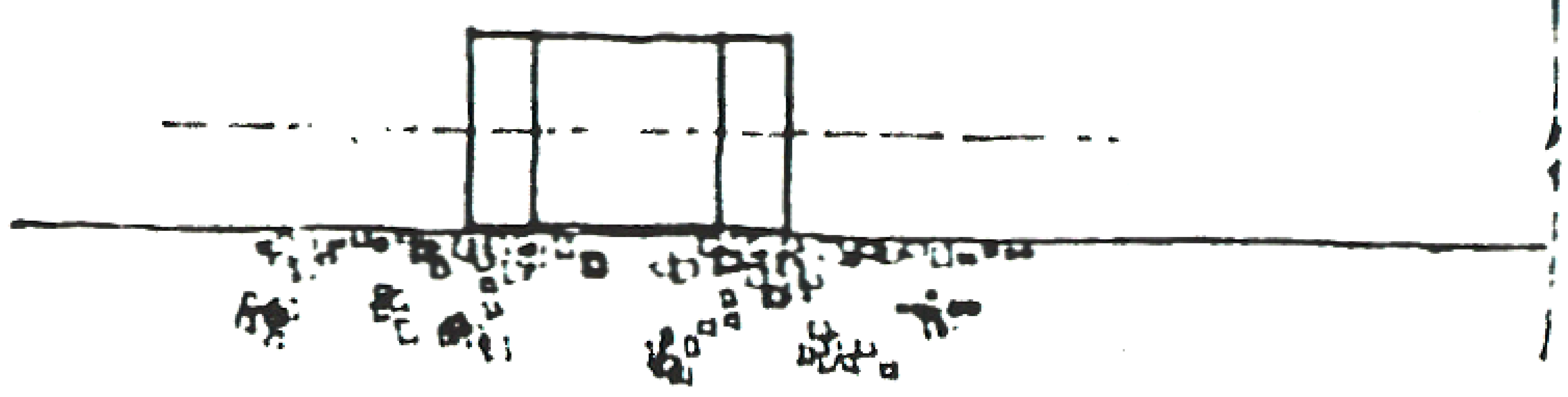


mit to a building *process* (that is, to a set of building operations, as we have defined them), and thereby to give permission, automatically, to every building that is built according to these operations and that also meets certain minimal rules of layout.

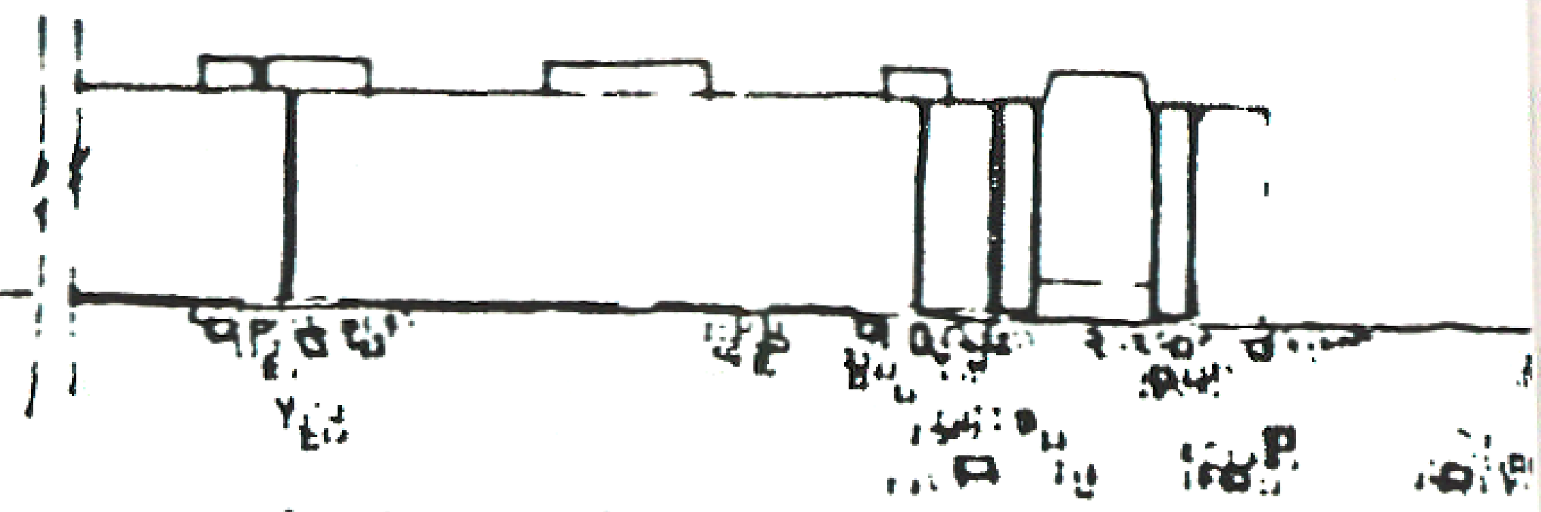
This is exactly what we did in Mexicali. We submitted a description of the building operations to the Public Works Department. The Chief Engineer of the Public Works Department asked for certain minor modifications in the location and spacing of reinforcing bars. Once we had made these changes, he approved the process.

REVISED FOUNDATION SEQUENCE

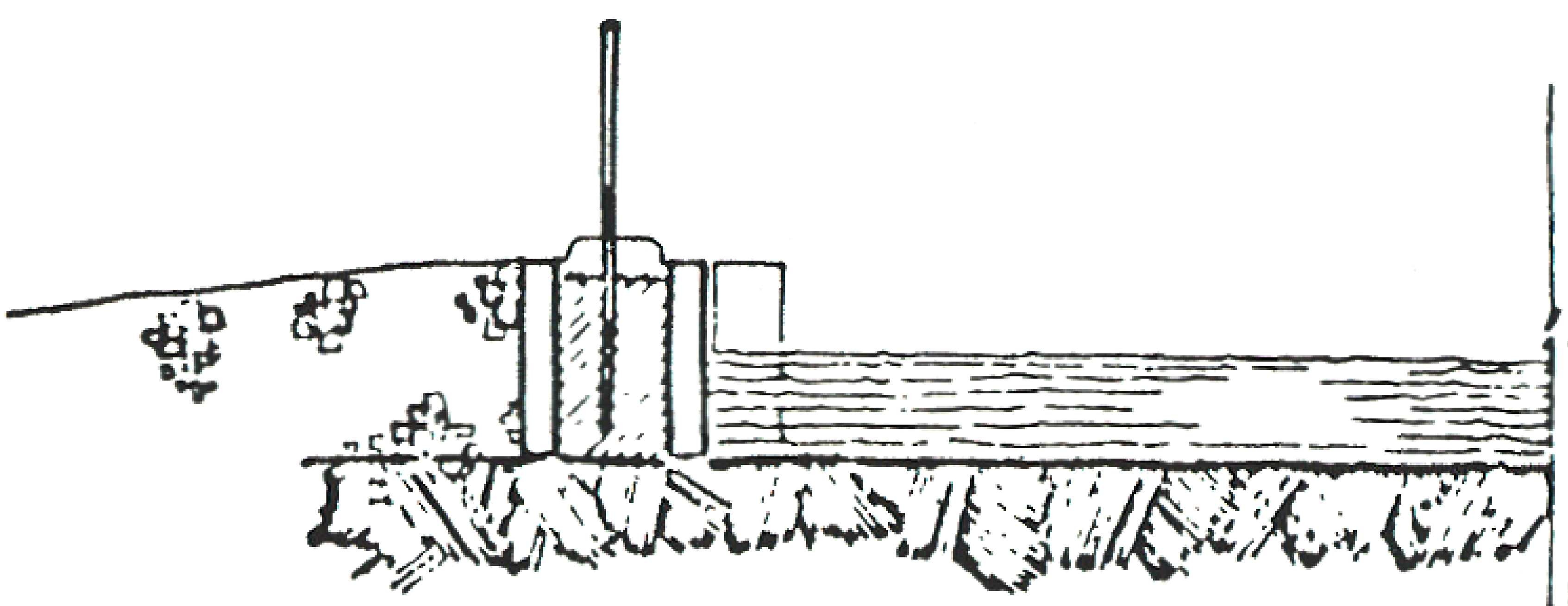
A SERIES OF TRANSPARENT OPERATIONS



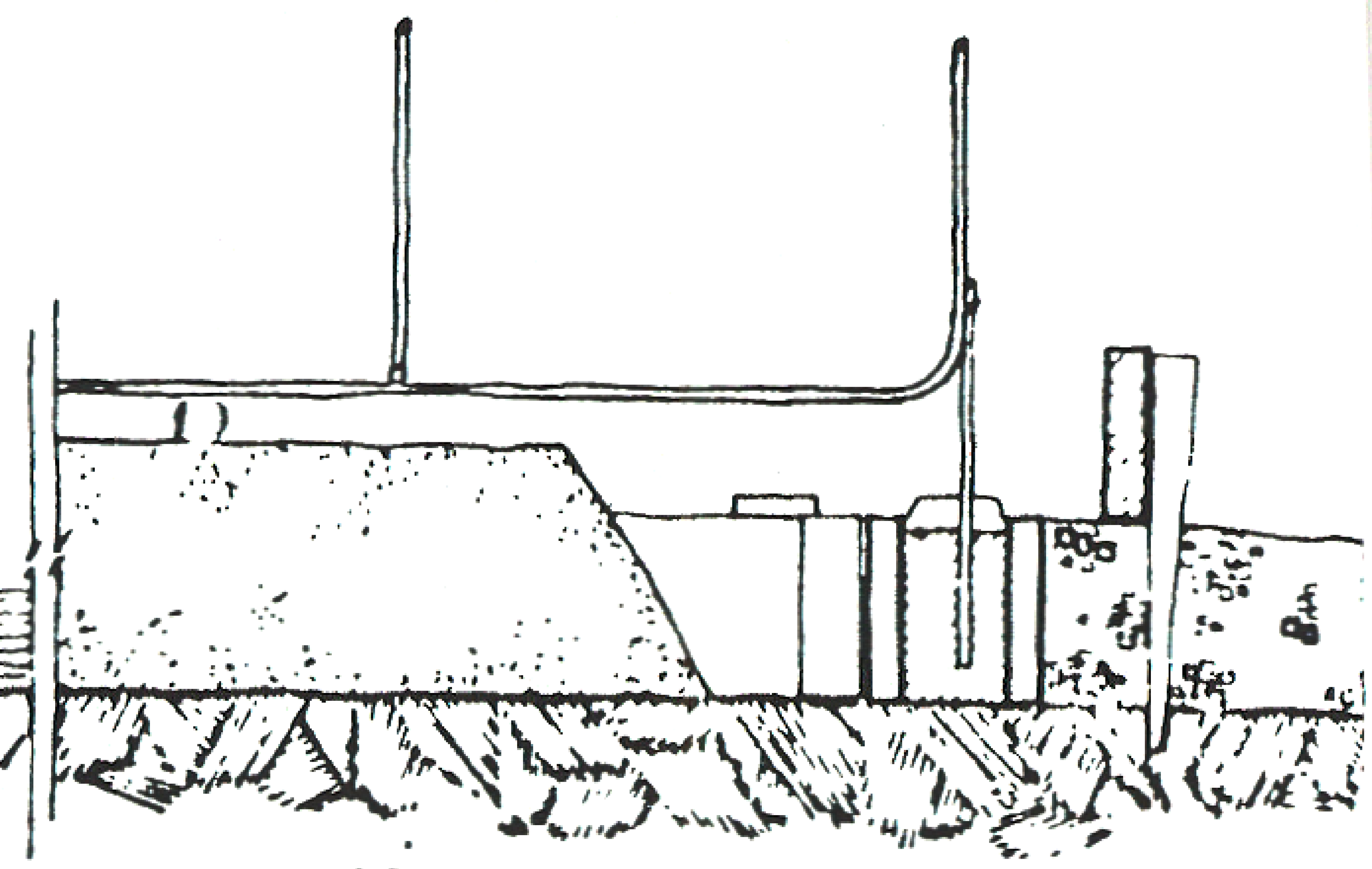
STRIP SURFACE SOIL.
LAY OUT PLAN W/ CORNER BLOCKS.



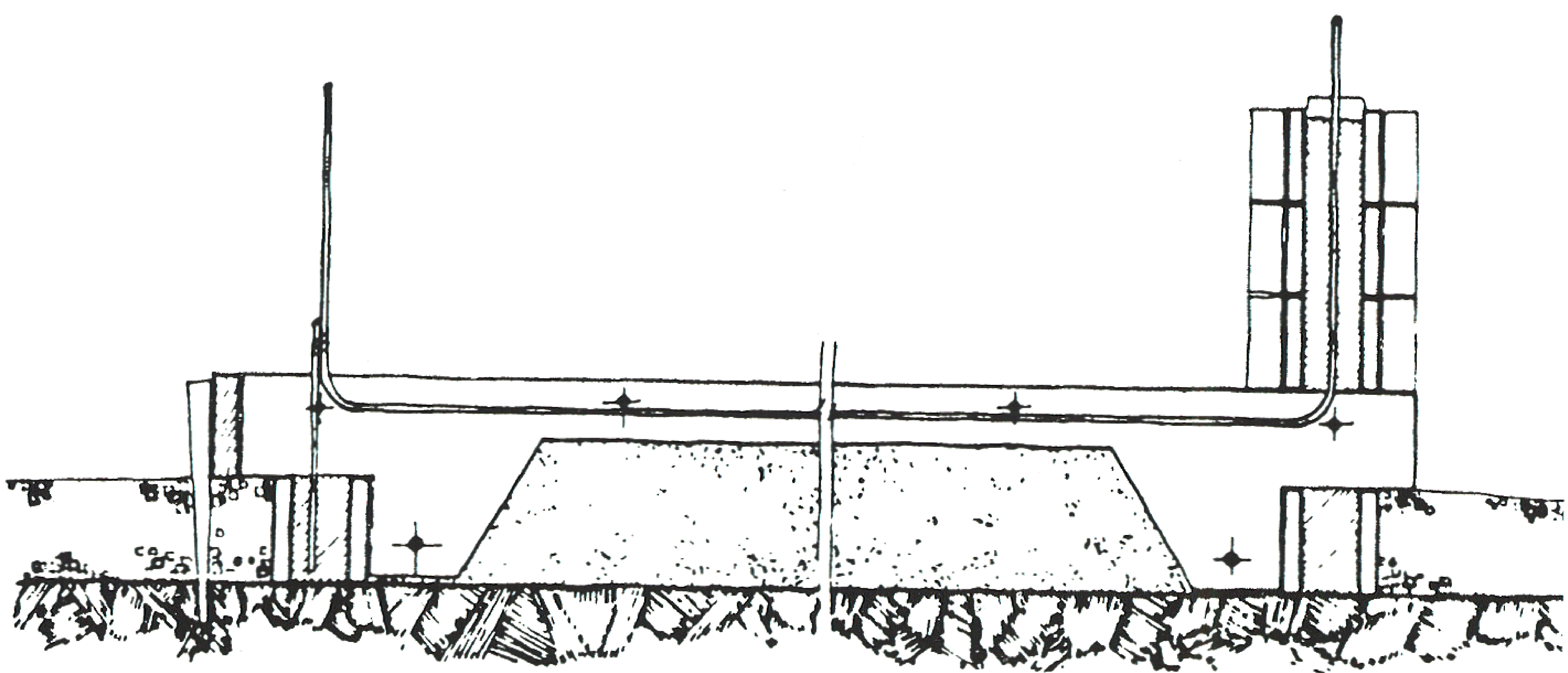
ADJUST PLAN TO MODULE LENGTHS
PLACE WALL BLOCKS.



GROUT BLOCKS W/ DOWELS @ 19" O.C.
BACKFILL & FLOOD W/ LIME SOLUTION
TO STABILIZE EXPANSIVE CLAY.



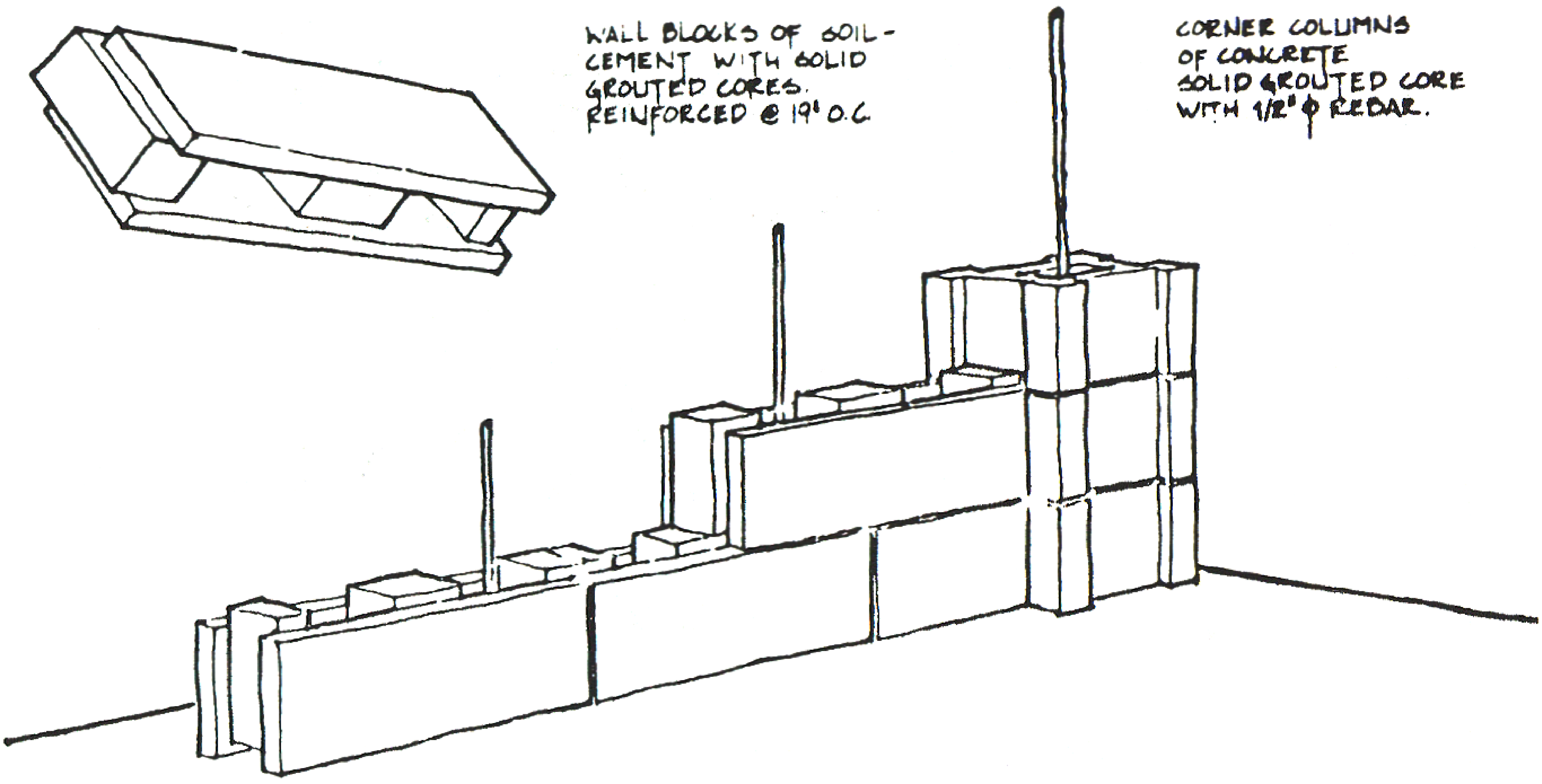
COMPACT EARTH.
FORM SLAB W/ WOOD & TIERRA LIMO.
TIE STEEL TO DOWELS.

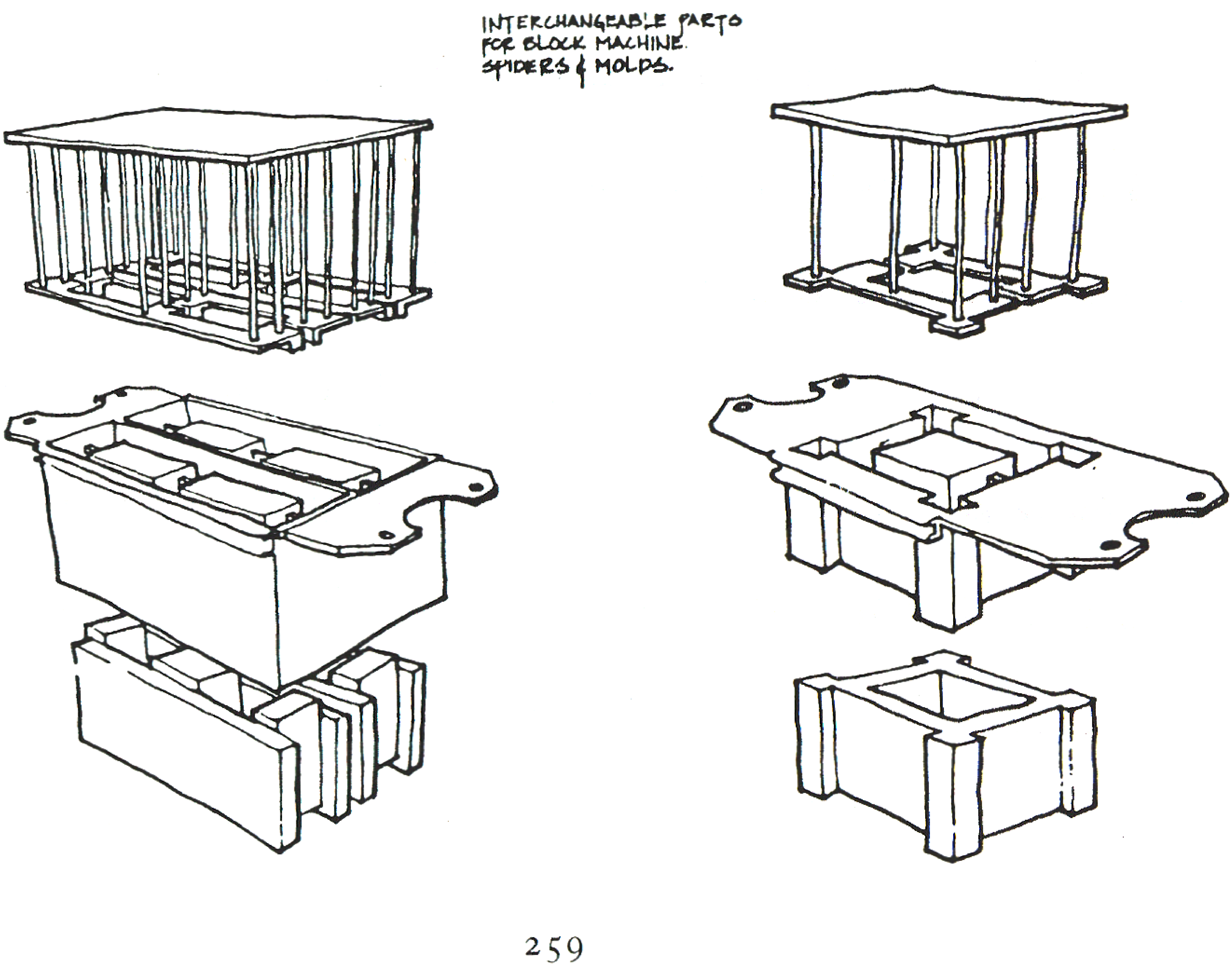


POUR SLAB.

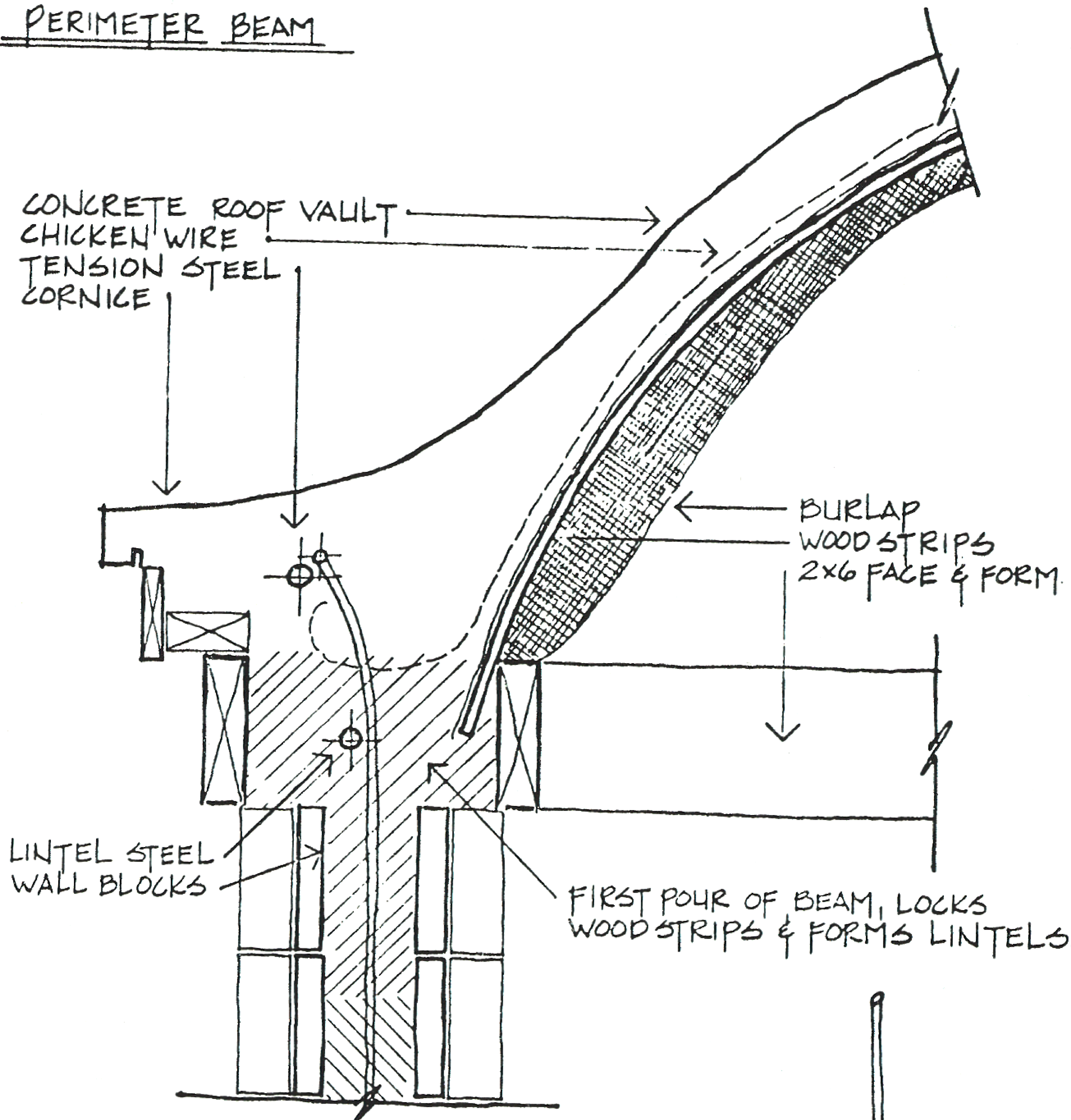
CONSTRUCT COLUMNS & WALLS.

BASIC INTERLOCKING BLOCK SYSTEM



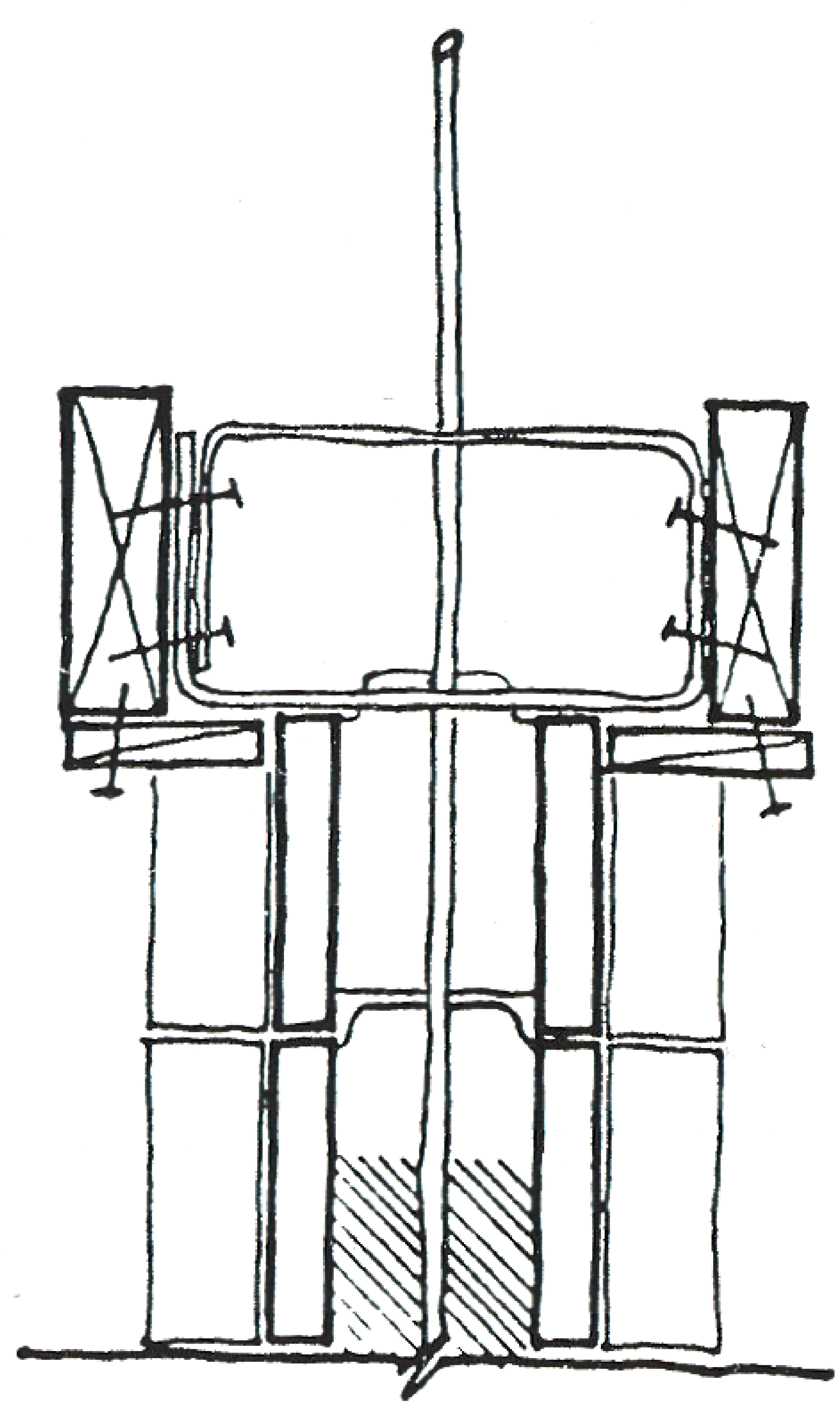


PERIMETER BEAM

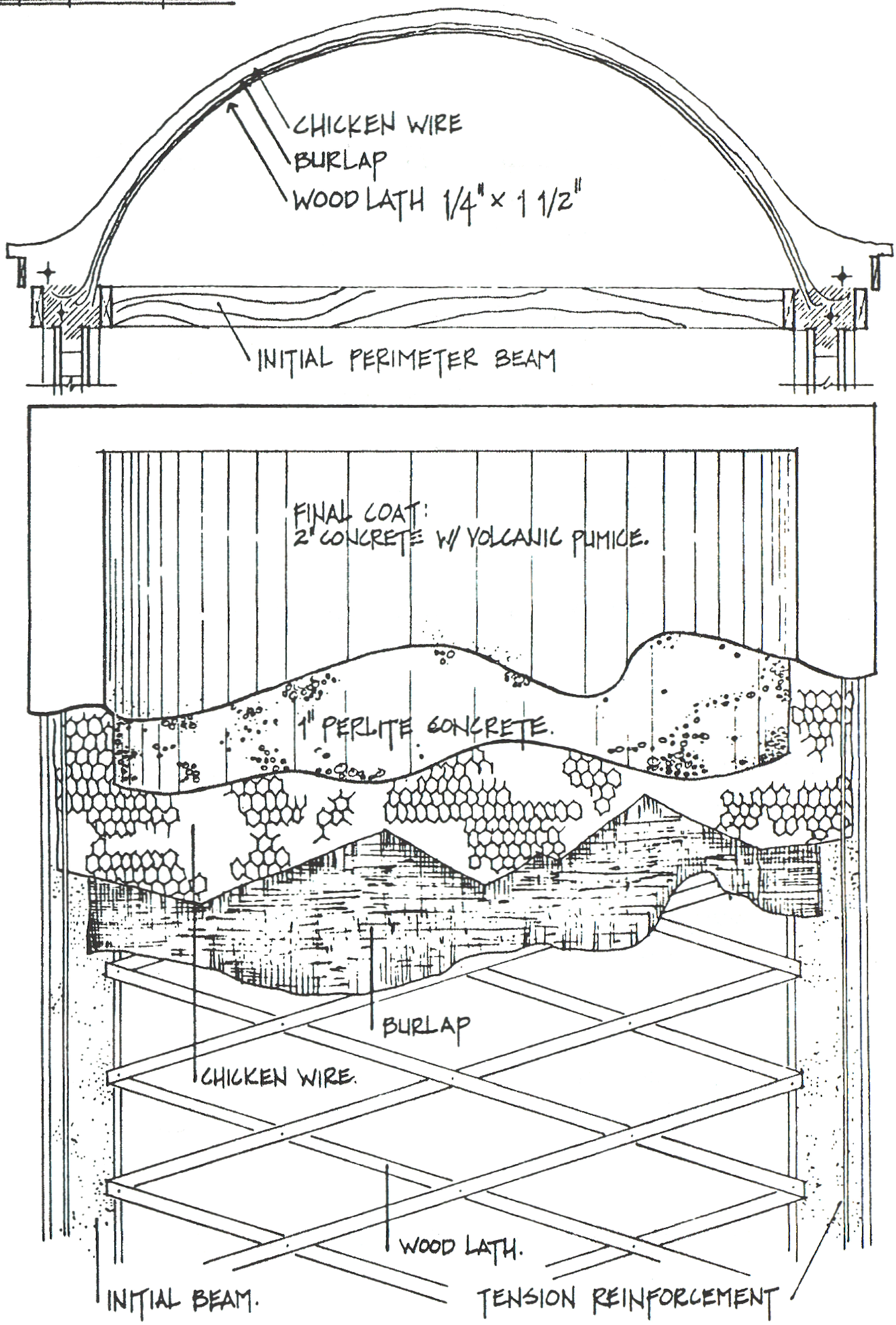


FORMING SEQUENCE:
2x6 LEVELED & HELD IN PLACE BY FLAT STEEL "O" PIECE.

1x4 FORMS BOTTOM OF BEAM AND IS STRIPPED AFTER POUR.



ROOF VAULTS.


CHICKEN WIRE
BURLAP
WOOD LATH 1/4" x 1 1/2"
INITIAL PERIMETER BEAM
FINAL COAT:
2" CONCRETE W/ VOLCANIC PUMICE.
1" PERLITE CONCRETE.
BURLAP
CHICKEN WIRE.
WOOD LATH.
INITIAL BEAM.
TENSION REINFORCEMENT

From that moment on, the *individual* buildings did not require building permits. The plans had to meet the following important conditions: (a) no clear span beam with the cross section specified in the operations could span more than six feet; and (b) no vault could span more than fifteen feet. But beyond that, the houses were built without specific permission being given to individual houses or to house plans. It was never necessary to go to the expense of having drawings made nor to run the risk of distorting the families' layouts by making drawings.

Each building in our process was therefore under construction within a few days of the time when it was first laid out!

Furthermore, we ourselves did not make any plan or drawing of any house at the time of its construction, even for our own use. To make a set of drawings would have been impossible, since each building was not known in detail until after it had actually been built. Also, the loss of time created by the drawing of plans and by the obtaining of permission would have killed the process stone dead.

It is essential to recognize that, as a precondition for its success, this process absolutely requires an agreement with the local government whereby permission is given to building operations, not to individual building plans.

THE PRODUCTION OF HOUSES

Christopher Alexander

with

Howard Davis

Julio Martinez

Donald Corner

Written with affection and respect for our apprentices in Mexico

Ramiro Ortuño
Julio Chavez
Emma Rivera
Gloria Hernandez
Donato Rechy
Jorge Torres
Enrique Ramirez
Javier Toscano

NEW YORK • OXFORD
OXFORD UNIVERSITY PRESS
1985