A PATTERN LANGUAGE

TOWNS · BUILDINGS · CONSTRUCTION

A Pattern Language is the second in a series of books which describe an entirely new attitude to architecture and planning. The books are intended to provide a complete working alternative to our present ideas about architecture, building, and planning—an alternative which will, we hope, gradually replace current ideas and practices.

volume 1 THE TIMELESS WAY OF BUILDING

volume 2 A PATTERN LANGUAGE

volume 3 THE OREGON EXPERIMENT

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A PATTERN LANGUAGE

TOWNS · BUILDINGS · CONSTRUCTION

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CONTENTS

USING THIS BOOK

CONSTRUCTION

At this stage, you have a complete design for an individual building. If you have followed the patterns given, you have a scheme of spaces, either marked on the ground, with stakes, or on a piece of paper, accurate to the nearest foot or so. You know the height of rooms, the rough size and position of windows and doors, and you know roughly how the roofs of the building, and the gardens are laid out.

The next, and last part of the language, tells you how to make a buildable building directly from this rough scheme of spaces, and tells you how to build it, in detail.

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The patterns in this last section present a physical attitude to construction that works together with the kinds of buildings which the second part of the pattern language generates. These construction patterns are intended for builders—whether professional builders, or amateur owner-builders.

Each pattern states a principle about structure and materials. These principles can be implemented in any number of ways when it comes time for actual building. We have tried to state various ways in which the principles can be built. But, partly because these patterns are the least developed, and partly because of the nature of building patterns, the reader will very likely have much to add to these patterns. For example, the actual materials used to implement them will vary greatly from region to region . . .

Perhaps the main thing to bear in mind, as you look over this material, is this: Our intention in this section has been to provide an alternative to the technocratic and rigid ways of building that have become the legacy of the machine age and modern architecture.

The way of building described here leads to buildings that are unique and tailored to their sites. It depends on builders taking responsibility for their work; and working out the details of the building as they go—mocking up entrances and windows and the dimensions of spaces, making experiments, and building directly according to the results.

The patterns in this section are unique in several ways.

First, the sequence of the patterns is more concrete than in any of the earlier portions of the language. It not only corresponds to the order in which a design matures *conceptually*, in the user's mind, but also corresponds to the actual physical order of construction. That is, except for the first four patterns, which deal with structural philosophy, the remaining patterns can actually be used, in the sequence given, to build a building. The sequence of the language corresponds almost exactly, to the actual sequence of operations on the building site. In addition, the patterns themselves in this section are both more concrete, and more abstract, than any other patterns in the language.

They are more concrete because, with each pattern, we have always given at least one interpretation which can be built directly. For instance, with the pattern ROOT FOUNDATION, we have given one particular interpretation, to show that it can be done, and also to give the reader an immediate, and practical, buildable approach to construction.

Yet at the same time, they are also more abstract. The particular concrete formulation which we have given for each pattern, can also be interpreted, and remade in a thousand ways. Thus, it is also possible to take the general idea of the pattern, the idea that the foundation functions like a tree root, in the way that it anchors the building in the ground—and invent a dozen entirely different physical systems, which all work in this fundamental way. In this sense, these patterns are more abstract than any others in the book, since they have a wider range of possible interpretations.

To illustrate the fact that a great variety of actual building systems can be developed, based on these patterns, we present three versions that we have developed, in response to different contexts.

In Mexico: Concrete block foundations with re-bar connectors; hollow self-aligning molded earth blocks reinforced with bamboo for walls and columns; burlap formed concrete beams; steep barrel vaults with earth and asphalt covering—everything whitewashed.

In Peru: Slab floors poured integrally with wall foundations; finished with soft baked tiles; hard wood (diablo fuerte) columns and beams; plaster on bamboo lath acting as shear walls between columns; diagonal wood plank ceiling/floors; bamboo lattice partitions.

In Berkeley: Concrete slab finished with colored wax; walls of exterior skin of 1 x boards and interior skin of gypboard filled with light weight concrete; box columns made of 1 x boards, filled with lightweight concrete; 2-inch concrete ceiling/floor vaults formed with wood lattice and burlap forms.

As you can see from these examples, we have formulated these patterns with very careful attention to cost. We have tried to give examples of these patterns which use the cheapest, and most easily available, materials; we have designed them in such a way that such buildings can be built by lay people (who can therefore avoid the cost of labor altogether); and we have designed it so that the cost of labor, if done professionally, is also low.

Of the three parts of the language, this third part is the least developed. Both the part on *Towns* and the part on *Buildings* have been tested, one partially, the other very thoroughly, in practice. This third part has so far only been tested in a small number of relatively minor buildings. That means, obviously, that this material needs a good deal of improvement.

However, we intend, as soon as possible, to test all these patterns thoroughly in various different buildings —houses, public buildings, details, and additions. Once again, as soon as we have enough examples to make it worth reporting on them, we shall publish another volume which describes them, and our findings.

In many ways, rough though it is, this is the most exciting part of the language, because it is here, in these few patterns, that we can most vividly see a building literally grow before our eyes, under the impact of the patterns.

The actual process of construction, in which the sequence of their patterns creates a building, is described in chapter 23 of *The Timeless Way*.

Before you lay out construction details, establish a philosophy of structure which will let the structure grow directly from your plans and your conception of the buildings.

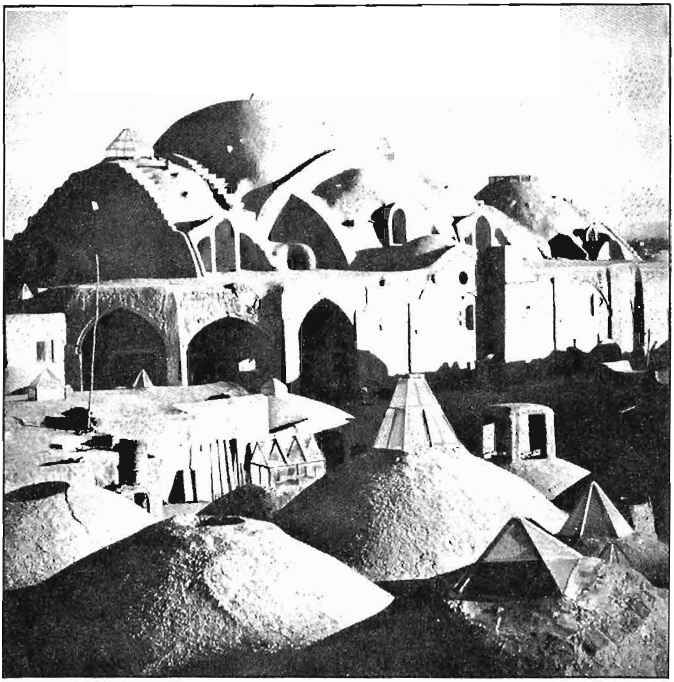
205. STRUCTURE FOLLOWS SOCIAL SPACES

206. EFFICIENT STRUCTURE

207. GOOD MATERIALS

208. GRADUAL STIFFENING

205 STRUCTURE FOLLOWS SOCIAL SPACES**



. . . if you have used the earlier patterns in the language, your plans are based on subtle arrangements of social spaces. But the beauty and subtlety of all these social spaces will be destroyed, when you start building, unless you find a way of building which is able to follow the social spaces without distorting or re-arranging them for engineering reasons.

This pattern gives you the beginning of such a way of building. It is the first of the 49 patterns which deal specifically with structure and construction; it is the bottleneck through which all languages pass from the larger patterns for rooms and building layout to the smaller ones which specify the process of construction. It not only has its own intrinsic arguments about the relation between social spaces and load-bearing structure—it also contains, at the end, a list of all the connections which you need for patterns on structure, columns, walls, floors, roofs, and all the details of construction.

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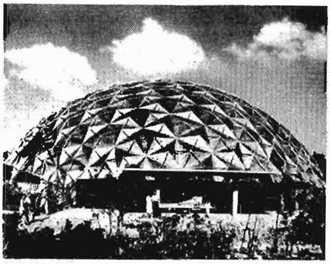
No building ever feels right to the people in it unless the physical spaces (defined by columns, walls, and ceilings) are congruent with the social spaces (defined by activities and human groups).

And yet this congruence is hardly ever present in modern construction. Most often the physical and social spaces are incongruent. Modern construction—that is, the form of construction most commonly practiced in the mid-twentieth century—usually forces social spaces into the framework of a building whose shape is given by engineering considerations.

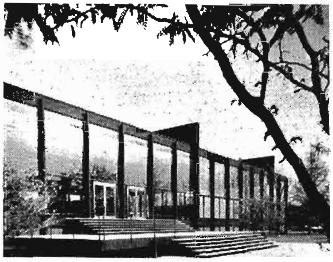
There are two different versions of this incongruence.

On the one hand, there are those buildings whose structural form is very demanding indeed and actually forces the social space to follow the shape of the construction—Buckminster Fuller domes, hyperbolic paraboloids, tension structures are examples.

On the other hand, there are those buildings in which there are very few structural elements—a few giant columns and no



Geodesic dome.

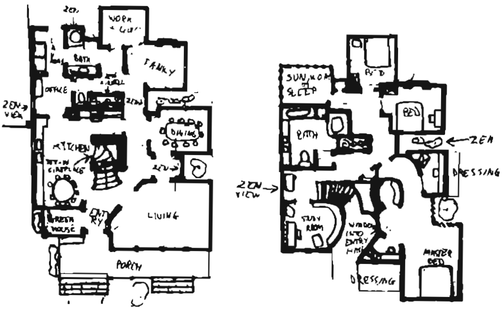


Steel and glass.

more. In these buildings the social spaces are defined by lightweight nonstructural partitions floating free within the "neutral" physical structure given by the engineering. The buildings of Mies van der Rohe and Skidmore Owings and Merrill are examples.

We shall now argue that both these kinds of incongruence do fundamental damage—for entirely different reasons.

In the first case the structure does damage simply because it constrains the social space and makes it different from what it naturally wants to be. To be specific: we know from our experiments that people are able to use this pattern language to design buildings for themselves; and that the plans they create, unhampered by other considerations, have an astonishing range of free arrangements, always finely tuned to the details of their lives and habits.



User's house plan.

Any form of construction which makes it impossible to implement these plans and forces them into the strait jacket of an alien geometry, simply for structural reasons, is doing social damage.

Of course, it could be argued that the structural needs of a building are as much a part of its nature as the social and psychological needs of its inhabitants. This argument might perhaps, perhaps, hold water if there were indeed no way of building buildings which conform more exactly to the loose plans based on activities alone.

But the next few patterns in this book make it very clear that there do exist ways of building which are structurally sound and yet perfectly congruent with social space, without any compromise whatever. It is therefore clear that we may legitimately reject any form of construction which cannot adapt itself perfectly to the forms of space required by social action.

What of the second kind of incongruence between social space and building form—the kind where the structure creates huge areas of almost uninterrupted "flexible" space, punctuated by occasional columns, and the social spaces are created inside this framework by nonstructural partitions.

Once again, many important patterns cannot be incorporated into the design—LIGHT ON TWO SIDES OF EVERY ROOM (159), for example simply cannot be included in a giant rectangle. But in this type of building, there is an additional kind of incongruence between social space and engineering structure which comes from the fact that the two are virtually independent of each other. The engineering follows its own laws, the social space follows its laws—and they do not match.

This mismatch is perceived and felt not merely as a mismatch, but as a fundamental and disturbing incoherence in the fabric of the building, which makes people feel uneasy and unsure of themselves and their relation to the world. We offer four possible explanations.

First: the spaces called for by the patterns dealing with social and psychological needs are critical. If the spaces are not right, the needs are not met and problems are not solved. Since these spaces are so critical, it stands to reason that they must be felt as real spaces, not flimsily or haphazardly partitioned spaces, which only pay lip-service to the needs people experience. For instance, if an entrance room is created with flimsy partitions, it will not take hold; people won't take it seriously. Only when the most solid elements of the building form the spaces will the spaces be fully felt and the needs which call for the space then fully be satisfied.

Second: a building will also seem alien unless it gives to its users a direct and intuitive sense of its structure—how it is put together. Buildings where the structure is hidden leave yet another gap in people's understanding of the environment around them. We know this is important to children and suspect it must be important to adults too.

Third: when the social space has, as its own surrounding, the fabric of the load-bearing structure which supports that space, then the forces of gravity are integrated with the social forces, and one feels the resolution of *all* the forces which are acting in this one space. The experience of being in a place where the forces are resolved together at once is completely restful and whole. It is like sitting under an oak tree: things in nature resolve all the forces acting on them together: they are, in this sense, whole and balanced.

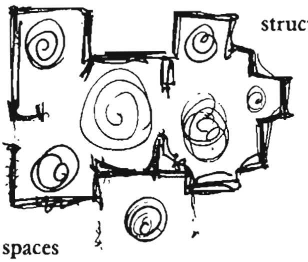
Fourth: it is a psychological fact that a space is defined by its corners. Just as four dots define a rectangle to your eye, so four posts (or more) define an imaginary space between them.

Four points make a rectangle.

This is the most fundamental way in which solids define space. Unless the actual solids which make up the building lie at the corners of its social spaces, they must, instead, be creating *other* virtual spaces at odds with the intended ones. The building will only be at rest psychologically if the corners of its rooms are clearly marked and coincide, at least in the majority of cases, with its most solid elements.

Therefore:

A first principle of construction: on no account allow the engineering to dictate the building's form. Place the load bearing elements—the columns and the walls and floors—according to the social spaces of the building; never modify the social spaces to conform to the engineering structure of the building.



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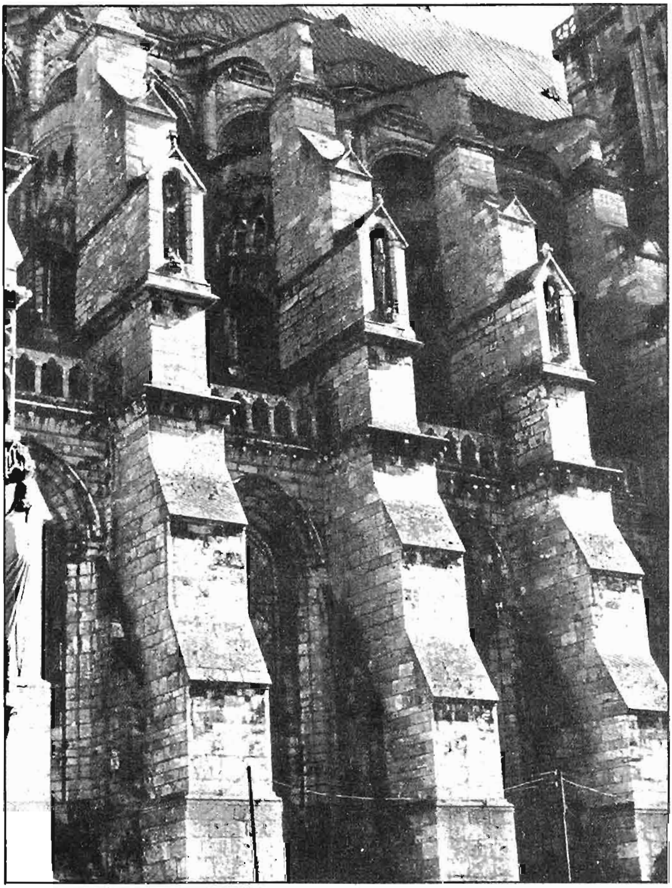
You will be able to guarantee that structure follows social spaces by placing columns at the corner of every social space—COLUMNS AT THE CORNERS (212); and by building a distinct and separate vault over each room and social space—FLOOR-CEILING VAULTS (219).

For the principles of structure which will make it possible to build your building according to this pattern, begin with EFFICIENT STRUCTURE (206); for the class of compatible materials, see GOOD MATERIALS (207); for the fundamentals of the process of construction, see GRADUAL STIFFENING (208). . . .

206 EFFICIENT STRUCTURE*



. . . this pattern complements the pattern STRUCTURE FOLLOWS SOCIAL SPACES (205). Where that pattern defines the relationship between the social spaces and the structure, this pattern lays down the kind of structure which is dictated by pure engineering. As you will see, it is compatible with STRUCTURE FOLLOWS SOCIAL SPACES, and will help to create it.

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Some buildings have column and beam structures; others have load-bearing walls with slab floors; others are vaulted structures, or domes, or tents. But which of these, or what mixture of them, is actually the most efficient? What is the best way to distribute materials throughout a building, so as to enclose the space, strongly and well, with the least amount of material?

Engineers usually say that there is no answer to this question. According to current engineering practice it is first necessary to make an arbitrary choice among the basic possible systems—and only then possible to use theory and calculation to fix the size of members within the chosen system. But, the basic choice itself—at least according to prevailing dogma—cannot be made by theory.

To anyone with an enquiring mind, this seems quite unlikely. That such a fundamental choice, as the choice between column and beams systems and load-bearing wall systems and vaulted systems, should lie purely in the realm of whim—and that the possible myriad of mixed systems, which lie between these archetypes, cannot even be considered—all this has more to do with the status of available theory than with any fundamental insight.

Indeed, as we shall now try to show, the archetypal, best solution to the problem of efficient structure in a building is one which does lie in between the three most famous archetypes. It is a system of load-bearing walls, supported at frequent intervals by thickened stiffeners like columns, and floored and roofed by a system of vaults.

We shall derive the character of the most efficient structure in three steps. First, we shall define the three-dimensional character of a typical system of rooms and spaces in a building. We shall then define an efficient structure as the smallest cheapest amount of stable material, placed only in the interstices between the rooms, which can support itself and the loads which the rooms generate. Finally, we shall obtain the details of an efficient structure. For a similar discussion, see Christopher Alexander, "An attempt to derive the nature of a human building system from first principles," in Edward Allen, *The Responsive House*, M.I.T. Press, 1974.

I. The three-dimensional character of a typical building based purely on the social spaces and the character of rooms.

In order to obtain this from fundamental considerations, let us first review the typical shape of rooms—see THE SHAPE OF INDOOR SPACE (191)—and then go on to derive the most efficient structure for a building made up of these kinds of rooms:

1. The boundary of any space, seen in plan, is formed by segments which are essentially straight lines—though they need not be perfectly straight.

2. The ceiling heights of spaces vary according to their social functions. Roughly speaking, the ceiling heights vary with floor areas—large spaces have higher ceilings, small ones lower—CEILING HEIGHT VARIETY (190).

3. The edges of the space are essentially vertical up to head height—that is, about 6 feet. Above head height, the boundaries of the space may come in toward the space. The upper corners between wall and ceiling of a normal room serve no function, and it is therefore not useful to consider them as an essential part of the space.

4. Each space has a horizontal floor.

5. A building then is a packing of polygonal spaces in which each polygon has a beehive cross section, and a height which varies according to its size.

If we follow the principle of STRUCTURE FOLLOWS SOCIAL SPACES (205), we may assume that this three-dimensional array of spaces must remain intact, and not be interrupted by structural

A packing of polygonal beehive spaces.

elements. This means that an efficient structure must be one of the arrangements of material which occupies only the interstices between the spaces.

We may visualize the crudest of these possible structures by means of a simple imaginary process. Make a lump of wax for each of the spaces which appears in the building, and construct a three-dimensional array of these lumps of wax, leaving gaps between all adjacent lumps. Now, take a generalized "structure fluid," and pour it all over this arrangements of lumps, so that it completely covers the whole thing, and fills all the gaps. Let this fluid harden. Now dissolve out the wax lumps that represent spaces. The stuff which remains is the most generalized building structure.

II. The most efficient structure for a given system of spaces.

Obviously, the imaginary structure made from the structure fluid is not real. And besides, it is rather inefficient: it would, if actually carried out, use a great deal of material. We must now ask how to make a structure, similar to this imaginary one, but one which uses the smallest amount of material. As we shall see, this most efficient structure will be *a compression structure*, in which bending and tension are reduced to a minimum and *a continuous structure*, in which all members are rigidly connected in such a way that each member carries at least some part of the stresses caused by any pattern of loading.

1. *A compression structure.* In an efficient structure, we want every ounce of material to be working to its capacity. In more precise terms, we want the stress distributed throughout the materials in such a way that every cubic inch is stressed to the same degree. This is not happening, for example, in a simple wooden beam. The material is most stressed at the top and bottom

of the beam; the middle of the beam has only very low stresses, because there is too much material there relative to the stress distribution.

As a general rule, we may say that members which are in bending always have uneven stress distributions and that we can therefore only distribute stresses evenly throughout the materials if the structure is entirely free of bending. In short, then, a perfectly efficient structure must be free of bending.

There are two possible structures which avoid bending altogether: pure tension structures and pure compression structures. Although pure tension structures are theoretically interesting and suitable for occasional special purposes, the considerations described in GOOD MATERIALS (207) rule them out overwhelmingly on the grounds that tension materials are hard to obtain, and expensive, while almost all materials can resist compression. Note especially that wood and steel, the two principle tension materials in buildings, are both scarce, and can—on ecological grounds—no longer be used in bulk—again, see GOOD MATERIALS (207).

2. *A continuous structure.* In an efficient structure, it is not only true that individual elements have even stress distributions in them when they are loaded. It is also true that the structure acts as a whole.

Consider, for example, the case of a basket. The individual strands of the basket are weak. By itself no one strand can resist much load. But the basket is so cunningly made, that all the strands work together to resist even the smallest load. If you press on one part of the basket with your finger, all the strands in the basket—even those in the part furthest from your finger—work together to resist the load. And of course, since the whole structure works as one, to resist the load, no one part has, individually, to be very strong.

This principle is particularly important in a structure like a building, which faces a vast range of different loading conditions. At one minute, the wind is blowing very strong in one direction; at another moment an earthquake shakes the building; in later years, uneven settlement redistributes dead loads because some foundations sink lower than others; and, of course, throughout its life the people and furniture in the building are moving all the time. If each element is to be strong enough, by itself, to resist the maximum load it can be subjected to, it will have to be enormous.

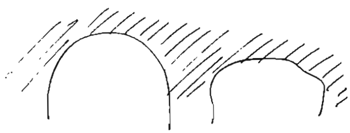
But when the building is continuous, like a basket, so that each part of the building helps to carry the smallest load, then, of course, the unpredictable nature of the loads creates no difficulties at all. Members can be quite small, because no matter what the loads are, the continuity of the building will distribute them among the members as a whole, and the building will act as a whole against them.

The continuity of a building depends on its connections: actual continuity of material and shape. It is very hard, almost impossible, to make continuous connections between different materials, which transfer load as efficiently as a continuous material; and it is therefore essential that the building be made of one material, which is actually continuous from member to member. And the shape of the connections between elements is vital too. Right angles tend to create discontinuities: forces can be distributed throughout the building only if there are diagonal fillets wherever walls meet ceilings, walls meet walls, and columns meet beams.

III. The details of an efficient structure.

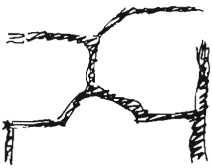
If we assume now that an efficient building will be both compressive and continuous, we can obtain the main morphological features of its structure by direct inference.

1. Its ceilings, floors, and rooms must all be vaulted. This follows directly. The dome or vault shape is the only shape which works in pure compression. Floors and roofs can only be continuous with walls, if they curve downward at their edges. And the shape of social spaces also invites it directly—since the triangle of space between the wall and ceiling serves no useful purpose, it is a natural place for structural material.



Vaults.

3. Walls must all be load-bearing. Any non load-bearing partition evidently contradicts the principle of continuity which says that every particle of the building is helping to resist loads. Furthermore, columns with non load-bearing partitions between them need shear support. The wall provides it naturally; and the continuity of the walls, floor, and ceiling can only be created by the action of a wall that ties them together.



Load-bearing walls.

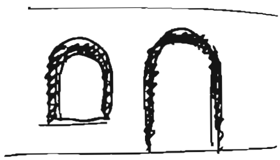
3. *Walls must be stiffened at intervals along their length by columnar ribs.* If a wall is to contain a given amount of material, then the wall acts most efficiently when its material is redistributed, nonhomogeneously, to form vertical ribs. This wall is most efficient in resisting buckling—indeed, at most thicknesses this kind of stiffening is actually *required* to let the wall act at its full compressive capacity—see FINAL COLUMN DISTRIBUTION (213). And it helps to resist horizontal loads, because the stiffeners act as beams against the horizontal forces.

Vertical stiffeners.

4. *Connections between walls and floors, and between walls and walls, must all be thickened by extra material that forms a fillet along the seam.* Connections are the weakest points for continuity, and right-angled connections are the worst. However, we know from THE SHAPE OF INDOOR SPACE (191) that we cannot avoid rough right angles where walls meet walls; and of course, there must be rough right angles where walls meet floors. To counteract the effect of the right angle, it is necessary to "fill" the angle with material. This principle is discussed under COLUMN CONNECTIONS (227).

Thickened connections.

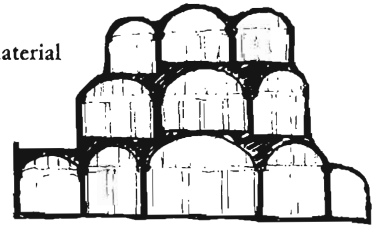
5. *Openings in walls must have thickened frames, and rounding in the upper corners.* This follows directly from the principle of continuity and is fully discussed in FRAMES AS THICKENED EDGES (225).



Openings.

Therefore:

Conceive the building as a building made from one continuous body of compressive material. In its geometry, conceive it as a three-dimensional system of individually vaulted spaces, most of them roughly rectangular; with thin load-bearing walls, each stiffened by columns at intervals along its length, thickened where walls meet walls and where walls meet vaults and stiffened around the openings.



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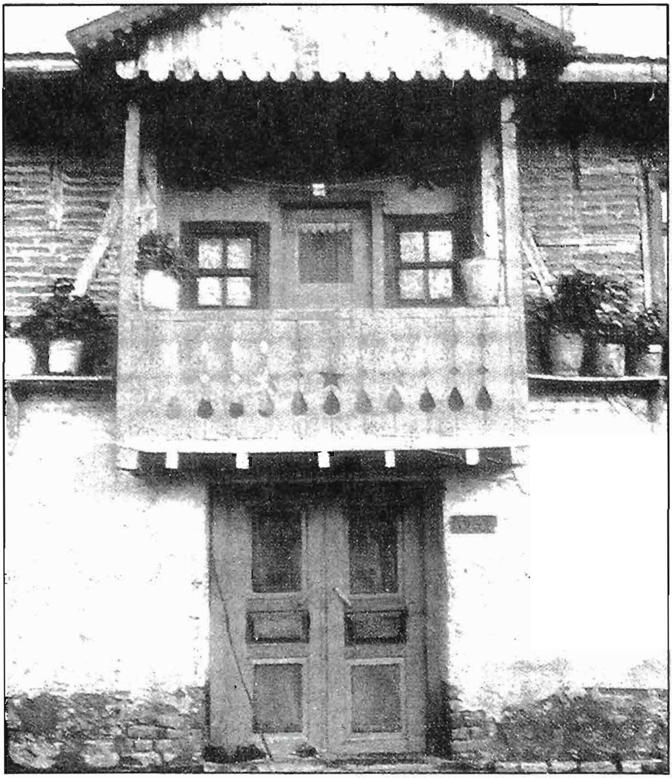
The layout of the inner vaults is given in FLOOR AND CEILING LAYOUT (210) and FLOOR-CEILING VAULTS (219); the layout of the outer vaults which form the roof is given in ROOF LAYOUT (209) and ROOF VAULTS (220). The layout of the stiffeners which make the walls is given in FINAL COLUMN DISTRIBUTION (213); the layout of the thickening where walls meet walls is given by COLUMNS AT THE CORNERS (212); the thickening where walls meet vaults is given by PERIMETER BEAMS (217); the construction of the columns and the walls is given by BOX COLUMNS (216) and WALL MEMBRANES (218); the thickening of doors and window frames is given by FRAMES AS THICKENED EDGES (225); and the non-right-angled connection between columns and beams by COLUMN CONNECTION (227). . . .

207 GOOD MATERIALS**



. . . the principles of structure allow you to imagine a building in which materials are distributed in the most efficient way, congruent with the social spaces given by the plan—STRUCTURE FOLLOWS SOCIAL SPACES (205), EFFICIENT STRUCTURE (206). But of course the structural conception is still only schematic. It can only become firm and cogent in your mind when you know what materials the building will be made of. This pattern helps you settle on materials.

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There is a fundamental conflict in the nature of materials for building in industrial society.

On the one hand, an organic building requires materials which consist of hundreds of small pieces, put together, each one of them hand cut, each one shaped to be unique according to its position. On the other hand, the high cost of labor, and the ease of mass production, tend to create materials which are large, identical, not cuttable or modifiable, and not adaptable to idiosyncracies of plan. These "modern" materials tend to destroy the organic quality of natural buildings and, indeed, to make it impossible. In addition, modern materials tend to be flimsy and hard to maintain—so that buildings deteriorate more rapidly than in a pre-industrial society where a building can be maintained and improved for hundreds of years by patient attention.

The central problem of materials, then, is to find a collection of materials which are small in scale, easy to cut on site, easy to work on site without the aid of huge and expensive machinery, easy to vary and adapt, heavy enough to be solid, longlasting or easy to maintain, and yet easy to build, not needing specialized labor, not expensive in labor, and universally obtainable and cheap.

Furthermore, this class of good materials must be ecologically sound: biodegradable, low in energy consumption, and not based on depletable resources.

When we take all these requirements together, they suggest a rather startling class of "good materials"—quite different from the materials in common use today. The following discussion is our attempt to begin to define this class of materials. It is certainly incomplete; but perhaps it can help you to think through the problem of materials more carefully.

We start with what we call "bulk materials"—the materials that occur in the greatest volume in a given building. They may account for as much as 80 per cent of the total volume of materials used in a building. Traditionally, bulk materials have been earth, concrete, wood, brick, stone, snow. . . . Today the bulk materials are essentially wood and concrete and, in the very large buildings, steel.

When we analyze these materials strictly, according to our criteria, we find that stone and brick meet most of the requirements, but are often out of the question where labor is expensive, because they are labor intensive.

Wood is excellent in many ways. Where it is available people use it in great quantities, and where it is not available people are trying to get hold of it. Unfortunately the forests have been terribly managed; many have been devastated; and the price of heavy lumber has skyrocketed. From today's paper: "Since the end of federal economic controls the price of lumber has been jumping about 15 percent a month and is now about 55 percent above what it was a year ago." *San Francisco Chronicle*, February 11, 1973. We shall therefore look upon wood as a precious material, which should not be used as a bulk material or for structural purposes.

Steel as a bulk material seems out of the question. We do not need it for high buildings since they do not make social sense—FOUR-STORY LIMIT (21). And for smaller buildings it is expensive, impossible to modify, high energy in production.

Earth is an interesting bulk material. But it is hard to stabilize, and it makes incredibly heavy walls because it has to be so thick. Where this is appropriate, and where the earth is available, however, it is certainly one of the "good materials."

Regular concrete is too dense. It is heavy and hard to work. After it sets one cannot cut into it, or nail into it. And its surface is ugly, cold, and hard in feeling, unless covered by expensive finishes not integral to the structure.

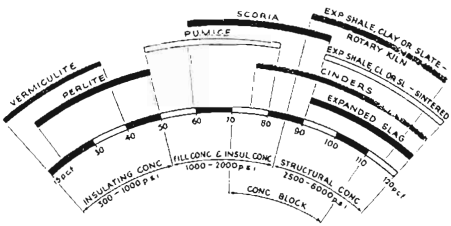
And yet concrete, in some form, is a fascinating material. It is fluid, strong, and relatively cheap. It is available in almost every part of the world. A University of California professor of engineering sciences, P. Kumar Mehta, has even just recently found a way of converting abandoned rice husks into Portland cement.

Is there any way of combining all these good qualities of concrete and also having a material which is light in weight, easy to work, with a pleasant finish? *There is. It is possible to use a whole range of ultra-lightweight concretes which have a density and compressive strength very similar to that of wood. They are easy to work with, can be nailed with ordinary nails, cut with a saw, drilled with wood-working tools, easily repaired.*

We believe that ultra-lightweight concrete is one of the most fundamental bulk materials of the future.

To make this as clear as possible, we shall now discuss the range of lightweight concretes. Our experiments lead us to believe that the best lightweight concretes, the ones most useful for building, are those whose densities lie in the range of 40 to 60 pounds per cubic foot and which develop some 600 to 1000 psi in compression.

Oddly enough, this particular specification lies in the least developed part of the presently available range of concretes. As we can see from the following diagram, the so-called "structural" concretes are usually more dense (at least 90 pounds per cubic foot) and much stronger. The most common "lightweight" concretes use vermiculite as an aggregate, are used for underflooring and insulation, and are very light, but they do not usually develop enough strength to be structurally useful—most



Currently available concrete mixes.

often about 300 psi in compression. However, a range of mixed lightweight aggregates, containing vermiculite, perlite, pumice, and expanded shale in different proportions, can easily generate 40–60 pound, 600 psi concretes anywhere in the world. We have had very good luck with a mix of 1-2-3: cement-kylite-vermiculite.

Beyond the bulk materials, there are the materials used in relatively smaller quantities for framework, surfaces, and finishes. These are the "secondary" materials.

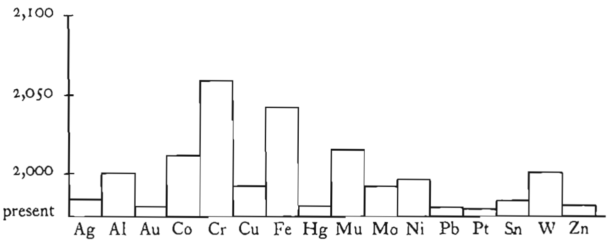
When buildings are built with manageable secondary materials, they can be repaired with the same materials: repair becomes continuous with the original building. And the buildings are more apt to be repaired if it is easy to do so and if the user can do it himself bit by bit without having to rely on skilled workers or special equipment. With prefabricated materials this is impossible, the materials are inherently unrepairable. When prefabricated finish materials are damaged they must be replaced with an entirely new component.

Take the case of a garden patio. It can be made as a continuous concrete slab. When the ground shifts slightly underneath this slab, the slab cracks and buckles. This is quite unrepairable for the user. It requires that the entire slab be broken out (which requires relatively heavy-duty equipment) and replaced—by professional skilled labor. On the other hand, it would have been possible to build the patio initially out of many small bricks, tiles, or stones. When the ground shifts, the user is then able to lift up the broken tiles, add some more earth, and replace the tile—all without the aid of expensive machinery or professional help. And if one of the tiles or bricks becomes damaged, it can be easily replaced.

What are the good secondary materials? Wood, which we want to avoid as a bulk material, is excellent as a secondary material for doors, finishes, windows, furniture. Plywood, particle board, and gypsum board can all be cut, nailed, trimmed, and are relatively cheap. Bamboo, thatch, plaster, paper, corrugated metals, chicken wire, canvas, cloth, vinyl, rope, slate, fiberglass, nonchlorinated plastics are all examples of secondary materials which do rather well against our criteria. Some are dubious ecologically—that is, the fiberglass and the corrugated metals—but again, these sheet materials need only be used in moderation, to form and finish and trim the bulk materials.

Finally, there are some materials which our criteria exclude entirely—either as bulk or secondary materials. They are expensive, hard to adapt to idiosyncratic plans, they require high energy production techniques, they are in limited reserves. . . . for example: steel panels and rolled steel sections; aluminum; hard and prestressed concrete; chlorinated foams; structural lumber; cement plaster; immense sections of plate glass. . . .

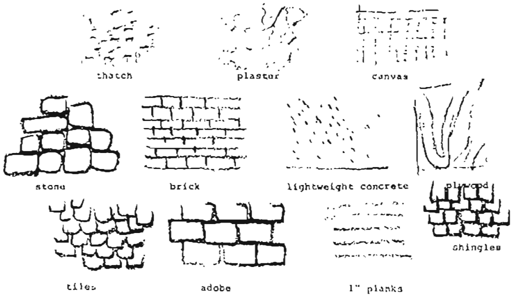
And, for any optimist who thinks he can go on using steel reinforcing bars forever—consider the following fact. Even iron, abundant as it is all over the earth's surface, is a depletable resource. If consumption keeps growing at its present rate of increase (as it very well may, given the vast parts of the world not yet using resources at American and western consumption levels), the resources of iron will run out in 2050.



Years at which various metals will be depleted assuming current usage rate continues to increase as it did between 1960 and 1968.

Therefore:

Use only biodegradable, low energy consuming materials, which are easy to cut and modify on site. For bulk materials we suggest ultra-lightweight 40–60 lbs. concrete and earth-based materials like tamped earth, brick, and tile. For secondary materials, use wood planks, gypsum, plywood, cloth, chickenwire, paper, cardboard, particle board, corrugated iron, lime plasters, bamboo, rope, and tile.



ultra-light weight concrete or organic or earth-based materials

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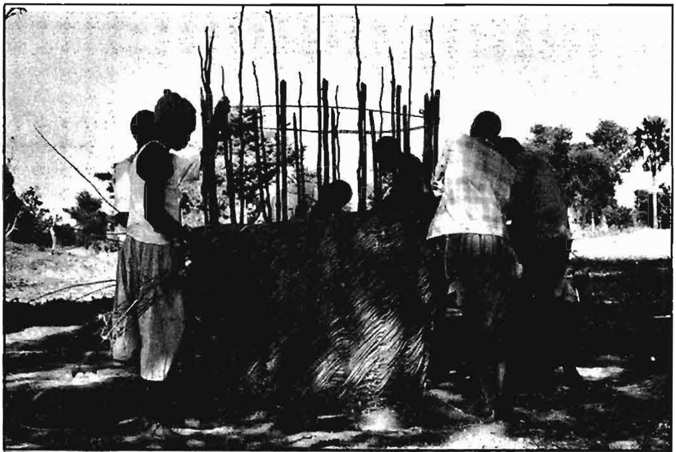
In GRADUAL STIFFENING (208), we shall work out the way of using these materials that goes with STRUCTURE FOLLOWS SOCIAL SPACES (205) and EFFICIENT STRUCTURE (206). Try to use the materials in such a way as to allow their own texture to show themselves—LAPPED OUTSIDE WALLS (234), SOFT INSIDE WALLS (235). . . .

208 GRADUAL STIFFENING**



. . . in STRUCTURE FOLLOWS SOCIAL SPACES (205) and EFFICIENT STRUCTURE (206) we have set down the beginnings of a philosophy, an approach, to construction. GOOD MATERIALS (207) tells us something about the materials we ought to use in order to meet human and ecological demands. Now, before we start the practical task of making a structural layout for a building, it is necessary to consider one more philosophical pattern: one which defines the process of construction that will make it possible to use the right materials and get the overall conception of the structure right.

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The fundamental philosophy behind the use of pattern languages is that buildings should be uniquely adapted to individual needs and sites; and that the plans of buildings should be rather loose and fluid, in order to accommodate these subtleties.

This requires an entirely new attitude toward the process of construction. We may define this attitude by saying that it is desirable to build a building in such a way that it starts out loose and flimsy while final adaptations in plan are made, and then gets stiffened gradually during the process of construction, so that each additional act of construction makes the structure sounder.

To understand this philosophy properly, it is helpful to imagine a building being made like a basket. A few strands are put in place. They are very flimsy. Other strands are woven in. Gradually the basket gets stiffer and stiffer. Its final structural strength is only reached from the cooperation of all the members, and is not reached until the building is completely finished. In this sense, such a process produces a building in which all parts of it are working structurally—see EFFICIENT STRUCTURE (206).

Why does the principle of gradual stiffening seem so sensible as a *process* of building?

To begin with, such a structure allows the actual building process to be a creative act. It allows the building to be built up gradually. Members can be moved around before they are firmly in place. All those detailed design decisions which can never be worked out in advance on paper, can be made during the building process. And it allows you to see the space in three dimensions as a whole, each step of the way, as more material is added.

This means that since each new material that is added in the process must adapt perfectly to the framework that is there, each new material must be more adaptable, more flexible, more capable of coping with variation, than the last. Thus, though the building as a whole goes from flimsy to strong, the actual materials that are added go from the strongest and stiffest, to the gradually less stiff, until finally fluid materials are added.

The essence of this process is very fundamental indeed. We may understand it best by comparing the work of a fifty-year-old carpenter with the work of a novice. The experienced carpenter keeps going. He doesn't have to keep stopping, because every action he performs, is calculated in such a way that some later action can put it right to the extent that it is imperfect now. What is critical here, is the sequence of events. The carpenter never takes a step which he cannot correct later; so he can keep working, confidently, steadily.

The novice, by comparison, spends a great deal of his time trying to figure out what to do. He does this essentially because he knows that an action he takes now may cause unretractable problems a little further down the line; and if he is not careful, he will find himself with a joint that requires the shortening of some crucial member—at a stage when it is too late to shorten that member. The fear of these kinds of mistakes forces him to spend hours trying to figure ahead: and it forces him to work as far as possible to exact drawings because they will guarantee that he avoids these kinds of mistakes.

The difference between the novice and the master is simply that the novice has not learnt, yet, how to do things in such a way that he can afford to make small mistakes. The master knows that the sequence of his actions will always allow him to cover his mistakes a little further down the line. It is this simple but essential knowledge which gives the work of a master carpenter its wonderful, smooth, relaxed, and almost unconcerned simplicity.

In a building we have exactly the same problem, only greatly magnified. Essentially, most modern construction has the character of the novice's work, not of the master's. The builders do not know how to be relaxed, how to deal with earlier mistakes by later detailing; they do not know the proper sequence of events; and they do not, usually, have a building system, or a construction process, which allows them to develop this kind of relaxed and casual wisdom. Instead, like the novice, they work exactly to finely detailed drawings; the building is extremely uptight as it gets made; any departure from the exact drawings is liable to cause severe problems, may perhaps make it necessary to pull out whole sections of the work.

This novice-like and panic-stricken attention to detail has two very serious results. First, like the novice, the architects spend a great deal of time trying to work things out ahead of time, not smoothly building. Obviously, this costs money; and helps create these machine-like "perfect" buildings. Second, a vastly more serious consequence: the details control the whole. The beauty and subtlety of the plan in which patterns have held free sway over the design suddenly becomes tightened and destroyed because, in fear that details won't work out, the details of connections, and components, are allowed to control the plan. As a result, rooms get to be slightly the wrong shape, windows go out of position, spaces between doors and walls get altered just enough to make them useless. In a word, the whole character of modern architecture, namely the control of larger space by piddling details of construction, takes over.

What is needed is the opposite—a process in which details are fitted to the whole. This is the secret of the master carpenter; it is described in detail in *The Timeless Way of Building* as the foundation of all organic form and all successful building. The process of gradual stiffening, which we describe here, is the physical and procedural embodiment of this essential principle. We now ask how, in practice, it is possible to create a gradually stiffened structure within the context defined by the pattern GOOD MATERIALS (207).

Facts about materials give us the starting point we need.

1. Sheet materials are easy to produce and make the best connections.

In traditional society there are few sheet materials. However, factory production tends to make sheets more easily than other forms of material. As we move into an age of mass production, sheet materials become plentiful and are naturally strong, light, and cheap. Gypsum board, plywood, cloth, vinyl, canvas, fiberglass, particle board, wood planks, corrugated metals, chicken wire, are all examples.

And sheet materials are the strongest for connections. Connections are the weak points in a structure. Sheet materials are easy to connect, because connections can join surfaces to one another. Anything made out of sheets is inherently stronger than something made of lumps or sticks.

2. *Ultra-lightweight concrete is an excellent fill material—it has the density of wood, is strong, light, easy to cut, easy to repair, easy to nail into—and is available everywhere.* This is discussed fully in GOOD MATERIALS (207).

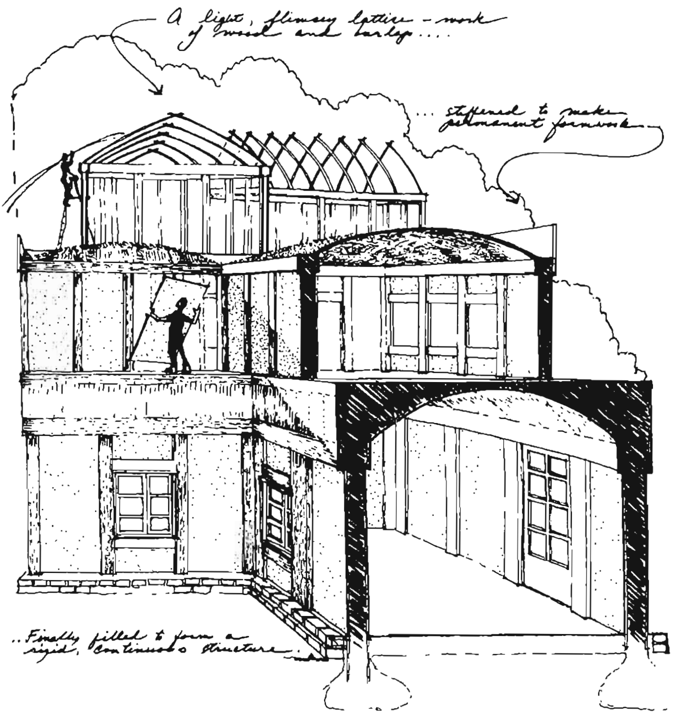
3. *However, any kind of concrete needs formwork: and the cost of formwork is enormous.*

This makes it very expensive indeed to build any complex form; and within conventional building systems, it more or less rules out the kind of "organic" structure which we have described. Furthermore, in regular concrete work, the formwork is eventually wasted, thrown away.

We believe that the finishes in any sensible building system should be integral with the process of construction and the structure itself (as they are in almost all traditional buildings)—and that any building system in which finishes have to be "added" to the building are wasteful, and unnatural.

4. *We therefore propose that ultra-lightweight concrete be poured into forms which are made of the easily available sheet materials: and that these materials are then left in place to form the finish.*

The sheet materials can be any combination of cloth, canvas, wood planks, gypsum boards, fiberboards, plywood, paper, plastered chickenwire, corrugated metals, and where it is possible, tile, brick, or stone—see GOOD MATERIALS (207). For the ultra-lightweight concrete we recommend a perlite, expanded shale, or pumice aggregate. Tamped earth, adobe, nonchlorinated foams, may also do instead of the concrete, if loads allow it.



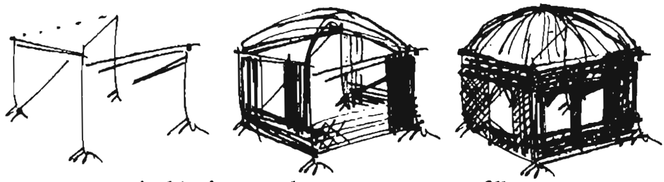
One version of gradual stiffening, using one inch planks, gypsum board and burlap as sheets, with ultra-lightweight concrete as fill.

The drawing above, shows one particular realisation of this kind of gradual stiffening. But the principle is far more general than this particular use of it. Indeed, it occurs, in one way or another, in almost all traditional forms of building. Eskimo igloo construction and African basket structures are both gradually stiffened structures, where each next step copes with the existing framework, adds to it, and stiffens it. The stone buildings of Alberobello in southern Italy are examples. So is Elizabethan half-timber construction.

Therefore:

Recognize that you are not assembling a building from components like an erector set, but that you are instead weaving a structure which starts out globally complete, but flimsy; then gradually making it stiffer but still rather flimsy; and only finally making it completely stiff and strong.

We believe that in our own time, the most natural version of this process is to put up a shell of sheet materials, and then make it fully strong by filling it with a compressive fill.



soft skin formwork **compressive fill**

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Choose the most natural materials you can, for the outer shell itself—thin wood planks for columns, canvas or burlap for the vaults, plaster board or plank or bricks or hollow tiles for walls—GOOD MATERIALS (207).

Use ultra-lightweight 40 to 60 pounds perlite concrete for the compressive fill—it has the same density as wood and can be cut and nailed like wood, both during the construction and in later years when repairs become necessary—GOOD MATERIALS (207).

Build up the columns first, then fill them with the ultra-lightweight concrete; then build up the beams and fill them; then the vaults, and cover them with a thin coat of concrete which hardens to form a shell; then fill that shell with even lighter weight materials to form the floors; then make the walls and window frames, and fill them; and finally, the roof, again a thin cloth vault covered with a coat of concrete to form a shell—BOX COLUMNS (216), PERIMETER BEAM (217), WALL MEMBRANE (218), FLOOR-CEILING VAULTS (219), ROOF VAULTS (220). . . .

within this philosophy of structure, on the basis of the plans which you have made, work out the complete structural layout; this is the last thing you do on paper, before you actually start to build;

209. ROOF LAYOUT

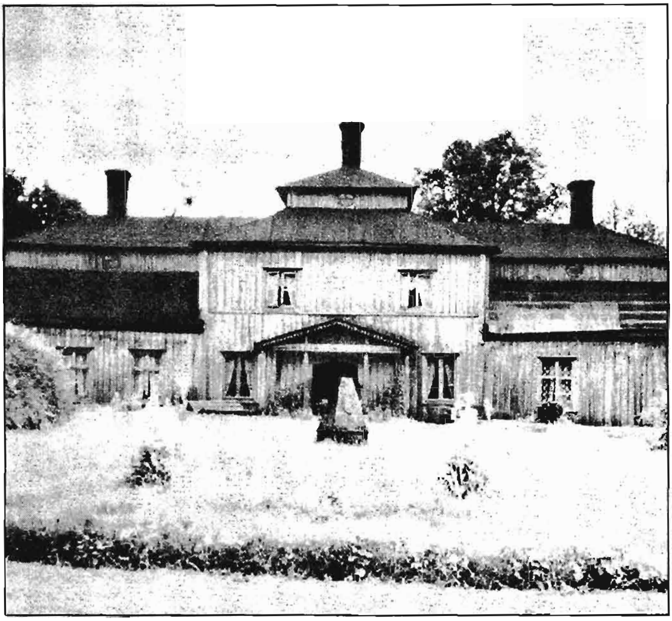
210. FLOOR AND CEILING LAYOUT

211. THICKENING THE OUTER WALLS

212. COLUMNS AT THE CORNERS

213. FINAL COLUMN DISTRIBUTION

209 ROOF LAYOUT*



. . . assume now that you have a rough plan, to scale, for each floor of the building. In this case you already know roughly how the roofs will go, from CASCADE OF ROOFS (116) and SHELTERING ROOF (117); and you know exactly where the roof is flat to form roof gardens next to rooms at different floors—ROOF GARDEN (118). This pattern shows you how to get a detailed roof plan for the building, which helps those patterns come to life, for any plan which you have drawn.

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What kind of roof plan is organically related to the nature of your building?

We know, from arguments presented in THE SHAPE OF INDOOR SPACE (191), that the majority of spaces in an organic building will have roughly—not necessarily perfectly—straight walls because it is only then that the space on *both* sides of the walls can be positive, or convex in shape.

And we know, from similar arguments, that the majority of the angles in the building will be roughly—again, not exactly—right angles, that is, in the general range of 80 to 100 degrees.

We know, therefore, that the class of natural plans may contain a variety of shapes like half circles, octagons, and so on—but that for the most part, it will be made of very rough, sloppy rectangles.

We also know, from SHELTERING ROOF (117), that entire wings should be under one roof whenever possible and that the building is to be roofed with a mixture of flat roofs and sloping or domical roofs, with the accent on those which are *not* flat.

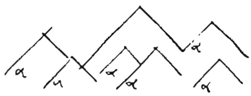
We may therefore state the problem of defining a roof layout as follows: *Given an arbitrary plan of the type described above, how can we fit to it an arrangement of roofs which conforms to the* CASCADE OF ROOFS *(116) and* SHELTERING ROOF *(117) and* ROOF GARDENS *(118)?*

Before explaining the procedure for laying out roofs in detail, we underline five assumptions which provide the basis for the procedure.

1. The "pitched" roofs may actually be pitched, or they may be vaults with a curved pitch, or barrel vaults—as described in ROOF VAULTS (220). The general procedure, in all three cases, is the same. (For curved vaults, define slope as height-to-width ratio.)

The "pitch" of a vaulted roof.

2. Assume that all roofs in the building, which are not flat, have roughly the same slope. For a given climate and roof construction, one slope is usually best; and this greatly simplifies construction.

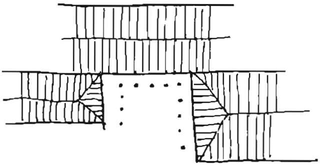


The same slope throughout.

3. Since all roofs have the same slope, the roofs which cover the widest wings and/or rooms will have the highest peaks; those covering smaller wings and rooms will be relatively lower. This is consistent with MAIN BUILDING (99), CASCADE OF ROOFS (116), and CEILING HEIGHT VARIETY (190).

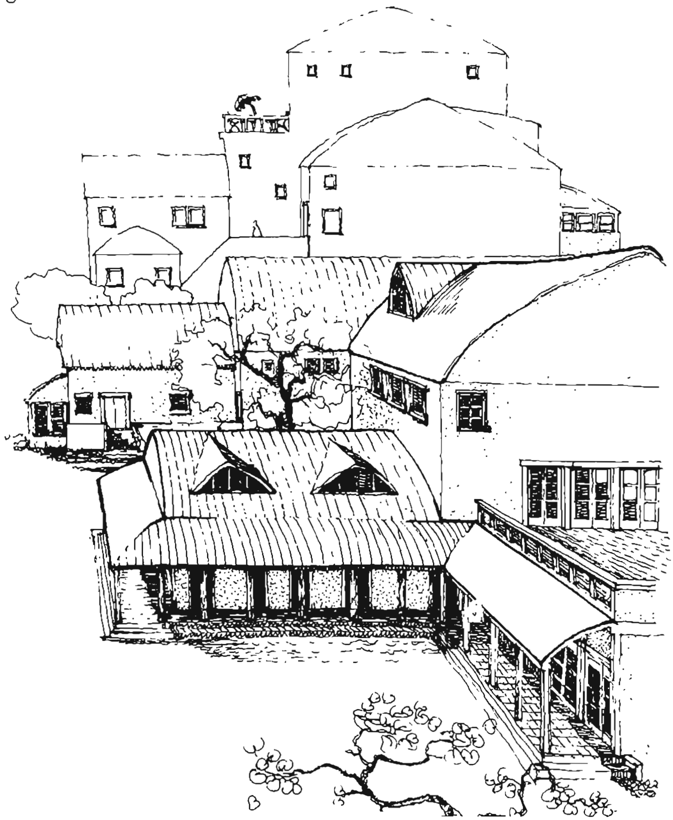
Wide roofs are highest.

4. Any place where the building helps to enclose an outdoor room or courtyard needs an even eave line so that it has the space of a "room." An irregular roof line, with gable ends, will usually destroy the space of a small courtyard. It is necessary, therefore, that roofs be hipped in these positions to make the roof edge horizontal.



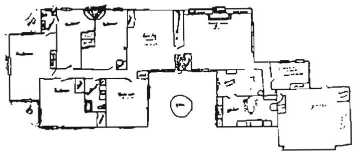
Low roof edge round a courtyard.

5. In all other positions, leave the ends of buildings and wings as gable ends.

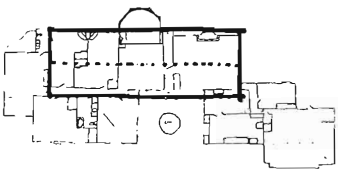


One version of a roof layout, using ultra-lightweight concrete vaults as roofs.

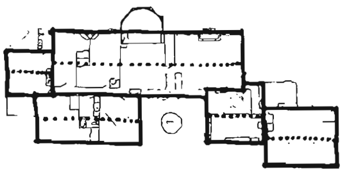
We shall now discuss the rules for roofing a building by using an example of a house designed by a layman using the pattern language. This building plan is shown below. It is a single-story house and it contains no roof gardens or balconies.



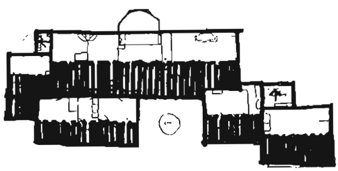
We first identify the largest rectangular cluster of rooms and roof it with a peaked roof, the ridge line of which runs the long direction:



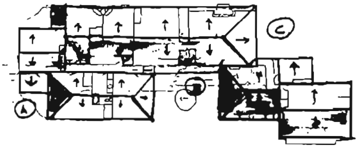
Then we do the same with smaller clusters, until all the major spaces are roofed.



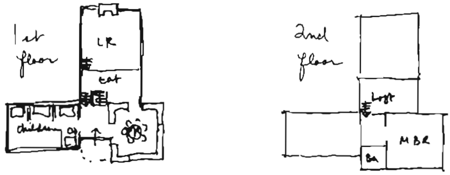
Then we roof remaining small rooms, alcoves, and thick walls with shed roofs sloping outward. These roofs should spring from the base of the main roofs to help relieve them of outward thrusts; their outside walls should be as low as possible.



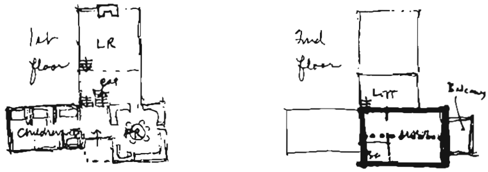
Finally, we identify the outdoor spaces (shown as A, B, and C), and hip the roofs around them to preserve a more continuous eave line around the spaces.



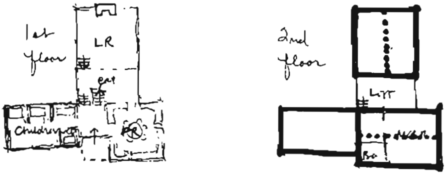
We shall now discuss a slightly more complicated example, a two story building.



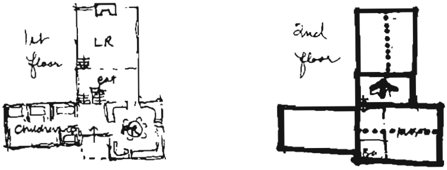
We begin with the top story, roofing the entire master bedroom and bath under one peaked roof with the ridge running lengthwise:



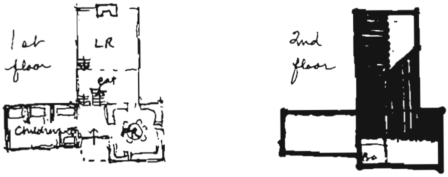
Next we move to the lower story, roofing the children's wing under a flat roof to form a ROOF GARDEN (118) for the master bedroom, and the larger living room under a pitched roof, again with the ridge running lengthwise.



Then we bring the roof over the master bedroom down over the interior loft.



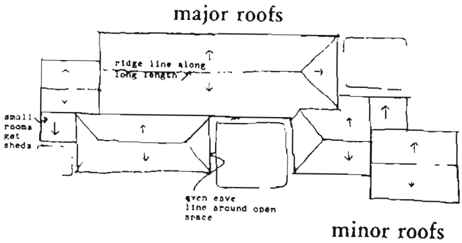
Finally, we smooth the living room roof ridge line into the side of the roof over the loft. This completes the roof layout.



It is very helpful, when you are laying out roofs, to remember the structural principle outlined in CASCADE OF ROOFS (116). When you have finished, the overall arrangement of the roofs should form a self-buttressing cascade in which each lower roof helps to take up the horizonal thrust generated by the higher roofs—and the overall section of the roofs, taken in very very general terms, tends toward a rough upside down catenary.

Therefore:

Arrange the roofs so that each distinct roof corresponds to an identifiable social entity in the building or building complex. Place the largest roofs—those which are highest and have the largest span—over the largest and most important and most communal spaces; build the lesser roofs off these largest and highest roofs; and build the smallest roofs of all off these lesser roofs, in the form of half-vaults and sheds over alcoves and thick walls.



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You can build all these roofs, and the connections between them, by following the instructions for roof vaults—ROOF VAULTS (220). When a wing ends in the open, leave the gable end at full height; when a wing ends in a courtyard, hip the gable, so that the horizontal roof edge makes the courtyard like a room—COURTYARDS WHICH LIVE (115).

Treat the smallest shed roofs, which cover thick walls and alcoves, as buttresses, and build them to help take the horizontal thrust from floor vaults and higher roof vaults—THICKENING THE OUTER WALLS (211). . . .

210 FLOOR AND CEILING LAYOUT

. . . EFFICIENT STRUCTURE (206) tells us that the spaces in the building should be vaulted so that the floors and ceilings can be made almost entirely of compression materials. To lay out the floor and ceiling vaults, we must fit them to the variety of ceiling heights over individual rooms—CEILING HEIGHT VARIETY (190) and, on the top story, to the layout of the roof vaults—ROOF LAYOUT (209).

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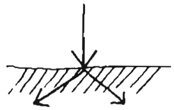
Again, the basic problem is to maintain the integrity of the social spaces in the plan.

We know, from STRUCTURE FOLLOWS SOCIAL SPACES (205), that floor and ceiling vaults must correspond to the important social spaces in the plan. But there are a great number of social spaces, and they range in size from spaces like WINDOW PLACE (180), perhaps five feet across, to spaces like FARMHOUSE KITCHEN (139), perhaps 15 feet across, to collections of spaces, like COMMON AREAS AT THE HEART (129), perhaps 35 feet across.

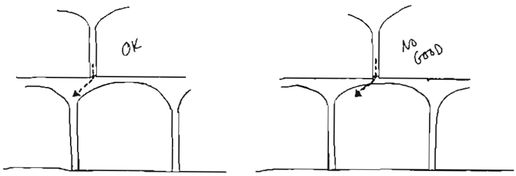
Where vaults of different width are near each other, you must remember to pay attention to the level of the floor above. Either you can level out the floor by making the smaller vaults have proportionately higher arches, or you can put extra material in between to keep the small vaults low—see CEILING HEIGHT VARIETY (190), or you can make steps in the floor above to correspond to changes in the vault sizes below.

Vaults on different floors do not have to line up perfectly with one another. In this sense they are far more flexible than column-beam structures, and for this reason also better adapted to STRUCTURE FOLLOWS SOCIAL SPACES (205). However, there are limits. If one vault is placed so that its loads come down over the arch of the vault below, this will put undue stress on the lower vault. Instead, we make use of the fact that vertical forces, passing through a continuous compressive medium, spread out downward in a 45 degree angle cone. If the lower columns are always within this cone, the upper vault will do no structural damage to the vault below it.



The angle at which a vertical force spreads downward.

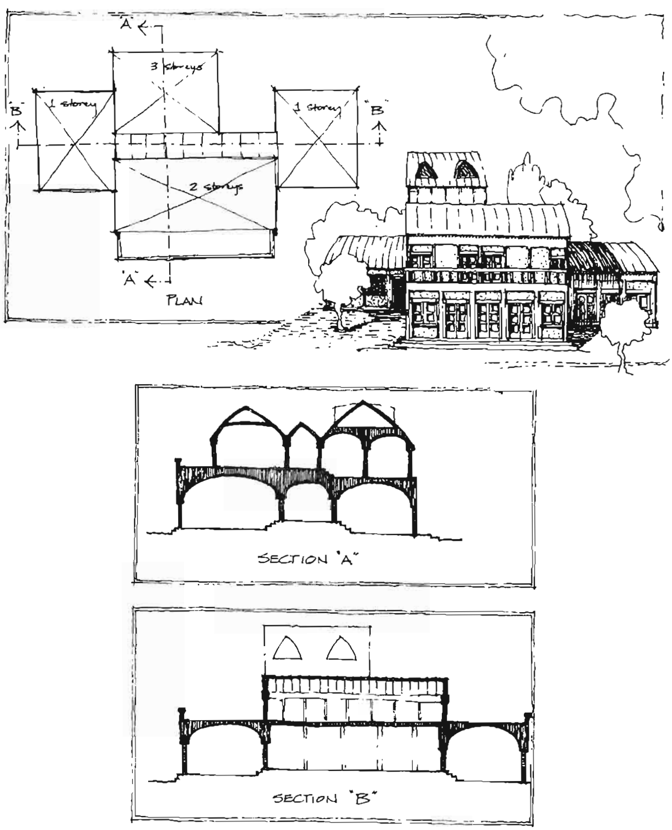
To maintain reasonable structural integrity in the system of vaults as a whole, we therefore suggest that every vault be placed so that its loads come down in a position from which the forces can go to the columns which support the next vault down, by following a 45 degree diagonal.



Good . . . . . . no good.

With all this in mind then, work out a vault plan for your building. We suggest that you try to keep the vaults aligned with the rooms, with occasional adjustments to suit a very big room, or a very small nook or alcove. The drawing on the next page shows a floor and ceiling layout for a simple building.

Each space that you single out for a vault may have either a two-way vault (a domical ceiling on a rectangular base) or a one-way vault (a barrel vault). The two-way vaults are the most efficient structurally; but when a space is long and narrow, the domical shape begins to act like a barrel vault. We therefore



A version of floor-ceiling layout, shown in plan and section, for a simple ultra-lightweight concrete building.

suggest domical vaults for spaces where the long side is not more than twice the short side and barrel vaults for the spaces which are narrower.

We also suggest that you use barrel vaults for the rooms immediately under the roof. The roof itself is generally a barrel vault—see ROOF VAULT (220)—so it is most natural to give the ceiling of the space just under the roof a barrel vault as well.

The vaults described in FLOOR-CEILING VAULTS (219) may span from 5 to 30 feet. And they require a rise of at least 13 per cent of the short span.

Therefore:

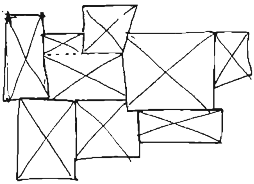
Draw a vault plan, for every floor. Use two-way vaults most often; and one-way barrel vaults for any spaces which are more than twice as long as they are wide. Draw sections through the building as you plan the vaults, and bear the following facts in mind:

1. Generally speaking, the vaults should correspond to rooms.

2. There will have to be a support under the sides of each vault: this will usually be the top of a wall. Under exceptional circumstances, it can be a beam or arch.

3. A vault may span as little as 5 feet and as much as 30 feet. However, it must have a rise equal to at least 13 per cent of its shorter span.

4. If the edge of one vault is more than a couple of feet (in plan) from the edge of the vault below it—then the lower vault will have to contain an arch to support the load from the upper vault.



vaults over rooms

upper vaults/lower vaults reconciled

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Put a PERIMETER BEAM (217) on all four sides of every vault, along the top of the bearing wall, or spanning openings. Get the shape of the vaults from FLOOR-CEILING VAULTS (219) and as you lay out the sections through the vaults, bear in mind that the perimeter beams get lower and lower on higher floors, because the columns on upper stories must be shorter (top floor columns about 4 feet, one below top 6 feet, two below top 6 to 7 feet, three below top 8 feet)—FINAL COLUMN DISTRIBUTION (213). Make sure that variations in floor level coincide with the distinctions between quiet and more public areas—FLOOR SURFACE (233). Complete the definition of the individual spaces which the vaults create with COLUMNS AT THE CORNERS (212). Include the smallest vaults of all, around the building edge, in THICKENING THE OUTER WALLS (211). . . .

211 THICKENING THE OUTER WALLS*

. . . the arrangement of roof and floor vaults will generate horizontal outward thrust, which needs to be buttressed—CASCADE OF ROOFS (116). It also happens, that in a sensibly made building every floor is surrounded, at various places, by small alcoves, window seats, niches, and counters which form "thick walls" around the outside edge of rooms—WINDOW PLACE (180), THICK WALLS (197), SUNNY COUNTER (199), BUILT-IN SEATS (202), CHILD CAVES (203), SECRET PLACE (204). The beauty of a natural building is that these thick walls—since they need lower ceilings, always, than the rooms they come from—can work as buttresses.

Once the ROOF LAYOUT (209), and the FLOOR AND CEILING LAYOUT (210) are clear these thick walls can be laid out in such a way as to form the most effective butresses, against the horizontal thrust developed by the vaults.

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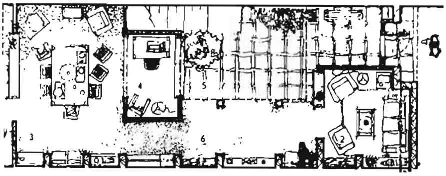
We have established in THICK WALLS (197), how important it is for the walls of a building to have "depth" and "volume," so that character accumulates in them, with time. But when it comes to laying out a building and constructing it, this turns out to be quite hard to do.

The walls will not usually be thick in the literal sense, except in certain special cases where mud construction, for example, lends itself to the making of walls. More often, the thickness of the wall has to be built up from foam, plaster, columns, struts, and membranes. In this case columns, above all, play the major role, because they do the most to encourage people to develop the walls. For instance, if the framework of a wall is made of columns standing away from the back face of the wall, then the wall invites modification—it becomes natural and easy to nail planks to the columns, and so make seats, and shelves, and changes there. But a pure, flat, blank wall does not give this kind of encouragement. Even though, theoretically, a person can always add things which stick out from the wall, the very smoothness of the wall makes it much less likely to happen. Let us assume then, that a thick wall becomes effective when it is a volume defined by columns.

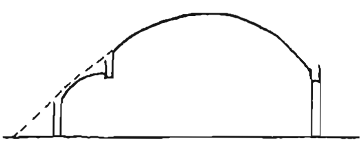


Thick walls made effective by columns.

How is it possible for a wall of this kind to justify its expense by helping the structure of the building? The fact that the building is conceived as a compressive structure, whose floors and roofs are vaults—EFFICIENT STRUCTURE (206), means that there are horizontal thrusts developed on the outside of the building, where the vaults do not counterbalance one another.

To some extent this horizontal thrust can be avoided by arranging the overall shape of the building as an upside down catenary—see CASCADE OF ROOFS (116). If it were a perfect catenary, there would be no outward thrust at all. Obviously, though, most buildings are narrower and steeper than the ideal structural catenary, so there are horizontal thrusts remaining. Although these thrusts can be resolved by tensile reinforcing in the perimeter beams—see PERIMETER BEAMS (217)—it is simplest, and most natural, and stable to use the building itself to buttress the horizontal thrusts.

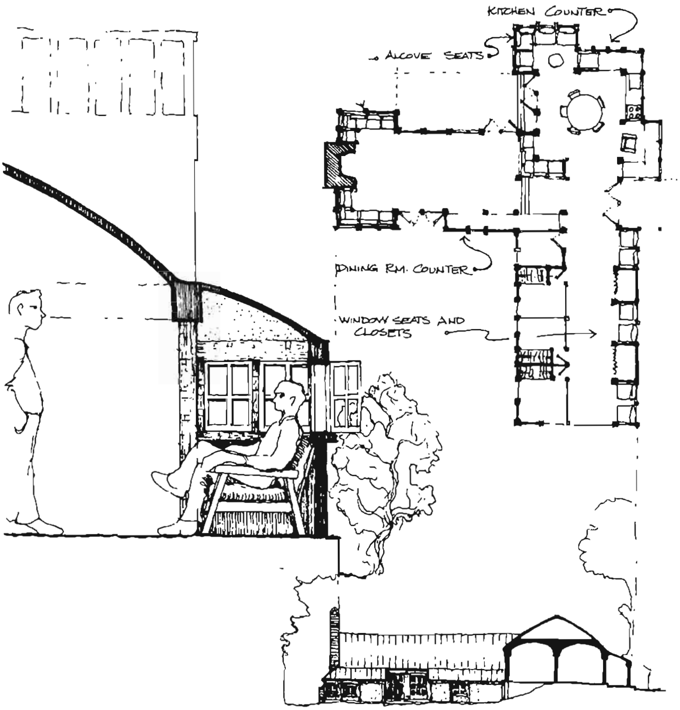
This possibility occurs naturally wherever there are "thick walls"—alcoves, window seats, or any other small spaces at the outside edge of rooms, which can have lower ceilings than the main room and can therefore have their roofs shaped as continuations of the ceiling vault inside. This requires that thick walls be outside the structure of the main room, so that their roofs and walls come close to forming a catenary with the main vault.



Alcoves within the catenary.

It is of course rare to be able to have the alcove or thick walls approach a true catenary section—we hardly ever want them that deep or that low. But even when the thick walls and alcoves are inside the line of the catenary, they are still helping to counter outward thrusts. And their buttressing effect can be improved still more by making their roofs heavy. The extra weight will tend to redirect the forces coming from the main vault slightly more toward the ground.

The drawing below shows the way this pattern works, and the kind of effect it has on a building.

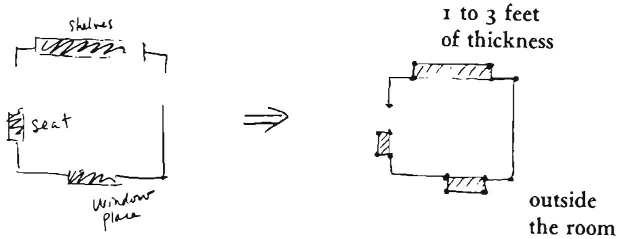


The effect of thickening the outer walls, shown in plan and section.

Therefore:

Mark all those places in the plan where seats and closets are to be. These places are given individually by ALCOVES (179), WINDOW PLACES (180), THICK WALLS (197), SUNNY COUNTER (199), WAIST-HIGH SHELF (201), BUILT-IN SEATS (202), and so on. Lay out a wide swath on the plan to correspond to these positions. Make it two or three feet deep; recognize that it will be outside the main space of the room; your seats, niches, shelves, will feel attached to the main space of rooms but not inside them. Then, when you lay out columns and minor columns, place the columns in such a way that they surround and define these thick volumes of wall, as if they were rooms or alcoves.

For shelves and counters less than 2 feet deep, there is no need to go to these lengths. The thickening can be built simply by deepening columns and placing shelves between them.



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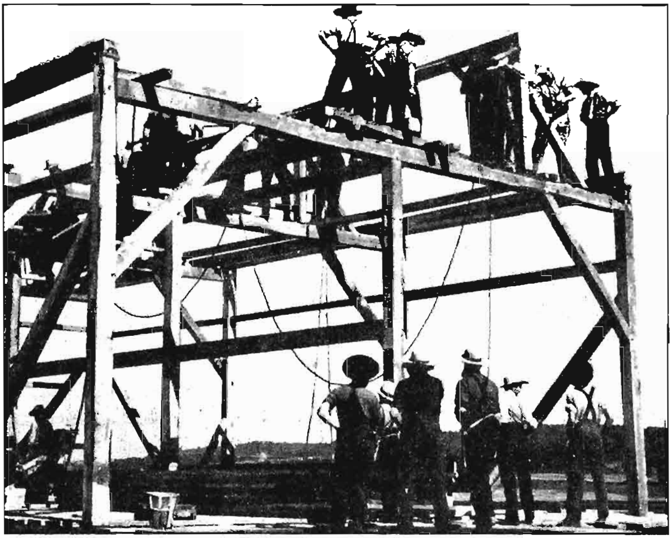
In order to make an alcove or thick wall work as a buttress, build its roof as near as possible to a continuation of the curve of the floor vault immediately inside. Load the roof of the buttress with extra mass to help change the direction of the forces—ROOF VAULTS (220). Recognize that these thick walls must be *outside* the main space of the room, below the main vault of the room—FLOOR-CEILING VAULTS (219), so that they help to buttress the horizontal forces generated by the main vault of the ceiling. When you lay out columns and minor colunms, put a column at the corner of every thick wall, so that the wall space, like other social spaces, becomes a recognizable part of the building structure—COLUMNS AT THE CORNERS (212). . . .

212 COLUMNS AT THE CORNERS**



. . . assume that you have worked out the roof plan, and laid out ceiling vaults for every room on every floor—ROOF LAYOUT (209), FLOOR AND CEILING LAYOUT (210). These vaults are not only the basis of the structure, but also define the social spaces underneath them. Now it is time to put columns at the corners of the vaults. This will both complete them as clearly defined social spaces—STRUCTURE FOLLOWS SOCIAL SPACES (205)—and also be the first constructive step in the erection of the building —GRADUAL STIFFENING (208).

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We have already established the idea that the structural components of a building should be congruent with its social spaces.

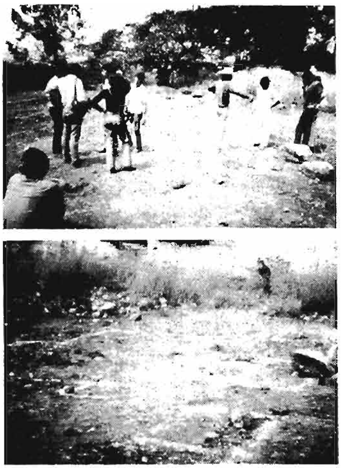
In STRUCTURE FOLLOWS SOCIAL SPACES (205) we have established that the columns need to be at corners of social spaces for psychological reasons. In EFFICIENT STRUCTURE (206) we have established that there needs to be a thickening of material at the corners of a space for purely structural reasons.

Now we give yet a third still different derivation of the same pattern—not based on psychological arguments or structural arguments, but on the process by which a person can communicate a complex design to the builder, and ensure that it can be built in an organic manner.

We begin with the problem of measurement and working drawings. For the last few decades it has been common practice to specify a building plan by means of working drawings. These measured drawings are then taken to the site; the builder transfers the measurements to the site, and every detail of the drawings is built in the flesh, on site.

This process cripples buildings. It is not possible to make such a drawing without a T-square. The necessities of the drawing itself change the plan, make it more rigid, turn it into the kind of plan which can be drawn and can be measured.

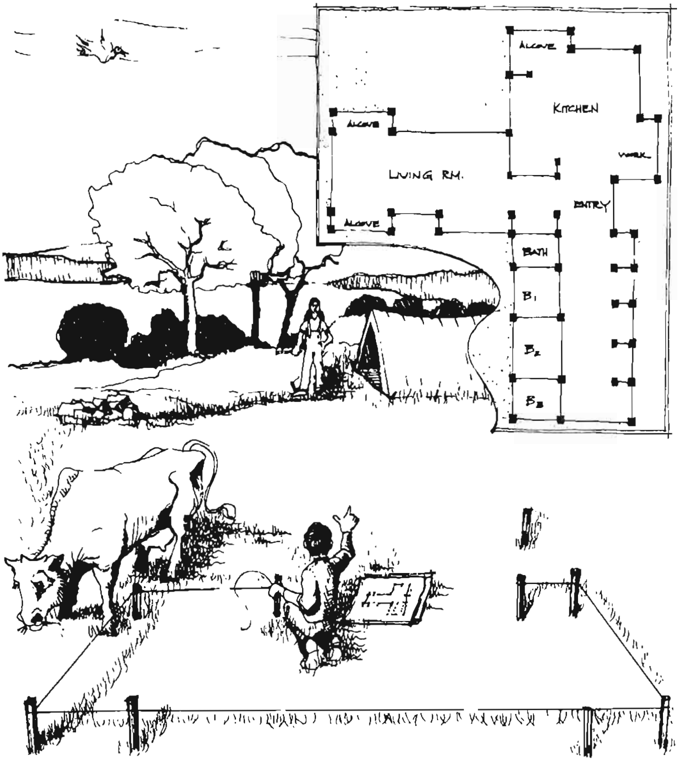
But the kind of plans which you can make by using the pattern language are much freer than that—and not so easy to draw and measure. Whether you conceive these plans out on the site—and mark them on the site with sticks and stones and chalk marks—or draw them roughly on the back of envelopes or scraps of tracing paper—in all events, the richness which you want to build into the plan can only be preserved if the builder is able to generate a living building, with all its slightly uneven lines and imperfect angles.



Chalk marks on the ground.

In order to achieve this aim, the building must be generated in an entirely different manner. It cannot be made by following a working drawing slavishly. What must be done, essentially, is to fix those points which generate the spaces—*as few of them as possible*—and then let these points generate the walls, right out on the building site, during the very process of construction.

You may proceed like this: first fix the corner of every major space by putting a stake in the ground. There are no more than a few dozen of these corners in a building, so this is possible, even if the measurements are intricate and irregular. Place these corner markers where they seem right, without regard for the exact distances between them. There is no reason whatever to try and make modular distances between them. If angles are slightly off, as they often will be, the modular dimensions are impossible anyway.



"Staking out"

These simple marks are all you need to build the building. Once construction starts, you can start very simply, by building a column, over each of these marks. These columns will then generate the rest of the building, by their mere presence, without any further need for detailed measurements or drawings, because the walls will simply be built along the lines which connect adjacent columns: and everything else follows.

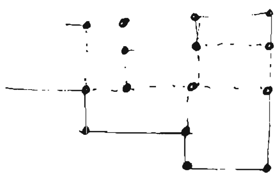
For the upper storys, you can make drawings of the column positions and once again transfer them to the actual building while it is being built. As you will see from FINAL COLUMN DISTRIBUTION (213), upper story columns do not need to line up perfectly with downstairs columns.

With this procedure, it becomes possible to transfer a rather complex building from your mind, or from a scrap of paper, to the site—and regenerate it in a way which makes it live out there.

The method hinges on the fact that you can fix the corners of the spaces first—and that these corners may then play a significant role in the construction of the building. It is interesting that although it is based on entirely different arguments from STRUCTURE FOLLOWS SOCIAL SPACES (205), it leads to almost exactly the same conclusion.

Therefore:

On your rough building plan, draw a dot to represent a column at the corner of every room and in the corners formed by lesser spaces like thick walls and alcoves. Then transfer these dots onto the ground out on the site with stakes.



columns at corners

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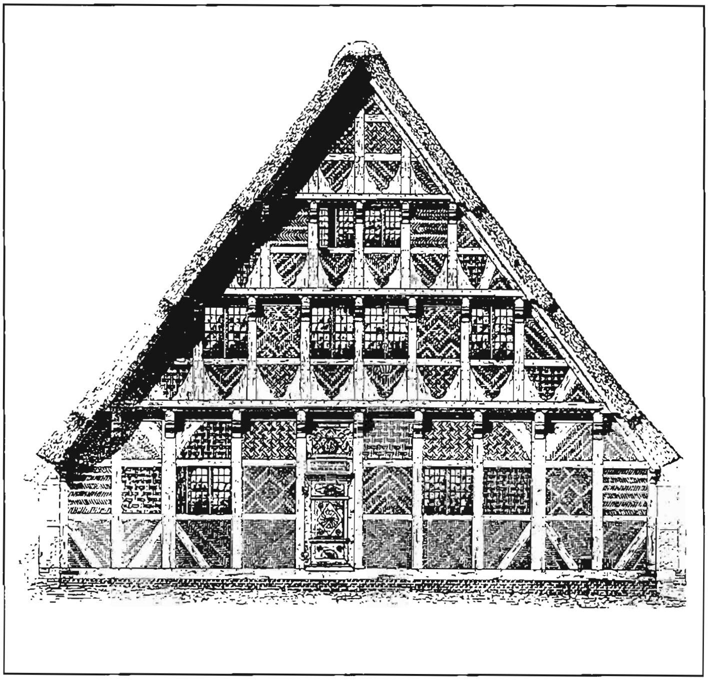
Once you have the columns for each floor on your vault plan, reconcile them from floor to floor and put in intermediate columns—FINAL COLUMN DISTRIBUTION (213). Note, especially, that it is not necessary for the corner columns to fall on a grid. The floor vaults and roof vaults can be made to fit any arrangement of columns, and still make a coherent structure—thus allowing the social spaces to determine the building shape without undue constraint from purely structural considerations—FLOOR-CEILING VAULTS (219), ROOF VAULTS (220).

These columns will not only guide your mental image of the building, they will also guide construction: first put the columns and the column foundations in place; then, to make the frame complete, tie the columns together around each room with the perimeter beam—ROOT FOUNDATIONS (214), BOX COLUMNS (216), PERIMETER BEAMS (217). Give special emphasis to all free-standing columns with the idea that when you build them, you will make them very thick—COLUMN PLACE (226). . . .

213 FINAL COLUMN DISTRIBUTION**



. . . assume that you have placed the corner columns which define the spaces—COLUMNS AT THE CORNERS (212). It is now necessary to fill in the gaps between the columns with intermediate stiffener columns as required by EFFICIENT STRUCTURE (206). This pattern gives the spacing of these intermediate stiffener columns, and helps to generate the kind of walls which EFFICIENT STRUCTURE (206) requires. It also helps to generate CEILING HEIGHT VARIETY (190).

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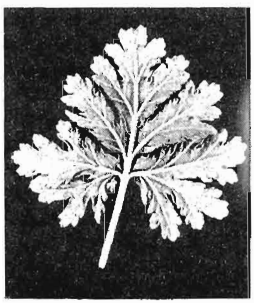
How should the spacing of the secondary columns which stiffen the walls, vary with ceiling height, number of stories and the size of rooms?

In some very gross intuitive way we know the answer to this question. Roughly, if we imagine a building with the walls stiffened at intervals along their length, we can see that the texture of these stiffeners needs to be largest near the ground, where social spaces are largest and where loads are largest, and smallest near the roof, where rooms are smallest and where loads are least. In its gross intuitive form this is the same as the intuition which tells us to expect the finest texture in the ribbing at the fine end of a leaf where everything is smallest, and to expect the grosser, cruder structure to be near the large part of the leaf.



Leaf.

These intuitions are borne out by many traditional building forms where columns, or frames, or stiffeners are larger and further apart near the ground, and finer and closer together higher up. Our key picture shows examples. But what is the structural basis for these intuitions?

Elastic plate theory gives us a formal explanation.

Consider an unstiffened thin wall carrying an axial load. This wall will usually fail in buckling before it fails in pure compression because it is thin. And this means that the material in the wall is not being used efficiently. It is not able to carry the compressive loads which its compressive strength makes possible because it is too thin.

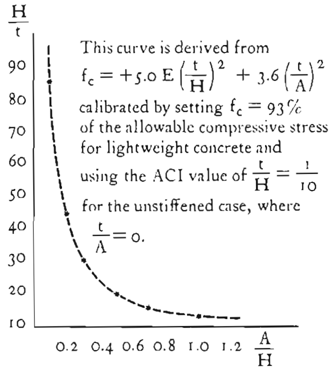
It is therefore natural to design a wall which is either thick enough or stiffened enough so that it can carry loads up to its full compressive capacity without buckling. Such a wall, which uses its material to the limits of its compressive capacity, will then also satisfy the demands of EFFICIENT STRUCTURE (206).

The critical factor is the slenderness of the wall: the ratio of its height to its thickness. For the simple case of an unstiffened concrete wall, the ACI code tells us that the wall will be able to work at 93 per cent efficiency (that is, carry 93 per cent of its potential compressive load without buckling), if it has a slenderness ratio of 10 or less. A wall 10 feet high and 1 foot thick is therefore efficient in this sense.

Suppose now, that we extrapolate to the case of a stiffened wall using elastic plate theory. By using the equation which relates allowable stress to the spacing of stiffeners, we can obtain similar figures for various walls with stiffeners. These figures are presented in the curve below. For example, a wall with a slenderness of 20 needs stiffeners at 0.5H apart (where H is the height) thus creating panels half as wide as they are high. In general, obviously, the thinner the wall is, in relation to its height, the more often it needs to be stiffened along its length.

In every case, the curve gives the spacing of stiffeners which is needed to make the wall work at 93 per cent of its compressive strength. In short, we may say that a wall built according to the principle of EFFICIENT STRUCTURE (206) ought to be stiffened in accordance with this curve.

The gradient of column spacing over different floors follows



The curve which relates wall slenderness to the spacing of stiffeners.

directly from this curve. We may see this in the following manner. The walls in a four story building carry loads which are very roughly in the ratio 4:3:2:1 (only very roughly). In any case, the loads the walls carry get less and less the higher we go in the building. If all the walls are reaching their full compressive capacity, this means that they must be getting steadily thinner too, the higher one goes in the building. If we assume that the walls all have the same height, then the four walls will therefore have progressively greater and greater slenderness ratios, and *will therefore fall further and further to the left on the curve, and will therefore need to be stiffened at closer and closer intervals.*

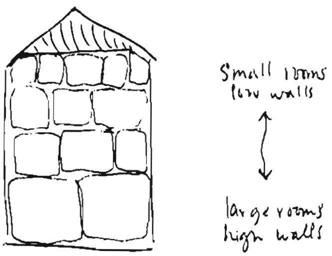
For example, suppose a four story building has 8 foot high walls on all floors and has wall thicknesses of 12 inches, 9 inches, 6 inches, and 3 inches on its four floors. The slenderness ratios are 8, 11, 17, and 33. In this case, reading off the curve, we find the ground floor has no stiffeners at all (they are infinitely far apart), the second floor has stiffeners at about 8 feet apart, the third floor has them about 5 feet apart, and the top floor has them about 2 feet apart.

In another case, where the walls are thinner (because materials are lighter and loads smaller), the spacing will be closer. Suppose, for example, that the necessary wall thicknesses are 8, 6, 4, and

2 inches. Then the slenderness ratios are 12, 16, 24, and 48, and the stiffeners need to be spaced closer together than before: nine feet apart on the ground story, 5 feet apart on the second story, 3 feet apart on the third, and 15 inches apart on the top.

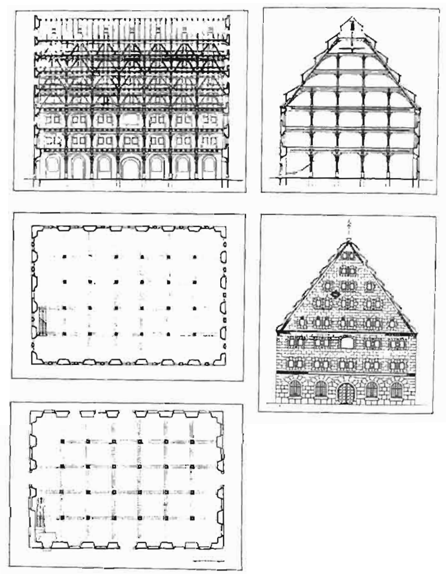
As you can see from these examples, the variation in column spacing is surprisingly great; greater, in fact, than intuition would allow. But the variation is so extreme because we have assumed that ceiling heights are the same on every floor. In fact, in a correctly designed building, the ceiling height will vary from floor to floor; and under these circumstances, as we shall see, the variation in column spacing becomes more reasonable. There are two reasons why the ceiling height needs to vary from floor to floor, one social and one structural.

In most buildings, the spaces and rooms on the first floor will tend to be larger—since communal rooms, meeting rooms, and so on, are generally better located near the entrance to buildings, while private and smaller rooms will be on upper stories, deeper into the building. Since the ceiling heights vary with the size of social spaces—see CEILING HEIGHT VARIETY (190)—this means that the ceiling heights are higher on the ground floor, getting lower as one goes up. And the roof floor has either very short walls or no wall at all—see SHELTERING ROOF (117).



Variation of room sizes.

And there is a second, purely structural explanation of the fact that ceilings need to be lower on upper stories. It is embodied in the drawing of the granary shown below. Suppose that a system of columns is calculated for pure structure. The columns on upper stories will be thinner, because they carry less load than those on lower stories. But because they are thinner, they have less capacity to resist buckling, and must therefore be shorter if we are to avoid wasting material. As a result, even in a granary, where there are no social reasons for variation in ceiling height, purely structural considerations create the necessity for thick columns and high ceilings on the lower stories and for thinner and thinner columns and lower and lower ceilings the higher one gets in the building.



German granary.

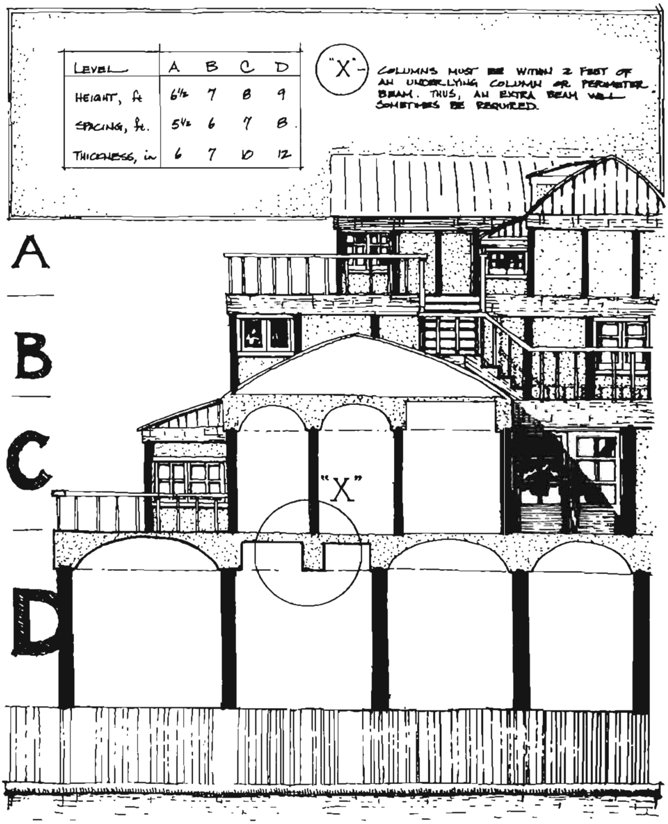
The same conclusion comes from consideration of our curve. We have used the curve, so far, to tell us that stiffeners need to be closer together on upper stories, because the walls are more slender. We may also use the curve to tell us that, for a given load, we should try to keep the slenderness ratio as low as possible. On the upper stories, where walls are most apt to be thin, we should therefore make the walls as low as possible, in order to keep the slenderness ratios low.

Let us assume now, that the wall heights do vary in a building, in a manner consistent with these arguments. A four story building, with an attic story on top, might then have these wall heights (remember that the vault height, in a vaulted room, is higher than the wall height): 9 feet on the ground floor, 7 feet on the second, 6 feet on the third, and 4 feet on the fourth, where the pitched roof comes down low over the eaves. And let us assume that the wall thicknesses are 12 inches, 6 inches, 5 inches, and 3 inches, respectively. In this case, the slenderness ratios will be 9, 14, 14, 15. The ground floor needs no stiffeners at all; the second has them 6 feet apart; the third has them 5 feet apart; and the fourth has them 3 feet apart. We show a similar distribution in the drawing opposite.

When you try to apply this pattern to floor plan, you will find a certain type of difficulty. Since the corners of rooms may already be fixed by COLUMNS AT THE CORNERS (212), it is not always possible to space the stiffeners correctly within the wall of any given room. Naturally this does not matter a great deal; the stiffeners only need to be *about* right; the spacing can comfortably vary from room to room to fit the dimensions of the walls. However, on the whole, you must try and put the stiffeners closer together where the rooms are small and further apart where rooms are large. If you do not, the building will seem odd, because it defies one's structural intuitions.

Consider two rooms on the same floor, one twice as large as the other. The larger room has twice the perimeter, but its ceiling generates four times the load; it therefore carries a greater load per unit length of wall. In an ideal efficient structure, this means that the wall must be thicker; and therefore, by the arguments already given, it will need stiffeners spaced further apart than the smaller room which carries less load and has thinner walls.

We recognize that few builders will take the trouble to make wall thicknesses vary from room to room on one floor of the building. However, even if the wall is uniformly thick, we believe that the stiffeners must at least not contradict this rule. If, for reasons of layout, it is necessary that the spacing of stiffeners varies from room to room, then it is essential that the larger spacings of the stiffeners fall on those walls which enclose the



The final column distribution in a four story building, built according to our patterns for columns, walls and vaults.

larger rooms. If the greater spacing of stiffeners were to coincide with smaller rooms, the eye would be so deceived that people might misunderstand the building.

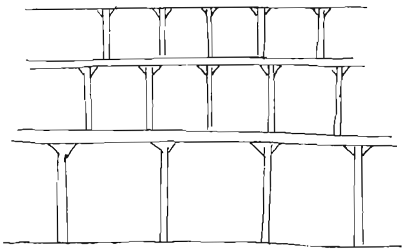
One important note. All of the preceding analysis is based on the assumption that walls and stiffeners are behaving as elastic plates. This is roughly true, and helps to explain the general phenomenon we are trying to describe. However, no wall behaves perfectly as an elastic plate—least of all the kind of lightweight concrete walls we are advocating in the rest of the construction patterns. We have therefore used a modified form of the elastic plate theory, calibrated according to the ACI code, so that the numbers in our analysis are based on the elastic behavior of concrete (and fall within the limits of its tension and compression). However, when the plate goes out of the elastic range and cracks, as it almost certainly will in a concrete design, other factors will enter in. We therefore caution the reader most strongly not to take the actual numbers presented in our analysis as more than illustrations. The numbers reflect the general mathematical behavior of such a system, but they are not reliable enough to use in structural computations.

Therefore:

Make column stiffeners furthest apart on the ground floor and closer and closer together as you go higher in the building. The exact column spacings for a particular building will depend on heights and loads and wall thicknesses. The numbers in the following table are for illustration only, but they show roughly what is needed.

building height in stories	ground floor	2nd floor	3rd floor	4th floor
1	2′-5′			
2	3′-6′	1′-3′		
3	4′-8′	3′-6′	1′-3′	
4	5′-∞′	4′-8′	3′-6′	1′-3′

Mark in these extra stiffening columns as dots between the corner columns on the drawings you have made for different floors. Adjust them so they are evenly spaced between each pair of corner columns; but on any one floor, make sure that they are closer together along the walls of small rooms and further apart along the walls of large rooms.



floor by floor variation

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To the extent consistent with CEILING HEIGHT VARIETY (190), make walls and columns progressively shorter the higher you go in the building to keep slenderness ratios low.

And make wall thicknesses and column thicknesses vary with the height—see WALL MEMBRANE (218). Our calculations, for a typical lightweight concrete building of the kind we have been discussing, suggest the following orders of magnitude for wall thicknesses: Top story—2 inches thick; one below top story—3 inches; two below top story—4 inches; three storys below top (ground floor on a four story building)—5 inches. Of course these numbers will change for different loads, or for different materials, but they show the type of variation you can expect.

Column thicknesses must be proportional to wall thicknesses, so that the thinnest walls have the thinnest columns. If they are very thin, it will be possible to make them simply by placing boards, or one thickness of material, outside the outer skins which form the wall membrane—see WALL MEMBRANE (218). If the walls are thick, they will need to be full columns, twice as thick as the walls, and roughly square in section, built before the walls, but made in such a way that they can be poured integrally with the walls—BOX COLUMNS (216). . . .

put stakes in the ground to mark the columns on the site, and start erecting the main frame according to the layout of these stakes;

214. ROOT FOUNDATIONS

215. GROUND FLOOR SLAB

216. BOX COLUMNS

217. PERIMETER BEAMS

218. WALL MEMBRANES

219. FLOOR-CEILING VAULTS

220. ROOF VAULTS

214 ROOT FOUNDATIONS

. . . once you have a rough column plan for the building—COLUMNS AT THE CORNERS (212), FINAL COLUMN DISTRIBUTION (213)—you are ready to start the site work itself. First, stake out the positions of the ground floor columns, before you do any other earthwork, so that you can move the columns whenever necessary to leave rocks or plants intact—SITE REPAIR (104), CONNECTION TO THE EARTH (168). Then dig the foundation pits and prepare to make the foundations.

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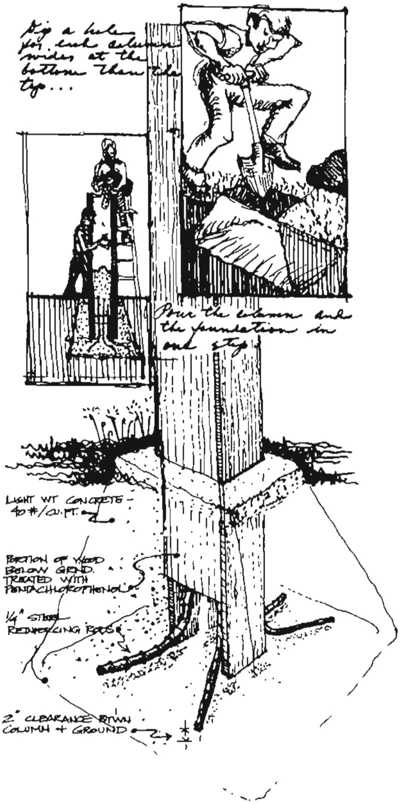
The best foundations of all are the kinds of foundations which a tree has—where the entire structure of the tree simply continues below ground level, and creates a system entirely integral with the ground, in tension and compression.

When the column and the foundations are separate elements which have to be connected, the connection becomes a difficult and critical joint. Both bending and shear stresses are extremely high just at the joint. If a connector is introduced as a third element, there are even more joints to worry about, and each member works less effectively to resist these stresses.

We suspect that it would be better to build the foundations and the columns in such a way that the columns get rooted in the foundation and become integral and continuous with the ground.

In the realization of this pattern which we illustrate, the root foundation takes a very simple form. Since columns start out hollow, BOX COLUMNS (216), we can form a root foundation by setting the hollow column into the foundation pit, and then pouring the lower part of the column and the foundation, integrally, in a single pour.

As far as the wood version is concerned, the problem of placing

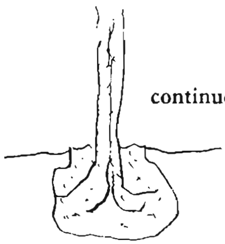


One version of a root foundation for a hollow wooden box column which we have built.

wood in contact with wet underground concrete is very serious. The wood of the column can be protected from dry rot and termites by pressure dipping in pentachlorophenol. We also believe that painting with thick asphalt or dampproof mastic might work; but the problem isn't really solved. Of course, masonry versions in which columns are made of terracotta pipe or concrete pipe and filled with dense concrete, ought to work alright. But even in these cases, we are doubtful about the exact structural validity of the pattern. We believe that some kind of structure which is continuous with the ground is needed: but we quite haven't been able to work it out. Meanwhile, we state this pattern as a kind of challenge.

Namely:

Try to find a way of making foundations in which the columns themselves go right into the earth, and spread out there—so that the footing is continuous with the material of the column, and the column, with its footing, like a tree root, can resist tension and horizontal shear as well as compression.



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To make foundations like this for hollow concrete, filled box columns, start with a pit for each foundation, place the hollow column in the pit, and pour the column and the foundation integrally, in one continuous pour—BOX COLUMNS (216). Later, when you build the ground floor slab, tie the concrete into the foundations—GROUND FLOOR SLAB (215).

215 GROUND FLOOR SLAB

. . . this pattern helps to complete CONNECTION TO THE EARTH (168), EFFICIENT STRUCTURE (206), COLUMNS AT THE CORNERS (212), and ROOT FOUNDATIONS (214). It is a simple slab, which forms the ground floor of the building, ties the root foundations to one another, and also allows you to form simple strip foundations as part of the slab, to support the walls.

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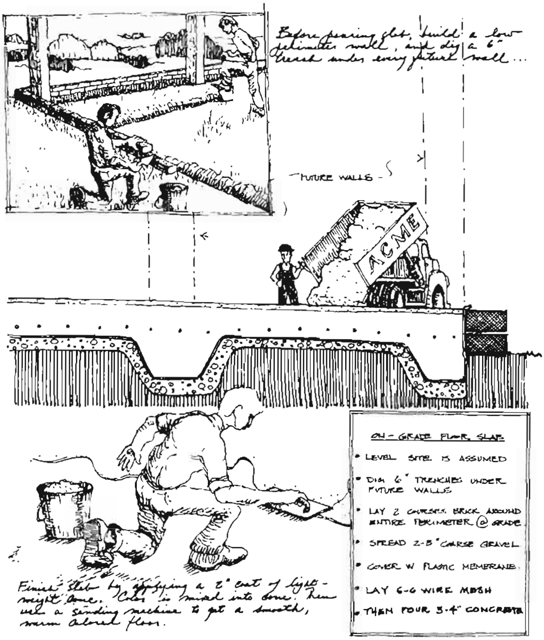
The slab is the easiest, cheapest, and most natural way to lay a ground floor.



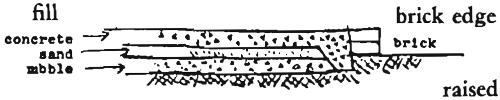
A raised ground floor slab built inside a brick perimeter wall.

When the ground is relatively level, a concrete slab which sits directly on the ground is the most natural and cheapest way of building a ground floor. Wood floors are expensive, need air space underneath them, and need to be built up on continuous foundation walls or beams. Prefabricated floor panels also need a structure of some sort to support them. A slab floor, on the other hand, uses the earth for support, and can supply the foundations which are needed to support walls, by simple thickening.

The one trouble with slabs is that they can easily feel cold and damp. We believe that this feeling is at least as much a psychological one as a physical one (given a well-made and insulated slab), and that the feeling is most pronounced with slabs that are on grade. We therefore propose that the slab be raised from the ground. This can be done by not excavating the ground at all, instead only leveling it, and placing the usual bed of rubble and gravel on top of the ground. (In normal practice, the ground is excavated so that the top of the rubble is slightly below grade, and the top of the slab only *just* above the ground.)

Therefore:

Build a ground floor slab, raised slightly—six or nine inches above the ground—by first building a low perimeter wall around the building, tied into the column foundations, and then filling it with rubble, gravel, and concrete.



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Finish the public areas of the floor in brick, or tile, or waxed and polished lightweight concrete, or even beaten earth; as for those areas which will be more private, build them one step up or one step down, with a lightweight concrete finish that can be felted and carpeted—FLOOR SURFACE (233).

Build the low wall which forms the edge of the ground floor slab out of brick, and tie it directly into all the terraces and paths around the building—CONNECTION TO THE EARTH (168), SOFT TILE AND BRICK (248). If you are building on a steep sloped site, build part of the ground floor as a vaulted floor instead of excavating to form a slab—FLOOR-CEILING VAULTS (219). . . .

216 BOX COLUMNS**

. . . if you use ROOT FOUNDATIONS (214), the columns must be made at the same time as the foundations, since the foundation and the column are integral. The height, spacing, and thickness of the various columns in the building are given by FINAL COLUMN DISTRIBUTION (213). This pattern describes the details of construction for the individual columns.

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In all the world's traditional and historic buildings, the columns are expressive, beautiful, and treasured elements. Only in modern buildings have they become ugly and meaningless.

The fact is that no one any longer knows how to make a column which is at the same time beautiful and structurally efficient. We discuss the problem under seven separate headings:

1. Columns feel uncomfortable unless they are reasonably thick and solid. This feeling is rooted in structural reality. A long thin column, carrying a heavy load, is likely to fail by buckling: and our feelings, apparently, are particularly tuned in to this possibility.

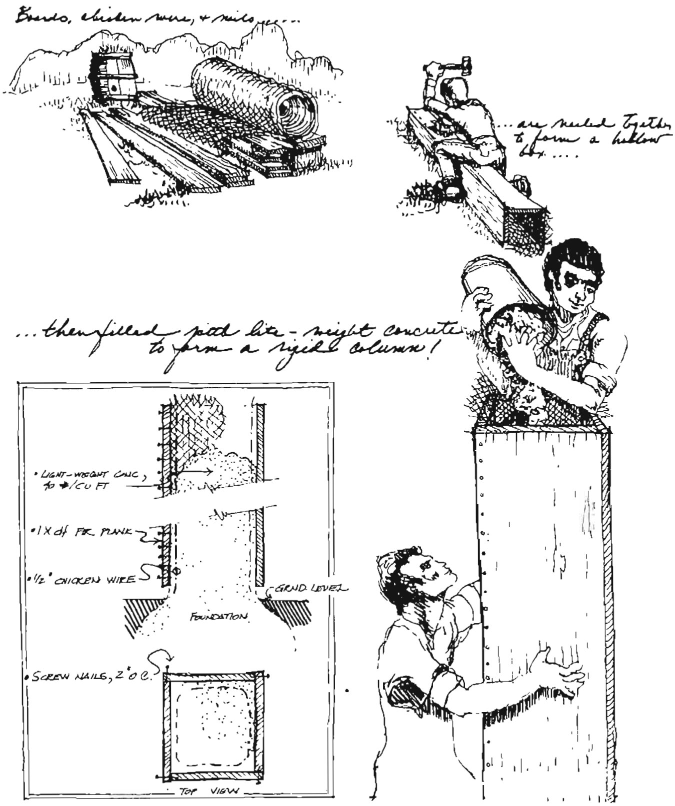
We do not wish to exaggerate the need for thickness. Taken too far, it could easily become a mannerism of a rather ridiculous sort. But columns do need to be comfortable and solid, and only thin when they are short enough to be in no danger of buckling. When the column is a free-standing one, then the need for thickness becomes essential. This is fully discussed under COLUMN PLACE (226).

2. Structural arguments lead to exactly the same conclusion. Thin, high strength materials, like steel tubes and prestressed concrete, are ruled out by GOOD MATERIALS (207). Lower strength materials which are ecologically sound have to be relatively fat to cope with the loads.

3. The column must be cheap. An 8 by 8 solid wood column is too expensive; thick brick or stone columns are almost out of the question in today's market.

4. It must be warm to the touch. Concrete columns and painted steel columns have an unpleasant surface and are not very easy to face.

5. If the column takes bending, the highest strength materials should be concentrated toward the outside. Buckling and bending strength both depend on the moment of inertia, which is highest when the material is as far as possible from the neutral axis. A stalk of grass is the archetypal example.



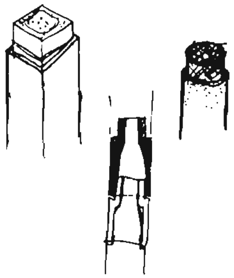
A version of box columns made of 1 inch wood planks, nailed together with spiral groove nails, and filled with chicken wire and ultra-lightweight concrete.

6. The column must be easy to connect to foundations, beams, and walls. Precast concrete columns are very hard to connect. So are metal columns. Brick columns are easy to connect to brick walls—not to the lighter weight skin structures required by WALL MEMBRANE (218).

7. The column must be hand nailable, and hand cuttable to make on-site modification and later repair as easy as possible. Again, current materials do not easily meet this requirement.

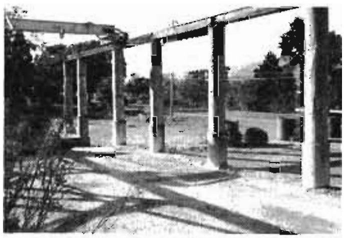
A column which has all these features is a box column, where the hollow tube can be made as thick as is required, and then filled with a strong compressive material. Such a column can be made cheaper than comparable wood and steel columns; the outer skin can be made with a material that is beautiful, easy to repair, and soft to the touch; the column can be stiffened for bending, either by the skin itself, or by extra reinforcing; and, for structural integrity, the fill material can be made continuous with the column's footings and beams.

An example of a box column which we have built and tested is a wooden box column, made with 1 inch wooden planks and filled with lightweight concrete the same density as wood, so that it has the overall volume and mass of a heavy 8 inch solid column. The drawing opposite shows these wooden box columns being made.



Possible box columns

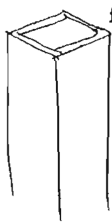
Box columns can be made in many other ways. One kind is made by stacking 8 by 8 inch lightweight concrete blocks, and filling the cavity with a concrete of the same density. Some wire reinforcing inside the column is required to give the column tensile strength. A hollow brick column, filled with earth is another possibility. Concrete, vinyl, and terracotta sewer pipe filled with lightweight concrete and reinforced with mesh; a resin-impregnated cardboard tube filled with earth; or two concentric cardboard tubes with the outer ring filled with concrete and the inner ring filled with earth; still another is made from a tube of chicken wire wesh, filled with rubble, plastered and whitewashed on the outside. And still another can be made with self-aligning hollow tiles for the skin. The tiles can be molded by hand with a hand press—in concrete or tile; the soft tile will make beautiful rose red, soft warm columns.



Box columns made from concrete sewer pipe, filled with concrete.

Therefore:

Make the columns in the form of filled hollow tubes, with a stiff tubular outer skin, and a solid core that is strong in compression. Give the skin of the column some tensile strength—preferably in the skin itself, but perhaps with reinforcing wires in the fill.



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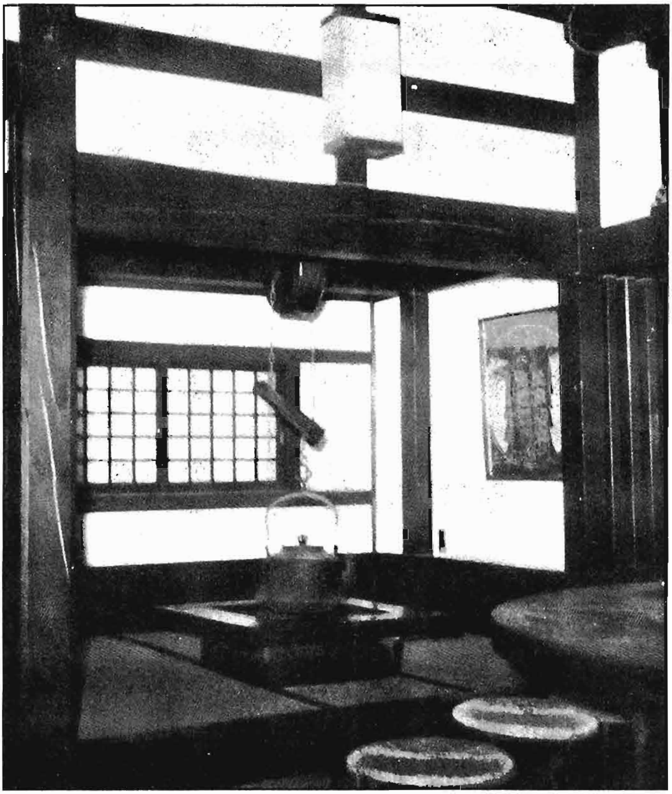
As you already know, it is best to build the columns integral with ROOT FOUNDATIONS (214) on the ground floor, or integral with the FLOOR-CEILING VAULTS (219) on upper floors, and to fill them in one continuous pour. Once the columns are in position, put in the PERIMETER BEAMS (217), and fill the beams at the same time that you fill the upper part of the column. If the column is free standing, put in column braces or column capitals—COLUMN CONNECTION (227)—to brace the connection between the two. And make the columns especially thick, or build them in pairs, where they are free-standing, so that they form a COLUMN PLACE (226). . . .

217 PERIMETER BEAMS*



. . . this pattern helps to complete BOX COLUMNS (216), by tying the tops of the columns together once they are in position. It also helps to form the bearing surface for the edge of the FLOOR-CEILING VAULTS (219). For this reason, the positions of the perimeter beams must correspond exactly to the edges of the vaults laid out in FLOOR AND CEILING LAYOUT (210).

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If you conceive and build a room by first placing columns at the corners, and then gradually weaving the walls and ceiling round them, the room needs a perimeter beam around its upper edge.

It is the beam, connecting the columns which creates a volume you can visualize, before it is complete; and when the columns are standing in the ground, you need the actual physical perimeter beam, to generate this volume before your eyes, to let you see the room as you are building it, and to tie the tops of the columns together, physically.

These reasons are conceptual. But of course, the conceptual simplicity and rightness of the beam around the room comes, in the end, from the more basic fact that this beam has a number of related structural functions, which make it an essential part of any room built as a natural structure. The perimeter beam has four structural functions:

1. It forms the natural thickening between the wall membrane and vault membrane, described in EFFICIENT STRUCTURE (206).

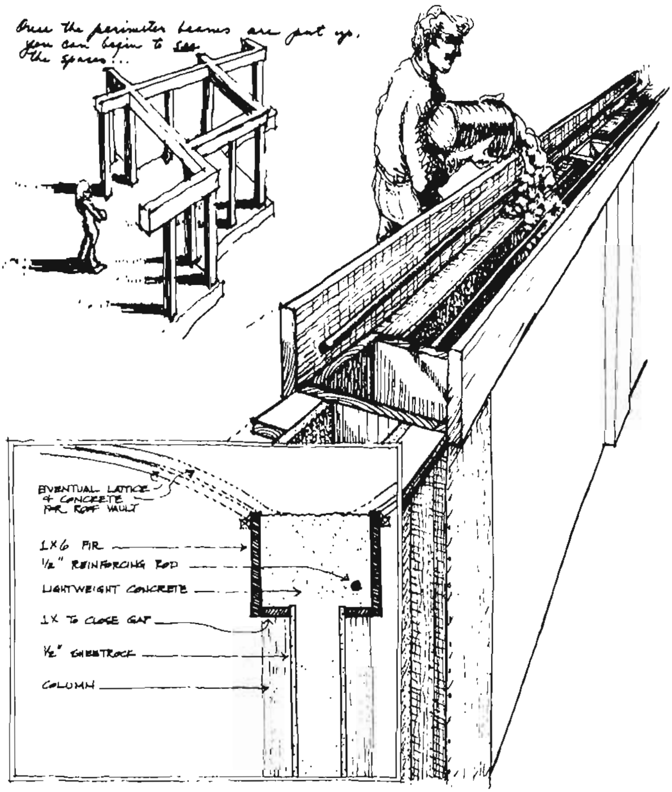
2. It resists the horizontal thrust of the ceiling vault, wherever there are no outside external buttresses to do it, and no other vaults to lean against.

3. It functions as a lintel, wherever doors and windows pierce the wall membrane.

4. It transfers loads from columns in upper storys to the columns and the wall membrane below it, and spreads these loads out to distribute them evenly between the columns and the membrane.

These functions of the perimeter beam show that the beam must be as continuous as possible with walls and columns above, the walls and columns below, and with the floor. If we follow GOOD MATERIALS (207), the beam must also be easy to make, and easy to cut to different lengths.

Available beams do not meet these requirements. Steel beams and precast or prestressed beams cannot easily be tied into the wall and floor to become continuous with these membranes. Far more important, they cannot easily be cut on site to conform to the exact dimensions of the different rooms which will occur in an organic plan.



A version of the perimeter beam consistent with the box column shown before.

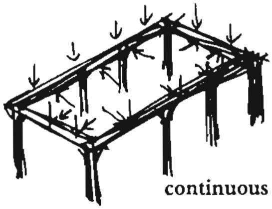
Of course, wood beams meet both requirements: they are easy to cut and can be tied along their lengths to wall and floor membranes. However, as we have said in GOOD MATERIALS (207), wood is unavailable in many places, and even where it is available, it is becoming scarce and terribly expensive, especially in the large sizes needed for beams.

To avoid the use of wood, we have designed a perimeter beam—shown opposite—which is consistent with our box column, and designed to be used together with it. It is a beam made by first nailing up a channel made of wooden planks to the columns, before the wall membranes are made; then putting in reinforcing, and filling up with ultra-lightweight 60 pounds per cubic foot concrete, after the walls are made and filled. This beam is excellent for continuity. The wooden channel can first be made continuous with other skin elements by nailing, and the fill can then be made continuous by filling columns and beams and walls and vault in one continuous pour—see WALL MEMBRANES (218) and FLOOR-CEILING VAULTS (219).

Of course, there are many other ways of making a perimeter beam. First of all, there are several variants of our design: the U-shaped channel can be made of fiberboard, plywood, precast lightweight concrete, and, in every case, filled with lightweight concrete. Then there are various traditional perimeter beams—the Japanese version or the early American versions come to mind. And then there are a variety of structures which are not exactly even beams—but still act to spread vertical loads and counteract horizontal thrusts. A row of brick arches might function in this way, in a far fetched case so might a tension ring of jungle creeper.

Therefore:

Build a continuous perimeter beam around the room, strong enough to resist the horizontal thrust of the vault above, to spread the loads from upper stories onto columns, to tie the columns together, and to function as a lintel over openings in the wall. Make this beam continuous with columns, walls and floor above, and columns and walls below.



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Remember to place reinforcing in such a way that the perimeter beam acts in a *horizontal* direction as well as vertical. When it forms the base for a FLOOR-CEILING VAULT (219) it must be able to act as a ring beam to resist all those residual horizontal outward thrusts not contained by the vault. Strengthen the connection between the columns and the perimeter beam with diagonal braces where the columns are free standing—COLUMN CONNECTION (227). . . .

218 WALL MEMBRANE*

. . . according to EFFICIENT STRUCTURE (206) and FINAL COLUMN DISTRIBUTION (213), the wall is a compressive load-bearing membrane, "stretched" between adjacent columns and continuous with them, the columns themselves placed at frequent intervals to act as stiffeners. The intervals vary from floor to floor, according to column height; and the wall thickness (membrane thickness) varies in a similar fashion. If the column stiffeners are already in place according to BOX COLUMN (216), this pattern describes the way to stretch the membrane from column to column to form the walls.

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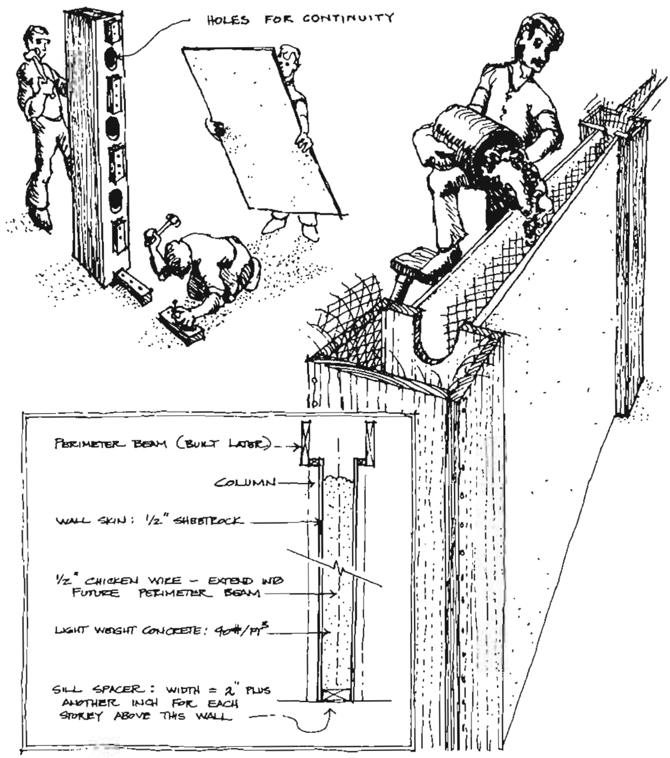
In organic construction the walls must take their share of the loads. They must work continuously with the structure on all four of their sides; and act to resist shear and bending, and take loads in compression.

When walls are working like this, they are essentially structural membranes: they are continuous in two dimensions; together with stiffeners and columns they resist loads in compression; and they create a continuous rigid connection between columns, beams, and floors, both above and below, to help resist shear and bending.

By contrast, curtain walls and walls which are essentially "in-fill," do not act as membranes. They may function as walls in other respects—they insulate, enclose, they define space—but they do not contribute to the overall structural solidity of the building. They let the frame do all the work; structurally they are wasted. [For the details of the argument that every part of the structure must cooperate to take loads, see EFFICIENT STRUCTURE (206).]

A membrane, on the other hand, makes the wall an integral thing, working with the structure around it. How should we build such a wall membrane?



A version of an interior wall membrane which uses gypsum board as skin, and ultra-lightweight concrete for the fill.

GOOD MATERIALS (207) tells us that we should use hand cuttable, nailable, ecologically sound materials, which one can work with home tools, with the emphasis on earthen fill materials and sheet materials.

GRADUAL STIFFENING (208) tells us that the process of building should be such that one can start with a flimsy structure and stiffen it during the course of construction, as materials are put in place, so that the process can be smooth and continuous.

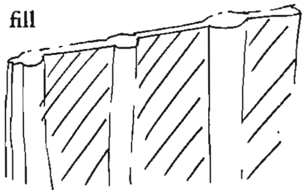
An example of such a wall that we have built and tested uses gypboard for the inner skin, ship-lapped wooden boards for the outer skin and ultra-lightweight concrete for the fill. The wall is built by fixing nailing blocks to the sides of columns. We nail the skin to the nailing blocks, put chickenwire into the cavity to reinforce the concrete against shrinkage, and then pour the lightweight concrete into the cavity. The wall needs to be braced during pouring, and you can't pour more than two or three feet at a time: the pressure gets too great. The last pour fills the perimeter beam and the top of the wall, and so makes them integral. The drawing opposite shows one way that we have made this particular kind of wall membrane.

This wall is solid (about the density of wood), has good acoustic and thermal properties, can easily be built to conform to free and irregular plans, and can be nailed into. And because of its stiffeners, the wall is very strong for its thickness.

Other versions of this pattern: (1) The skin can be formed from hollow structural tiles or concrete blocks, with a concrete or earthen fill. (2) The exterior skin might be brick, the interior skin plywood or gypboard. In either case the columns would have to be hollow tile, or concrete pipe, or other masonry box columns. (3) The skin might be formed with wire mesh, gradually filled with concrete and rubble, and stuccoed on the outside, with plaster on the inside. The columns in this case can be built in the same way—out of a wire mesh tube filled with rubble and concrete. (4) It may also be possible to use gypboard for both skins, inside and out. The gypboard on the outer side could then be covered with building paper, lath, and stucco.

Therefore:

Build the wall as a membrane which connects the columns and door frames and windows frames and is, at least in part, continuous with them. To build the wall, first put up an inner and an outer membrane, which can function as a finished surface; then pour the fill into the wall.



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Remember that in a stiffened wall, the membranes can be much thinner than you might expect, because the stiffeners prevent buckling. In some cases they can be as thin as two inches in a one story building, three inches at the bottom of a two-story building and so on—see FINAL COLUMN DISTRIBUTION (213).

Membranes can be made from hollow tile, lightweight concrete block, plywood, gypboard, wood planks, or any other sheet type material which would make a nice surface, which is easy to nail into, comfortable to touch, and so on. If the inner sheet is gypsum board, it can be finished with a skim coat of plaster—SOFT INSIDE WALLS (235). The outer sheet can be made of 1 inch boards, tongue and grooved; or exterior grade plywood; or exterior board hung with tile, shingles, or plastered—LAPPED OUTSIDE WALLS (234). It is also possible to build the outer skin of brick or tile: in this case, columns must be of the same material—SOFT TILE AND BRICK (248). . . .

219 FLOOR-CEILING VAULTS**

. . . we have already discussed the fact that ordinary joist floors and slab floors are inefficient and wasteful because the tension materials they use to resist bending are less common than pure compression materials—EFFICIENT STRUCTURE (206), GOOD MATERIALS (207), and that it is therefore desirable to use vaults wherever possible. This pattern gives the shape and construction of the vaults. The vaults will help to complete FLOOR AND CEILING LAYOUT (210), and PERIMETER BEAMS (217); and, most important of all, they will help to create the CEILING HEIGHT VARIETY (190) in different rooms.

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We seek a ceiling vault shape which will support a live load on the floor above, form the ceiling of the room below, and generate as little bending and tension as possible so that compressive materials can be relied on.

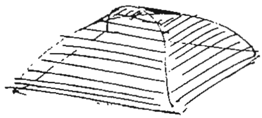
The vault shape is governed by two constraints: the ceiling cannot be lower than about 6 feet at the edge of the room, except in occasional attic rooms; and the ceiling in the middle of the room should vary with the room size (8 to 12 feet for large rooms, 7 to 9 feet for middle sized rooms, and 6 to 7 feet for the very smallest alcoves and corners—see CEILING HEIGHT VARIETY (190)).

We know, from structural considerations, that a circular shell dome will generate virtually no bending moments when its rise is at least 13 to 20 per cent of its diameter. (This is established in studies and tests of shell structures, and is corroborated by our own computer studies.) For a room 8 feet across, this requires a rise of about 18 inches, making a total height of 7 to 8 feet in the middle; for a room 15 feet across, it requires a rise of 2–3 feet, making a height of 8 to 10 feet in the middle.

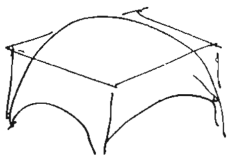
Luckily, these vault heights are just congruent with the needed ceiling heights. We may say, therefore, that the ideal vault for an inhabited space is one which springs from 6 to 7 feet at the edge, and rises 13 to 20 per cent of the smaller diameter.

There are various possible ways of making a circular or elliptical vault spring from a square or rectangular room.

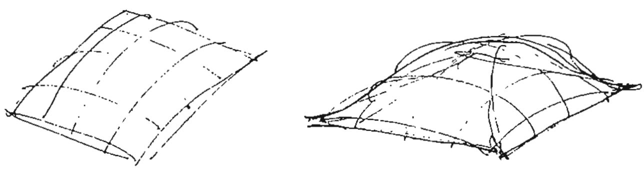
1. One type of vault is made by arching diagonal ribs from corner to corner; and then spacing straight line elements across the ribs.



2. Another type is a pure dome supported on squinches.



3. Another is based on a rectangular grid of arched ribs. The edge ribs are entirely flat, and the center ribs have the greatest curvature. In the end, each part of the vault is curved in three dimensions, and the corners are slightly flattened.



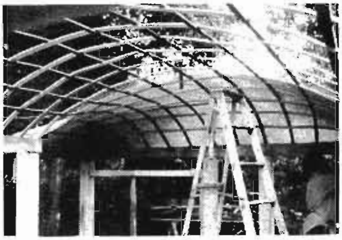
Each of these three vaults makes sense in slightly different circumstances. The first is the easiest to conceive, but it has a slight structural disadvantage: its surface panels are curved in one direction only—because they are made of straight line elements—and cannot therefore achieve the strength of a doubly curved vault. The second is the hardest to conceive; however, it comes naturally from the intersection of a spherical shape and a rectangular one. If one were to make a vault by using a balloon as a form, pushed up within the perimeter beams, the second type would be the easiest to use. In the particular building technique we have been using, the third type is easiest to use, because it is particularly simple to lay out the arched ribs which provide the formwork. It flattens out at the corners, which could create bending moments and require tension materials. However, in lightweight concrete we have found that it does not require any more than the shrinkage reinforcement, which is needed anyway.

We shall now describe a very simple way of making a vault. Bear in mind that we considered it essential that the vault be built up gradually, and that it could be fitted to any room shape, without difficulty. This technique is not only cheap and simple. It is also one of the only ways we have found of fitting a vault to an arbitrary room shape. It works for rectangular rooms, rooms that are just off-rectangles, and odd-shaped rooms. It can be applied to rooms of any size. The height of the vault can be varied according to its position in the overall array of ceiling heights and floors—CEILING HEIGHT VARIETY (190), STRUCTURE FOLLOWS SOCIAL SPACES (205), FLOOR AND CEILING LAYOUT (210).

First, place lattice strips at one foot centers, spanning in one direction, from one perimeter beam to the opposite perimeter beam, bending each strip to make a sensible vault shape. Now weave strips in the other direction, also at almost one foot centers, to form a basket. The strips can be nailed onto the form of the perimeter beam around the room. You will find that the basket is immensely strong and stable.

Lattice strips in position.

Now stretch burlap over the lattice strips, tacking it on the strips so it fits tightly. Paint the burlap with a heavy coat of polyester resin to stiffen it.



Burlap over the lattice work.

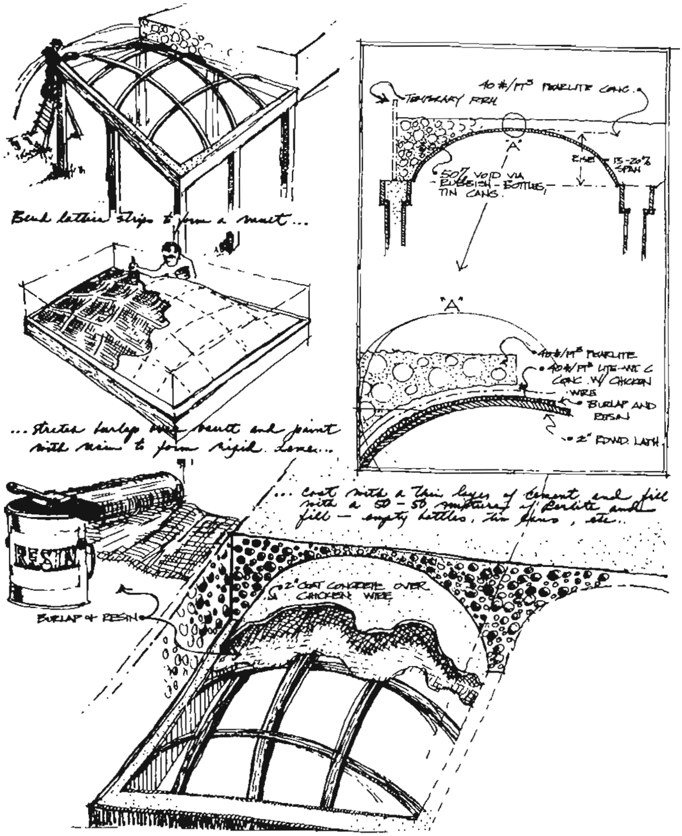
The burlap-resin skin is strong enough to support 1 to 2 inches of lightweight concrete. In preparation for this, put a layer of chickenwire, as shrinkage reinforcement, over the stiffened burlap. Then trowel on a 1- to 2-inch layer of lightweight concrete. Once again, use the ultra-lightweight 40–60 pound concrete described in GOOD MATERIALS (207).

Resin over burlap.

The shell which forms is strong enough to support the rest of the vault, and the floor above.

Lightweight concrete on.

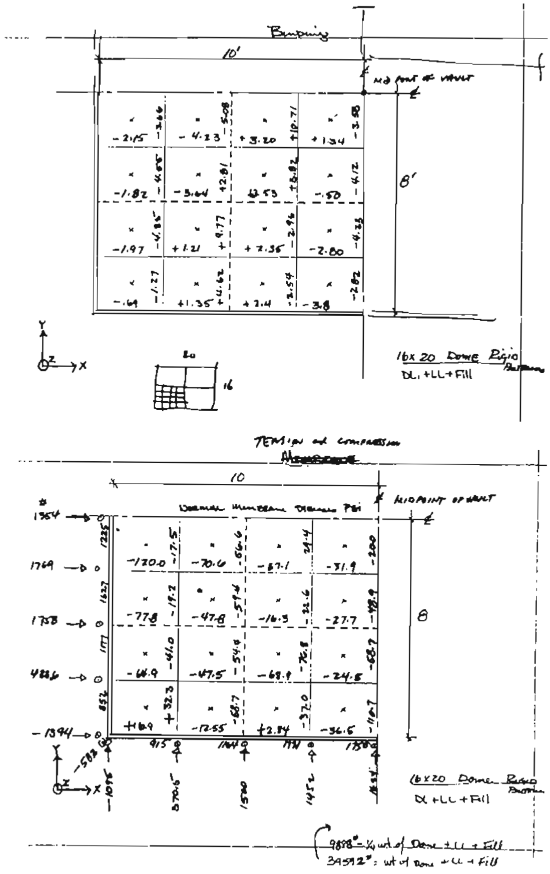
The rest of the vault should not be poured until all edges are in, columns for the next floor are in position, and ducts are in—see BOX COLUMNS (216), DUCT SPACE (229). In order to keep the weight of the vault down, it is important that even the ultra-lightweight concrete be further lightened, by mixing it with 50 per cent voids and ducts. Any kind of voids can be used—empty



One version of a floor-ceiling vault, made of thin wooden lattice strips woven like a basket, burlap, resin, chicken-wire and ultra lightweight concrete.

beer cans, wine jugs, sono tubes, ducts, chunks of polyurethane. Or voids can be made very much like the vaults themselves by making arches with latticing between columns and then stretching burlap from these arches to the dome. The drawing opposite shows the sequence of construction.

A 16 by 20 foot vault similar to the one shown in our photographs has been analyzed by a computerized finite element analysis. The concrete was assumed to be 40 pounds perlite, with a



Results of computer analysis.

test compressive strength of 600 psi. Tensile strength is taken as 34 psi, and bending as 25.5 inch pounds per inch. These figures are based on the assumption that the concrete is unreinforced. Dead loads were figured at 60 pounds per square foot assuming 50 per cent voids in the spandrels of the vault. Live loads were taken to be 50 pounds per square foot.

According to the analysis, under such loading the largest compressive stress in this dome occurs near the base at mid points of all four sides and is 120 psi. Outward thrust is the greatest at quarter points along all four walls, and is 1769 pounds. The maximum tension of 32 psi occurs at the corners. Maximum bending is 10 inch pounds per inch. All of these are well within the capacity of the vault, and besides, shrinkage reinforcement in the vault will make it even stronger.

The analysis shows, then, that even though the vault is an impure form (it contains square panels which are actually sagging within the overall configuration of the vault shape), its structural behavior is still close enough to that of a pure vault to work essentially as a compression structure. There are small amounts of local bending; and the corner positions of the dome suffer small amounts of tension, but the chickenwire needed for shrinkage will take care of both these stresses.

Here are some other possible ways of building such a vault:

To begin with, instead of wood for the lattice work, many other materials can be used: plastic strips, thin metal tubes, bamboos. Other resins besides polyester resins can be used to stiffen the burlap. If resins are unavailable, then the form for the vault can be made by placing lattice strips as described, and then stretching chickenwire over it, then burlap soaked in mortar which is allowed to harden before concrete is placed. It might also be possible to use matting stiffened with glue, perhaps even papier mache.

It is possible that similar vaults could be formed by altogether different means: perhaps with pneumatic membranes or balloons. And it is of course possible to form vaults by using very traditional methods: bricks or stones, on centering, like the beautiful vaults used in renaissance churches, gothic cathedrals, and so on.

Therefore:

Build floors and ceilings in the form of elliptical vaults which rise between 13 and 20 per cent of the shorter span. Use a type of construction which makes it possible to fit the vault to any shaped room after the walls and columns are in position: on no account use a prefabricated vault.

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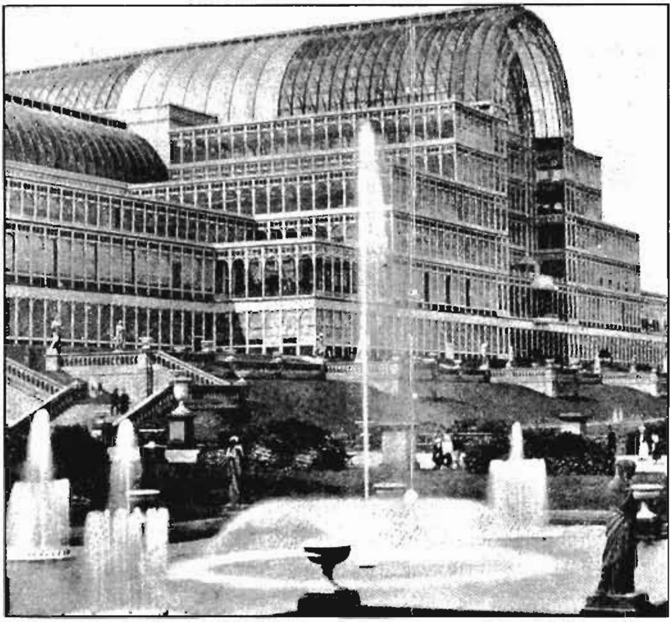
When the main vault is finished, mark the positions of all those columns which will be placed on the floor above it—FINAL COLUMN DISTRIBUTION (213). Whenever there are columns which are more than 2 feet away from the perimeter beam, strengthen the vault with ribs and extra reinforcing to withstand the vertical forces.

Put all the upper columns in position before you pour the floor of the vault, so that when you pour it, the concrete will pour around the column feet, and anchor them firmly in the same way that they are anchored in the foundations—ROOT FOUNDATIONS (214).

To finish the under surface of the vault paint it or plaster it—SOFT INSIDE WALLS (235). As for the floor surface above, either wax it and polish it or cover it with soft materials—FLOOR SURFACE (233). . . .

220 ROOF VAULTS*



. . . if the roof is a flat ROOF GARDEN (118), it can be built just like any FLOOR-CEILING VAULT (219). But when it is a sloping roof, according to the character of SHELTERING ROOF (117), it needs a new construction, specifically adapted to the shape which can enclose a volume.

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What is the best shape for a roof?

For some reason, this is the most loaded, the most emotional question, that can be asked about building construction. In all our investigations of patterns, we have not found any other pattern which generates so much discussion, so much disagreement, and so much emotion. Early childhood images play a vital role; so does cultural prejudice. It is hard to imagine an Arab building with a pitched roof; hard to imagine a New England farmhouse with a Russian onion roof over a tower; hard to imagine a person who has grown up among pitched steep wooden roofs, happy under the stone cones of the trulli.

All over the world.

For this reason, in this pattern we make our discussion as fundamental as we can. We shall do everything we can to obtain the necessary features which we can treat as invariant for all roofs, regardless of people or culture—yet deep enough to allow a rich assortment of cultural variations.

We approach the problem with the assumption that there are no constraints created by techniques or availability of materials. We are merely concerned with the optimum shape and distribution of materials. Given a roughly rectangular plan, or plan composed of rectangular pieces connected, what is the best shape for the shell of the roof which covers them?

The requirements influencing the shape are these:

1. The feeling of shelter—SHELTERING ROOF (117). This requires that the roof cover a whole wing (that is, not merely room by room). It requires that some of the roof be highly visible—hence, that it have a fairly steep slope—and that some of the roof be flat and usable for gardens or terraces.

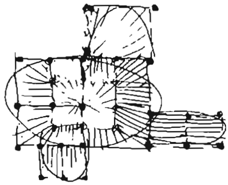
2. The roof must definitely contain lived-in space—that is, not just sit on top of the rooms which are all below—see SHELTERING ROOF (117). This means it needs rather a steep slope at the edge—because otherwise there is no headroom. This requires an elliptical section dome, or a barrel vault (which starts going up vertically at the edge), or a very steep slope.

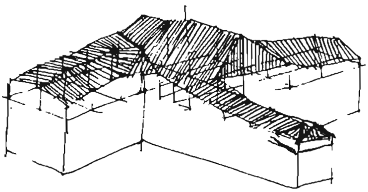
3. In plan, each individual roof is a very rough rectangle, with occasional variations. This follows from the way the roofs of a building must, together, follow the social layout of the plan—ROOF LAYOUT (209).

4. The roof shape must be relaxed—that is, it can be used in any plan layout—and can be generated very simply from a few generating lines which follow automatically from the plan—that is, it must not be a tricky or contrived shape which needs a lot of fiddling around to define it—STRUCTURE FOLLOWS SOCIAL SPACES (205).

5. Structural considerations require a curved shell, dome or vault to eliminate as much bending as possible—see EFFICIENT STRUCTURE (206) and GOOD MATERIALS (207). Of course, to the extent that wood or steel or other tension materials are available, this requirement can be relaxed.

6. The roof is steep enough to shed rain and snow in climates





. . . *relaxed.*

where they occur. Obviously, this aspect of the roof will vary from climate to climate.

These requirements eliminate the following kinds of roofs:

1. *Flat roofs.* Flat roofs, except ROOF GARDENS (118), are already eliminated by the psychological arguments of SHELTERING ROOFS (117) and, of course, by structural considerations. A flat roof is necessary where people are going to walk on it; but it is a very inefficient structural shape since it creates bending.

2. *Pitched Roofs.* Pitched roofs still require materials that can withstand bending moment. The most common material for pitched roofs—wood—is becoming scarce and expensive. As we have said in GOOD MATERIALS (207), we believe it is most sensible to keep wood for surfaces and not to use it as a structural material, except in wood rich areas. Pitched roofs also need to be very steep, indeed, to enclose habitable space as required by SHELTERING ROOF (117)—and hence rather inefficient.

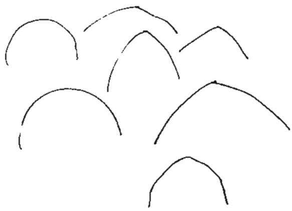
3. *Dutch barn and mansard roofs.* These roofs enclose habitable space more efficiently than pitched roofs; but they have the same structural drawbacks.

4. *Geodesic domes.* These domes cover essentially circular areas, and are not therefore useful in their ordinary form—CASCADE OF ROOFS (116), STRUCTURE FOLLOWS SOCIAL SPACES (205). In the modified form, which comes when you stretch

the base into a rough rectangle, they become more or less congruent with the class of vaults defined by this pattern.

5. *Cable nets and tents.* These roofs use tensile materials instead of compressive ones—they do not conform to the requirements of GOOD MATERIALS (207). They are also very inefficient when it comes to enclosing habitable space—and thus fail to meet the requirements of STRUCTURE FOLLOWS SOCIAL SPACES (205).

The roofs which satisfy the requirements are all types of rectangular barrel vaults or shells, with or without a peak, gabled or hipped, and with a variety of possible cross sections. Almost any one of these shells will be further strengthened by additional undulations in the direction of the vault. Examples of possible cross sections are given below. (Remember that this does not include those flat ROOF GARDENS (118) built over FLOOR-CEILING VAULTS (219).)



Possible roof vaults.

We have developed a range of roof vaults which are rather similar to a pitched roof—but with a convex curve great enough to eliminate bending, in some cases actually approaching barrel vaults. One is shown in the drawing opposite; another is shown below.

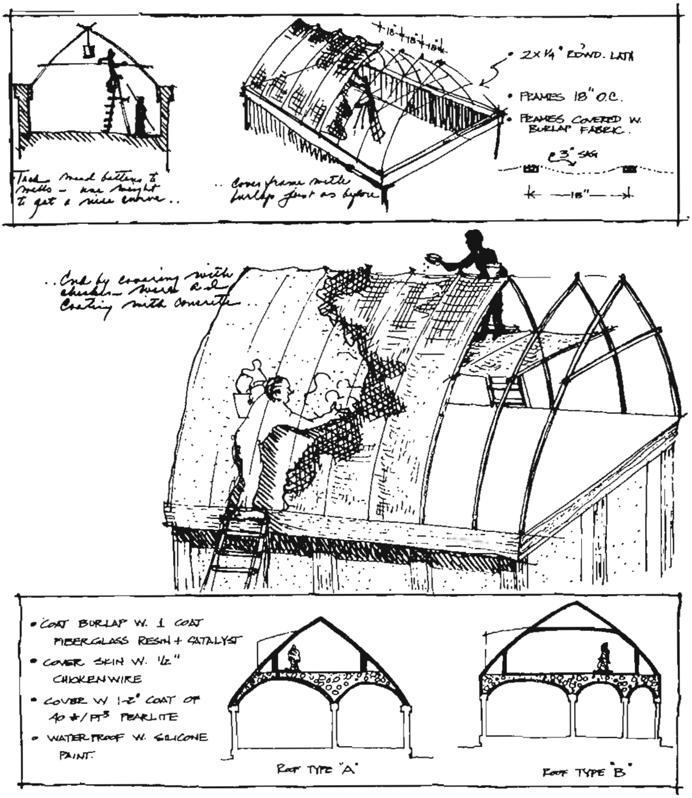
Another version of a roof vault, built by Bob Harris in Oregon.

We build the roof vault very much like the floor vaults:

1. First span the wing to be roofed with pairs of lattice strips which are securely nailed at their ends to the perimeter beam, and weighted at their apex so that the two pieces become slightly curved.

2. Make the frame for the ceiling under the roof frame at the same time according to FLOOR-CEILING VAULTS (219).

3. Repeat this frame every 18 inches, until the entire wing is



A type of roof vault, similar to the floor-ceiling vault, made from lattice strips, burlap, chicken-wire and ultra-lightweight concrete, but with an apex, and a pitch, and undulations for strength.

framed. The outer one will be the same, while the inner frame for the ceiling may change according to the rooms under it.

4. Now lay burlap over the ceiling frame, then resin, then 1½ inches of ultra-lightweight concrete—as for FLOOR-CEILING VAULTS (219).

5. Now lay burlap over the roof frame, tacking it onto the lattice strips so that there is a 3-inch scallop in between the ribs—to form structural undulations in the skin. Again, paint the burlap with resin; lay chickenwire and put a layer of lightweight concrete over the entire roof.

We have analyzed a 48-foot roof of this type by means of a computerized finite element analysis similar to the one described for FLOOR-CEILING VAULTS (219). The analysis shows that the maximum membrane compressive stress in the roof is 39.6 psi; the maximum membrane tensile stress is 2.5 psi, and the maximum diagonal membrane stress which develops from the maximum shear of 41.7 psi is 15.2 psi. These stresses are within the capacity of the material (See allowable stresses given in FLOOR-CEILING VAULT (219)). The maximum membrane bending moment is 46 inch pounds per inch which is higher than the capacity of the unreinforced section, but extrapolations from our data show that this will be comfortably taken care of by the reinforcing which is needed anyway for shrinkage. Roofs with smaller spans, for a typical WING OF LIGHT (106), will be even stronger.

Of course there are dozens of other ways to make a roof vault. Other versions include ordinary barrel vaults, lamella structures in the form of barrel vaults, elongated geodesic domes (built up from struts), vaults built up from plastic sheets, or fiberglass, or corrugated metal.

But, in one way or another, build your roofs according to the invariant defined below, remembering that it lies somewhere in between the Crystal Palace, the stone vaults of Alberobello, mud huts of the Congo, grass structures of the South Pacific, and the corrugated iron huts of our own time. This shape is required whenever you are working with materials which are in pure compression.

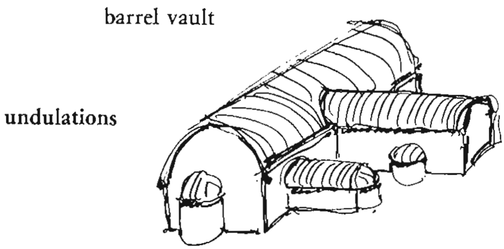
Obviously, if you have access to wood or steel and want to use it, you can modify this shape by adding tension members. However, we believe that these tension materials will become more

Experimental roof vaults.

and more rare as time goes on and that the pure compression shape will gradually become a universal.

Therefore:

Build the roof vault either as a cylindrical barrel vault, or like a pitched roof with a slight convex curve in each of the two sloping sides. Put in undulations along the vault, to make the shell more effective. The curvature of the main shell, and of the undulations, can vary with the span; the bigger the span, the deeper the curvature and undulations need to be.



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Leave space for dormers at intervals along the vault—DORMER WINDOWS (231), and build them integral with it. Finish the roof with ROOF CAPS (232). And once the vault is complete, it needs a waterproof paint or skin applied to its outer surface—LAPPED OUTSIDE WALLS (234). It can be painted white to protect it against the sun; the undulations will carry the rainwater. . . .

within the main frame of the building, fix the exact positions for openings—the doors and the windows —and frame these openings.

221. NATURAL DOORS AND WINDOWS

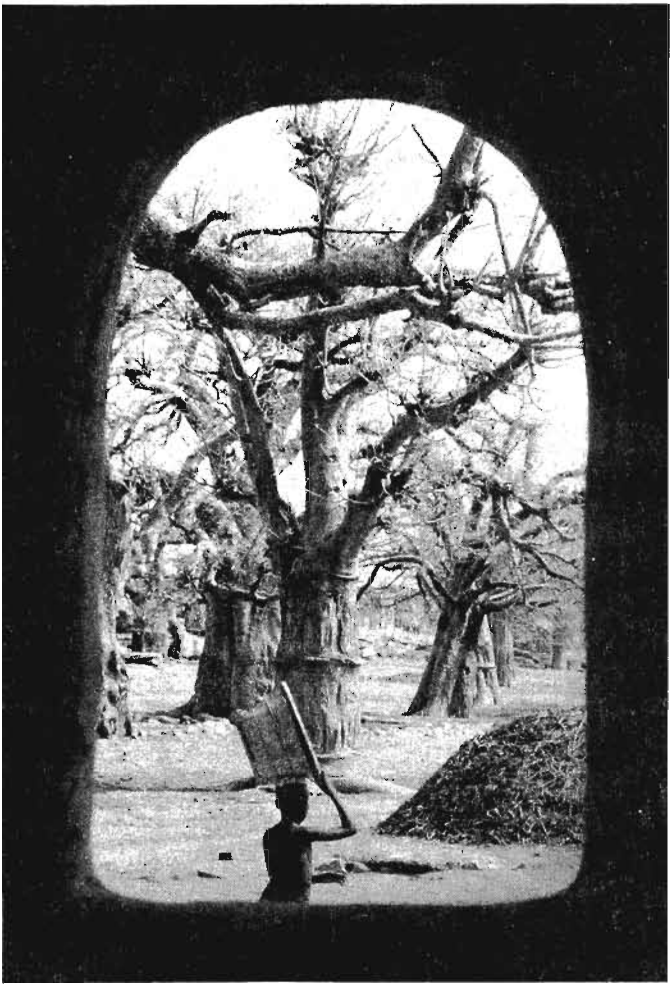
222. LOW SILL

223. DEEP REVEALS

224. LOW DOORWAY

225. FRAMES AS THICKENED EDGES

221 NATURAL DOORS AND WINDOWS**



. . . imagine that you are now standing in the built-up frame of a partly constructed building, with the columns and beams in place—BOX COLUMNS (216), PERIMETER BEAMS (217). You know roughly where you want doors and windows from ZEN VIEW (134), STREET WINDOWS (164), WINDOW PLACE (180), WINDOWS OVERLOOKING LIFE (192), CORNER DOORS (196). Now you can settle on the exact positions of the frames.

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Finding the right position for a window or a door is a subtle matter. But there are very few ways of building which take this into consideration.

In our current ways of building, the delicacy of placing a window or a door has nearly vanished. But it is just this refinement, down to the last foot, even to the last inch or two, which makes an immense difference. Windows and doors which are just right are always like this. Find a beautiful window. Study it. See how different it would be if its dimensions varied a few inches in either direction.

Now look at the windows and doors in most buildings made during the last 20 years. Assume that these openings are in roughly the right place, but notice how they could be improved if they were free to shift around, a few inches here and there, each one taking advantage of its own special circumstances—the space immediately inside and the view outside.

It is almost always a rigid construction system, combined with a formal aesthetic, which holds these windows in such a death grip. There is nothing else to this regularity, for it is possible to relax the regularity without losing structural integrity.

It is also important to realize that this final placing of windows and doors can only be done on site, with the rough frame of the building in position. It is impossible to do it on paper. But on the site it is quite straightforward and natural: mock up the openings with scraps of lumber or string and move them around until they feel right; pay careful attention to the organization of the view and the kind of space that is created inside.

Getting it just right.

As we shall see in a later pattern—SMALL PANES (239), it is not necessary to make the windows any special dimensions, or to try and make them multiples of any standard pane size. Whatever dimensions this pattern gives each window, it will then be possible to divide it up, to form small panes, which will be different in their exact shape and size, according to the window they are in.

However, although there is no constraint on the exact dimension of the windows, there is a general rule of thumb, which will make window sizes vary: Windows, as a rule, should become smaller as you get higher up in the building.

1. The area of windows needed for light and ventilation depends on the size of rooms, and rooms are generally smaller on upper stories of the building—the communal rooms are generally on the ground floor and more private rooms upstairs.

2. The amount of daylight coming through a window depends on the area of open sky visible through the window. The higher the window, the more open sky is visible (because nearby trees and buildings obscure less)—so less window area is needed to get sufficient daylight in.

3. To feel safe on the upper stories of a building, one wants more enclosure, smaller windows, higher sills—and the higher off the ground one is, the more one needs these psychological protections.

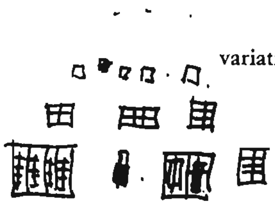
Therefore:

On no account use standard doors or windows. Make each window a different size, according to its place.

Do not fix the exact position or size of the door and win-

dow frames until the rough framing of the room has actually been built, and you can really stand inside the room and judge, by eye, exactly where you want to put them, and how big you want them. When you decide, mark the openings with strings.

Make the windows smaller and smaller, as you go higher in the building.



the position of the doors and windows "felt"

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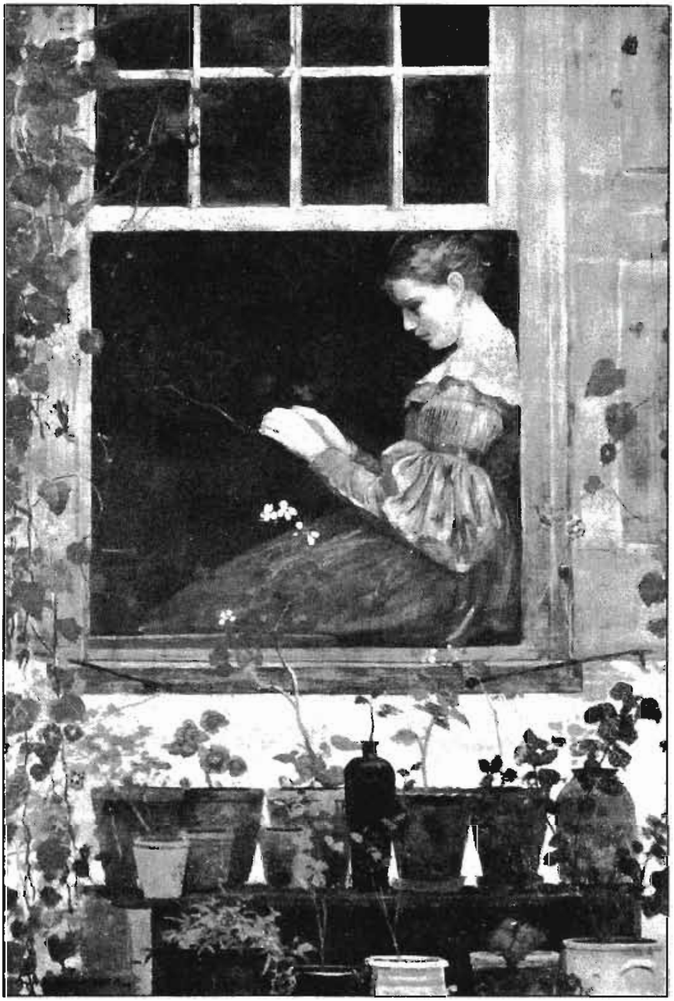
Fine tune the exact position of each edge, and mullion, and sill, according to your comfort in the room, and the view that the window looks onto—LOW SILL (222), DEEP REVEALS (223). As a result, each window will have a different size and shape, according to its position in the building. This means that it is obviously impossible to use standard windows and even impossible to make each window a simple multiple of standard panes. But it will still be possible to glaze each window, since the procedure for building the panes makes them divisions of the whole, instead of making up the whole as a multiple of standard panes—SMALL PANES (239). . . .

222 LOW SILL



. . . this pattern helps to complete NATURAL DOORS AND WINDOWS (221), and the special love for the view, and for the earth outside, which ZEN VIEW (134), WINDOW PLACE (180) and WINDOWS OVERLOOKING LIFE (192) all need.

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One of a window's most important functions is to put you in touch with the outdoors. If the sill is too high, it cuts you off.

The "right" height for a ground floor window sill is astonishingly low. Our experiments show that sills which are 13 or 14 inches from the floor are perfect. This is much lower than the window sills which people most often build: a standard window sill is about 24 to 36 inches from the ground. And it is higher than French doors and windows which usually have a bottom rail of 8 to 10 inches. The best height, then, happens to be a rather uncommon one.

We first give the detailed explanation for this phenomenon, and we then explain the modifications which are necessary on upper floors.

People are drawn to windows because of the light and the view outside—they are natural places to sit by when reading, talking, sewing, and so on, yet most windows have sill heights of 30 inches or so, so that when you sit down by them you cannot see the ground right near the window. This is unusually frustrating—you almost have to stand up to get a complete view.

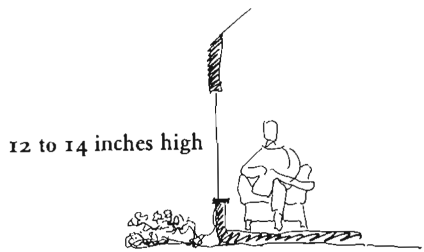
In "The Function of Windows: A Reappraisal" (*Building Science*, Vol. 2, Pergamon Press, 1967, pp. 97–121), Thomas Markus shows that the primary function of windows is not to provide light but to provide a link to the outside and, furthermore, that this link is most meaningful when it contains a view of the ground and the horizon. Windows with high sills cut out the view of the ground.

On the other hand, glass all the way down to the floor is undesirable. It is disturbing because it seems contradictory and even dangerous. It feels more like a door than a window; you have the feeling that you ought to be able to walk through it. If the sill is 12 to 14 inches high, you can comfortably see the ground, even if you are a foot or two away from the window, and it still feels like a window rather than a door.

On upper stories the sill height needs to be slightly higher. The sill still needs to be low to see the ground, but it is unsafe if it is too low. A sill height of about 20 inches allows you to see most of the ground, from a chair nearby, and still feel safe.

Therefore:

When determining exact location of windows also decide which windows should have low sills. On the first floor, make the sills of windows which you plan to sit by between 12 and 14 inches high. On the upper stories, make them higher, around 20 inches.



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Make the sill part of the frame, and make it wide enough to put things on—WAIST-HIGH SHELF (201), FRAMES AS THICKENED EDGES (225), WINDOWS WHICH OPEN WIDE (236). Make the window open outward, so that you can use the sill as a shelf, and so that you can lean out and tend the flowers. If you can, put flowers right outside the window, on the ground or raised a little, too, so that you can always see the flowers from inside the room—RAISED FLOWERS (245). . . .

223 DEEP REVEALS

. . . this pattern helps to complete the work of LIGHT ON TWO SIDES OF EVERY ROOM (159), by going even further to reduce glare; and it helps to shape the FRAMES AS THICKENED EDGES (225).

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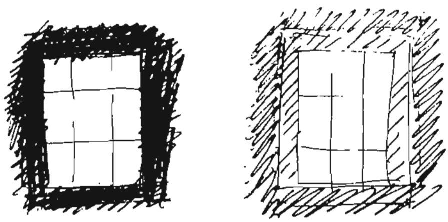
Windows with a sharp edge where the frame meets the wall create harsh, blinding glare, and make the rooms they serve uncomfortable.

They have the same effect as the bright headlights of an oncoming car: the glare prevents you from seeing anything else on the road because your eye cannot simultaneously adapt to the bright headlights and to the darkness of the roadway. Just so, a window is always much brighter than an interior wall; and the walls tend to be darkest next to the window's edge. The difference in brightness between the bright window and the dark wall around it also causes glare.



Glare . . . and no glare.

To solve this problem, the edge of the window must be splayed, by making a reveal between the window and the wall. The splayed reveal then creates a transition area—a zone of intermediate brightness—between the brightness of the window and the darkness of the wall. If the reveal is deep enough and the angle just right, the glare will vanish altogether.

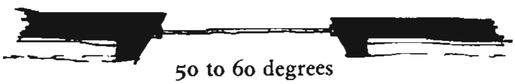
But the reveal must be quite deep, and the angle of the splay quite marked. In empirical studies of glare, Hopkinson and

Petherbridge have found: (1) that the larger the reveal is, the less glare there is; (2) the reveal functions best, when its brightness is just halfway between the brightness of the window and the brightness of the wall. ("Discomfort Glare and the Lighting of Buildings," *Transactions of the Illuminating Engineering Society*, Vol. XV, No. 2, 1950, pp. 58–59.)

Our own experiments show that this happens most nearly, when the reveal lies at between 50 and 60 degrees to the plane of the window; though, of course, the angle will vary with local conditions. And, to satisfy the need for a "large" reveal, we have found that the reveal itself must be a good 10 to 12 inches wide.

Therefore:

Make the window frame a deep, splayed edge: about a foot wide and splayed at about 50 to 60 degrees to the plane of the window, so that the gentle gradient of daylight gives a smooth transition between the light of the window and the dark of the inner wall.



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Build the depth of the frame so that it is continuous with the structure of the walls—FRAMES AS THICKENED EDGES (225); if the wall is thin, make up the necessary depth for the reveal on the inside face of the wall, with bookshelves, closets or other THICK WALLS (197); embellish the edge of the window even further, to make light even softer, with lace work, tracery, and climbing plants—FILTERED LIGHT (238), HALF-INCH TRIM (240), CLIMBING PLANTS (246). . . .

224 LOW DOORWAY

. . . some of the doors in a building play a special role in creating transitions and maintaining privacy: it may be any of the doors governed by FAMILY OF ENTRANCES (102), or MAIN ENTRANCE (110), or THE FLOW THROUGH ROOMS (131) or CORNER DOORS (196), or NATURAL DOORS AND WINDOWS (221). This pattern helps to complete these doors by giving them a special height and shape.

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High doorways are simple and convenient. But a lower door is often more profound.

The 6′ 8″ rectangular door is such a standard pattern, and is so taken for granted, that it is hard to imagine how strongly it dominates the experience of transition. There have been times, however, when people were more sensitive to the moment of passage, and made the shape of their doors convey the feeling of transition.

An extreme case is the Japanese tea house, where a person entering must literally kneel down and crawl in through a low hole in the wall. Once inside, shoes off, the guest is entirely a guest, in the world of his host.

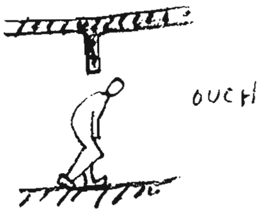
Among architects, Frank Lloyd Wright used the pattern many times. There is a beautifully low trellised walk behind Taliesin West, marking the transition out of the main house, along the path to the studios.

If you are going to try this pattern, test it first by pinning cardboard up to effectively lower the frame. Make the doorway low enough so that it appears "lower than usual"—then people will immediately adapt to it, and tall people will not hit their heads.

Therefore:

Instead of taking it for granted that your doors are simply 6′ 8″ rectangular openings to pass through, make at least some of your doorways low enough so that the act of going through the door is a deliberate thoughtful passage

from one place to another. Especially at the entrance to a house, at the entrance to a private room, or a fire corner—make the doorway lower than usual, perhaps even as low as 5′ 8″.



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Test the height before you build it, in place—NATURAL DOORS AND WINDOWS (221). Build the door frame as part of the structure—FRAMES AS THICKENED EDGES (225), and make it beautiful with ORNAMENT (249) around the frame. If there is a door, glaze it, at least partially—SOLID DOORS WITH GLASS (237). . . .

225 FRAMES AS THICKENED EDGES**

. . . assume that columns and beams are in and that you have marked the exact positions of the doors and windows with string or pencil marks—NATURAL DOORS AND WINDOWS (221). You are ready to build the frames. Remember that a well made frame needs to be continuous with the surrounding wall, so that it helps the building structurally—EFFICIENT STRUCTURE (206), GRADUAL STIFFENING (208).

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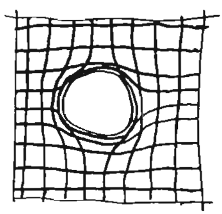
Any homogeneous membrane which has holes in it will tend to rupture at the holes, unless the edges of the holes are reinforced by thickening.

The most familiar example of this principle at work is in the human face itself. Both eyes and mouth are surrounded by extra bone and flesh. It is this thickening, around the eyes and mouth, which gives them their character and helps to make them such important parts of human physiognomy.

A building also has its eyes and mouth: the windows and the doors. And following the principle which we observe in nature, almost every building has its windows and doors elaborated, made more special, by just the kind of thickening we see in eyes and mouths.

The fact that openings in naturally occurring membranes are invariably thickened can be easily explained by considering how the lines of force in the membrane must flow around the hole.



The density of the lines represent increasing stress concentrations.

The increasing density of lines of force around the perimeter of the hole requires that additional material be generated there to prevent tearing.

Consider a soap film. When you prick the film, the tension pulls the film apart, and it disintegrates. But if you insert a ring of string into the film, the hole will hold, because the tensile forces which accumulate around the opening can be held by the thicker ring. This is in tension. The same is true for buckling and compression. When a thin plate is functioning in compression and a hole is made in it, the hole needs stiffening. It is important to recognize that this stiffening is not only supporting the opening itself against collapse, but it is taking care of the stresses in the membrane which would normally be distributed in that part of the membrane which is removed. Familiar examples of such stiffening in plates are the lips of steel around the portholes in a ship or in a locomotive cab.

A door frame as a thickening.

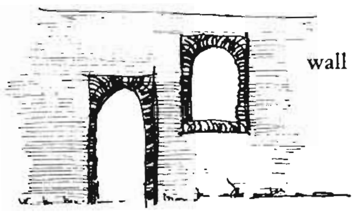
The same is true for doors and windows in a building. Where the walls are made of wood planks and lightweight concrete fill—see WALL MEMBRANES (218)—the thickened frames can be made from the same wood planks, placed to form a bulge, and then filled to be continuous with the wall. If other types of skin are used in the wall membranes, there will be other kinds of thickening: edges formed with chicken wire, burlap, and resin, filled with concrete; edges formed with chicken wire filled with rubble, and then mortar, plaster; edges formed with brick, filled, then plastered.

More general examples of frames as thickened edges exist all over the world. They include the thickening of the mud around the windows of a mud hut, the use of stone edges to the opening in a brick wall because the stone is stronger, the use of double studs around an opening in stud construction, the extra stone around the windows in a gothic church, the extra weaving round the hole in any basket hut.

Therefore:

Do not consider door and window frames as separate rigid structures which are inserted into holes in walls. Think of them instead as thickenings of the very fabric of the wall itself, made to protect the wall against the concentrations of stress which develop around openings.

In line with this conception, build the frames as thickenings of the wall material, continuous with the wall itself, made of the same materials, and poured, or built up, in a manner which is continuous with the structure of the wall.



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In windows, splay the thickening, to create DEEP REVEALS (223); the form of doors and windows which will fill the frame, is given by the later patterns—WINDOWS WHICH OPEN WIDE (236), SOLID DOORS WITH GLASS (237), SMALL PANES (239). . . .

as you build the main frame and its openings, put in the following subsidiary patterns where they are appropriate;

226. COLUMN PLACE

227. COLUMN CONNECTION

228. STAIR VAULT

229. DUCT SPACE

230. RADIANT HEAT

231. DORMER WINDOWS

232. ROOF CAPS

226 COLUMN PLACE*

. . . certain columns, especially those which are free standing, play an important social role, beyond their structural role as COLUMNS AT THE CORNERS (212). These are, especially, the columns which help to form arcades, galleries, porches, walkways, and outdoor rooms—PUBLIC OUTDOOR ROOM (69), ARCADES (119), OUTDOOR ROOM (163), GALLERY SURROUND (166), SIX-FOOT BALCONY (167), TRELLISED WALK (174). This pattern defines the character these columns need to make them function socially.

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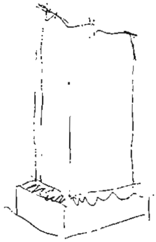
Thin columns, spindly columns, columns which take their shape from structural arguments alone, will never make a comfortable environment.

The fact is, that a free-standing column plays a role in shaping human space. It marks a point. Two or more together define a wall or an enclosure. The main function of the columns, from a human point of view, is to create a space for human activity.

In ancient times, the structural arguments for columns coincided in their implications with the social arguments. Columns made of brick, or stone, or timber were always large and thick. It was easy to make useful space around them.



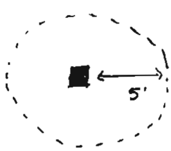
A big thick column.

But with steel and reinforced concrete, it is possible to make a very slender column; so slender that its social properties disappear altogether. Four inch steel pipes or 6 inch reinforced concrete columns break up space, but they destroy it as a place for human action, because they do not create "spots" where people can be comfortable.

Thin columns of the plastic world.

In these times, it is therefore necessary to reintroduce, consciously, the social purposes which columns have, alongside their structural functions. Let us try to define these social purposes exactly.

A column affects a volume of space around it, according to the situation. The space has an area that is roughly circular, perhaps 5 feet in radius.



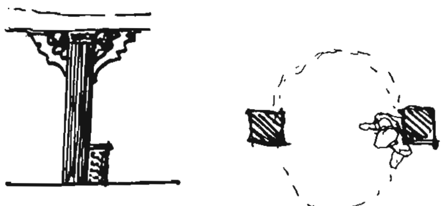
The space around the column.

When the column is too thin, or lacks a top or bottom, this entire volume—an area of perhaps 75 square feet—is lost. It cannot be a satisfactory place in its own right: the column is too thin to lean against, there is no way to build a seat up against it, there is no natural way to place a table or a chair against the column. On the other hand, the column still breaks up the space. It subtly prevents people from walking directly through that area: we notice that people tend to give these thin columns a wide berth; and it prevents people from forming groups.

In short, if the column has to be there, it will destroy a considerable area unless it is made to be a place where people feel comfortable to stay, a natural focus, a place to sit down, a place to lean.

Therefore:

When a column is free standing, make it as thick as a man—at least 12 inches, preferably 16 inches: and form places around it where people can sit and lean comfortably: a step, a small seat built up against the column, or a space formed by a pair of columns.



thick columns

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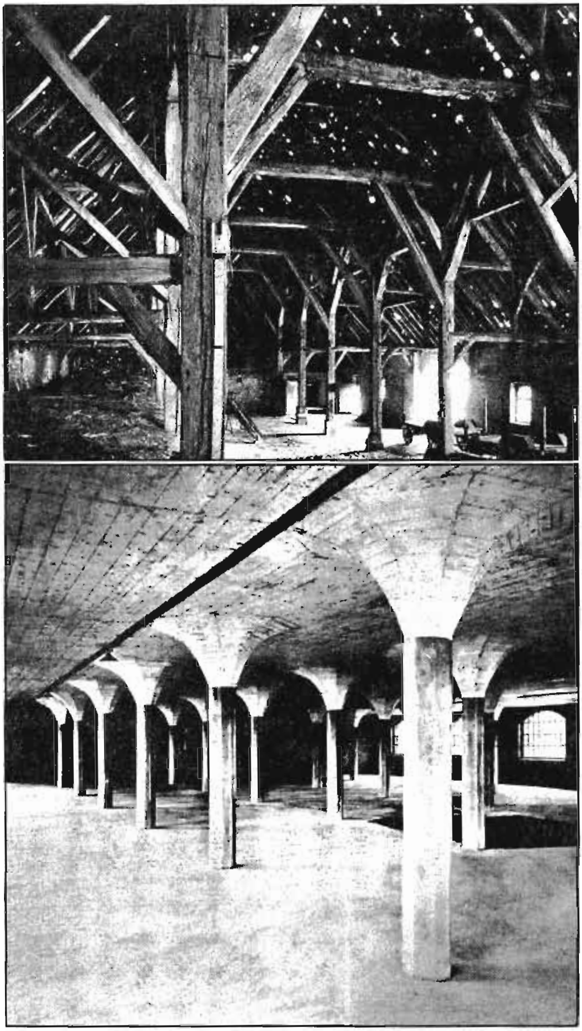
You can get the extra thickness quite cheaply if you build the column as a BOX COLUMN (216); complete the "place" the column forms, by giving it a "roof" in the form of a column capital, or vault which springs from the column, or by bracing the column against the beams—COLUMN CONNECTION (227). And when it makes sense, make the column base a SITTING WALL (243), a place for flowers—RAISED FLOWERS (245), or a place for a chair or table—DIFFERENT CHAIRS (251). . . .

227 COLUMN CONNECTIONS**



. . . the columns are in position, and have been tied together by a perimeter beam—BOX COLUMNS (216), PERIMETER BEAMS (217). According to the principles of continuity which govern the basic structure—EFFICIENT STRUCTURE (206), the connections need stiffening to lead the forces smoothly from the beams into the columns, especially when the columns are free standing as they are in an arcade or balcony—ARCADE (119), GALLERY SURROUND (166), SIX-FOOT BALCONY (167), COLUMN PLACE (226). You may also do the same in the upper corners of your door and window frames—FRAMES AS THICKENED EDGES (225)—making arched openings.

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The strength of a structure depends on the strength of its connections; and these connections are most critical of all at corners, especially at the corners where the columns meet the beams.

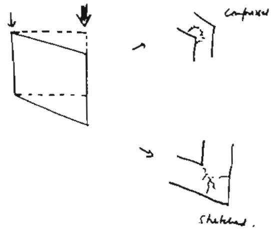
There are two entirely different ways of looking at a connection:

1. As a source of rigidity, which can be strengthened by triangulation, to prevent racking of the frame. This is a moment connection: a brace. See the upper picture.

2. As a source of continuity, which helps the forces to flow easily around the corner in the process of transferring loads by changing the direction of the force. This is a continuity connection: a capital. See the lower picture.

1. A column connection as a brace.

As a building is erected, and throughout its life, it settles, creating tiny stresses within the structure. When the settling is uneven, as it most always is, the stresses are out of balance; there is strain in every part of the building, whether or not that part of the building was designed to accept strain and transmit the forces on down to the ground. The parts of the building that are not designed to carry these forces become the weak points of the building subject to fracture and rupture.



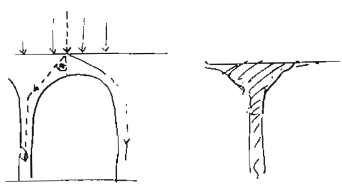
Effects of uneven stresses on a frame.

Rectangular frames, especially, have these cracks at the corners because the transmission of the load is discontinuous there. To solve this problem the frame must be braced—made into a rigid frame that transmits the forces around it as a whole without distorting. The bracing is required at any right-angled corner between columns and beams or in the corners of door and window frames.

2. A column connection as a capital.

This happens most effectively in an arch. The arch creates a continuous body of compressive material, which transfers vertical forces from one vertical axis to another. It works effectively because the line of action of a vertical force in a continuous compressive medium spreads out downward at about 45 degrees.

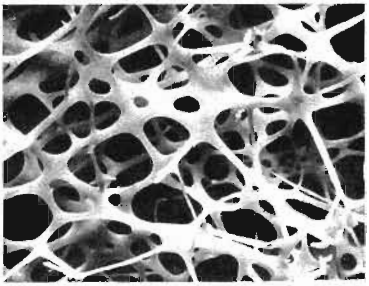
And a column capital is, in this sense, acting as a small, underdeveloped arch. It reduces the length of the beam—and so reduces bending stress. And it begins to provide the path for the forces as they move from one vertical axis to another, through the medium of the beam. The larger the capital, the better.



A capital that acts the same way as an arch.

A column connection will work best when it acts both as a column capital and as a column brace. This means that it needs to be thick and solid, like a capital, so that there is a lot of material for the forces to travel through, and stiff and strong and completely continuous with the column and perimeter beam, like the brace, so that it can work against shear and bending.

The bone structure, shown below uses both principles, to transfer compressive stress from one strut to another, continuously, throughout a three-dimensional space frame of struts. The structure is most massive at the connections, where the forces change direction.



Connections inside a bone.

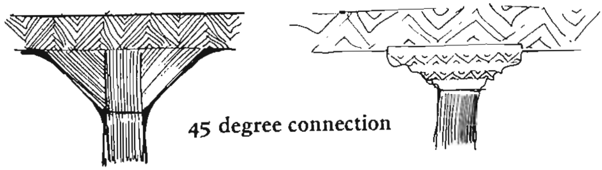
A similar column connection can be made integral with poured hollow columns and beams. The forms for the connection are gussets made of skin material: then fill the column and the gussets and the beam in a continuous concrete pour.

Of all the patterns in the book, this is one of the most widespread and has taken the greatest variety of outward forms throughout the course of history. A solid wood capital on a wood column, or a continuously poured column top, and arches of stone, brick, or poured concrete are all examples. And, of course, typical column capitals—a larger stone on a stone column or typical gusset plate or brace—even if weak in some ways, also help a great deal. But only relatively few of the historical column connections succeed fully in acting both as braces and as capitals.

Therefore:

Build connections where the columns meet the beams. Any distribution of material which fills the corner up will do: fillets, gussets, column capitals, mushroom column, and

most general of all, the arch, which connects column and beam in a continuous curve.



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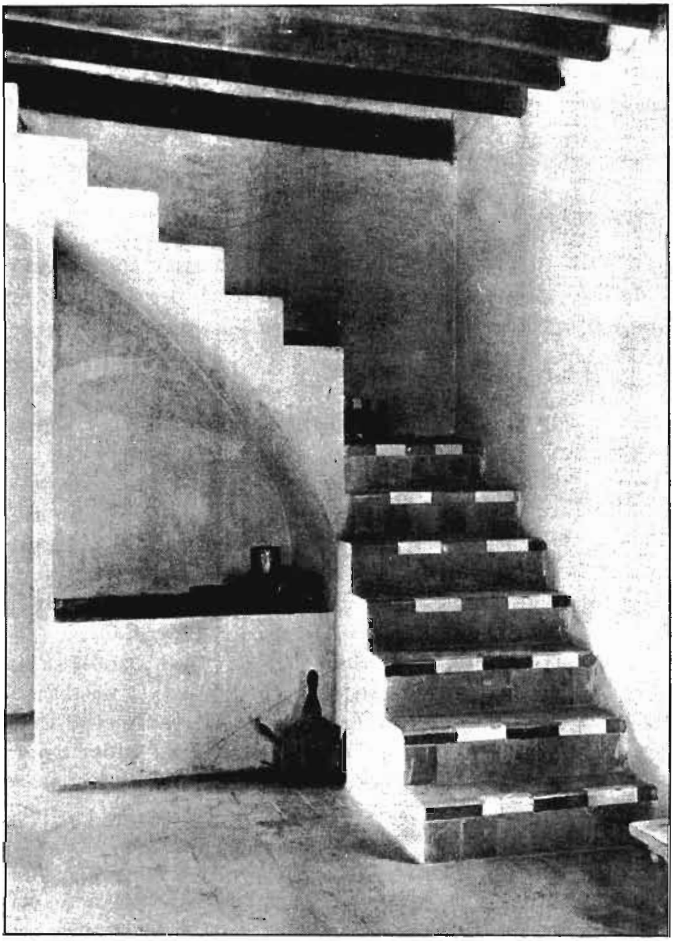
The connection is one of the most natural places for ORNAMENT (249): there is a wide variety of possible connections, carvings, fretwork, painting, for this critical position. In certain cases, the connection may act as an umbrella for a COLUMN PLACE (226). . . .

228 STAIR VAULT*



. . . this pattern helps complete the rough shape and location of stairs given by STAIRCASE AS A STAGE (133) and by STAIRCASE VOLUME (195). If you want to build a conventional stair, you can find what you need in any handbook. But how to build a stair in a way which is consistent with the compressive structure of EFFICIENT STRUCTURE (206), without using wood or steel or concrete—GOOD MATERIALS (207)?

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Within a building technology which uses compressive materials as much as possible, and excludes the use of wood, it is natural to build stairs over a vaulted void, simply to save weight and materials.

A concrete stair is usually made from precast pieces supported by steel stringers; or it is formed in place, and then stripped of its forms. But for the reasons already given in GOOD MATERIALS (207), precast concrete and steel are undesirable materials to use—they call for modular planning; they are unpleasant materials to touch, look at, and walk on; they are hard to work with and modify in any relaxed way, since they call for special tools.

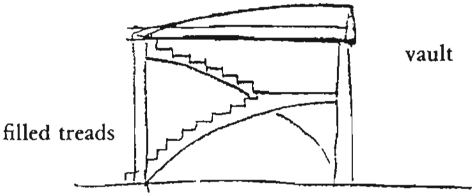
Given the principles of EFFICIENT STRUCTURE (206), GOOD MATERIALS (207), and GRADUAL STIFFENING (208), we suggest that stairs be made like FLOOR-CEILING VAULTS (219)—by making a half-vault (to the slope of the stair), with lattice strips, burlap, resin, chickenwire, and lightweight concrete. The steps themselves can then be formed by using wood planks, or tiles, as risers, and filling in the steps with trowelled concrete.

When we first wrote this pattern, we thought it was very doubtful—and put it in mainly to be consistent with floor and roof vaults. Since then we have built a vaulted stair. It is a great success—beautiful—and we recommend it heartily.

Therefore:

Build a curved diagonal vault in the same way that you

build your FLOOR-CEILING VAULTS (219). Once the vault hardens, cover it with steps of lightweight concrete, trowel-formed into position.



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A lightweight concrete tread, colored, waxed, and polished can be quite beautiful and soft enough to be comfortable—see FLOOR SURFACE (233)—and will eventually take on the patina of wear called for in SOFT TILE AND BRICK (248).

The vaulted space under the stair can be used as an ALCOVE (179) a CHILD CAVE (203), or CLOSETS BETWEEN ROOMS (198). If it is plastered, like a regular ceiling—see FLOOR-CEILING VAULTS (219), it makes a much more pleasant and useful space than the space under an ordinary stair.

229 DUCT SPACE

. . . in a building built according to the principles of EFFICIENT STRUCTURE (206) and built with vaulted floors—FLOOR-CEILING VAULTS (219), there is a triangular volume, unused, around the edge of every room. This is the most natural place to put the ducts.

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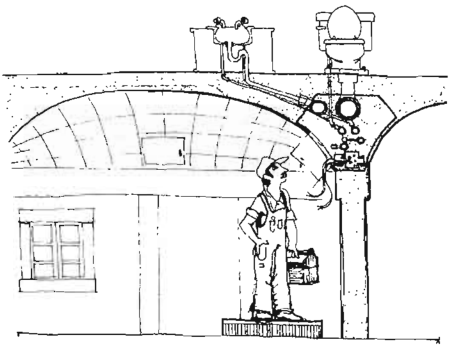
You never know where pipes and conduits are; they are buried somewhere in the walls; but where exactly are they?

In most buildings electric conduits, plumbing, drains, gas pipes, telephone wires, and so on, are buried in the walls, in a completely uncoordinated and disorganized way. This makes the initial construction of the building complicated since it is difficult to coordinate the installation of the various services with the building of various parts of the building. It makes it difficult to think about making any changes or additions to the building once it is built since you don't know where the service lines are. And it leaves a gap in our understanding of our surroundings: the organization of utilities and services in the buildings we live in are a mystery to us.

We propose that all the services be located together and run around the ceiling of each room in the spandrel between the vaulted ceiling and the floor above—FLOOR-CEILING VAULTS (219).

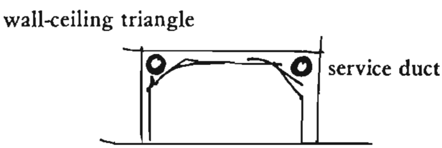
Heating and electrical conduits will be universal throughout the building and should thus be run around every room. Plumbing and gas lines will be around some rooms only. All lines will also be concentrated vertically at the corners of rooms. Thus the lines form vertical trunks from which horizontal loops spring. This configuration of pipes and conduits is easy to understand and plug into.



All in one place.

Therefore:

Make ducts to carry hot air conduit, plumbing, gas, and other services in the triangular space, within the vault, around the upper edge of every room. Connect the ducts for different rooms by vertical ducts, in special chases, in the corners of rooms. Build outlets and panels at intervals along the duct for access to the conduits.



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Once the duct is in, you can fill up the triangle with lightweight concrete—FLOOR-CEILING VAULTS (219). Place heating panels along the surface of the triangle—RADIANT HEAT (230); and place outlets for lights at frequent intervals below the duct, with leads and conduits running down in rebates along the window frames—POOLS OF LIGHT (252). . . .

230 RADIANT HEAT*

. . . to complete WALL MEMBRANES (218), FLOOR-CEILING VAULTS (219) and DUCT SPACE (229), use a biologically sensible heating system.

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This pattern is a biologically precise formulation of the intuition that sunlight and a hot blazing fire are the best kinds of heat.

Heat can be transmitted by radiation (heat waves across empty space), convection (flow in air or liquids by mixing of molecules and hot air rising), and conduction (flow through a solid).

In most places, we get heat in all three ways from our environment: conducted heat from the solids we touch, convected heat in the air around us, and radiated heat from those sources of radiation in our line of sight.

Of the three, conducted heat is trivial, since any surface hot enough to conduct heat to us directly is too hot for comfort. As far as the other two are concerned—convected heat and radiant heat—we may ask whether there is any biological difference in their effects on human beings. In fact there is.

It turns out that people are most comfortable when they receive radiant heat at a slightly higher temperature than the temperature of the air around them. The two most primitive examples of this situation are: (1) Outdoors, on a spring day when the air is not too hot but the sun is shining. (2) Around an open fire, on a cool evening.

Most people will recognize intuitively that these are two unusually comfortable situations. And in view of the fact that we evolved as organisms in the open air, with plenty of sun, it is not surprising that this condition happens to be so comfortable for us. It is built into our systems, biologically.

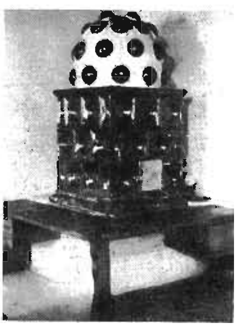
Unfortunately, it happens that many of the most widely used heating systems ignore this basic fact.

Hot air systems, and buried pipes, and the so-called hot water "radiators" do transmit some of their heat to us by means of radiation, but most of the heat we get from them comes from convection. The air gets heated and warms us as it swirls around us. But, as it does so it creates that very uncomfortable stuffy, over-heated, dry sensation. When convection heaters are warm enough to heat us we feel stifled. If we turn the heat down, it gets too cold.

The conditions in which people feel most comfortable require a subtle balance of convected heat and radiant heat. Experiments have established that the most comfortable balance between the two, occurs when the average radiant temperature is about two degrees higher than the ambient temperature. To get the average radiant temperature in a room, we measure the temperature of all the visible surfaces in a room, multiply the area of each surface by its temperature, add these up, and divide by the total area. For comfort, this average radiant temperature needs to be about two degrees higher than the air temperature.

Since some of the surfaces in a room (windows and outside walls), will usually be cooler than the indoor air temperature, this means that at least some surfaces must be considerably warmer to get the average up.

An open fire, which has a small area of very high temperature, creates this condition in a cool room. The beautiful Austrian and Swedish tiled stoves also do it very well. They are massive stoves, made of clay bricks or tiles, with a tiny furnace



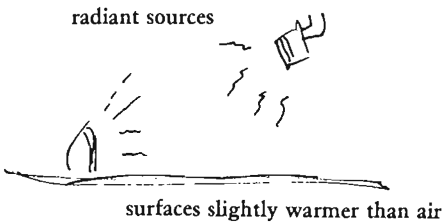
Austrian tiled stove.

in the middle. A handful of twigs in the furnace give all their heat to the clay of the stove itself, and this clay, like the earth, keeps this heat and radiates it slowly over a period of many hours.

Radiant panels, with individual room control, and infrared heaters hung from walls and ceilings, are possible high technology sources of radiant heat. It is possible that sources of low-grade radiant heat—like a hot water tank—might also work to very much the same effect. Instead of insulating the tank, it might be an excellent source of radiant heat, right in the center of the house.

Therefore:

Choose a way of heating your space—especially those rooms where people are going to gather when it is cold—that is essentially a radiative process, where the heat comes more from radiation than convection.



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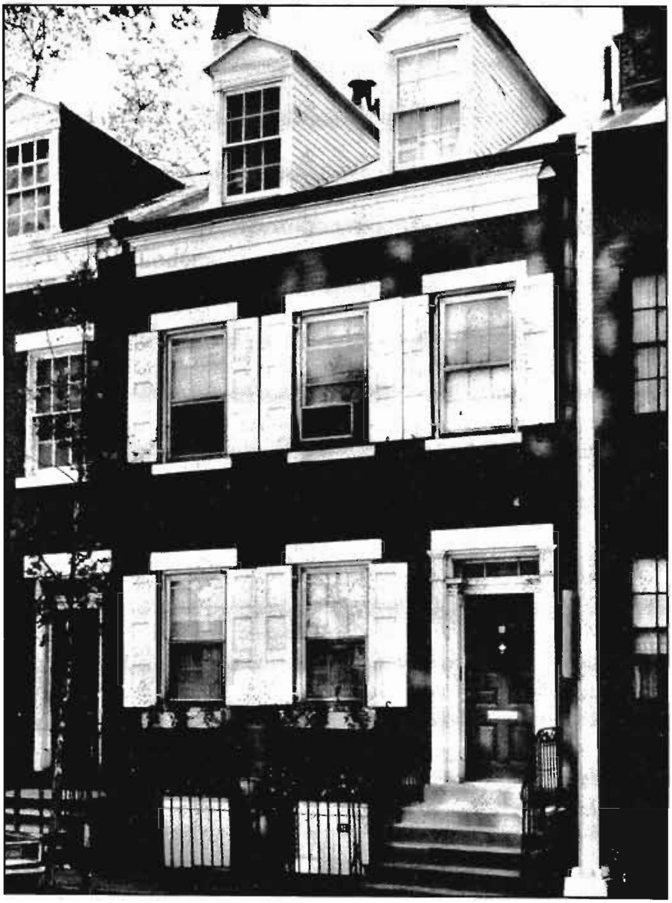
If you have followed earlier patterns, you may have rooms which have a vaulted ceiling, with a steeply sloping surface close to the wall, and with the major ducts behind that surface—FLOOR-CEILING VAULTS (219), DUCT SPACE (229). In this case, it is natural to put the radiant heating panels on that sloping surface.

But it is also very wonderful to make at least some part of the radiant surfaces low enough so that seats can be built round them and against them; on a cold day there is nothing better than a seat against a warm stove—BUILT-IN SEATS (202). . . .

231 DORMER WINDOWS*



. . . this pattern helps to complete SHELTERING ROOF (117). If you have followed sheltering roof, your roof has living space within it: and it must therefore have windows in it, to bring light into the roof. This pattern is a special kind of WINDOW PLACE (180), which completes the ROOF VAULTS (220), in these situations.

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We know from our discussion of SHELTERING ROOF (117) that the top story of the building should be right inside the roof, surrounded by it.

Obviously, if there is habitable space inside the roof, it must have some kind of windows; skylights are not satisfactory as windows—except in studios or workshops—because they do not create a connection between the inside and the outside world—WINDOWS OVERLOOKING LIFE (192).

It is therefore natural to pierce the roof with windows; in short, to build dormer windows. This simple, fundamental fact would hardly need mentioning if it were not for the fact that dormer windows have come to seem archaic and romantic. It is important to emphasize how sensible and ordinary they are—simply because people may not build them if they believe that they are old fashioned and out of date.

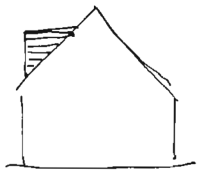
Dormers make the roof livable. Aside from bringing in light and air and the connection to the outside, they relieve the low ceilings along the edge of the roofs and create alcoves and window places.

How should the dormers be constructed? Within the roof vault we have described, the basket which forms the vault can simply be continued to form the roof of the dormer, over a frame of columns and perimeter beams which form the opening.

The other ways of building dormer windows depend on the construction system you are using. Whatever you are using for lintels, columns, and walls, can simply be modified and used in combination to build the dormer.

Therefore:

Wherever you have windows in the roof, make dormer windows which are high enough to stand in, and frame them like any other alcoves in the building.



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Frame them like ALCOVES (179) and WINDOW PLACE (180) with GRADUAL STIFFENING (208), COLUMNS AT THE CORNERS (212), BOX COLUMNS (216), PERIMETER BEAMS (217), WALL MEMBRANES (218), FLOOR-CEILING VAULTS (219), ROOF VAULTS (220) and FRAMES AS THICKENED EDGES (225).

Put WINDOWS WHICH OPEN WIDE (236) in them, and make SMALL PANES (239). . . .

232 ROOF CAPS

. . . and this pattern finishes the ROOF GARDENS (118) or the ROOF VAULTS (220). Assume that you have built the roof vaults —or at least that you have started to build up the splines which will support the cloth which forms the vault. Or assume that you have begun to build a roof garden, and have begun to fence it or surround it. In either case—how shall the roof be finished?

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There are few cases in traditional architecture where builders have not used some roof detail to cap the building with an ornament.

The pediments on Greek buildings; the caps on the trulli of Alberobello; the top of Japanese shrines; the venting caps on barns. In each of these examples there seems to be some issue of the building system that needs resolution, and the builder takes the opportunity to make a "cap."

We suspect there is a reason for this which should be taken seriously. The roof cap helps to finish the building; it tops the building with a human touch. Yet, the power of the cap, its overall effect on the feeling of the building, is of much greater proportions than one would expect. Look at these sketches of a building, with and without a roof cap. They look like different buildings. The difference is enormous.

With and without a roof cap.

Why is it that these caps are so important and have such a powerful effect on the building as a whole?

Here are some possible reasons.

1. They crown the roof. They give the roof the status that it deserves. The roof is important, and the caps emphasize this fact.

2. They add detail. They make the roof less homogeneous, and

they relieve the roof from being a single uninterrupted thing. The walls get this relief from windows, doors, balconies, which add scale and character; when a roof has many dormers, it seems to need the caps less.

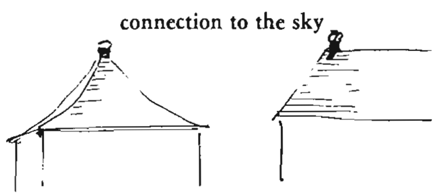
3. The caps provide a connection to the sky, in a way that might have had religious overtones at one time. Just as the building needs a sense of connection to the earth—see CONNECTION TO THE EARTH (168)—perhaps the roof needs a connection to the sky.

In the building system we propose, the roof caps are weights we use at the ridge of the roof to make the slight curve in the pitched sides of the roof. They happen at regular intervals, at the ridges of the scallops. They need not be large—a small bag of sand or a stone will do, plastered with concrete and shaped so the bulge is obvious. It may be nice to paint them a different color from the roof.

Of course, there are hundreds of other possible kinds of roof caps. They can be brick chimneys, statues, vents, structural details, the pinnacles on a gothic buttress, weather vanes, or even windmills.

Therefore:

Choose a natural way to cap the roof—some way which is in keeping with the kind of construction, and the meaning of the building. The caps may be structural; but their main function is decorative—they mark the top—they mark the place where the roof penetrates the sky.



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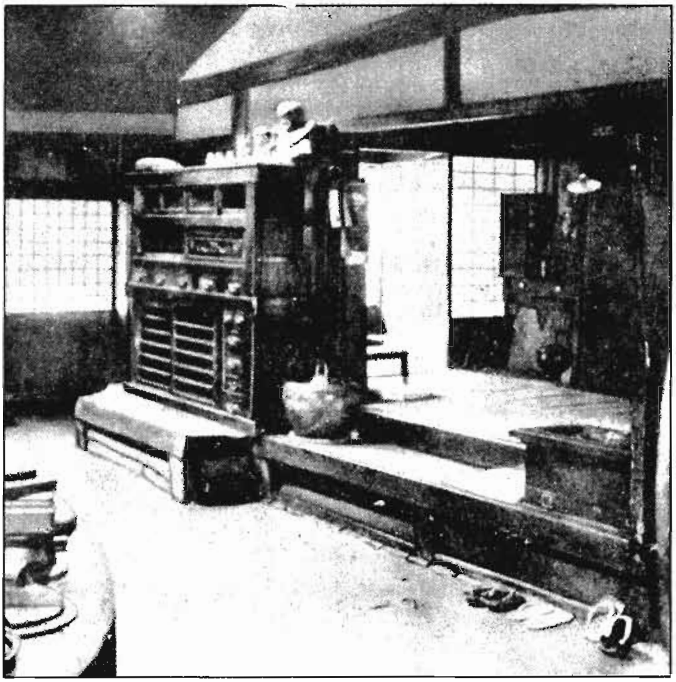
Finish the roof caps any way you want, but don't forget them—ORNAMENT (249). . . .

put in the surfaces and the indoor details;

233. FLOOR SURFACE
234. LAPPED OUTSIDE WALLS
235. SOFT INSIDE WALLS
236. WINDOWS WHICH OPEN WIDE
237. SOLID DOORS WITH GLASS
238. FILTERED LIGHT
239. SMALL PANES
240. HALF-INCH TRIM

233 FLOOR SURFACE**



. . . this pattern tells you how to put the surface on the floors, to finish the GROUND FLOOR SLAB (215) and FLOOR-CEILING VAULTS (219). When properly made, the floor surfaces will also help intensify the gradient of intimacy in the building—INTIMACY GRADIENT (127).

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We want the floor to be comfortable, warm to the touch, inviting. But we also want it to be hard enough to resist wear, and easy to clean.

When we think of floors, we think of wood floors. We hope, if we can afford it, to have a wooden floor. Even in hot countries, where tiles are beautiful, many people want hardwood floors whenever they can afford them. But the wood floor, though it seems so beautiful, does little to solve the fundamental problem of floors. The fact is that a room in which there is a bare wood floor, seems rather barren, forbidding, makes the room sound hollow and unfurnished. To make the wooden floor nice, we put down carpets. But then it is not really a wood floor at all. This confusion makes it clear that the fundamental problem of "the floor" has not been properly stated.

When we look at the problem honestly, we realize that the wooden floor, *and* the wooden floor with a carpet on it, are both rather uneven compromises. The bare wooden floor is too bare, too hard to be comfortable; but not in fact hard enough to resist wear particularly well if it is left uncovered—it scratches and dents and splinters. And when the floor is covered with a carpet, the whole point of the beauty of the wood is lost. You cannot see it any more, except round the edges of the carpet; and the carpet on the floor is certainly not hard enough to resist any substantial wear. Furthermore, the most beautiful carpets, handmade rugs and tapestries, are so delicate that they cannot take very rough wear. The practice of walking on a Persian rug with outdoor shoes on is a barbarian habit, never practiced by the people who make those rugs, and know how to treat them—they always take their shoes off. But the modern nylon and acrylic rugs, machine-made for hard wear, lose all the sumptuousness and pleasure of the carpet: they are, as it were, soft kinds of concrete.

The problem cannot be solved. The conflict is fundamental. The problem can only be *avoided* by making a clear distinction in the house between those areas which have heavy traffic and so need hard wearing surfaces which are easy to clean, and those other areas which have only very light traffic, where people can take off their shoes, and where lush, soft, beautiful rugs, pillows, and tapestries can easily be spread.

Traditional Japanese houses and Russian houses solve the problem in exactly this way: they divide the floor into two zones—serviceable and comfortable. They use very clean, and often precious materials in the comfortable zone, and often make the serviceable zone an extension of the street—that is, dirt, paving, and so on. People take their shoes off, or put them on, when they pass from one zone to the other.

The threshold between hard and soft.

We are not sure whether taking shoes off and on could become a natural habit in our culture. But it still makes sense to zone the house so that the floor material changes as one gets deeper into the house. The pattern INTIMACY GRADIENT (127) calls for a gradient of public, semi-public, and private rooms. It follows that one wants the floor to get softer as one goes deeper into the house—that is, the entrance and the kitchen are better floored with a hard, serviceable surface, while the dining, family room, and children's playrooms need a serviceable floor but with comfortable spots, and the bedrooms, studies, rooms of one's own need soft comfortable floors, on which people can sit, lie, and walk barefoot.

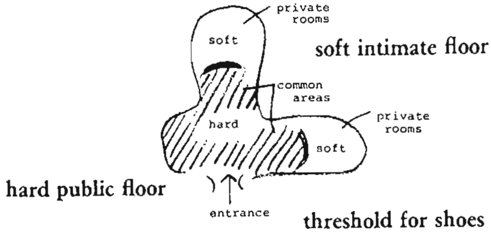
What should the materials be? Of the hard and soft materials, the hard is more of a problem. Since children are close to these floors, as well as the soft ones, they must be warm to the touch, —and at the same time they must be easy to clean. For these hard floors, a "soft" concrete might work. It can be made serviceable and pleasant at the same time if it is finished off with a lightweight textured floor finish, which is relatively porous. It can be made to wear and repel water by making the color integral with the mix and by waxing and polishing after it is set. It is fairly cheap and makes sense if the floor is a concrete floor anyway. Other materials which would work as hard floors are earth, rubber or cork tile, soft unbaked tile known as pastelleros in Peru—see SOFT TILE AND BRICK (248)—and wood planks, but these materials are more expensive.

For soft materials, carpet is the most satisfactory—for sitting, lying, and being close to the ground. We doubt that an improvement can be made on it—in fact we guess that if a substitute is used instead, it will eventually get carpeted over, anyway. This means that the areas which are going to be carpeted might as well have a cheap subfloor with matting laid wall to wall.

To emphasize the two zones, and to promote the taking off and on of shoes from one zone to the next, we suggest that there be a step up or a step down between the zones. This will help tremendously in keeping each zone "pure," and it is sure to help the activities in each zone.

Therefore:

Zone the house, or building, into two kinds of zones: public zones, and private or more intimate zones. Use hard materials like waxed, red polished concrete, tiles, or hardwood in the public zones. In the more intimate zone, use an underfloor of soft materials, like felt, cheap nylon carpet, or straw matting, and cover it with cloths, and pillows, and carpets, and tapestries. Make a clearly marked edge between the two—perhaps even a step—so that people can take their shoes off when they pass from the public to the intimate.



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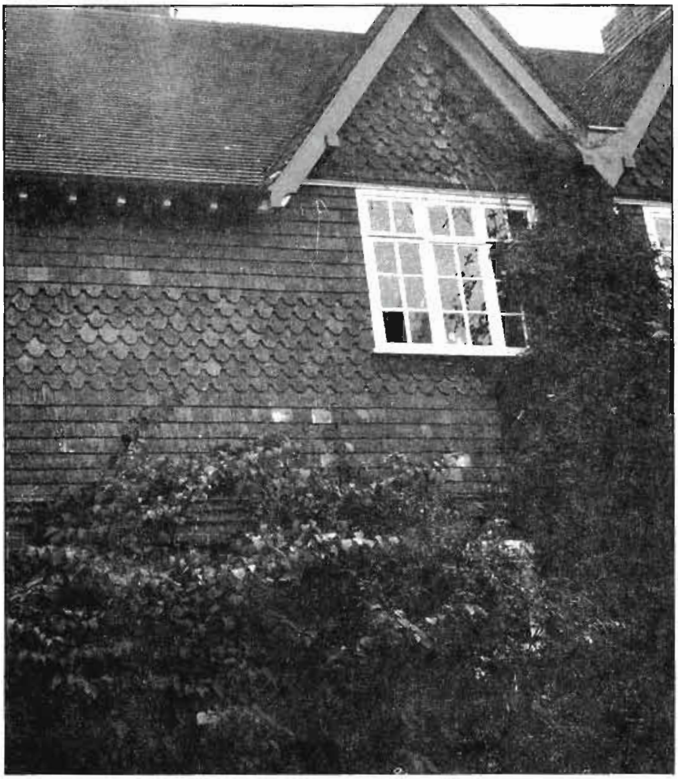
On the hard floor, you can use the same floor as you use on outdoor paths and terraces—hand fired brick and tile—SOFT TILE AND BRICK (248). On the soft intimate floors, use materials and cloths that are rich in ornament and color—ORNAMENT (249), WARM COLORS (250). . . .

234 LAPPED OUTSIDE WALLS



. . . this pattern finishes the WALL MEMBRANES (218), and ROOF VAULTS (220). It defines the character of their outside surfaces.

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The main function of a building's outside wall is to keep weather out. It can only do this if the materials are joined in such a way that they cooperate to make impervious joints.

At the same time, the wall must be easy to maintain; and give the people outside some chance of relating to it.

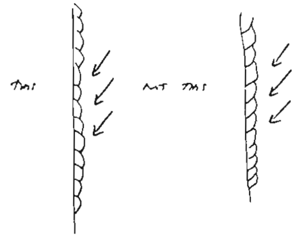
None of these functions can be very well managed by great sheets of impervious material. These sheets, always in the same plane, have tremendous problems at the joints. They require highly complex, sophisticated gaskets and seals, and, in the end, it is these seals and joints which fail.

Consider a variety of natural organisms: trees, fish, animals. Broadly speaking, their outside coats are rough, and made of large numbers of similar but not identical elements. And these elements are placed so that they often overlap: the scales of a fish, the fur of an animal, the crinkling of natural skin, the bark of a tree. All these coats are made to be impervious and easy to repair.

In simple technologies, buildings follow suit. Lapped boards, shingles, hung tiles, thatch, are all examples. Even stone and brick though in one plane, are still in a sense lapped internally to prevent cracks which run all the way through. And all of these walls are made of many small elements, so that individual pieces can be replaced as they are damaged or wear out.

Bear in mind then, as you choose an exterior wall finish, that it should be a material which can be easily lapped against the weather, which is made of elements that are easy to repair locally, and which therefore can be maintained piecemeal, indefinitely. And of course, whatever you choose, make it a surface which invites you to touch it and lean up against it.

In making our filled lightweight concrete structures, we have

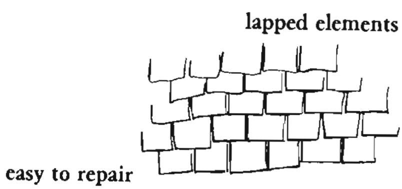


The internal structure of an imaginary lapped material.

used lapped boards as the exterior formwork for the lightweight concrete fill. And it is, of course, possible to use many other kinds of external cladding if they are available and if one can afford them. Slate, corrugated iron, ceramic tiles will produce excellent shingled wall claddings, and can all be placed in such a way as to provide exterior formwork for the pouring of a wall. It is also conceivable (though we have no evidence for it), that scientists might be able to create an oriented material whose internal crystal or fiber structure is in effect "lapped," because all the split lines run diagonally outward and downward.

Therefore:

Build up the exterior wall surface with materials that are lapped against the weather: either "internally lapped," like exterior plaster, or more literally lapped, like shingles and boards and tiles. In either case, choose a material that is easy to repair in little patches, inexpensively, so that little by little, the wall can be maintained in good condition indefinitely.



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235 SOFT INSIDE WALLS*

. . . and this pattern finishes the inner surface of the WALL MEMBRANES (218), and the under surface of FLOOR-CEILING VAULTS (219). If it is possible to use a soft material for the inner sheet of the wall membrane, then the wall will have the right character built in from the beginning.

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A wall which is too hard or too cold or too solid is unpleasant to touch; it makes decoration impossible, and creates hollow echoes.

A very good material is soft white gypsum plaster. It is warm in color (even though white), warm to the touch, soft enough to take tacks and nails and hooks, easy to repair, and makes a mellow sound, because its sound absorption capacity is reasonably high.

However, cement plaster, though only slightly different—and even confused with gypsum plaster—is opposite in all of these respects. It is too hard to nail into comfortably; it is cold and hard and rough to the touch; it has very low absorption acoustically—that is, very high reflectance—which creates a harsh, hollow sound; and it is relatively hard to repair, because once a crack forms in it, it is hard to make a repair that is homogeneous with the original.

In general, we have found that modern construction has gone more and more toward materials for inside walls that are hard and smooth. This is partly an effort to make buildings clean and impervious to human wear. But it is also because the kinds of materials used today are machine made—each piece perfect and exactly the same.

Buildings made of these flawless, hard and smooth surfaces leave us totally unrelated to them. We tend to stay away from them not only because they are psychologically strange, but because in fact they are physically uncomfortable to lean against; they have no give; they don't respond to us.

The solution to the problem lies in the following:

1. Gypsum plaster as opposed to cement plaster. Soft baked tiles as opposed to hard fired ones. When materials are porous and low in density they are generally softer and warmer to the touch.

2. Use materials which are granular and have natural texture, and which can be used in small pieces, or in such a way that there is repetition of the same small element. Walls finished in wood have the quality—the wood itself has texture; boards repeat it at a larger scale. Plaster has this character when it is hand finished. First there is the granular quality of the plaster and then the larger texture created by the motion of the human hand.

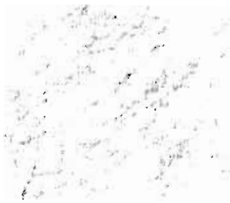
One of the most beautiful versions of this pattern is the one used in Indian village houses. The walls are plastered, by hand, with a mixture of cow dung and mud, which dries to a beautiful soft finish and shows the five fingers of the plasterer's hand all over the walls.

Cow dung plaster in an Indian village house.

Therefore:

Make every inside surface warm to the touch, soft enough to take small nails and tacks, and with a certain slight "give" to the touch. Soft plaster is very good; textile hangings, canework, weavings, also have this character. And wood is fine, where you can afford it.

soft to the touch



enough "give" for nails

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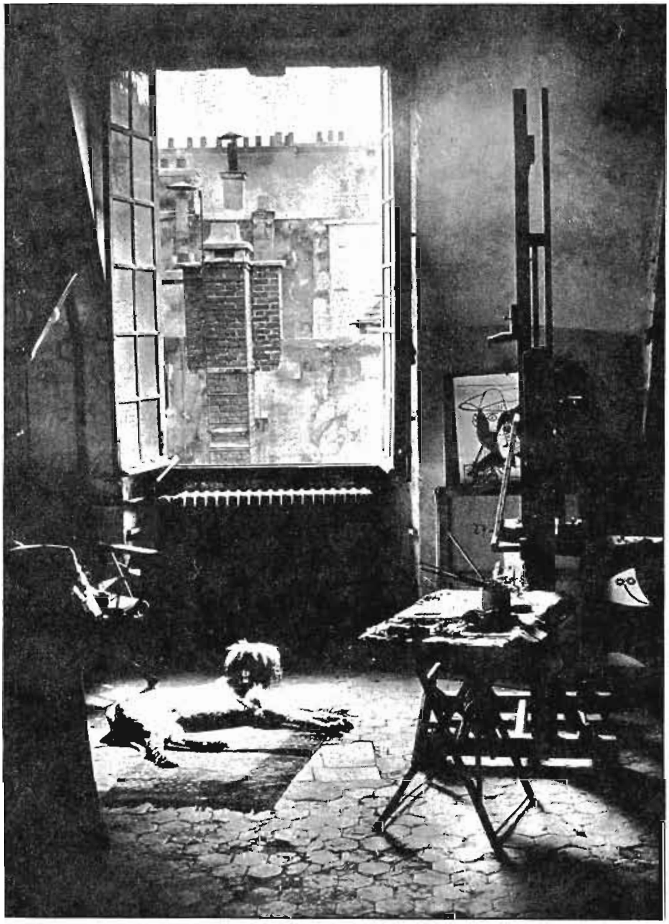
In our own building system, we find it is worth putting on a light skim coat of plaster over the inner surfaces of the WALL MEMBRANE (218) and FLOOR-CEILING VAULTS (219). Wherever finish plaster meets columns, and beams, and doors and window frames, cover the joint with half-inch wooden trim—HALF-INCH TRIM (240). . . .

236 WINDOWS WHICH OPEN WIDE*



. . . this pattern helps to complete WINDOW PLACE (180), WINDOWS OVERLOOKING LIFE (192), and NATURAL DOORS AND WINDOWS (221).

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Many buildings nowadays have no opening windows at all; and many of the opening windows that people do build, don't do the job that opening windows ought to do.

It is becoming the rule in modern design to seal up windows and create "perfect" indoor climates with mechanical air conditioning systems. This is crazy.

A window is your connection to the outside. It is a source of fresh air; a simple way of changing the temperature, quickly, when the room gets too hot or too cold; a place to hang out and smell the air and trees and flowers and the weather; and a hole through which people can talk to each other.

What is the best kind of window?

Double-hung windows cannot be fully opened—only half of the total window area can ever be opened at once. And they often get stuck—sometimes because they have been painted, sometimes because their concealed operating system of cords, counter-weights, and pulleys gets broken; it becomes such an effort to open them that no one bothers.

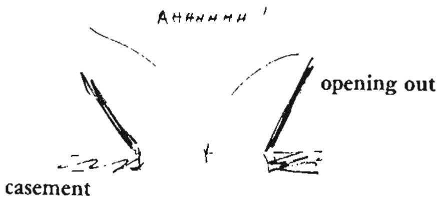
Sliding windows have much of the same problem—only part of the window area can be open, since one panel goes behind another; and they often get stuck too.

The side hung casement is easy to open and close. It gives the greatest range of openings, and so creates the greatest degree of control over air and temperature; and it makes an opening which is large enough to put your head and shoulders through. It is the easiest window to climb in and out of too.

The old time French windows are a stunning example of this pattern. They are narrow, full length upstairs windows, which swing out onto a tiny balcony, large enough only to contain the open windows. When you open them you fill the frame, and can stand drinking in the air: they put you intensely close to the outside—yet in a perfectly urban sense, as much in Paris or Madrid as in the open countryside.

Therefore:

Decide which of the windows will be opening windows. Pick those which are easy to get to, and choose the ones which open onto flowers you want to smell, paths where you might want to talk, and natural breezes. Then put in side-hung casements that open outward. Here and there, go all the way and build full French windows.



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Complete the subframe of the casement with SMALL PANES (239). . . .

237 SOLID DOORS WITH GLASS

. . . this pattern finishes the doors defined by CORNER DOORS (196) and LOW DOORWAY (224). It also helps to finish TAPESTRY OF LIGHT AND DARK (135) and INTERIOR WINDOWS (194), since it requires glazing in the doors, and can help to create daylight in the darker parts of indoor places.

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An opaque door makes sense in a vast house or palace, where every room is large enough to be a world unto itself; but in a small building, with small rooms, the opaque door is only very rarely useful.

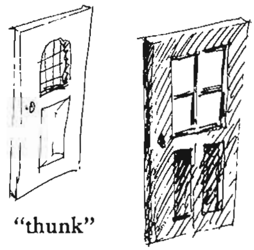
What is needed is a kind of door which gives some sense of visual connection together with the possibility of acoustic isolation: a door which you can see through but can't hear through.

Glazed doors have been traditional in certain periods—they are beautiful, and enlarge the sense of connection and make the life in the house one, but still leave people the possibility of privacy they need. A glazed door allows for a more graceful entrance into a room and for a more graceful reception by people in the room, because it allows both parties to get ready for each other. It also allows for different degrees of privacy: You can leave the door open, or you can shut it for acoustical privacy but maintain the visual connection; or you can curtain the window for visual and acoustic privacy. And, most important, it gives the feeling that everyone in the building is connected—not isolated in private rooms.

Therefore:

As often as possible build doors with glazing in them, so that the upper half at least, allows you to see through them. At the same time, build the doors solid enough, so

that they give acoustic isolation and make a comfortable "thunk" when they are closed.



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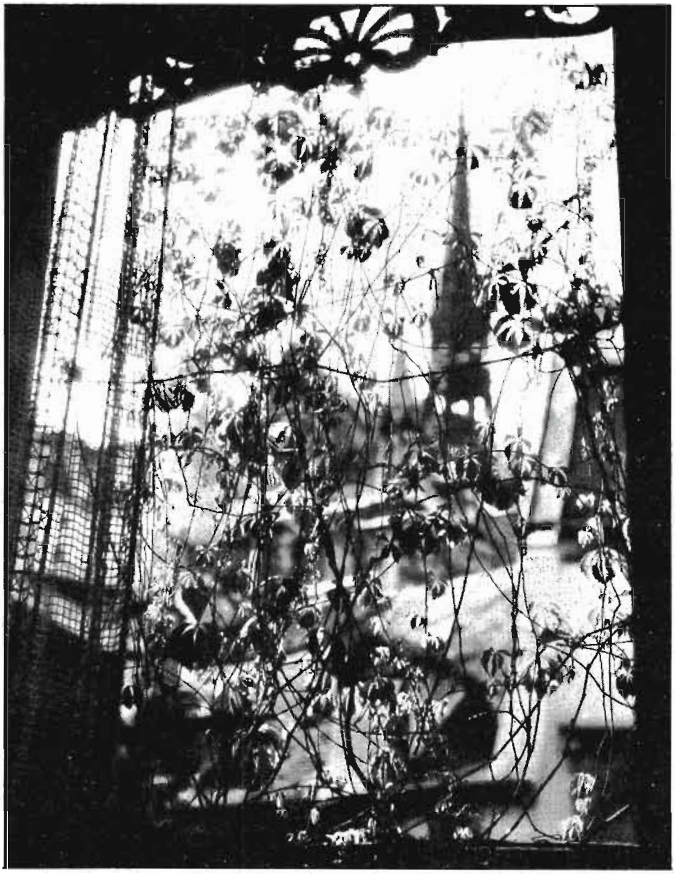
Glaze the door with small panes of glass—SMALL PANES (239); and make the doors more solid, by building them like WALL MEMBRANES (218). . . .

238 FILTERED LIGHT*



. . . even if the windows are beautifully placed, glare can still be a problem—NATURAL DOORS AND WINDOWS (221). The softness of the light, in and around the window, makes an enormous difference to the room inside. The shape of the frames can do a part of it—DEEP REVEALS (223)—but it still needs additional help.

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Light filtered through leaves, or tracery, is wonderful. But why?

We know that light filtering through a leafy tree is very pleasant—it lends excitement, cheerfulness, gaiety; and we know that areas of uniform lighting create dull, uninteresting spaces. But why?

1. The most obvious reason: direct light coming from a point source casts strong shadows, resulting in harsh images with strong contrasts. And people have an optical habit which makes this contrast worse: our eye automatically reinforces boundaries so that they read sharper than they are. For example, a color chart with strips of different colors set next to each other will appear as though there are dark lines between the strips. These contrasts and hard boundaries are unpleasant—objects appear to have a hard character, and our eyes, unable to adjust to the contrast, cannot pick up the details.

For all these reasons, we have a natural desire to diffuse light with lamp shades or indirect lighting, so that the images created by the light will be "softer," that is, that the boundaries perceived are not sharp, there is less contrast, fewer shadows, and the details are easier to see. This is also why photographers use reflected light instead of direct light when photographing objects; they pick up details which otherwise would be lost in shadow.

2. The second reason: to reduce the glare around the window. When there is bright light coming in through the window, it creates glare against the darkness of the wall around the window —see DEEP REVEALS (223). Filtering the light especially at the

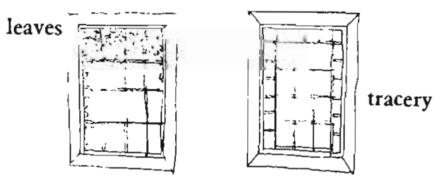
edges of the window cuts down the glare by letting in less light.

3. A third reason which is pure conjecture: it may simply be that an object which has small scale patterns of light dancing on it is sensually pleasing, and stimulates us biologically. Some film-makers claim the play of light upon the retina is naturally sensuous, all by itself.

To create filtered light, partially cover those windows which get direct sunlight, with vines and lattices. Leaves are special because they move. And the edge of the window can have fine tracery—that is, the edge of the glass itself, not the frame, so that the light coming in is gradually stronger from the edge to the center of the window; the tracery is best toward the top of the window where the light is strongest. Many old windows combine these ideas.

Therefore:

Where the edge of a window or the overhanging eave of a roof is silhouetted against the sky, make a rich, detailed taspestry of light and dark, to break up the light and soften it.



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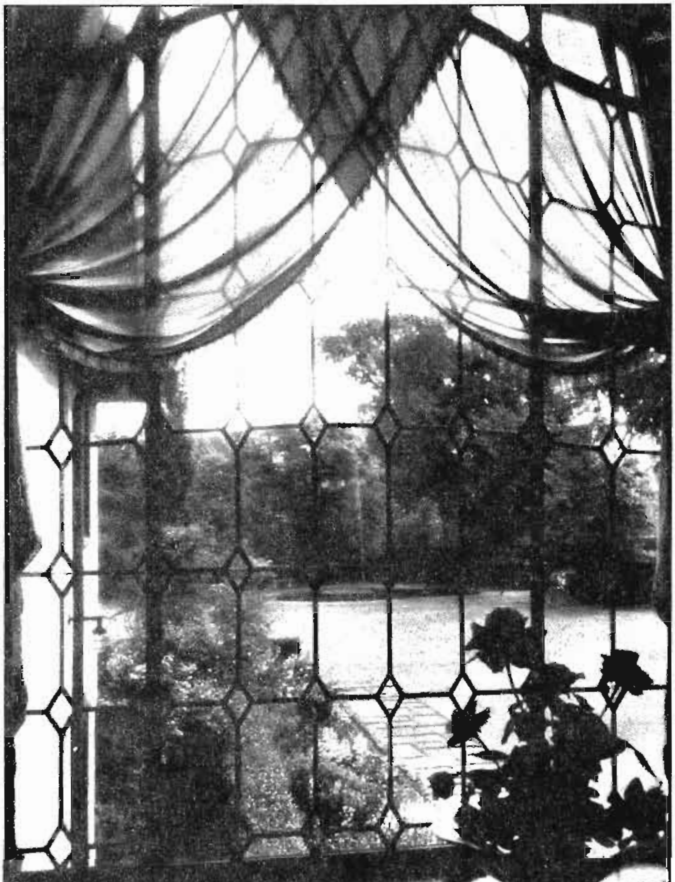
You can do this, most easily, with climbing plants trained to climb around the outside of the window—CLIMBING PLANTS (246). If there are no plants, you can also do it beautifully with simple canvas awnings—CANVAS ROOFS (244), perhaps colored—WARM COLORS (250). You can also help to filter light by making the panes smaller, more delicate, and more elaborate high in the window where the light is strong—SMALL PANES (239). . . .

239 SMALL PANES**



. . . this pattern gives the glazing for the windows in INTERIOR WINDOWS (194), NATURAL DOORS AND WINDOWS (221), WINDOWS WHICH OPEN WIDE (236), and SOLID DOORS WITH GLASS (237). In most cases, the glazing can be built as a continuation of the FRAMES AS THICKENED EDGES (225).

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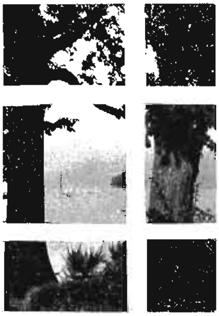
When plate glass windows became possible, people thought that they would put us more directly in touch with nature. In fact, they do the opposite.

They alienate us from the view. The smaller the windows are, and the smaller the panes are, the more intensely windows help connect us with what is on the other side.

This is an important paradox. The clear plate window seems as though it ought to bring nature closer to us, just because it seems to be more like an opening, more like the air. But, in fact, our contact with the view, our contact with the things we see through windows is affected by the way the window frames them. When we consider a window as an eye through which to see a view, we must recognize that it is the extent to which the window frames the view, that increases the view, increases its intensity, increases its variety, even increases the number of views we seem to see—and it is because of this that windows which are broken into smaller windows, and windows which are filled with tiny panes, put us so intimately in touch with what is on the other side. It is because they create far more frames: and it is the multitude of frames which makes the view.

Thomas Markus, who has studied windows extensively, has arrived at the same conclusion: windows which are broken up make for more interesting views. ("The Function of Windows—A Reappraisal," *Building Science*, Vol. 2, 1967, pp. 101–4). He points out that small and narrow windows afford different views from different positions in the room, while the view tends to be the same through large windows or horizontal ones.

We believe that the same thing, almost exactly, happens within the window frame itself. The following picture shows a simple landscape, broken up as it might be by six panes. Instead of one view, we see six views. The view becomes alive because the small panes make it so.



Six views.

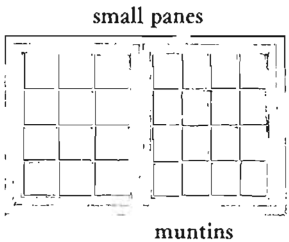
Another argument for small panes: Modern architecture and building have deliberately tried to make windows less like windows and more as though there was nothing between you and the outdoors. Yet this entirely contradicts the nature of windows. It is the function of windows to offer a view and provide a relationship to the outside, true. But this does not mean that they should not at the same time, like the walls and roof, give you a sense of protection and shelter from the outside. It is uncomfortable to feel that there is nothing between you and the outside, when in fact you are *inside* a building. It is the nature of windows to give you a relationship to the outside *and* at the same time give a sense of enclosure.

Small panes in Mendocino.

Not only that. Big areas of clear glass are sometimes even dangerous. People walk into plate glass windows, because they look like air. By comparison, windows with small panes give a clear functional message—the frames of the panes definitely tell you that something is there separating you from the outside. And they help to create FILTERED LIGHT (238).

Therefore:

Divide each window into small panes. These panes can be very small indeed, and should hardly ever be more than a foot square. To get the exact size of the panes, divide the width and height of the window by the number of panes. Then each window will have different sized panes according to its height and width.



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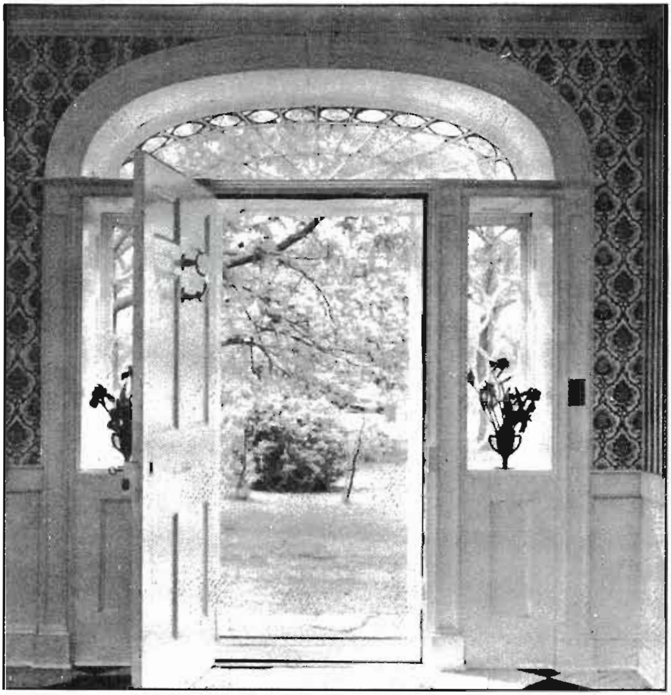
In certain cases you may want to make the small panes even finer near the window edge, to filter the light around the upper edge of windows which stand out against the sky—FILTERED LIGHT (238). As for the muntins, they can be made from the same materials as trim—HALF-INCH TRIM (240). . . .

240 HALF-INCH TRIM**



. . . and this pattern finishes the joints between SOFT INSIDE WALLS (235), or LAPPED OUTSIDE WALLS (234) and the various floors and vaults and frames and stiffeners and ornaments which are set into the walls: BOX COLUMNS (216), PERIMETER BEAMS (217), FLOOR-CEILING VAULTS (219), FRAMES AS THICKENED EDGES (225), and ORNAMENT (249).

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Totalitarian, machine buildings do not require trim because they are precise enough to do without. But they buy their precision at a dreadful price: by killing the possibility of freedom in the building plan.

A free and natural building cannot be conceived without the possibility of finishing it with trim, to cover up the minor variations which have arisen in the plan, and during its construction.

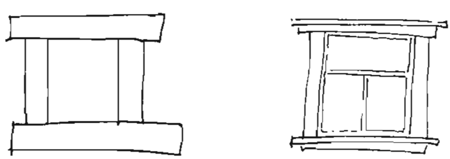
For example, when nailing a piece of gypsum board to a column—if the board is cut on site—it is essential that the cut can be inaccurate within a half-inch or so. If it has to be more accurate, there will be a great waste of material, and on-site cutting time and labor will increase, and, finally, the very possibility of adapting each part of the building to the exact subtleties of the plan and site will be in jeopardy.

It is in response to difficulties of this sort that modern system building has arisen. Here tolerances are very low indeed—⅛ inch and even lower—and there is no need for trim to cover up inaccuracies. However, the precision of the components can only be obtained by the most tyrannical control over the plan. This one aspect of construction has by itself destroyed the builder's capacity to make a building which is natural, organic, and adapted to the site.

If, as we suggest, the building procedure is looser and allows much larger tolerance—even mistakes on the order of half an inch or more—then the use of trim to cover the connection between materials becomes essential. Indeed, within this attitude to building, the trim is not a trivial decoration added as a finishing touch, but an essential phase of the construction. We see, then, that trim, so often associated with older buildings, and treated as an emblem of nostalgia, is in fact a vital part of the process of making buildings natural.

Finally, it is worth adding a note about the actual size of the trim pieces. Buildings built in the last 25 years often make a virtue out of boldness, and there is a tendency to use very large oversized pieces of trim instead of small pieces. Within the framework of this philosophy, it might seem right to use pieces of trim 2 or 3 inches thick for their effect and heaviness. We believe that this is wrong: Trim which is too large, or too thick, doesn't do its job. This is not a matter of style. There is a psychological reason for making sure that every component in the building has at least some pieces of trim which are of the order of half an inch or an inch thick, *and no more.*

Compare the following two examples of trim. For some reason the right-hand one, in which the trim is finer, is closer and better adapted to our feelings than the left-hand one.



Chunky trim . . . . . fine scale trim.

The reason for this seems to be the following. Our own bodies and the natural surroundings in which we evolved contain a continuous hierarchy of details, ranging all the way from the molecular fine structure to gross features like arms and legs (in our own bodies) and trunks and branches (in our natural surroundings).

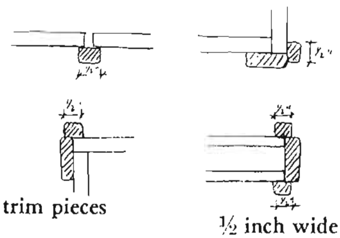
We know from results in cognitive psychology that any one step in this hierarchy can be no more than 1:5, 1:7, or 1:10 if we are to perceive it as a natural hierarchy. We cannot understand a hierarchy in which there is a jump in scale of 1:20 or more. It is this fact which makes it necessary for our surroundings, even when man-made, to display a similar continuum of detail.

Most materials have some kind of natural fibrous or crystalline structure at the scale of about $1/20$ inch. But if the smallest building detail dimensions are of the order of 2 or 3 inches, this leaves a jump of 1:40 or 1:60 between these details and the fine structure of the material.

In order to allow us to perceive a connection between the fine building construction and the fine structure of the materials, it is essential that the smallest building details be of the order of a half inch or so, so that it is no more than about 10 times the size of the granular and fibrous texture of the materials.

Therefore:

Wherever two materials meet, place a piece of trim over the edge of the connection. Choose the pieces of trim so that the smallest piece, in each component, is always of the order of ½ inch wide. The trim can be wood, plaster, terracotta. . . .



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In many cases, you may be able to use the trim to form the ornaments—ORNAMENT (249); and trims may occasionally be colored: even tiny amounts can help to make the light in a room warm—WARM COLORS (250). . . .

build outdoor details to finish the outdoors as fully as the indoor spaces;

241. SEAT SPOTS

242. FRONT DOOR BENCH

243. SITTING WALL

244. CANVAS ROOFS

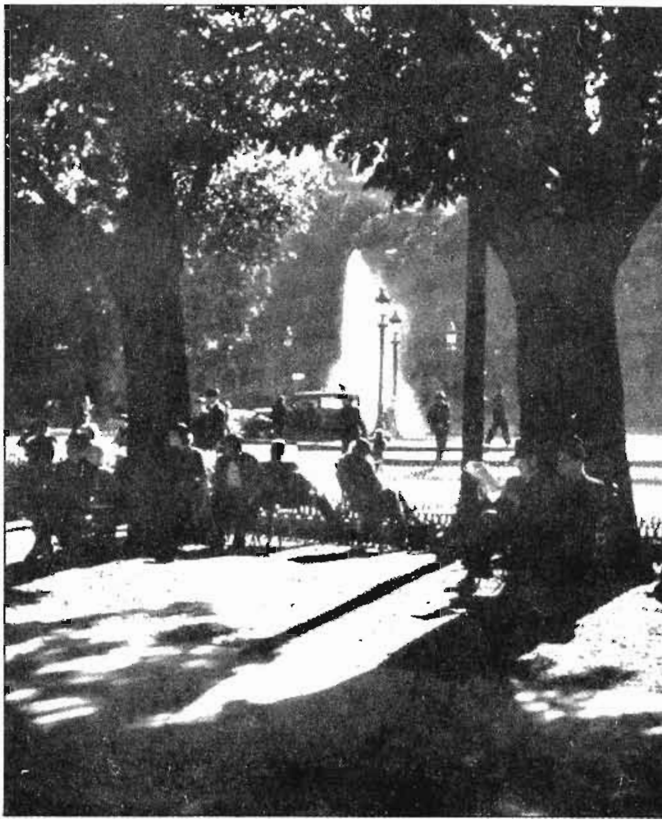
245. RAISED FLOWERS

246. CLIMBING PLANTS

247. PAVING WITH CRACKS BETWEEN THE STONES

248. SOFT TILE AND BRICK

241 SEAT SPOTS**



. . . assume that the main structure of the building is complete. To make it perfectly complete you need to build in the details of the gardens and the terraces around the building. In some cases, you will probably have laid out the walls and flowers and seats, at least in rough outline; but it is usually best to make the final decisions about them after the building is really there—so that you can make them fit the building and help to tie it into its surroundings—PATH SHAPE (121), ACTIVITY POCKETS (124), PRIVATE TERRACE ON THE STREET (140), BUILDING EDGE (160), SUNNY PLACE (161), OUTDOOR ROOM (163), CONNECTION TO THE EARTH (168), TRELLISED WALK (174), GARDEN SEAT (176), etc. First, the outdoor seats, public and private.

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Where outdoor seats are set down without regard for view and climate, they will almost certainly be useless.

We made random spot checks on selected benches in Berkeley, California, and recorded these facts about each bench: Was it occupied or empty? Did it give a view of current activity or not? Was it in the sun or not? What was the current wind velocity? Three of the eleven benches were occupied; eight were empty.

At the moment of observation, all three occupied benches looked onto activity, were in the sun, and had a wind velocity of less than 1.5 feet per second. At the moment of observation, none of the eight empty benches had all three of these characteristics. Three of them had shelter and activity but no sun; three of them had activity but no sun, and wind greater than 3 feet per second; two of them had sun and shelter but no activity.

A second series of observations compared the numbers of old people sitting in Union Square at 3:00 P.M. on a sunny day with the number at 3:00 P.M. on a cloudy day: 65 people on the sunny day and 21 on the cloudy day, even though the air temperature was the same on both days.

It's obvious, of course—but the point is this—when you are going to mark in spots in your project for the location of outdoor seats, sitting walls, stair seats, garden seats, look for places with these characteristics:

1. Benches facing directly onto pedestrian activity.

2. Benches open to the south for sun exposure during winter months.

3. A wall on those sides where the winter wind comes down.

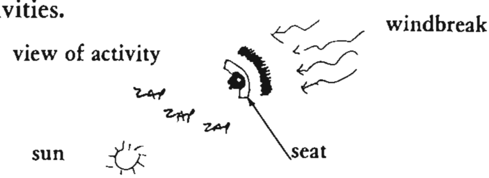
4. In hot climates—cover to give sun protection during the midday hours of summer months, and the bench open to the direction of the summer breeze.

New England benches.

Therefore:

Choosing good spots for outdoor seats is far more important than building fancy benches. Indeed, if the spot is right, the most simple kind of seat is perfect.

In cool climates, choose them to face the sun, and to be protected from the wind; in hot climates, put them in shade and open to summer breezes. In both cases, place them to face activities.



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If these seats can be made continuous with stairs or building entrances or low walls or ballustrades, so much the better—STAIR SEATS (125), FRONT DOOR BENCH (242), SITTING WALL (243). . . .

242 FRONT DOOR BENCH*

. . . SEAT SPOTS (241), acting within several larger patterns, creates an atmosphere around the edge of the building which invites lingering—ARCADES (119), BUILDING EDGE (160), SUNNY PLACE (161), CONNECTION TO THE EARTH (168); it is most marked and most important near the entrance—ENTRANCE ROOM (130). This pattern defines a special SEAT SPOT (241): a bench which helps to form the entrance room and the building edge around the entrance. It is always important; but perhaps most important of all, at the door of an OLD AGE COTTAGE (155).

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People like to watch the street.

But they do not always want a great deal of involvement with the street. The process of hanging out requires a continuum of degrees of involvement with the street, ranging all the way from the most private kind to the most public kind. A young girl watching the street may want to be able to withdraw the moment anyone looks at her too intently. At other times people may want to be watching the street, near enough to it to talk to someone who comes past, yet still protected enough so that they can withdraw into their own domain at a moment's notice.

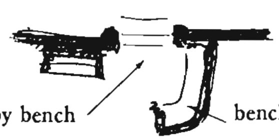
The most public kind of involvement with the street is sitting out. Many people, especially older people, pull chairs out to the front door or lean against the front of their houses, either while

Front door benches in Peru.

they are working at something or just for the pleasure of watching street life. But since there is some reluctance to be too public, this activity requires a bench or seat which is clearly private, even though in the public world. It is best of all when the bench is placed so that people are sitting on the edge of *their* world on private land—yet so placed that the personal space it creates overlaps with land that is legally public.

Therefore:

Build a special bench outside the front door where people from inside can sit comfortably for hours on end and watch the world go by. Place the bench to define a half-private domain in front of the house. A low wall, planting, a tree, can help to create the same domain.



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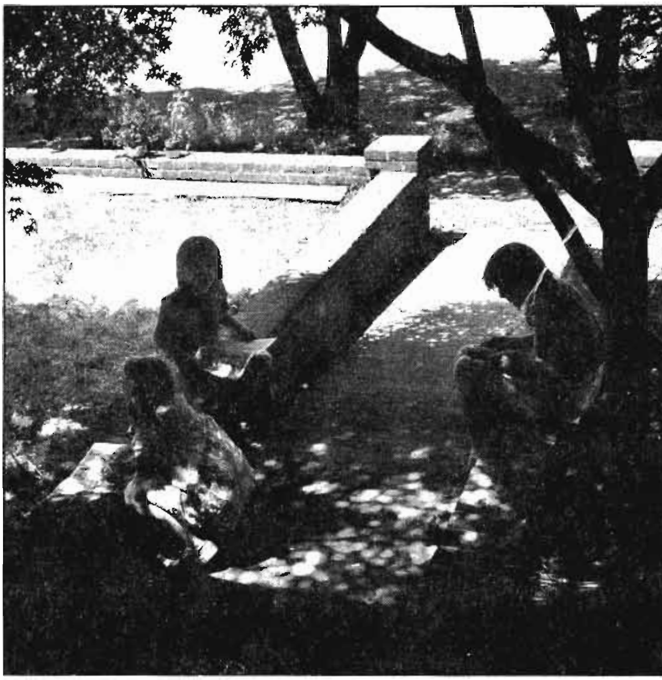
The bench may help to make the entrance visible—MAIN ENTRANCE (110); it can be part of a wall—SITTING WALL (243), with flowers in the sunshine next to it—RAISED FLOWERS (245). Place it with care, according to the rules given in SEAT SPOTS (241). . . .

243 SITTING WALL**



. . . if all is well, the outdoor areas are largely made up of positive spaces—POSITIVE OUTDOOR SPACES (106); in some fashion you have marked boundaries between gardens and streets, between terraces and gardens, between outdoor rooms and terraces, between play areas and gardens—GREEN STREETS (51), PEDESTRIAN STREET (100), HALF-HIDDEN GARDEN (111), HIERARCHY OF OPEN SPACE (114), PATH SHAPE (121), ACTIVITY POCKETS (124), PRIVATE TERRACE ON THE STREET (140), OUTDOOR ROOM (163), OPENING TO THE STREET (165), GALLERY SURROUND (166), GARDEN GROWING WILD (172). With this pattern, you can help these natural boundaries take on their proper character, by building walls, just low enough to sit on, and high enough to mark the boundaries.

If you have also marked the places where it makes sense to build seats—SEAT SPOTS (241), FRONT DOOR BENCH (242)—you can kill two birds with one stone by using the walls as seats which help enclose the outdoor space wherever its positive character is weakest.

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In many places walls and fences between outdoor spaces are too high; but no boundary at all does injustice to the subtlety of the divisions between the spaces.

Consider, for example, a garden on a quiet street. At least somewhere along the edge between the two there is a need for a seam, a place which unites the two, but does so without breaking down the fact that they are separate places. If there is a high wall or a hedge, then the people in the garden have no way of being connected to the street; the people in the street have no way of being connected to the garden. But if there is no barrier at all—then the division between the two is hard to maintain. Stray dogs can wander in and out at will; it is even uncomfortable to sit in the garden, because it is essentially like sitting in the street.

The problem can only be solved by a kind of barrier which functions as a barrier which separates, and as a seam which joins, at the same time.

A low wall or balustrade, just at the right height for sitting, is perfect. It creates a barrier which separates. But because it invites people to sit on it—invites them to sit first with their legs on one side, then with their legs on top, then to swivel round still further to the other side, or to sit astride it—it also functions as a seam, which makes a positive connection between the two places.

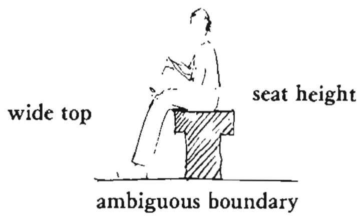
Examples: A low wall with the children's sandbox on one side, circulation path on the other; low wall at the front of the garden, connecting the house to the public path; a sitting wall that is a retaining wall, with plants on one side, where people can sit close to the flowers and eat their lunch.

Ruskin describes a sitting wall he experienced:

Last summer I was lodging for a little while in a cottage in the country, and in front of my low window there were, first, some beds of daisies, then a row of gooseberry and currant bushes, and then a low wall about three feet above the ground, covered with stone-cress. Outside, a corn-field, with its green ears glistening in the sun, and a field path through it, just past the garden gate. From my window I could see every peasant of the village who passed that way, with basket on arm for market, or spade on shoulder for field. When I was inclined for society, I could lean over my wall, and talk to anybody; when I was inclined for science, I could botanize all along the top of my wall—there were four species of stone-cress alone growing on it; and when I was inclined for exercise, I could jump over my wall, backwards and forwards. That's the sort of fence to have in a Christian country; not a thing which you can't walk inside of without making yourself look like a wild beast, nor look at out of your window in the morning without expecting to see somebody impaled upon it in the night. (John Ruskin, *The Two Paths*, New York: Everyman's Library, 1907, p. 203.)

Therefore:

Surround any natural outdoor area, and make minor boundaries between outdoor areas with low walls, about 16 inches high, and wide enough to sit on, at least 12 inches wide.



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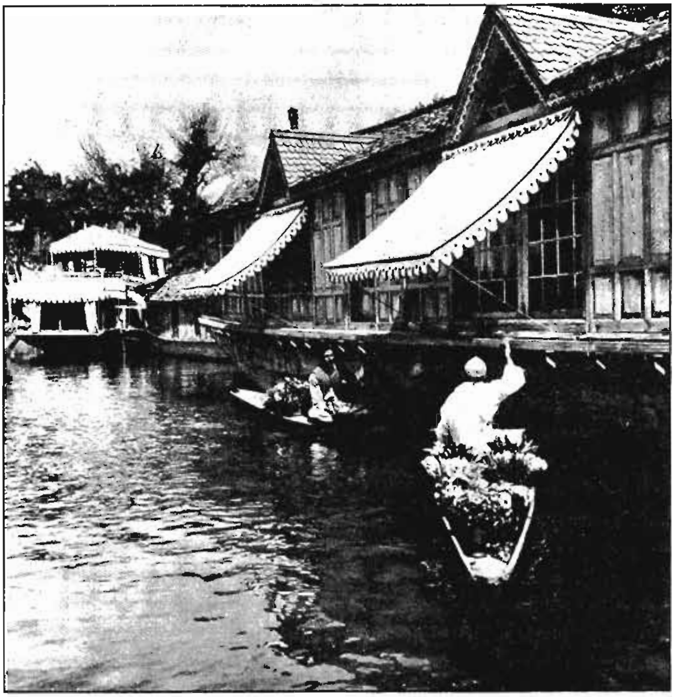
Place the walls to coincide with natural seat spots, so that extra benches are not necessary—SEAT SPOTS (241); make them of brick or tile, if possible—SOFT TILE AND BRICK (248); if they separate two areas of slightly different height, pierce them with holes to make them balustrades—ORNAMENT (249). Where they are in the sun, and can be large enough, plant flowers in them or against them—RAISED FLOWERS (245). . . .

244 CANVAS ROOFS*



. . . around every building there are ROOF GARDENS (118), ARCADES (119), PRIVATE TERRACES ON THE STREET (140), OUTDOOR ROOMS (163), GALLERY SURROUNDS (166), TRELLISED WALKS (174), and WINDOW PLACES (180), even SMALL PARKING LOTS (103), which all become more subtle and more beautiful with canvas roofs and awnings. And the awnings always help to create FILTERED LIGHT (238).

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There is a very special beauty about tents and canvas awnings. The canvas has a softness, a suppleness, which is in harmony with wind and light and sun. A house or any building built with some canvas will touch all the elements more nearly than it can when it is made only with hard conventional materials.

In conventional building, it is easy to think that walls and roofs must either be solid, or missing altogether. But cloth and canvas lie just exactly halfway in between. They are translucent, let a little breeze pass through, and they are very cheap, and easy to roll up and easy to pull down.

We can identify three kinds of places that need these properties:

1. Awnings—sunshades over windows, retractable, and used to filter very bright hot sunlight.

2. Curtains—moveable, half-open walls on outdoor rooms, balconies, and galleries—places that are occupied mainly during the day, but might benefit from extra wind protection.

3. Tent-like roofs on outdoor rooms—a tent which can hold off a drizzle and make outdoor rooms, or trellises, or courtyards habitable in the spring and autumn and at night.

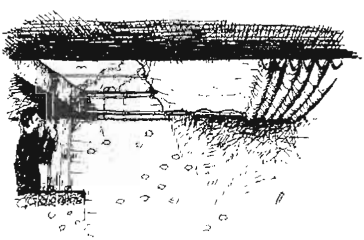
Here is Frank Lloyd Wright describing his use of the canvas roof in the very early structures at Taliesin West:

> . . . the Taliesin Fellowship (is a) desert camp on a great Arizona mesa which the boys, together with myself, are now building to work and live in during the winter-time. Many of the building units have canvas tops carried by red-wood framing resting on massive

stone walls made by placing the flat desert stones into wood boxes and throwing in stones and concrete behind them. Most of the canvas frames may be opened or kept closed. . . . The canvas overhead being translucent, there is a very beautiful light to live and work in; I have experienced nothing like it elsewhere except in Japan somewhat, in their houses with sliding paper walls or "shoji." (*The Future of Architecture*, London: The Architectural Press, 1955, pp. 255–56.)

Another example: In Italy, the canvas awning is used quite commonly as a simple awning over south and west windows. The canvas is often a bright and beautiful orange, giving color to the street and a warm glow to the interior rooms.

As a final example, we report on our own use of this pattern in the housing project in Lima. We roofed interior patios with movable canvas material. In hot weather the covers are rolled back, and a breeze blows through the house. In cold weather, the canvas is rolled out, sealing the house, and the patio is still useful. In Lima, there is a winter dew which normally makes patio floors damp and cold for eight months in the year. The cover on the patios keeps them dry and warm and triples their useful life. They eliminate the need for glass windows almost entirely. The windows which look into patios give light to rooms and may be curtained for visual control—but since the cold and damp are kept out by the patio canvas there need be no glass in the windows and no expensive moving parts.

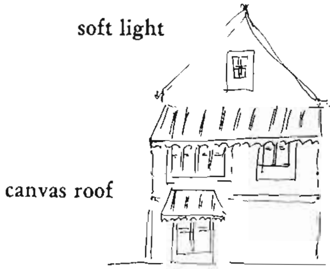


Our patio covers in Peru.

Therefore:

Build canvas roofs and walls and awnings wherever there are spaces which need softer light or partial shade in sum-

mer, or partial protection from mist and dew in autumn and winter. Build them to fold away, with ropes or wires to pull them, so that they can easily be opened.



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Use the canvas awnings, especially, to filter light over those windows which face west and south and glare because they face the sky—FILTERED LIGHT (238). Colored canvas will add special life—ORNAMENT (249), WARM COLORS (250). . . .

245 RAISED FLOWERS*

. . . outdoors there are various low walls at sitting height—SITTING WALL (243); terraced gardens, if the garden has a natural slope in it—TERRACED SLOPE (169); and paths and steps and crinkled building edges—PATHS AND GOALS (120), STAIR SEATS (125), BUILDING EDGE (160), GARDEN WALL (173). These are the best spots for flowers, and flowers help to make them beautiful.

⁂ ⁂ ⁂

Flowers are beautiful along the edges of paths, buildings, outdoor rooms—but it is just in these places that they need the most protection from traffic. Without some protection they cannot easily survive.

Look at the positions that wildflowers take in nature. They are as a rule in protected places when they occur in massive quantities: places away from traffic—often on grassy banks, on corners of fields, against a wall. It is not natural for flowers to grow in bundles like flower beds; they need a place to nestle.

What are the issues?

1. The sun—they need plenty of sun.
2. A position where people can smell and touch them.
3. Protection from stray animals.
4. A position where people see them, either from inside a house or along the paths which they naturally pass coming and going.

Typical flower borders are often too deep and too exposed. And they are so low the flowers are out of reach. Concrete planter boxes made to protect flowers often go to the other extreme. They are so protected that people have no contact with them, except from a distance. This is next to useless. The flowers need to be close, where you can touch them, smell them.

Therefore, instead of putting the flowers in low borders, on the ground, where people walk, or in massive concrete tubs, build them up in low beds, with sitting walls beside them, along the sides of paths, around entrances and edges. Make quite certain that the flowers are placed in positions where people really can enjoy them—and not simply as ornament: outside favorite windows, along traveled paths, near entrances and round doorways, by outdoor seats.

Raised flowers.

Therefore:

Soften the edges of buildings, paths, and outdoor areas with flowers. Raise the flower beds so that people can touch the flowers, bend to smell them, and sit by them. And build the flower beds with solid edges, so that people can sit on them, among the flowers too.

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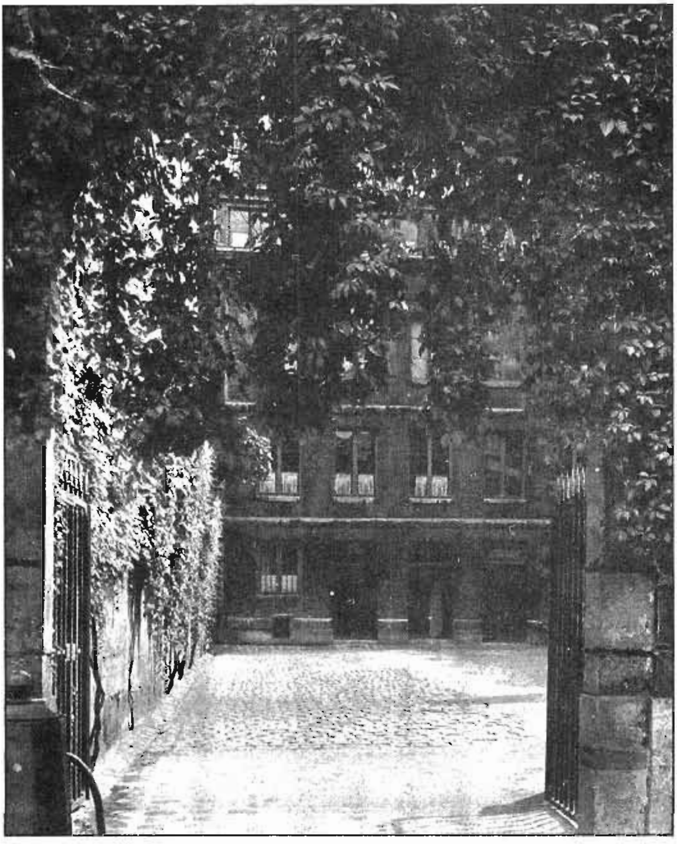
246 CLIMBING PLANTS



. . . two earlier patterns can be helped by climbing plants around the building: TRELLISED WALK (174) and FILTERED LIGHT (238).

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A building finally becomes a part of its surroundings when the plants grow over parts of it as freely as they grow along the ground.

There is no doubt that buildings with roses or vines or honeysuckle growing on them mean much more to us than buildings whose walls are blank and bare. That is reason enough to plant wild clematis around the outside of a building, to make boxes to encourage plants to grow at higher storys, and to make frames and trellises for them to climb on.

We can think of four ways to ground this intuition in function.

1. One argument, consistent with others in the book, is that climbing plants effect a smooth transition between the built and the natural. A sort of blurring of the edges.

2. The quality of light. When the plants grow around the openings of buildings, they create a special kind of filtered light inside. This light is soft, reduces glare, and stark shadows—FILTERED LIGHT (238).

3. The sense of touch. Climbing and hanging plants also give the outside walls a close and subtle texture. The same kind of texture can be achieved in the building materials, but it is uniquely beautiful when it comes from a vine growing across a wall or winding around the eaves of an arcade. Then, the texture invites you to touch and smell it, to pick off a leaf. Perhaps most important, the texture of climbing plants is ever different; it is subtly different from day to day, as the wind and sun play upon it; and it is greatly different from season to season.

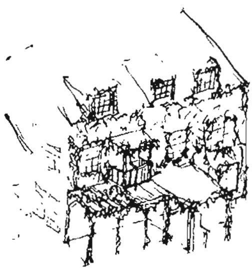
4. Tending the plants. When they are well-tended, healthy plants and flowers growing around the windows and out of flower boxes in the upper storys, make the street feel more

comfortable. They bespeak a social order of some repose within the buildings, and therefore it is comfortable to be on the streets —one feels at home. It is as if the plants were a gift from the people inside to people on the street.

The contribution to the street.

Therefore:

On sunny walls, train climbing plants to grow up round the openings in the wall—the windows, doors, porches, arcades, and trellises.



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247 PAVING WITH CRACKS BETWEEN THE STONES**

. . . many patterns call for paths and terraces and places where the outdoor areas around a building feel connected to the earth—GREEN STREETS (51), PATH SHAPE (121), PRIVATE TERRACE ON THE STREET (140), OUTDOOR ROOM (163), CONNECTION TO THE EARTH (168), TERRACED SLOPE (169). This pattern provides a way of building the ground surface that makes these larger patterns come to life.

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Asphalt and concrete surfaces outdoors are easy to wash down, but they do nothing for us, nothing for the paths, and nothing for the rainwater and plants.

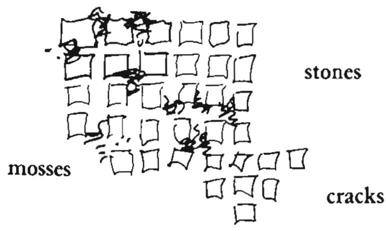
Look at a simple path, made by laying bricks or paving stones directly in the earth, with ample cracks between the stones. It is good to walk on, good for the plants, good for the passage of time, good for the rain. You walk from stone to stone, and feel the earth directly under foot. It does not crack, because as the earth settles, the stones move with the earth and gradually take on a rich uneven character. As time goes by, the very age and history of all the moments on that path are almost recorded in its slight unevenness. Plants and mosses and small flowers grow between the cracks. The cracks also help preserve the delicate ecology of worms and insects and beetles and the variety of plant species. And when it rains, the water goes directly to the ground; there is no concentrated run-off, no danger of erosion, no loss of water in the ground around the path.

All these are good reasons to set paving stones loosely. As for the flat, smooth, hard concrete and asphalt surfaces, they have almost nothing to recommend them. They are built when people forget these small advantages that come about when paving is made out of individual stones with cracks between the stones.

Therefore:

On paths and terraces, lay paving stones with a 1 inch crack between the stones, so that grass and mosses and

small flowers can grow between the stones. Lay the stones directly into earth, not into mortar, and, of course, use no cement or mortar in between the stones.



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Use paving with cracks, to help make paths and terraces which change and show the passage of time and so help people feel the earth beneath their feet—CONNECTION TO THE EARTH (168); the stones themselves are best if they are simple soft baked tiles—SOFT TILE AND BRICK (248). . . .

248 SOFT TILE AND BRICK

. . . several patterns call for the use of tiles and bricks—CONNECTION TO THE EARTH (168), GOOD MATERIALS (207), FLOOR SURFACE (233), SITTING WALL (243), PAVING WITH CRACKS BETWEEN THE STONES (247).

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How can a person feel the earth, or time, or any connection with his surroundings, when he is walking on the hard mechanical wash-easy surfaces of concrete, asphalt, hard-fired architectural paving bricks, or artificially concocted mixes like terrazo.

It is essential, above all, that the ground level surfaces we walk on—both around our buildings and indoors in those places like passages and kitchens where the floor has to be hard—be soft enough, at least, to show the passage of time, in gradual undulations and unevenness, that tell the story of a thousand passing feet, and make it clear that buildings are like people—not impervious and alien, but alive, changing with time, remembering the paths which people tread.

Nothing shows the passage of time so well as very soft, baked or lightly fired, bricks and tiles. They are among the cheapest tiles that can be made; they use ordinary clay, are biodegradable, and always develop a beautiful sense of wear and time in the undulations made by people walking over them.

In addition, those paved areas around a building required by CONNECTION TO THE EARTH (168) play a special role. They are the places which are halfway between the building—with its artificial materials—and the earth—which is entirely natural. To make this connection felt, the materials themselves must also be halfway, in character, between the building and the earth. Again, soft, lightly fixed tiles are most appropriate.

We consider this so important, that we advocate, specifically, that the people who are making the building, make the quantity of bricks and tiles they need for ground floor and outdoor surfaces—and that these be made in local clay and soft fired, in stacks, right on the site.

It is easy to do. We shall now give detailed instructions for making the tiles themselves and for making a rudimentary outdoor firing pit.

We start with the clay: it would be best to make one's own clay from scratch.

Clay is decomposed feldspathic rock. There is an abundance of it all over the earth. One may be fortunate enough to find it in one's back yard.

To test whether it is clay, pick up a bit of it and wet it. If it is plastic and sticky enough to form a smooth ball, it is clay. . . .

Process the clay as follows:

1. First, remove impurities such as twigs, leaves, roots and stones.
2. Then, let the chunks dry in the sun.
3. Break up these chunks and grind them up as finely as possible.
4. Put this ground-up clay in water so that there is a mound above water.
5. Let this mixture soak for one day, then stir it, and sieve it through a screen.
6. Let stand again for another day, and remove excess water.
7. Then put the clay in a plaster container; plaster absorbs water, thus stiffening the mixture into workable clay.
8. Work the clay a little to test it. If cracks appear, it is "short"; when that happens, add to the mixture, up to 7% bentonite. If clay is too plastic, add "grog." . . .

Shrinkage may be decreased by adding flint or grog to the clay. Grog is clay that has been biscuit-fired and then crushed. Some people prepare their own grog from broken biscuit-fired pieces. It can be bought at very little cost at any supply company in varying degrees of fineness. The coarser the particles of grog added to the clay, the coarser the texture of the fired object will be.

Grog makes clay porous and is used for objects which are not intended to hold water. Grog also prevents warpage and is, therefore, very useful for tile making and for sculpture. 20% is a good proportion of grog in a clay mixture.

(Muriel Pargh Turoff, *How to Make Pottery and Other Ceramic Ware*, New York: Crown Publishers, 1949, p. 13.)

Once you have the clay, you can make the tiles.

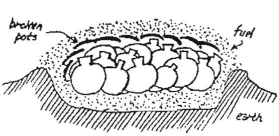
In this method of tile making, a wooden form is used that has the dimensions desired for the finished tiles. It is put together by nailing four strips of wood to a smooth piece of board. The strips should be 1 inch wide and their height may vary from 3/8 inch to 3/4 inch, depending on how thick you wish the finished tiles to be. It is a good plan to put a piece of oilcloth on the base board before nailing down the strips. This will keep the board from warping. . . .

Roll out a slab of clay. . . . Then cut from the slab a piece that will fit comfortably into the form and roll it down with a rolling pin. Do not roll the pin all the way across the surface of the clay, but work from the center outwards to all four sides. . . . Let the tile dry until it is leather-hard; then separate it from the form by running a knife around its edges. . . .

Clay tiles should be allowed to dry very slowly, and for this reason should be put in a cool place. If they dry too quickly under heat, they are apt to crack or warp. The edges have a tendency to dry more rapidly than the center and usually should be dampened from time to time to prevent this. (Joseph Leeming, *Fun With Clay*, Philadelphia and New York: J. B. Lippincott Company.)

To fire soft tiles and bricks, it is not necessary to build real kilns. They can be fired in open pits much like those which primitive potters used to fire their pottery. This type of open pit firing is described in detail by Daniel Rhodes, in *Kilns: Design, Construction and Operation*, Philadelphia: Chilton Book Company. Briefly:

Dig a shallow pit about 14 to 20 inches deep, and several square feet in area. Line this pit (bottom and sides) with branches, reeds, twigs, etc. Place the tiles and bricks to be fired on the lining, so that they are compactly piled with just a tiny bit of airspace between them—(they can be criss-crossed). . . . If you use old tiles to line the pit, it will keep the heat in even better; and air holes low down at one end will help combustion. . . . Put some fuel in between stacks and over them. Then light the fuel in the pit, and allow it to burn slowly—which it will to begin with because not much air can get to it. Pile more fuel on as the fire burns up to a level above the pit. After the entire pit and its contents reach red heat, allow the fire to die down, and cover the top of the fire with wet leaves, dung or ashes to retain the heat. After the fire has died down, and the embers cooled, the tiles can be removed.

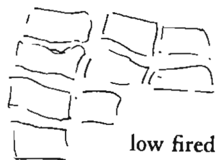


A simple kiln.

Therefore:

Use bricks and tiles which are soft baked, low fired—so that they will wear with time, and show the marks of use.

You can make them in a simple mold from local clay, right on the site; surround the stack with twigs and firewood; and fire them, to a soft pink color which will leave them soft enough to wear with time.



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The soft pink color helps to create WARM COLORS (250). Before firing, you may want to give the tiles some ORNAMENT (249). . . .

complete the building with ornament and light and color and your own things.

249. ORNAMENT

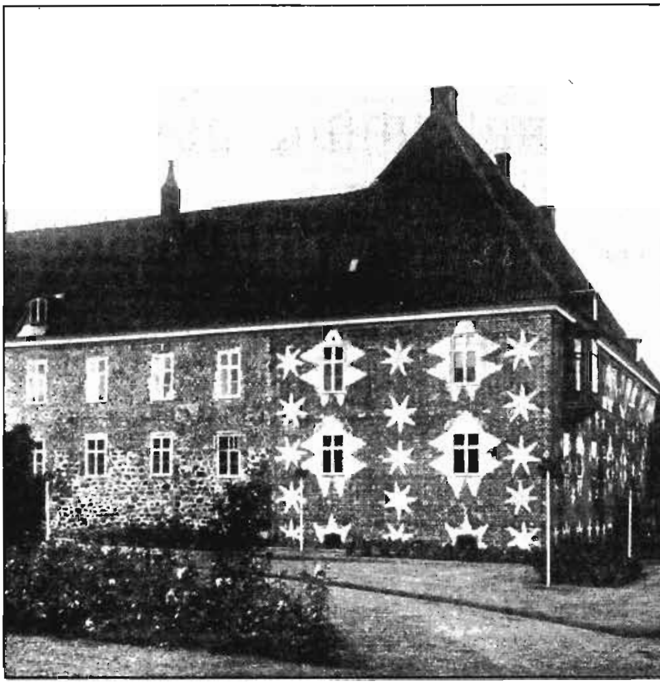
250. WARM COLORS

251. DIFFERENT CHAIRS

252. POOLS OF LIGHT

253. THINGS FROM YOUR LIFE

249 ORNAMENT**



. . . once buildings and gardens are finished; walls, columns, windows, doors, and surfaces are in place; boundaries and edges and transitions are defined—MAIN ENTRANCE (110), BUILDING EDGE (160), CONNECTION TO THE EARTH (168), GARDEN WALL (173), WINDOW PLACE (180), CORNER DOORS (196), FRAMES AS THICKENED EDGES (225), COLUMN PLACE (226), COLUMN CONNECTION (227), ROOF CAPS (232), SOFT INSIDE WALLS (235), SITTING WALL (243), and so on—it is time to put in the finishing touches, to fill the gaps, to mark the boundaries, by making ornament.

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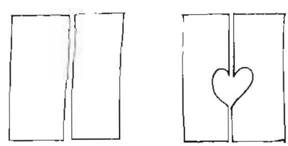
All people have the instinct to decorate their surroundings.

But decorations and ornaments will only work when they are properly made: for ornaments and decorations are not only born from the natural exuberance and love for something happy in a building; they also have a function, which is as clear, and definite as any other function in a building. The joy and exuberance of carvings and color will only work, if they are made in harmony with this function. And, further, the function is a necessary one —the ornaments are not just optional additions which may, or may not be added to a building, according as the spirit moves you—a building needs them, just as much as it needs doors and windows.

In order to understand the function of ornament, we must begin by understanding the nature of space in general. Space, when properly formed, is whole. Every part of it, every part of a town, a neighborhood, a building, a garden, or a room, is whole, in the sense that it is both an integral entity, in itself, and at the same time, joined to some other entities to form a larger whole. This process hinges largely on the boundaries. It is no accident that so many of the patterns in this pattern language concern the importance of the boundaries between things, as places that are as important as the things themselves—for example, SUBCULTURE BOUNDARY (13), NEIGHBORHOOD BOUNDARY (15), ARCADES (119), BUILDING EDGE (160), GALLERY SURROUND (166), CONNECTION TO THE EARTH (168), HALF-OPEN WALLS (193), THICK WALLS (197), FRAMES AS THICKENED EDGES (225), HALF-INCH TRIM (240), SITTING WALL (243).

A thing is whole only when it is itself entire and also joined to its outside to form a larger entity. But this can only happen when the boundary between the two is so thick, so fleshy, so ambiguous, that the two are not sharply separated, but can function either as separate entities or as one larger whole which has no inner cleavage in it.

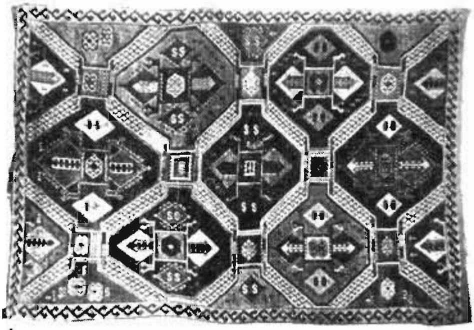


Split . . . and whole.

In the left-hand diagram where there is a cleavage that is sharp, the thing and its outside are distinct entities—they function individually as wholes—but they do not function together as a larger whole. In this case the world is split. In the right-hand diagram where there is ambiguous space between them, the two entities are individually entire, as before, but they are also entire together as a larger whole. In this case the world is whole.

This principle extends throughout the material universe, from the largest organic structures in our surroundings, to the very atoms and molecules.

Extreme examples of this principle at work in manmade objects are in the endless surfaces of objects from the so-called "dark ages" and in the carpets and tilework of Turkey and Persia. Leaving aside the profound meaning of these "ornaments," it is a fact that they function mainly by creating surfaces in which each part is simultaneously figure and boundary and in which the design acts as boundary and figure at several different levels simultaneously.



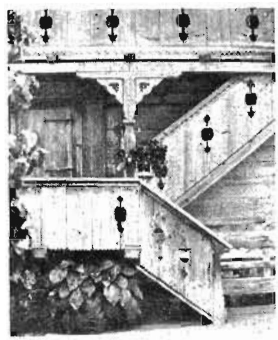
A decoration which is whole, because it cannot be broken into parts.

Since none of the parts can be separated from their surroundings, because each part acts as figure and as boundary, at several levels, this ancient carpet is whole, to an extraordinary degree.

The main purpose of ornament in the environment—in buildings, rooms, and public spaces—is to make the world more whole by knitting it together in precisely the same way this carpet does it.

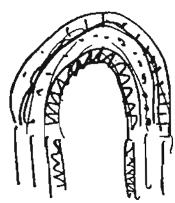
If the patterns in this language are used correctly, then these unifying boundaries will already come into existence without ornament at almost all the scales where they are necessary in spaces and materials. It will happen in the large spaces, like the entrance transition or the building edge. And, of course, it happens of its own accord, in those smaller structures which occur within the materials themselves—in the fibers of wood, in the grain of brick and stone. But there is an intermediate range of scales, a twilight zone, where it will not happen of its own accord. *It is in this range of scales that ornament fills the gap.*

As far as specific ways of doing it are concerned, there are hundreds, of course. In this balustrade the ornament is made entirely of the boundary, of the space between the boards. The boards are cut in such a way, that when they are joined together in the fence, they make something of the space between them.



. . . *A balustrade.*

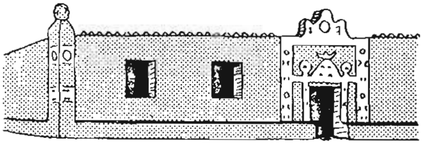
Here is a more complicated case—the entrance to a Romanesque church.



A doorway.

The ornament is built up around the edge of the entrance. It creates a unifying seam between the entrance *space* and the stone. Without the ornament, there would be a gap between the arch of the entry and the passage itself: the ornament works on the seam, between the two, and holds them together. It is especially lavish and developed in this place, because just this seam—the boundary of the entrance to the church—is so important, symbolically, to the people who worship there.

In fact, doors and windows are always important for ornament, because they are places of connection between the elements of buildings and the life in and around them. It is very likely that we shall find a concentration of ornament at the edges of doors and windows, as people try to tie together these edges with the space around them.



Nubian door.

And exactly the same happens at hundreds of other places in the environment; in rooms, around our houses, in the kitchen, on a wall, along the surface of a path, on tops of roofs, around a column—in fact, anywhere at all where there are edges between things which are imperfectly knit together, where materials or objects meet, and where they change.

Early American stencilling.

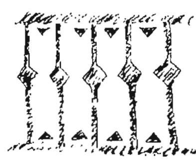
Most generally of all, the thing that makes the difference in the use of ornament is the eye for the significant gap in the continuum: the place where the continuous fabric of interlock and connectivity is broken. When ornament is applied badly it is always put into some place where these connections are not really missing, so it is superfluous, frivolous. When it is well used, it is always applied in a place where there is a genuine gap, a need for a little more structure, a need for what we may call metaphorically "some extra binding energy," to knit the stuff together where it is too much apart.

Therefore:

Search around the building, and find those edges and transitions which need emphasis or extra binding energy.

Corners, places where materials meet, door frames, windows, main entrances, the place where one wall meets another, the garden gate, a fence—all these are natural places which call out for ornament.

Now find simple themes and apply the elements of the theme over and again to the edges and boundaries which you decide to mark. Make the ornaments work as seams along the boundaries and edges so that they knit the two sides together and make them one.



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Whenever it is possible, make the ornament while you are building—not after—from the planks and boards and tiles and surfaces of which the building is actually made—WALL MEMBRANE (218), FRAMES AS THICKENED EDGES (225), LAPPED OUTSIDE WALLS (234), SOFT INSIDE WALLS (235), SOFT TILE AND BRICK (248). Use color for ornament—WARM COLORS (250); use the smaller trims which cover joints as ornament—HALF-INCH TRIM (240); and embellish the rooms themselves with parts of your life which become the natural ornaments around you—THINGS FROM YOUR LIFE (253). . . .

250 WARM COLORS**

. . . this pattern helps to create and generate the right kind of GOOD MATERIALS (207), FLOOR SURFACE (233), SOFT INSIDE WALLS (235). Where possible leave the materials in their natural state. Just add enough color for decoration, and to make the light inside alive and warm.

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The greens and greys of hospitals and office corridors are depressing and cold. Natural wood, sunlight, bright colors are warm. In some way, the warmth of the colors in a room makes a great deal of difference between comfort and discomfort.

But just what are warm colors and cold colors? In a very simple minded sense, red and yellow and orange and brown are warm; blue and green and grey are cold. But, obviously, it is not true that rooms with red and yellow feel good; while rooms with blue and grey feel cold. There is some superficial truth to this simple statement: it is true that reds and browns and yellows *help* to make rooms comfortable; but it is also true that white and blue and green can all make people comfortable too. After all, the sky is blue, and grass is green. Obviously, we feel comfortable out in the green grass of a meadow, under the blue sky.

The explanation is simple and fascinating. It is not the color of the things, the surfaces, which make a place warm or cold, *but the color of the light.* What exactly does this mean? We can estimate the color of the light at a particular point in space by holding a perfectly white surface there. If the light is warm, this surface will be slightly tinted toward the yellow-red. If the light is cold, this surface will be slightly tinted toward the blue-green. This tinting will be very slight: indeed, on a small white surface it may be so hard to see that you need a spectrometer to do it.

But when you realize that everything in that space is lightly tinted—people's faces, hands, shirts, dresses, food, paper, everything—it is not so hard to see that this can have a huge effect on the emotional quality that people experience there.

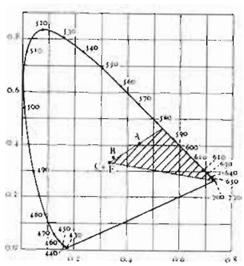
Now, the color of the light in a space does not depend in any simple way on the color of the surface. It depends on a complex interaction between the color of the light sources and the way this light then bounces on and off the many surfaces. In a meadow, on a spring day, the sunlight bouncing off the green grass is still warm light—that is, in the yellowish reddish range. The light in a hospital corridor, lit by fluorescent tubes, bouncing off green walls is cold light—in the green-blue range. In a room with lots of natural light, the overall light is warm. In a room whose windows face onto a grey building across the street, the light may be cold, unless there is a very strong concentration of yellow and red fabrics.

If you are in any doubt about the objective character of the light in the room and you don't have a spectrometer, all you need to do is to try to use color film. If the light is warm and the film is properly exposed, white walls will come out slightly pink. If the light is cold, white walls will come out slightly blue.

So, in order to make a room comfortable, you must use a collection of colors which together with the sources of light and the reflecting surfaces outside the room, combine to make the reflected light which exists in the middle of the room warm, that is, toward the yellow-red. Yellow and red colors will always do it. Blues and greens and whites will only do it in the proper places, balanced with other colors, and when the light sources are helping.

To complete the discussion we now make the concept of warm light precise in terms of chromaticity. Consider the light falling on any given surface in the middle of the room. This light contains a variety of different wavelengths. Its character is specified, exactly, by some distribution of spectral energies $p(\lambda)$, which gives the relative proportions of different wavelengths present in this light.

We know that any light whatsoever—in short, any $p(\lambda)$—can be plotted as a single point on the color triangle—more formally known as the two-dimensional chromaticity diagram—by means of the standard color matching functions given in Gunter Wyszecki and W. S. Stiles, *Color Science*, New York, 1967, pp. 228–317. The coordinates of a plot in this color triangle define the *chromaticity* of any given energy distribution.



Chromaticity diagram.

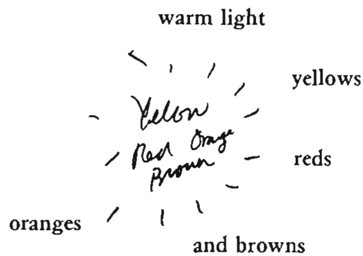
We may now identify a region on the chromaticity diagram which we shall call the *warm region*. It is shown hatched on the drawing.

This hatched area is based on a number of empirical results. For example, we know that people have a clear subjective impression of the relative warmth, or coldness, of different spaces. See, for instance, Committee on Colorimetry of the Optical Society of America, *The Science of Color*, New York, 1953, p. 168. One study which attempts to identify the objective correlates of perceived "warmth" is S. M. Newhall, "Warmth and Coolness of Colors," *Psychological Record*, 4, 1941, pp. 198–212. This study revealed a maximum for "warmest" judgments at dominant wave-length 610 millimicrons, which is in the middle of the orange range. And individual observer stability in such judgments is high. Thus, one study gives reliability coefficients of 0.95 for warmth and 0.82 for coolness—N. Collins, "The Appropriateness of Certain Color Combinations in Advertising," M. A. thesis, Columbia University, New York, 1924.

Finally, it is vital to remember that this pattern requires only that the *light*—the total light in the middle of a room, coming from sunlight, artificial lights, reflections from walls, reflections from outside, from carpets—the total *light*, lies in that part of the color triangle we call "warm." It does not require that any individual color surfaces in the room should be red or orange or yellow—only that the combined effect of all the surfaces and lights together, creates light in the middle of the room which lies in the warm part of the color triangle.

Therefore:

Choose surface colors which, together with the color of the natural light, reflected light, and artificial lights, create a warm light in the rooms.



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This means that yellows, reds, and oranges will often be needed to pick out trim and lampshades and occasional details—HALF-INCH TRIM (240), ORNAMENT (249), POOLS OF LIGHT (252). Colored CANVAS ROOFS (244) and SOFT TILE AND BRICK (248) also help to make warm colored light. Blues and greens and greys are much harder to use; especially on the north side where the light is cold and grey, but they can always be used for ornament, where they help to set off the warmer colors—ORNAMENT (249). . . .

251 DIFFERENT CHAIRS

. . . when you are ready to furnish rooms, choose the variety of furniture as carefully as you have made the building, so that each piece of furniture, loose or built in, has the same unique and organic individuality as the rooms and alcoves have—each different, according to the place it occupies—SEQUENCE OF SITTING SPACES (142), SITTING CIRCLE (185), BUILT-IN SEATS (202).

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People are different sizes; they sit in different ways. And yet there is a tendency in modern times to make all chairs alike.

Of course, this tendency to make all chairs alike is fueled by the demands of prefabrication and the supposed economies of scale. Designers have for years been creating "perfect chairs"—chairs that can be manufactured cheaply in mass. These chairs are made to be comfortable for the average person. And the institutions that buy chairs have been persuaded that buying these chairs in bulk meets all their needs.

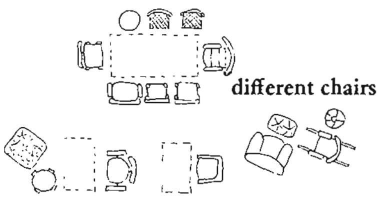
But what it means is that some people are chronically uncomfortable; and the variety of moods among people sitting gets entirely stifled.

Obviously, the "average chair" is good for some, but not for everyone. Short and tall people are likely to be uncomfortable. And although situations are roughly uniform—in a restaurant everyone is eating, in an office everyone is working at a table—even so, there are important distinctions: people sitting for different lengths of time; people sitting back and musing; people sitting aggressively forward in a hot discussion; people sitting formally, waiting for a few minutes. If the chairs are all the same, these differences are repressed, and some people are uncomfortable.

What is less obvious, and yet perhaps most important of all, is this: we project our moods and personalities into the chairs we sit in. In one mood a big fat chair is just right; in another mood, a rocking chair; for another, a stiff upright; and yet again, a stool or sofa. And, of course, it isn't only that we like to switch according to our mood; one of them is our favorite chair, the one that makes us most secure and comfortable; and that again is different for each person. A setting that is full of chairs, all slightly different, immediately creates an amosphere which supports rich experience; a setting which contains chairs that are all alike puts a subtle straight jacket on experience.

Therefore:

Never furnish any place with chairs that are identically the same. Choose a variety of different chairs, some big, some small, some softer than others, some rockers, some very old, some new, with arms, without arms, some wicker, some wood, some cloth.



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Where chairs are placed alone and where chairs are gathered, reinforce the character of the places which the chairs create with POOLS OF LIGHT (252), each local to the group of chairs it marks. . . .

252 POOLS OF LIGHT**

. . . this pattern helps to finish small social spaces like ALCOVES (179) and WORKSPACE ENCLOSURE (183), larger places like COMMON AREAS AT THE HEART (129), ENTRANCE ROOM (130), and FLEXIBLE OFFICE SPACE (146), and the furnishing of rooms like EATING ATMOSPHERE (182), SITTING CIRCLE (185), and DIFFERENT CHAIRS (251). It even helps to generate WARM COLORS (250).

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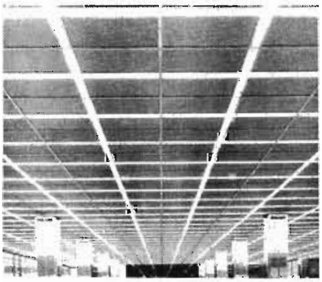
Uniform illumination—the sweetheart of the lighting engineers—serves no useful purpose whatsoever. In fact, it destroys the social nature of space, and makes people feel disoriented and unbounded.

Look at this picture. It is an egg-crate ceiling, with dozens of evenly spaced fluorescent lights above it. It is meant to make the light as flat and even as possible, in a mistaken effort to imitate the sky.



Flat, even light.

But it is based on two mistakes. First of all, the light outdoors is almost never even. Most natural places, and especially the conditions under which the human organism evolved, have dappled light which varies continuously from minute to minute, and from place to place.

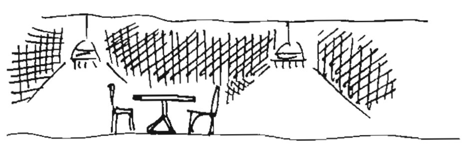
More serious, it is a fact of human nature that the space we use as social space is in part defined by light. When the light is perfectly even, the social function of the space gets utterly destroyed: it even becomes difficult for people to form natural human groups. If a group is in an area of uniform illumination, there are no light gradients corresponding to the boundary of the group, so the definition, cohesiveness, and "existence" of the group will be weakened. If the group is within a "pool" of light, whose size and boundaries correspond to those of the group, this enchances the definition, cohesiveness, and even the phenomenological existence of the group.

One possible explanation is suggested by the experiments of Hopkinson and Longmore, who showed that small bright light sources distract the attention less than large areas which are less bright. These authors conclude that local lighting over a work table allows the worker to pay more attention to his work than uniform background lighting does. It seems reasonable to infer that the high degree of person to person attention required to maintain the cohesiveness of a social group is more likely to be sustained if the group has local lighting, than if it has uniform background lighting. (See R. G. Hopkinson and J. Longmore, "Attention and Distraction in the Lighting of Workplaces," *Ergonomics*, 2, 1959, p. 321 ff. Also reprinted in R. G. Hopkinson, *Lighting*, London: HMSO, 1963, pp. 261–68.)

On-the-spot observation supports this conjecture. At the International House, University of California, Berkeley, there is a large room which is a general waiting and sitting lounge for guests and residents. There are 42 seats in the room, 12 of them are next to lamps. At the two times of observation we counted a total of 21 people sitting in the room; 13 of them chose to sit next to lamps. These figures show that people prefer sitting near lights ($X^2 = 11.4$, significant at the 0.1% level). Yet the overall light level in the room was high enough for reading. We conclude that people do seek "pools of light."

Everyday experience bears out the same observation in hundreds of cases. Every good restaurant keeps each table as a separate pool of light, knowing that this contributes to its privai and intimate ambience. In a house a truly comfortable old chaii "yours," has its own light in dimmer surroundings—so tha you retreat from the bustle of the family to read the paper ir peace. Again, house dining tables often have a single lamp suspended over the table—the light seems almost to act like glue for all the people sitting round the table. In larger situations the same thing seems to be true. Think of the park bench, under a solitary light, and the privacy of the world which it creates for a pair of lovers. Or, in a trucking depot, the solidarity of the group of men sipping coffee around a brightly lit coffee stand.

One word of caution. This pattern is easy to understand; and perhaps it is easy to agree with. But it is quite a subtle matter to actually create functioning pools of light in the environment. We know of many failures: for example, places where small lights do break down even illumination, but do not correspond in any real way with the places where people tend to gather in the space.



Light pools at odds with social space.

Therefore:

Place the lights low, and apart, to form individual pools of light which encompass chairs and tables like bubbles to reinforce the social character of the spaces which they form. Remember that you can't have pools of light without the darker places in between.

pools of light

⁘ ⁘ ⁘

Color the lampshades and the hangings near the lights to make the light which bounces off them warm in color—WARM COLORS (250). . . .

253 THINGS FROM YOUR LIFE*

. . . lastly, when you have taken care of everything, and you start living in the places you have made, you may wonder what kinds of things to pin up on the walls.

✣ ✣ ✣

"Decor" and the conception of "interior design" have spread so widely, that very often people forget their instinct for the things they really want to keep around them.

There are two ways of looking at this simple fact. We may look at it from the point of view of the person who owns the space, and from the point of view of the people who come to it. From the owner's point of view, it is obvious that the things around you should be the things which mean most to you, which have the power to play a part in the continuous process of self-transformation, which is your life. That much is clear.

But this function has been eroded, gradually, in modern times because people have begun to look outward, to others, and over their shoulders, at the people who are coming to visit them, and have replaced their natural instinctive decorations with the things which they believe will please and impress their visitors. This is the motive behind all the interior design and decor in the women's magazines. And designers play on these anxieties by making total designs, telling people they have no right to move anything, paint the walls, or add a plant, because they are not party to the mysteries of Good Design.

But the irony is, that the visitors who come into a room don't want this nonsense any more than the people who live there. It is far more fascinating to come into a room which is the living expression of a person, or a group of people, so that you can see their lives, their histories, their inclinations, displayed in manifest form around the walls, in the furniture, on the shelves. Beside such experience—and it is as ordinary as the grass—the artificial scene-making of "modern decor" is totally bankrupt.

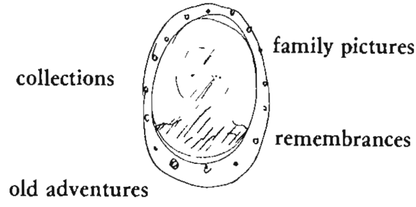
Jung describes the room that was his study, how he filled the stone walls with paintings that he made each day directly on the stones—mandalas, dream images, preoccupations—and he tells us that the room came gradually to be a living thing to him—the outward counterpart to his unconscious.

Examples we know: A motel run by a Frenchman, mementos of the Resistance all around the lounge, the letter from Charles de Gaulle. An outdoor market on the highway, where the proprietor has mounted his collection of old bottles all over the walls; hundreds of bottles, all shapes and colors; some of them are down for cleaning; there is an especially beautiful one up at the counter by the cash register. An anarchist runs the hot dog stand, he plasters the walls with literature, proclamations, manifestoes against the State.

A hunting glove, a blind man's cane, the collar of a favorite dog, a panel of pressed flowers from the time when we were children, oval pictures of grandma, a candlestick, the dust from a volcano carefully kept in a bottle, a picture from the news of prison convicts at Attica in charge of the prison, not knowing that they were about to die, an old photo, the wind blowing in the grass and a church steeple in the distance, spiked sea shells with the hum of the sea still in them.

Therefore:

Do not be tricked into believing that modern decor must be slick or psychedelic, or "natural" or "modern art," or "plants" or anything else that current taste-makers claim. It is most beautiful when it comes straight from your life —the things you care for, the things that tell your story.



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