ture. This appears to be true empirically, as I have found in numerous examples. Again and again during the last twenty years I have discovered that if we make a pattern of members which has life according to the geometric centers formed in the space, then just embellishing the system of centers according to its own pattern will turn it into something which is efficient and good from a structural point of view.

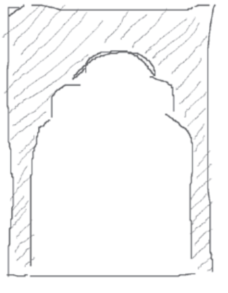
Apparently good engineering structure follows, directly or indirectly, from the use of living process. The deep nature of space appears to be so profound that just the geometric unfolding, when it is done properly, leads to results which make sense from an engineering point of view. This is most surprising. A process which places focus on the space, on positive space, positive rhythms of elements, positive shape of members, positive shaping of gaps and spaces and volumes of thin air between the members — all that, governed by what seems like an almost abstract artistic process — does tend to create structures which work as engineering structure. They are efficient, stable, well-behaved, coherent in their deformations. Why this happens is a deep matter, too difficult to analyze here. Mathematically, it is still a mystery.

I believe it occurs for the reasons that I have touched on in Book 1, chapter 11. There I suggested that function follows from well-ordered space, apparently because the forces we think of as functional are themselves geometric and themselves space-like. That, roughly speaking, is what we also find with engineering. When the process followed in unfolding an engineering structure is a version of the fundamental process, and we use it to create coherent space, the nice behavior and the good engineering qualities of the resulting structure follow naturally. And occasionally this process leads to a structure which has never been invented before, to a structure that is innovative even to an engineer (see page 223).

5 / THREE-DIMENSIONAL FORMATION OF POSITIVE AND NEGATIVE

Let us first examine the creation of a single building, in such a way as to generate this interlocking pattern of mass and space in three dimensions.

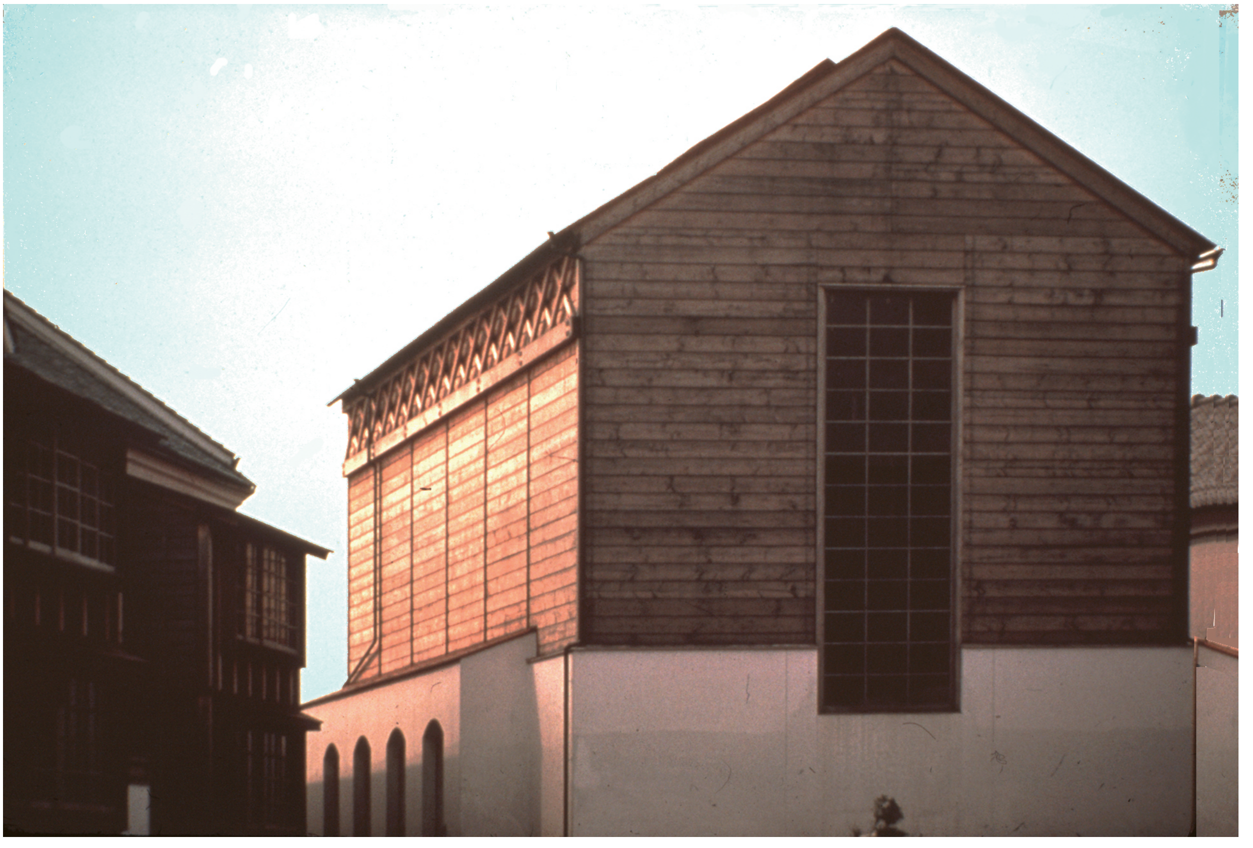
I take for my example the process of engineering the structure of the Central Hall, in the Eishin project in Japan. This building was to be a general gathering space for students, owned by them, at the center of gravity of the campus. I started by sketching an upside down horseshoe, embodying my feeling about the *space* it was to contain, as a social and emotional thing, but already containing the germ of a structural idea. The essence of the idea was that the beautifully shaped space would be formed by the mass in the shaded area above it (diagram, right), thus providing the structural strength, and also making both the space within and the structural volume above, positive in their own right.



First sketch of the space and volume for the Central building. The space below is positive in shape; the volume above, needed for mass elements to provide the structure, is also positive in shape. Both are positive so that, from the beginning, we have a conception of a rectangle-filling pattern in which both void and solid are both made of POSITIVE SPACE.

First came the truss itself (next page). Here we have a structure which produces centers very clearly. It has a major center produced by the arch; and the center is reinforced and intensified, by the way the arch jumps up, in steps, always focussing on the main space down below. Gary Black and I designed the wooden truss members

Interior of the Central Building



The Central Building, Eishin Campus. Christopher Alexander with Gary Black, Hajo Neis and others, 1985.

and their connections, in detail, using the finite-element techniques described on pages 210–23.

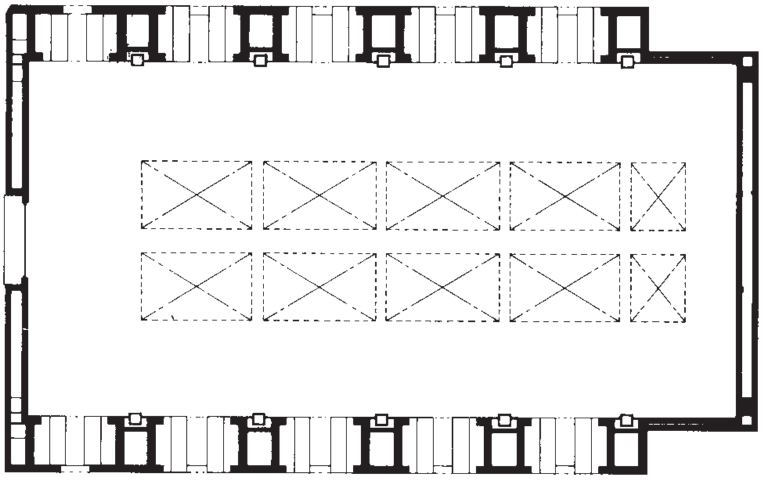
It should be noted that in the truss itself (opposite) each partition created by the wooden members forms POSITIVE SPACE — and it is this fact above all which gives the truss its beauty. Even more interesting, the very same positive space which creates its beauty *also creates its structural stability and good structural behavior.*

Let us now move on to the three-dimensional disposition of mass and space within the building as a whole. The base of each column, is a massive pier. This pier is not only a center in itself — the source of the ability of the arches to withstand horizontal forces — but is also a center in a social sense. It creates space next to it, and in front of it. And of course, it creates the beautiful concrete arches between the piers.

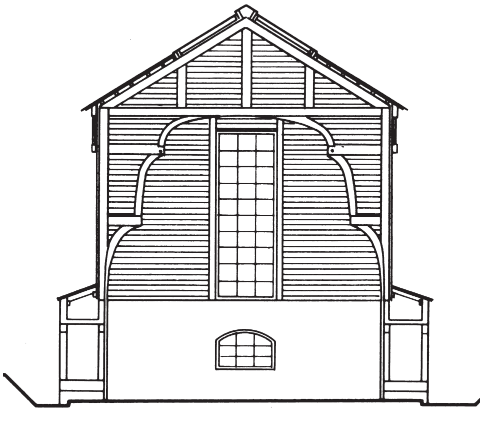
When we first laid out this building we did full-scale experiments to calculate, very carefully, just how big each arch with its seat had to be and how big each pier had to be in order to create a system of double centers, both in the space and in the volume of the concrete mass.

In three dimensions, the building had to produce its centers too. The longitudinal wind force was the most difficult thing. It seemed essential to make the strength of the building come from the massive piers. So we made sure that each wooden column was trapped in the pier, thus forming a moment-connection at its base.

But this was not quite enough. To resist longitudinal wind force, we had to make a second X-braced truss running the length of the building, high on the side. This system of X-braces forms a row of centers high along each side, and also leaves the plain side beloe as a bigger center. If we had made big braces, running across the side, or sheathed the braces so that they func-

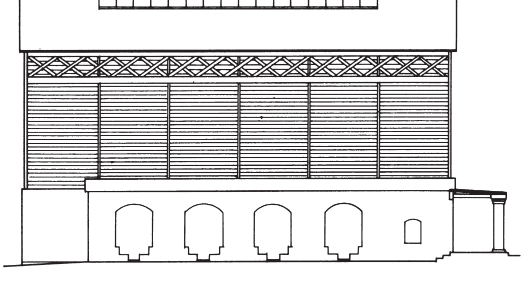


Christopher Alexander, Gary Black, Hajo Neis, Central building. Plan.

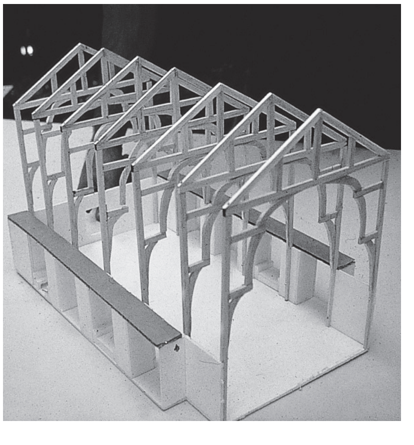


Central building; interior end elevation

X-braces of the Central building, showing the POSITIVE SPACE *between the wooden members.*

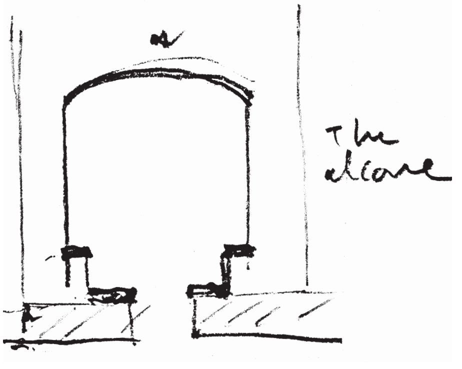


Exterior elevation

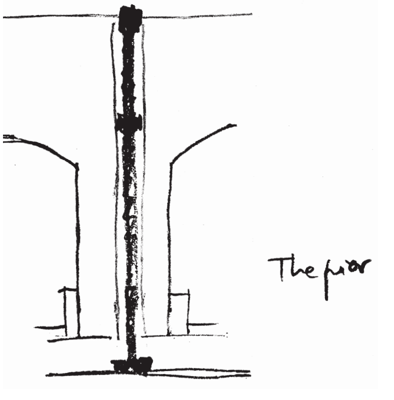


The centers formed by the trusses themselves

Sequence of piers and alcoves



The form of the alcove is both positive and negative: the space is positive, the volume of the seats is positive. That is what defines this slightly complex, filled-out, shape.



The pier, too, is both positive and negative; it traps the key structural element — the column that comes down — in a chase formed at the heart of the pier.

tioned as a shear wall, this would not have produced the character of a powerful center in the long wall. But as we did it, the row of X's along the upper edge makes each long wall into a single massive center, strengthened and intensified by the small system of centers that the X's create.

Finally, the finishing touch in the creation of strong centers: There is a single big window at the northern end to let in light. And at the southern end, a single seat looking in from the arcade above. Doing all this requires a strict adherence to certain principles of order, above all to

When a structure is coherent, it invites life to come to it. Break dancing in the Central building, 1987

the sequence in which these items are created. The crux of the problem is as follows. We are trying to make a system of space in which each part is positive, where the spaces are coherent in their own terms, and where the solid structure of the building as a whole, is orderly, too.

Both the spaces and the solids must form deep centers. This is the volume of the actual physical stuff of which the building is made.

To get both systems of spaces and solids to form beautiful and coherent centers, we must go step by step, from large to small. First we have to get the largest room, in the most beautiful place, just where we want it. Then we have to go gradually to the next largest rooms, then the still smaller ones, each one adjusted perfectly in its proper place. To make this work, there is always some kind of syncopated arrangement. Often there is a little leftover space, tucked in among the big spaces. We cannot get it all to work perfectly. In fact we should not try. What matters is that the big room is perfect, with regard to position, height, volume, view. Get that exactly right. Then adjust others rooms in relation to it, and get them exactly right. To do this, there will always be funny little bits of space left over — forming closets, walls, toilets, rather thick, in between the other spaces as a kind of buffer — allowing the larger spaces to have exactly the right feeling.

At the same time that all this is developing, the structure itself, a syncopated system of grids, columns, beams, floors, walls, and arches, must also form a beautiful and coherent thing, in which these solid elements again have their own perfect shape, and in which moments and shears — with overall stability — work perfectly. Once again, it is the hierarchy of the biggest and most fundamental decisions coming early at the time the largest spaces are formed — then working our way down to the smaller ones, and all the time, keeping the rhythm of repetition, and spaces between the repetition just right — that is crucial.

To get coherent structure, the engineer Antonio Gaudi often used an interesting kind of living process. He hung wires and strings, with weights on them, to form a rough upside-down model of the building while he was working it out. The wires and strings naturally fell into parabolic curves and catenaries under the impact of pure tension — finding balance with the system of weights. When he turned the configuration discovered by the model upside down, it then formed a system of pure compression arches, one of the most natural ways of using mass material to form a building.[2]

Here the living process not only created space in a natural way, but also found positions for compression members that were congruent with the space. Later in the chapter, I shall describe a way that modern finite-element methods can be used in a still more sophisticated fashion, to supplement the use of a living process to elaborate and unfold a structural design. In the next few pages, I shall show, by example, how the unfolding of living structure can be made to work in other, larger situations, how it can actually be done, and why it will work properly only if one repeats the fundamental process again and again.

6 / THE GREAT HALL AT EISHIN

The essence of the problem lies in the process through which we understand solid and void as two balanced opposites.

To explain it, I give the following example of the Great Hall at Eishin (pages 102–110) where the process of working out the solid-void relationship took place in a large but rough-and-ready three-dimensional model. This rough model of the main hall itself, focusing on its interior, was built at a scale of 1:20. It was about 8 feet long, 4 feet wide, and some 2 feet high.[3]

We began with the overall space, made in paper, getting its shape and feeling right — just as far as space and dimensions and light were concerned. This was done in paper. Then we began introducing columns. These solid wood columns, milled on our table saw, played an important role, since one of the first things to get clear was the size and scale of members that would create profound feeling in the space. After playing with different-sized pieces of wood we were able to determine that the best size for these columns (the one that made the strongest emotional impact) was a square section of about 1 meter by 1 meter: in the model this was a stick of wood 16 inches long, with a square cross section of about 2 inches by 2 inches. Having determined the column-size which had the most powerful depth of feeling, we made a number of them, and began standing them up in the space to get a clearer understanding of their *spacing* — the shape of the space between the columns. The space between the columns came to play a crucial role, and we finally settled on a space of two meters clear — i.e., the columns placed at three meters on center. This made the shape of the space between adjacent columns two meters by one meter in plan — a well-shaped rectangle, which had the capacity to form positive space, interlocked with the structure.

All the steps taken so far came from the fundamental process: making the shape, size, of the space, the shape and size of the columns, and shape and size of the space between the columns, making all these work as centers in their own right.

Having done all that, it began to dawn on us — just from looking at the model — that the overwhelming issue was the quality of light created in the space. The overall feeling showed itself mainly through the light that came into the Hall, and the way this subtle light was partially carried into the main space, lingering softly over the aisles. It also had to govern the structure. We then made a more solid model, capable of blocking light so that we weren't