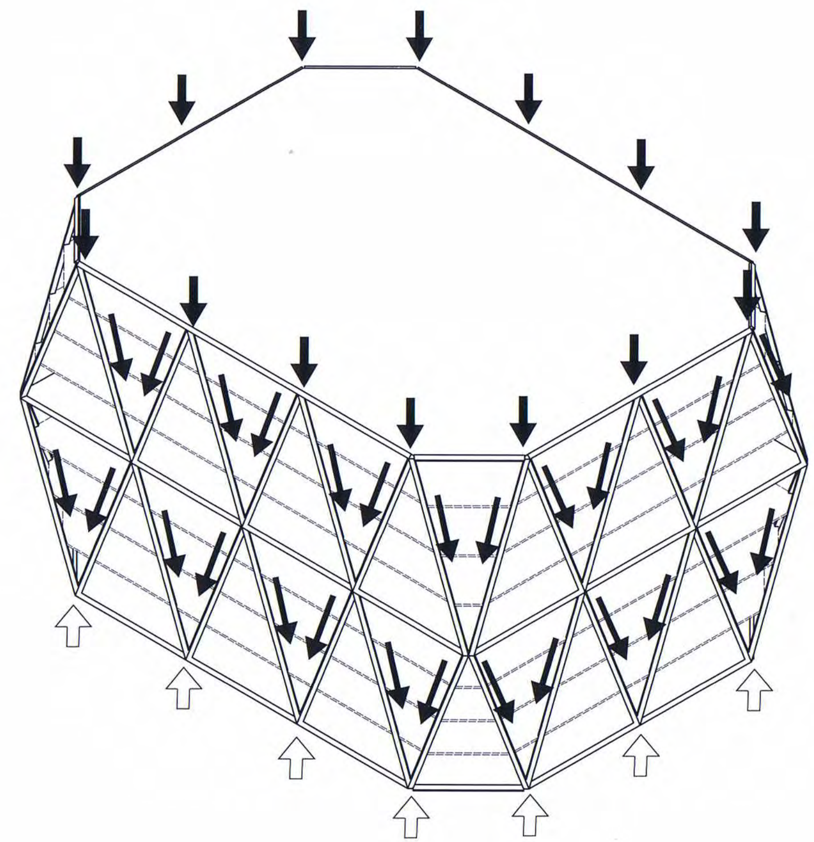
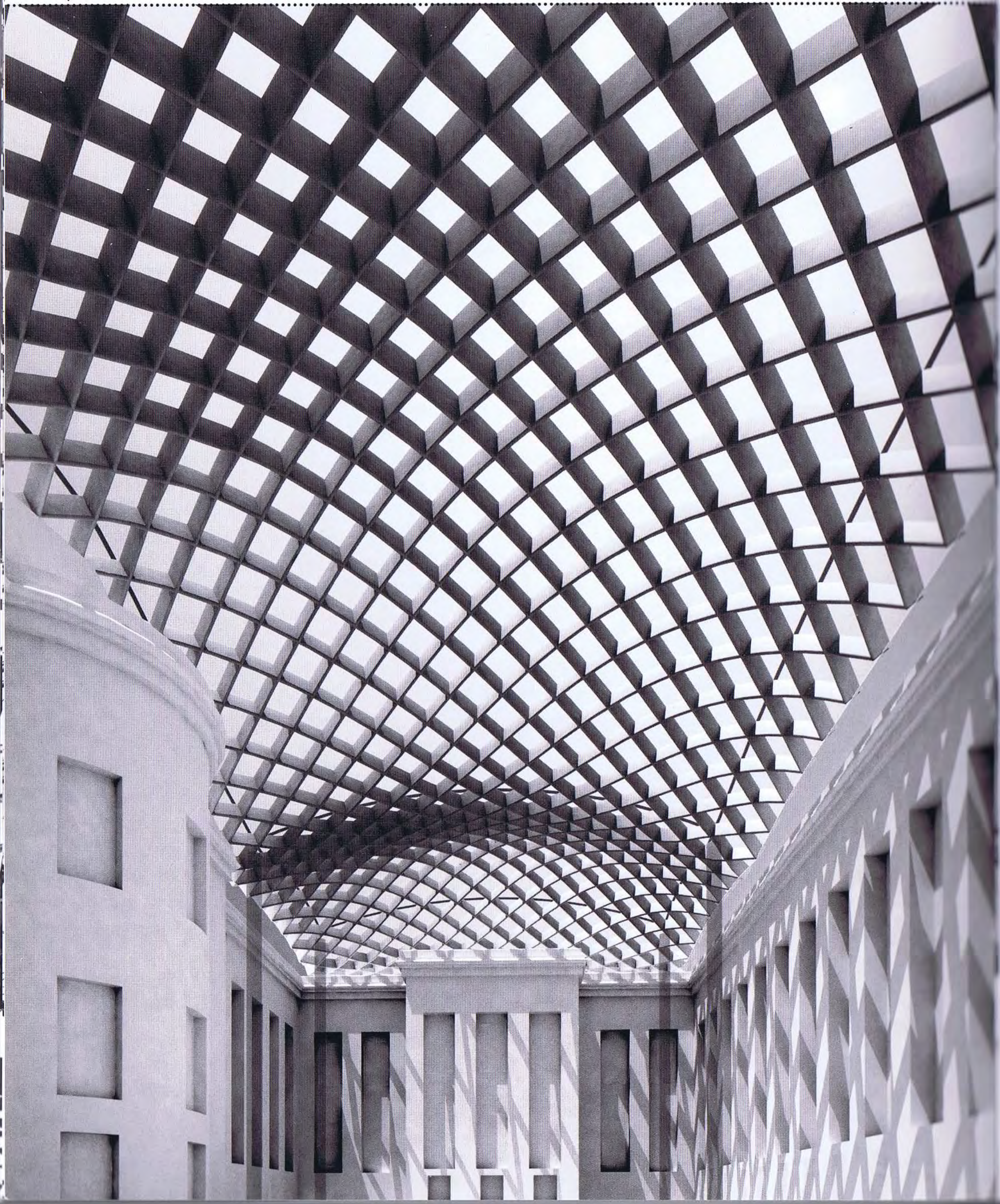
The base unit of a diagrid is composed of interconnected support beams that form a diagonal grid. Diagrids work in plane and are resistant to axial forces when vertical. Horizontal diagrids usually have some curvature to allow loads to be carried by axial compression as well as in torsion and bending. The diagonal geometry, with angles of less than 45 degrees in the direction of predominant loading, enhances the unit stiffness resistance to bending moments by increasing cross-bracing resistance, which is far more efficent than an orthogonal grid. The distribution of loads along the diagonal lattice embeds the diagrid base unit with an optical affect of lightness and crystallinity that remains consistent within any space it defines. A frame together with its overlaid surfaces can have an affect of specularity, focusing or diffusion, depending on the degree of its openness and lightness, and the contours of the surfaces.

The protogeometry of a diagrid is flexible in several ways:
Scale: It can subdivide as a regular lattice, with the size of each diamond remaining the same, or as an irregular lattice, with the size of each diamond varying. In all cases, the depth of each diagonal support beam varies in proportion to the scale of the diamond grid.
Angles: The angles of a diagrid can vary. They can be uniform, or they can change gradually along the height or length of a structure in response to architectural and structural requirements.
Depth: The depth of the diagrid can be varied by altering the density of the diamond pattern. For example, the pattern can be doubled or tripled to accommodate variations in the depth of the structure.
Profile: Diagrids can tessellate to produce forms which are horizontal (domes and vaulted sheds), vertical (towers), or curved (domes and vaulted sheds). Because the diagrid base unit can vary as it tessellates, it can allow for both regular and irregular plan forms and profiles.
Affect: The affective properties of a diagrid can be multiplied when the base unit imbricates or intertwines with external factors, such as asymmetries that respond to the physical constraints of the site, environmental considerations, programmatic requirements, etc. As a result, in addition to lightness and crystallinity, a structure formed by a diagrid can transmit other optical affects, including repetition, latticing, verticality, gradation, differentiation, conicality, diagonality, amorphousness, twistedness. A diagrid can modify or dominate the acoustical affect of the overlaid surface by adding an affect of diffusion.



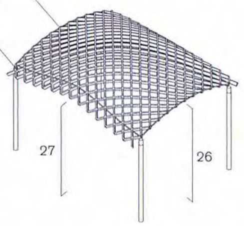
A vertical diagrid system is illustrated. Horizontal diagrids tend to be curved to achieve resistance of loads in axial compression or tension.

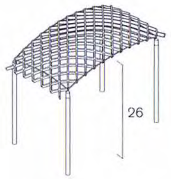
Latticing, Vaulting, Variability, Lightness, Diffusion

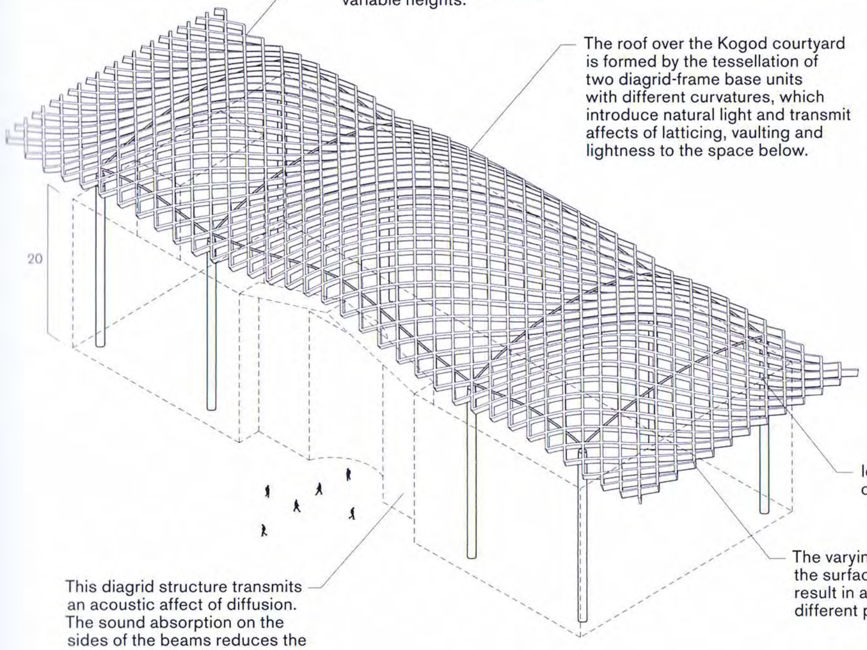


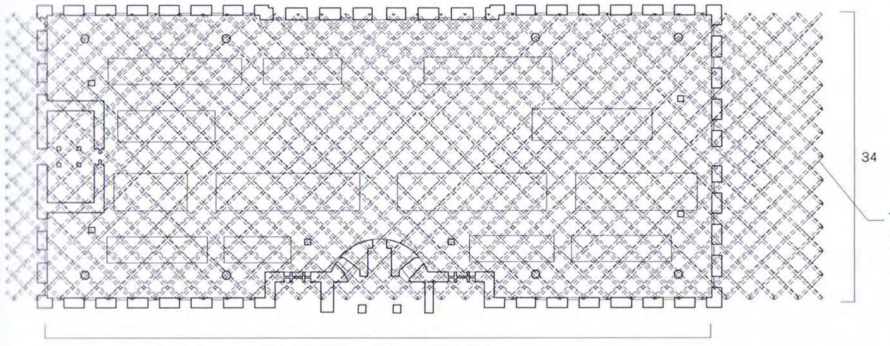
Horizontal / Diagrid

KOGOD COURTYARD, SMITHSONIAN REYNOLDS CENTER FOR AMERICAN ART AND PORTRAITURE	FOSTER + PARTNERS, SMITH GROUP INC; BURO HAPPOLD; SANDY BROWN ASSOCIATES	WASHINGTON DC, USA	2004–07







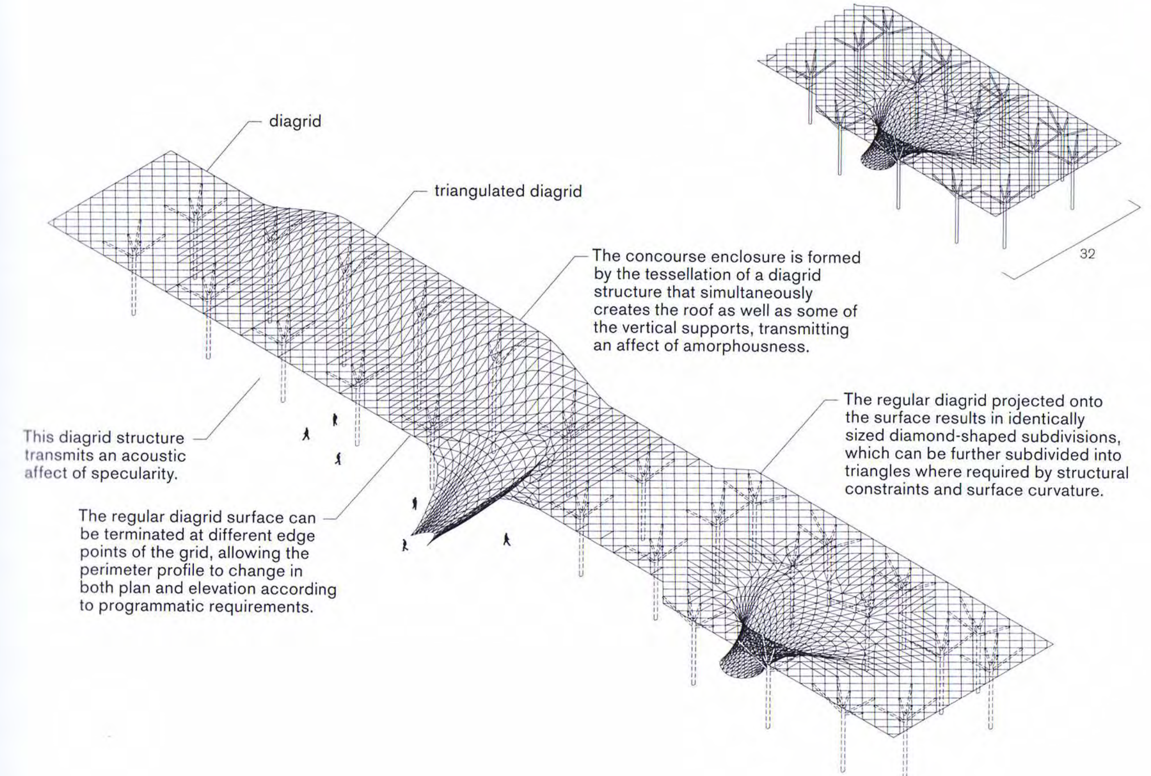


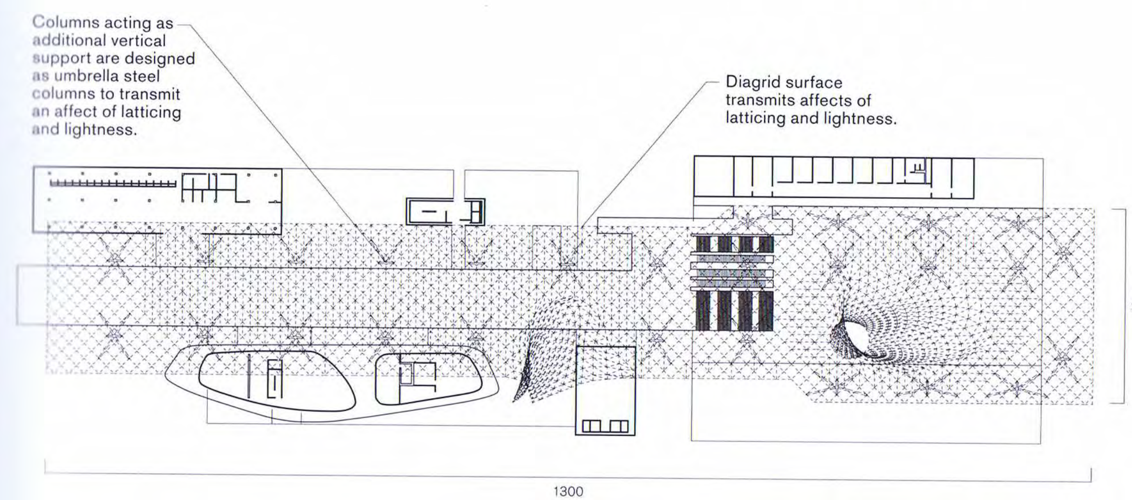
The Kogod Courtyard of the Smithsonian American Art Museum is formed by the horizontal tessellation of a diagrid base unit to create an undulating horizontal roof for the existing rectangular courtyard. The base unit varies in scale and section, slightly scaling the diamonds to adjust to the changing curvature of the surface as it spans the courtyard, producing a shallow and undulating arched section. The Kogod Courtyard transmits an optical affect of latticing, vaulting, variability and lightness, and an acoustical affect of diffusion.

Amorphousness, Latticing, Lightness, Specularity

Horizontal / Diagrid

MILAN TRADE FAIR CENTER | M. FUKSAS; SCHLAICH BERGERMANN, F. MARZULLO | MILAN, ITALY | 2003–05



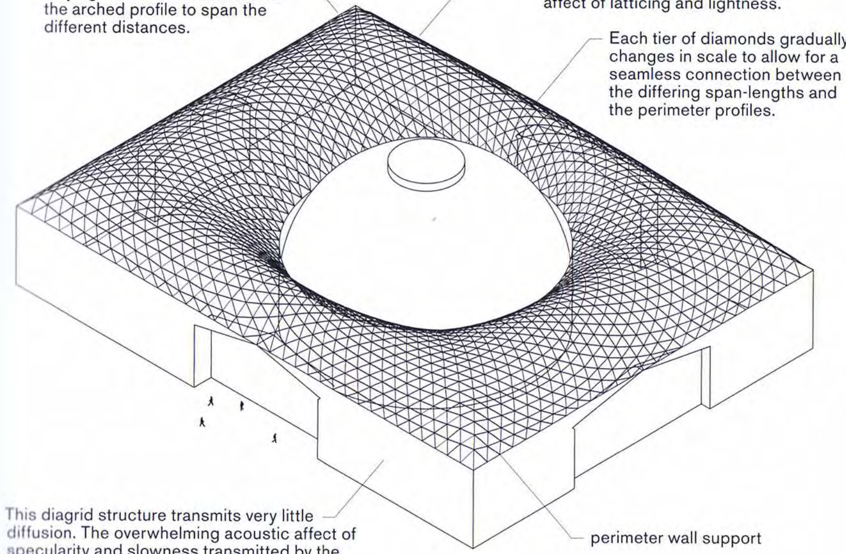


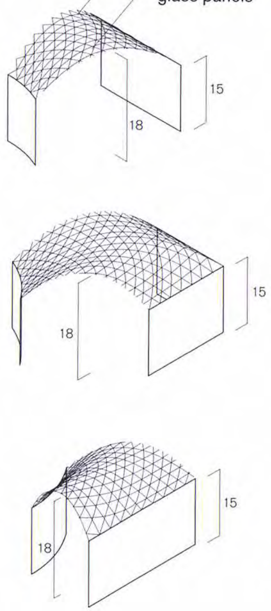
The Milan Fair Trade Center is formed by the tessellation of a diagrid base unit, creating a continuous surface that includes both the ceiling and the enclosing walls. Diamond shapes are used in the parts of the surface where there is a single curvature, while triangles are used where there is a double curvature. La Fiera concourse transmits an optical affect of amorphousness, latticing and lightness, and an acoustical affect of specularity.

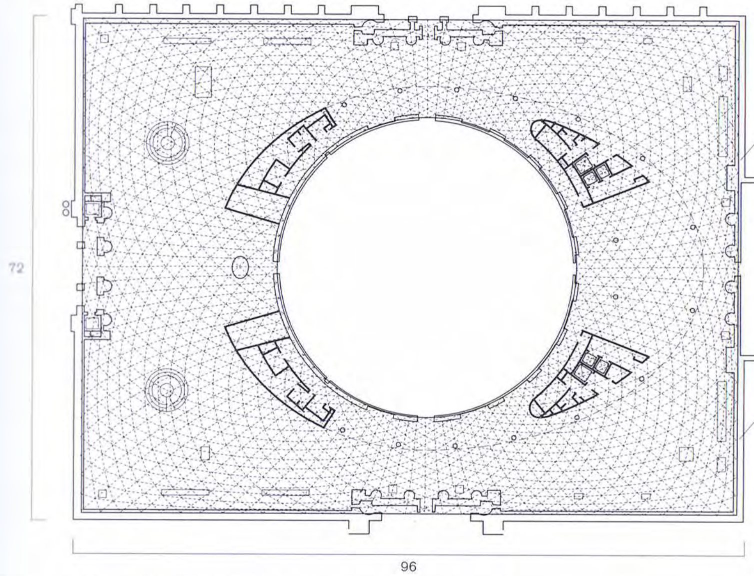
Latticing, Lightness, Specularity, Slowness

Horizontal / Diagrid

GREAT COURT, BRITISH MUSEUM | FOSTER + PARTNERS; BURO HAPPOLD; SANDY BROWN ASSOCIATES | LONDON, UK | 1994–2000



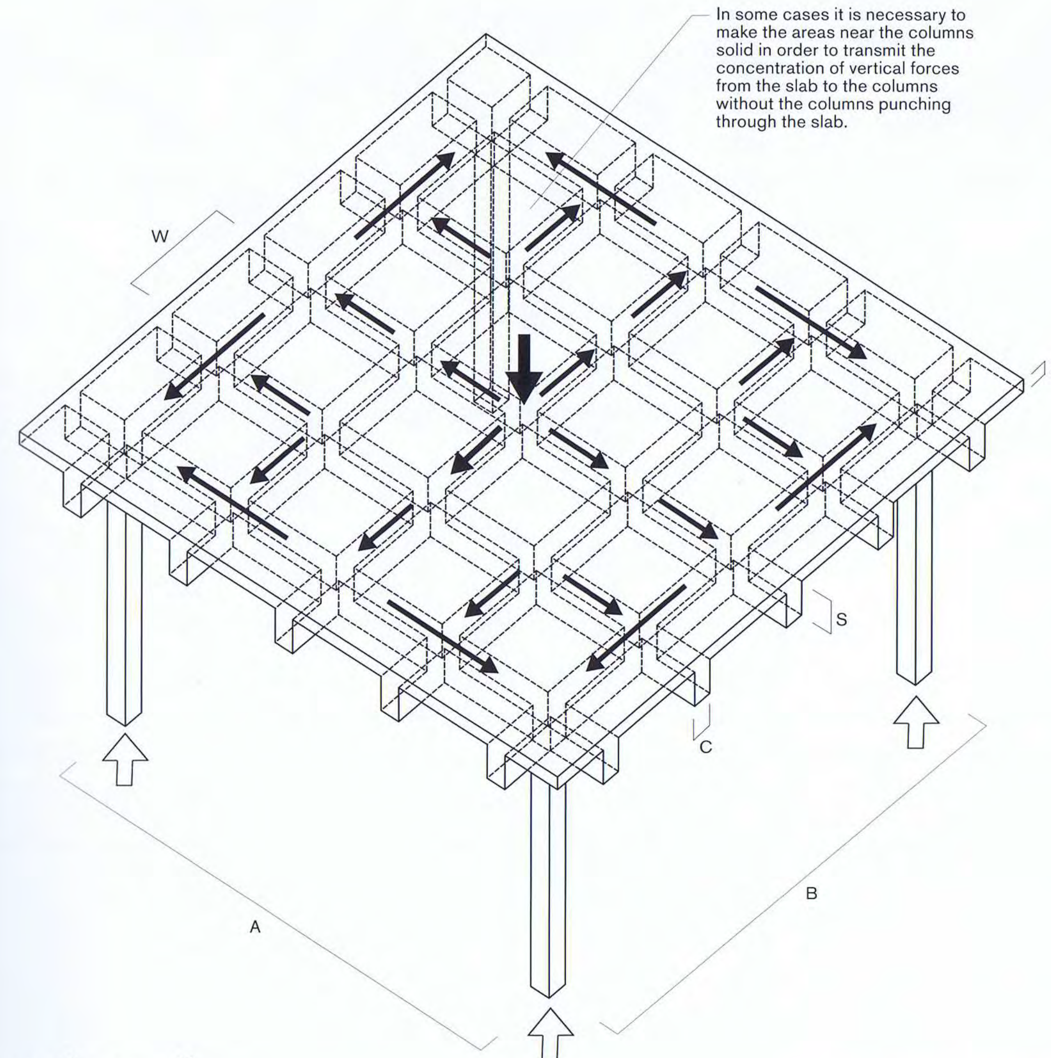




The roof of the Great Court in the British Museum is produced by the tessellation of a diagrid base unit composed of triangulated cells to create a horizontal form that spans from a cylindrical volume in the center to the edges of the existing courtyard. The base unit in this case varies in scale and sectional profile as each of the triangles adjusts to the changing curvature of the surface. The enclosure changes in section as it spans irregular lengths to bridge from the circular footprint at the centre to the rectangular footprint at the edges. The Great Court transmits an optical affect of latticing and lightness, and an acoustical affect of specularity and slowness.

The base unit of a grid-slab frame is composed of a thin reinforced-concrete slab integral with a lattice of beams arranged in a waffle pattern. Vertical loads in grid slabs are distributed in two directions, with the composite section of slab and beams acting together, to the columns upon which the grid slab rests, to produce a rigid structure. The distribution of loads through the steel-reinforced concrete produces a slab form, the structural strength of which is proportional to the depth of its section, allowing a range of spans between the columns or load-bearing walls. Grid slabs can achieve very large spans through a very thin section as their self-weight is lower than that of solid slabs. Similarly to two-way frames, grid slabs need to have an aspect ratio of less than 2:1. Grid slabs transmit an optical affect of griddedness and striation that remains consistent within all spaces it defines. Grid-slab frames can vary according to the arrangement of the beams, for example square grid, rectangular grid, polygonal grid, or diagrid. These patterns can be designed to follow approximately the isostatic lines of the slab. Intermediate beams that follow isostatic lines help to distribute forces more evenly; however, each of the beams still has to span the same distance and must therefore remain at the same depth. If more beams are added to the slab, the depth of the top slab could be reduced.

The grid-slab frame is flexible in several ways:
Span: The protogeometry of the grid slab is not fixed to an exact dimension but works with relative depths to span ratios of 1:30, depending on continuity. This ratio allows for a range of spans between columns or load-bearing walls.
Depth: The depth of the slab varies according to the width of the span, with the structural strength of the slab proportional to its depth and the density of the isostatic pattern that is introduced on the underside of the slab.
Profile: Grid-slabs can tessellate horizontally, vertically, or as a curved surface, to produce forms that can be horizontal (mats), vertical (towers), or curved (vaulted sheds and domes).
Affect: The affective properties of a grid slab can be multiplied when the base unit imbricates or intertwines with external factors, such as asymmetries that respond to the physical constraints of the site, environmental considerations, programmatic requirements, etc. As a result, in addition to griddedness and striation, a grid-slab structure can transmit other optical affects, including boundlessness, waffling, hierarchy, porosity, lacing, vaulting, differentiation, segmention, continuity, uniformity, aggregation. A grid-slab can modify or dominate the acoustical affect of the overlaid surface by adding an affect of diffusion.



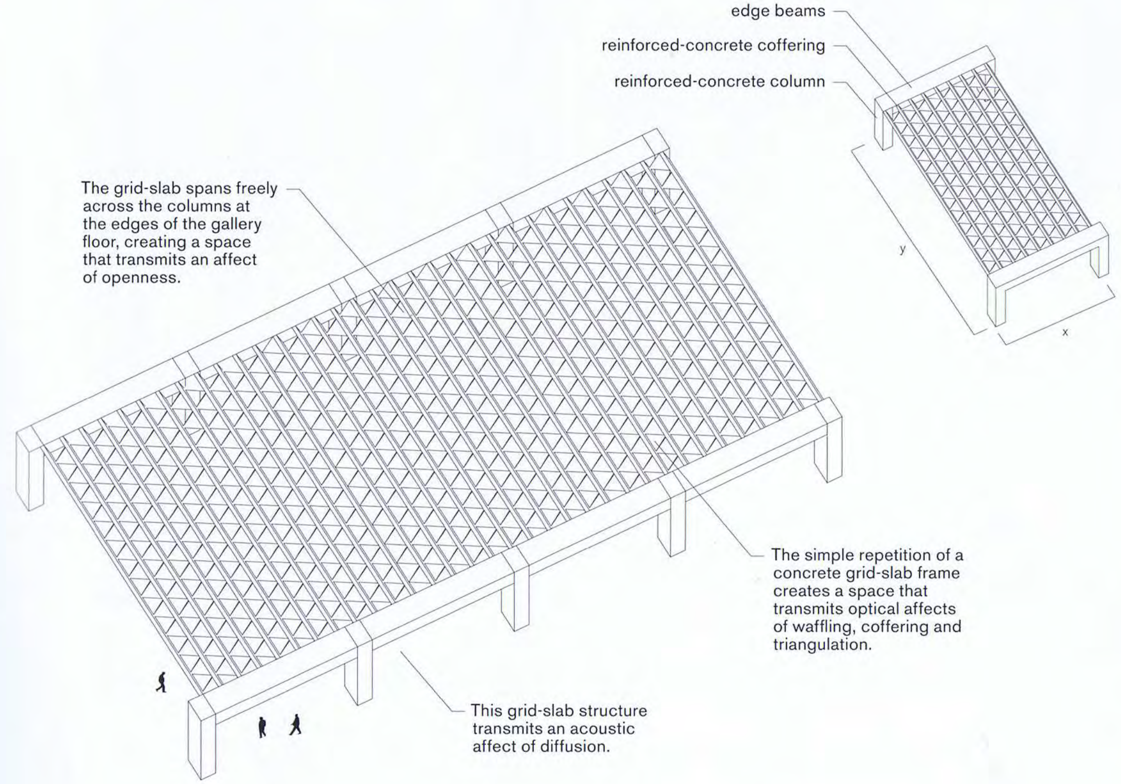
$W = \frac{A}{10}$ $\quad S = \frac{B}{26 \sim 35}$

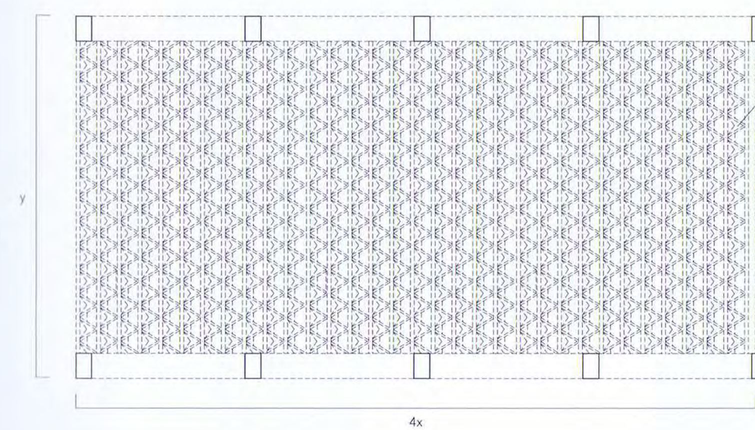
If W is reduced, then Z and C are reduced.

Waffling, Coffering, Openness, Triangulation, Diffusion

Horizontal / Grid-Slab Frame

YALE ART GALLERY | L. KAHN | NEW HAVEN, USA | 1953

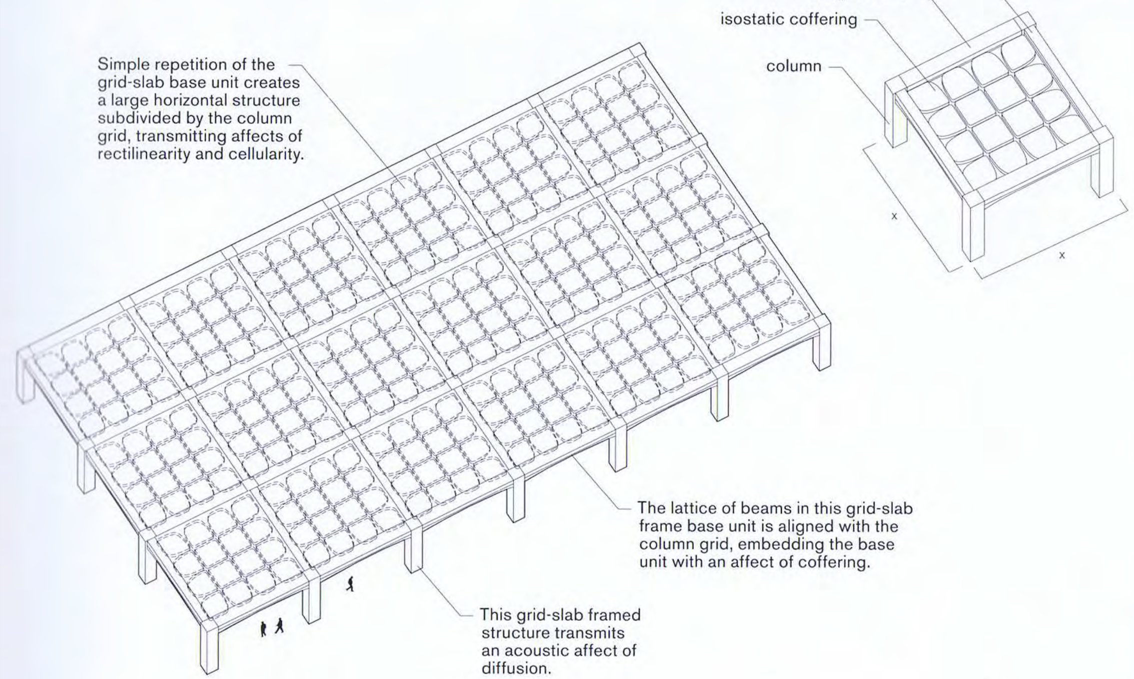


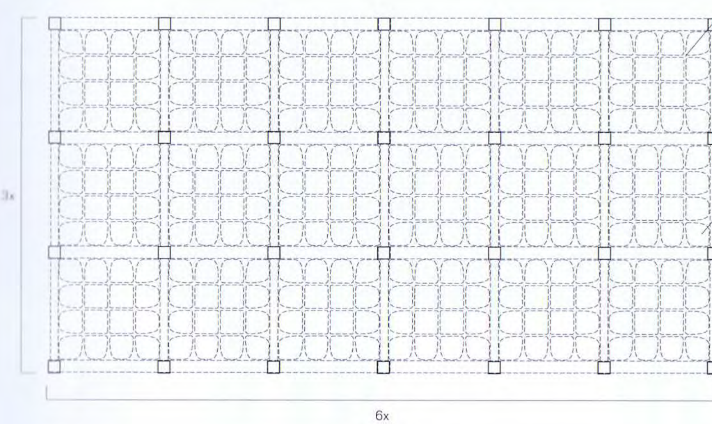


The Yale Art Gallery is formed by the horizontal tessellation of the base unit composed of a steel-reinforced concrete slab in the form of a triangulated grid of concrete beams. Simple repetition of the base unit forms a coffered ceiling that freely spans the perimeter walls and can house lighting or other service equipment. Though simply repeated here, the triangular grid slab can tessellate into a more complex grid that can vary in scale and depth to produce an irregular ceiling height and an irregular perimeter. The Yale Art Gallery transmits an optical affect of waffling, coffering, openness, and triangulation, and an acoustical affect of diffusion.

Horizontal / Grid-Slab Frame

TOBACCO FACTORY | P. L. NERVI | BOLOGNA, ITALY | 1952



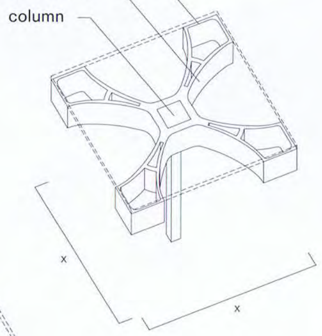


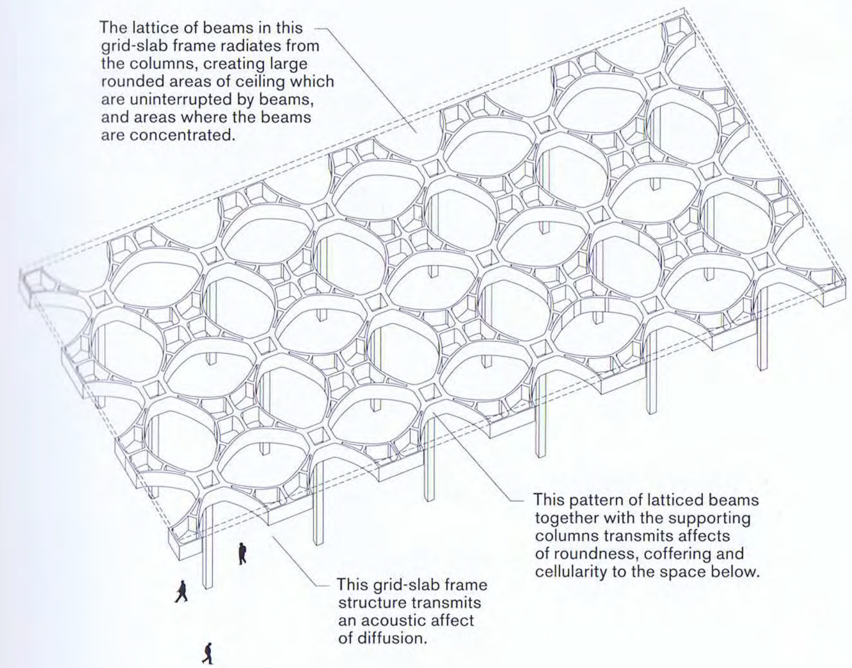
The Tobacco Factory is formed by the horizontal tessellation of a base unit composed of a steel-reinforced concrete slab and a tapered orthogonal grid of concrete beams resting on a grid of steel-reinforced concrete columns. Simple repetition of the base unit forms a coffered ceiling and an interior which is compartmentalized by the grid of columns. However, the tessellation could be made more complex by varying the scale and depth of the base unit as it repeats. The base unit can also repeat across an irregular grid, and produce an irregular perimeter. The Tobacco Factory transmits an optical affect of rectilinearity, coffering and cellularity, and an acoustical affect of diffusion.

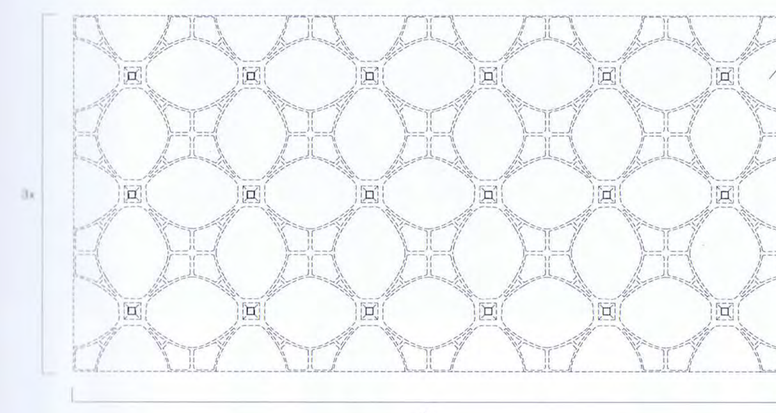
AFFECT

Roundness, Coffering, Cellularity, Diffusion

Horizontal / Grid-Slab Frame





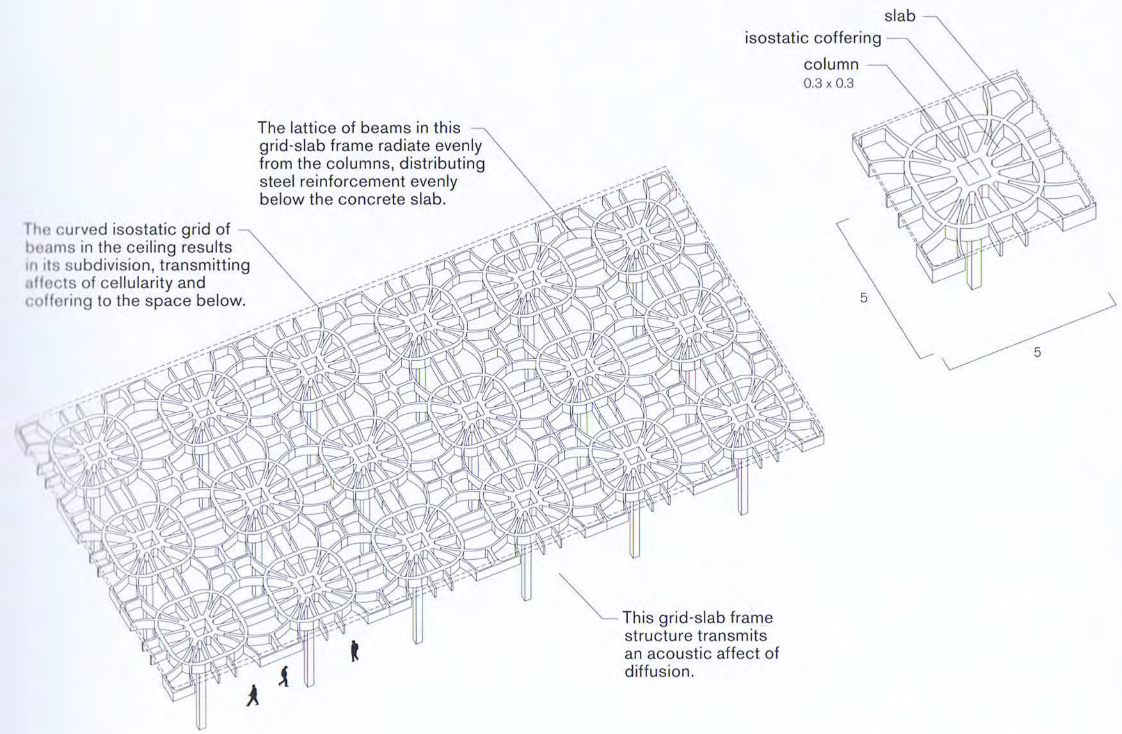


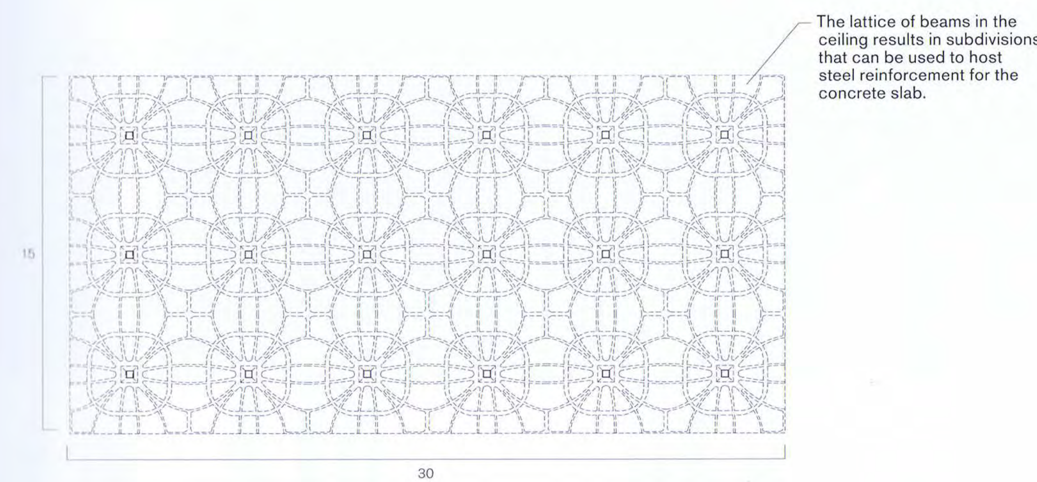
This horizontal form is produced by the tessellation of a base unit composed of a steel-reinforced concrete slab with a deepened isostatic grid of beams. This produces a coffered ceiling with two scales that differentiate between the area of ceiling which is central to each base unit, and the area of ceiling at the edge of each base unit. These two scales introduce micro-centers in spaces which are otherwise homogeneous on account of the even distribution of the columns. This assemblage transmits an optical affect of roundness, coffering and cellularity, and an acoustical affect of diffusion.

Cellularity, Coffering, Diffusion

Horizontal / Grid-Slab Frame

GATTI WOOL FACTORY | P. L. NERVI | ROME, ITALY | 1953

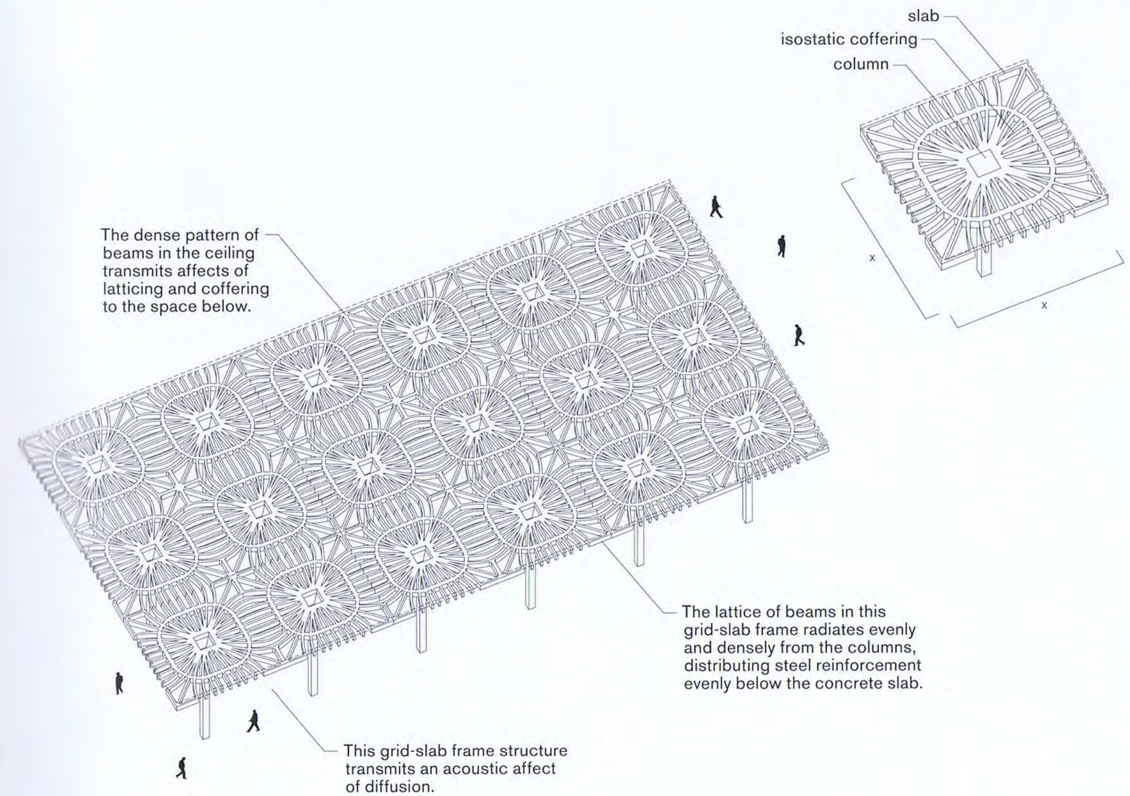


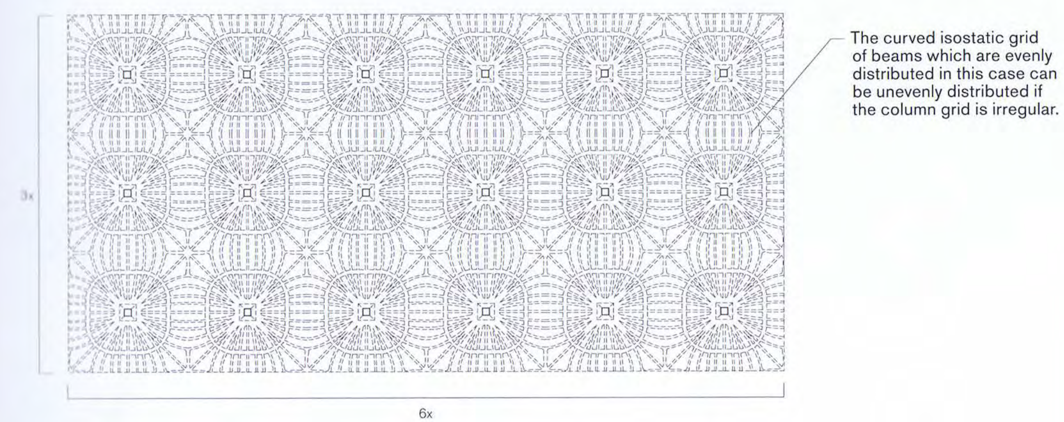


The Gatti Wool Factory is produced by the horizontal tessellation of a base unit composed of a steel-reinforced concrete slab in the form of a deepened isostatic grid. Though the isostatic lines radiate from the columns in an even pattern, they radiate and encircle each column in such a way as to avoid the affect of infinity, emphasizing instead the cellularization of the space by the columns. The Gatti Wool Factory transmits an optical affect of cellularity and coffering, and an acoustical affect of diffusion.

Latticing, Coffering, Diffusion

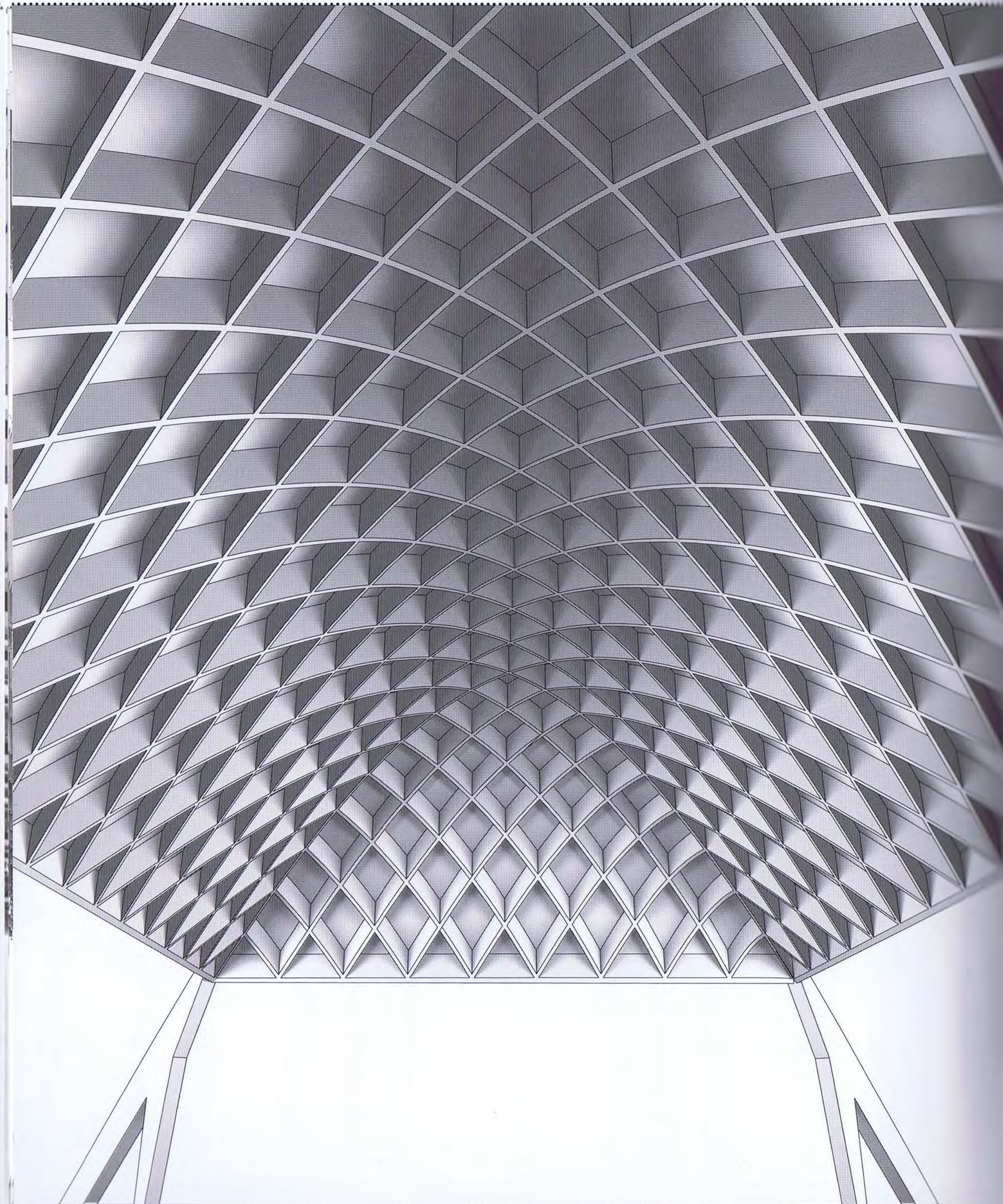
Horizontal / Grid-Slab Frame





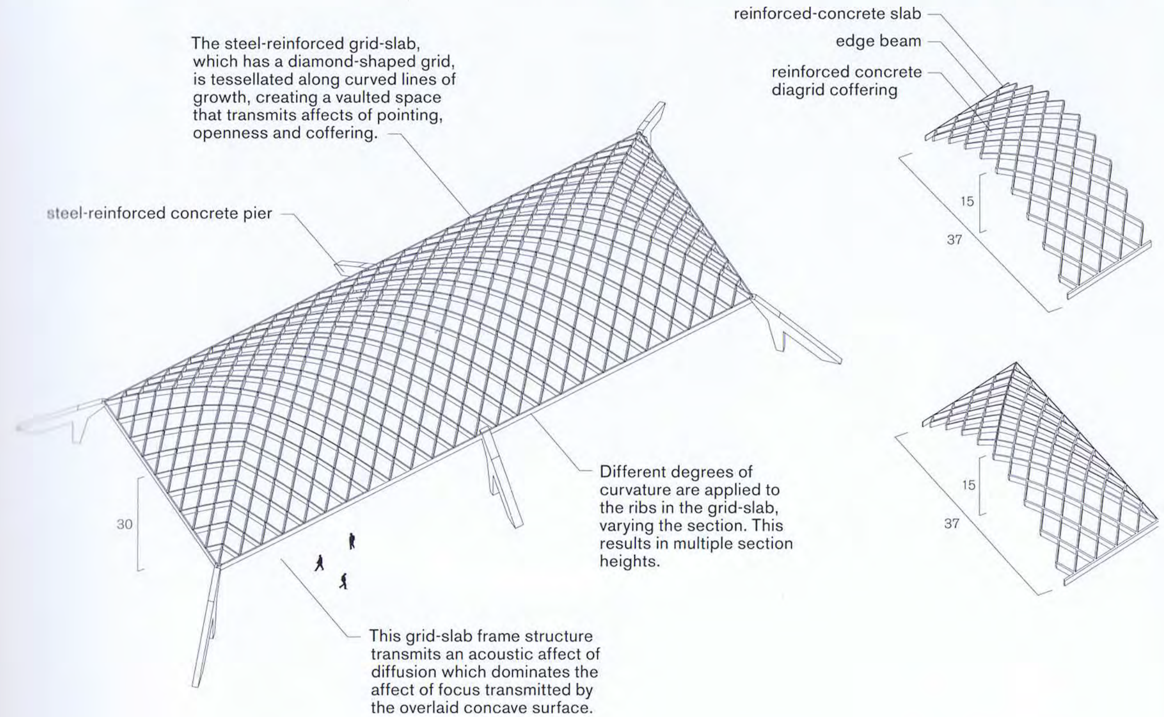
This horizontal form is produced by the tessellation of a base unit composed of a steel-reinforced concrete slab with a deepened isostatic grid of beams, the density of which is greater than that of the Gatti Wool Factory (pp. 136–7). It therefore produces a dense, lattice-like ceiling with the illusion of less depth. This assemblage transmits an optical affect of latticing and coffering, and an acoustical affect of diffusion.

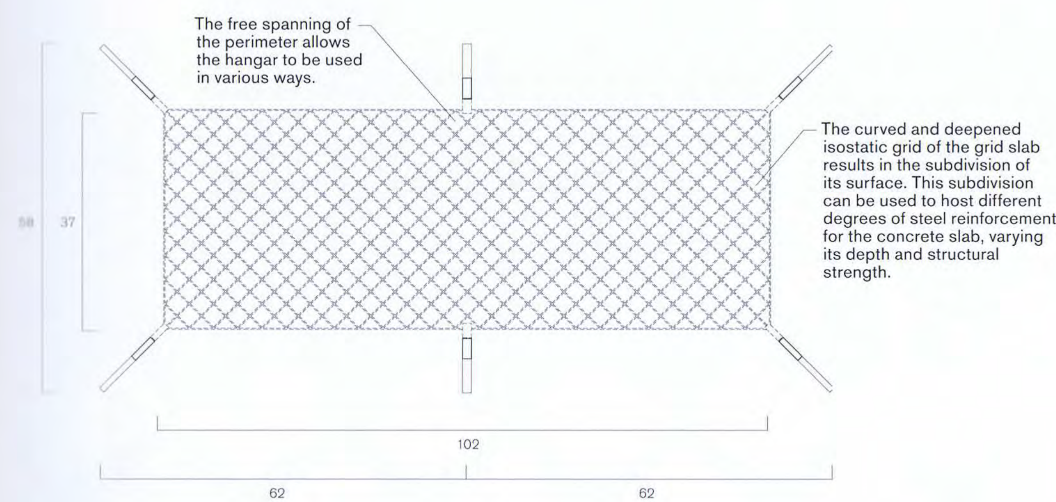
Vaulting, Coffering, Openness, Pointing, Diffusion



Curved / Grid-Slab Frame

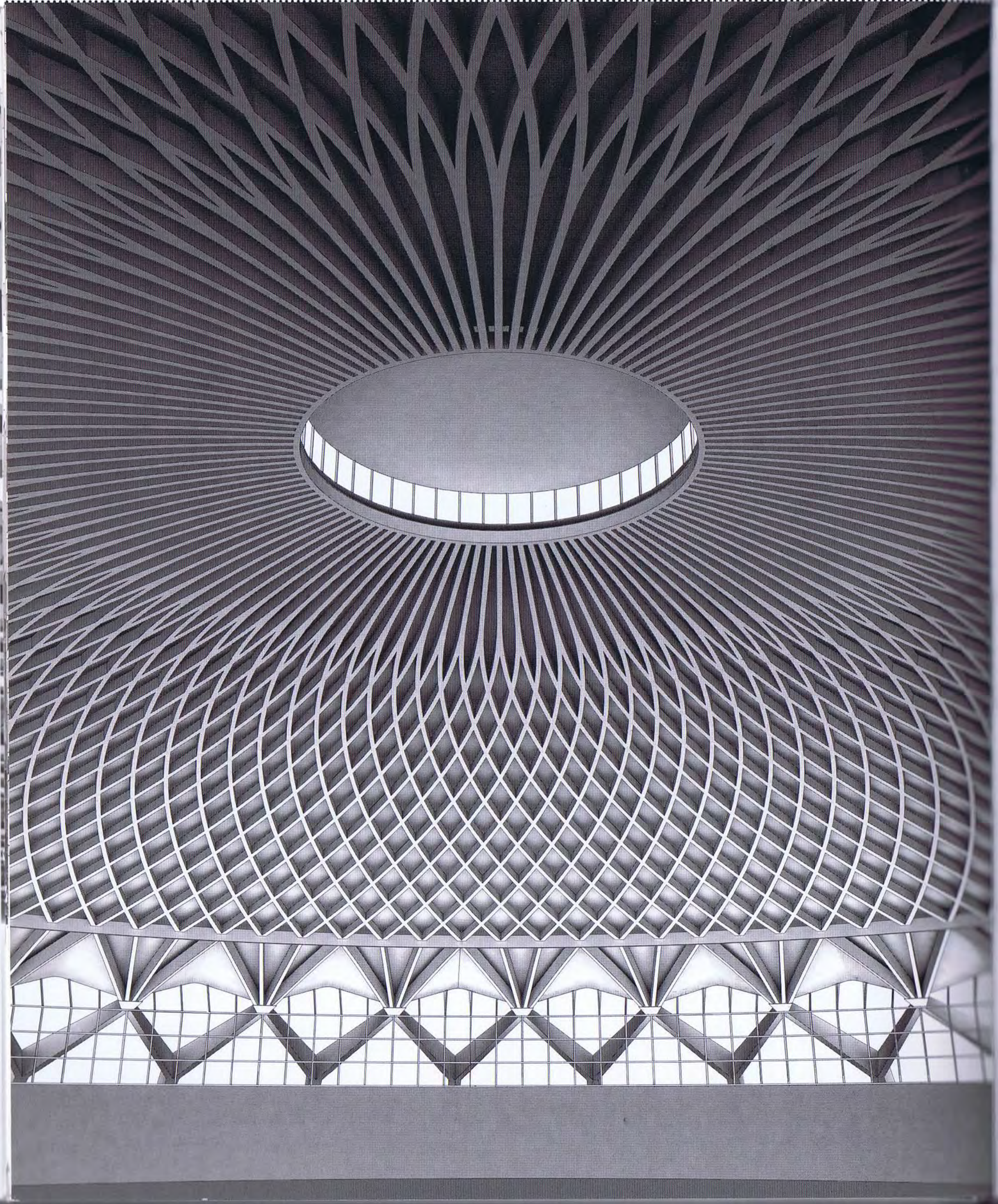
AIR FORCE HANGAR | P. L. NERVI | ORVIETO, ITALY | 1935





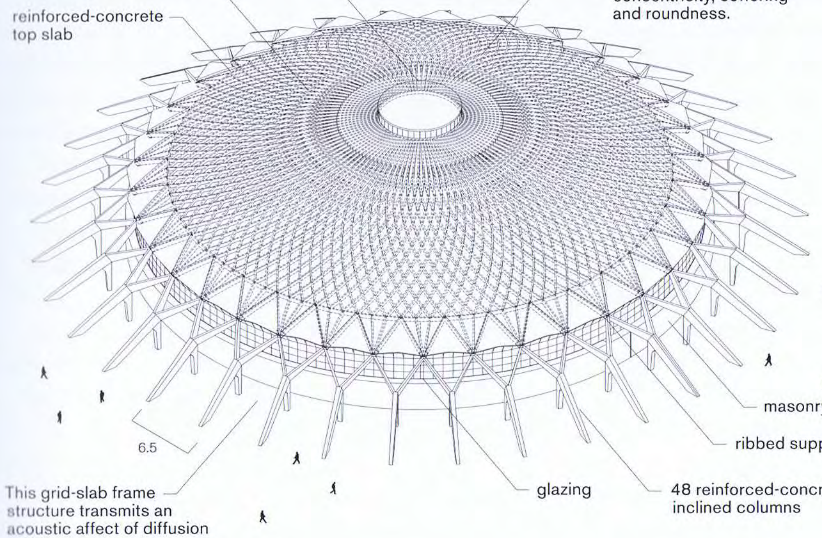
This Air Force hangar is formed by the curved tessellation of a base unit composed of a steel-reinforced concrete slab with a diamond-shaped grid of beams beneath. The grid-slab repeats along curved lines of growth to produce a barrel-vaulted ceiling that rests on steel-reinforced concrete piers and an edge beam at the perimeters. Though here the grid-slab repeats simply, it can also tessellate into more complex forms by adopting varying curvatures or by changing depth along its extension. This assemblage transmits an optical affect of vaulting, coffering, and openness, and an acoustical affect of diffusion.

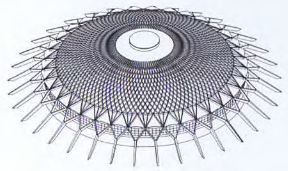
Concentricity, Coffering, Roundness, Diffusion

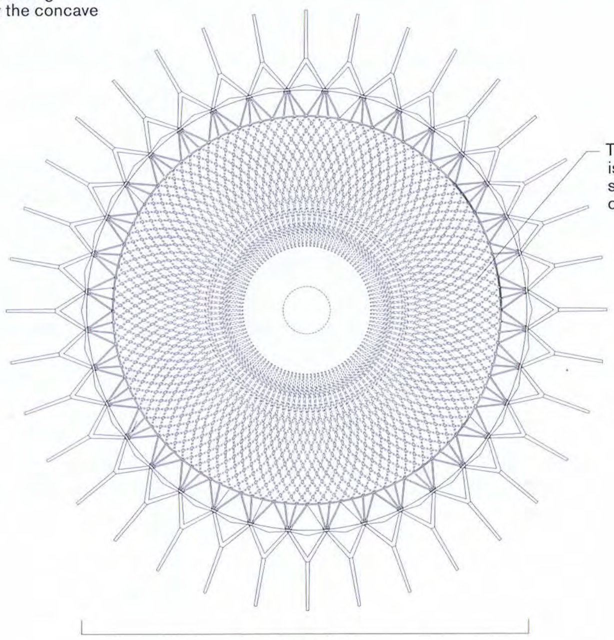


Curved / Grid-Slab Frame

PALAZZETTO DELLO SPORT | P. L. NERVI, A. VITELLOZZI | ROME, ITALY | 1958–60



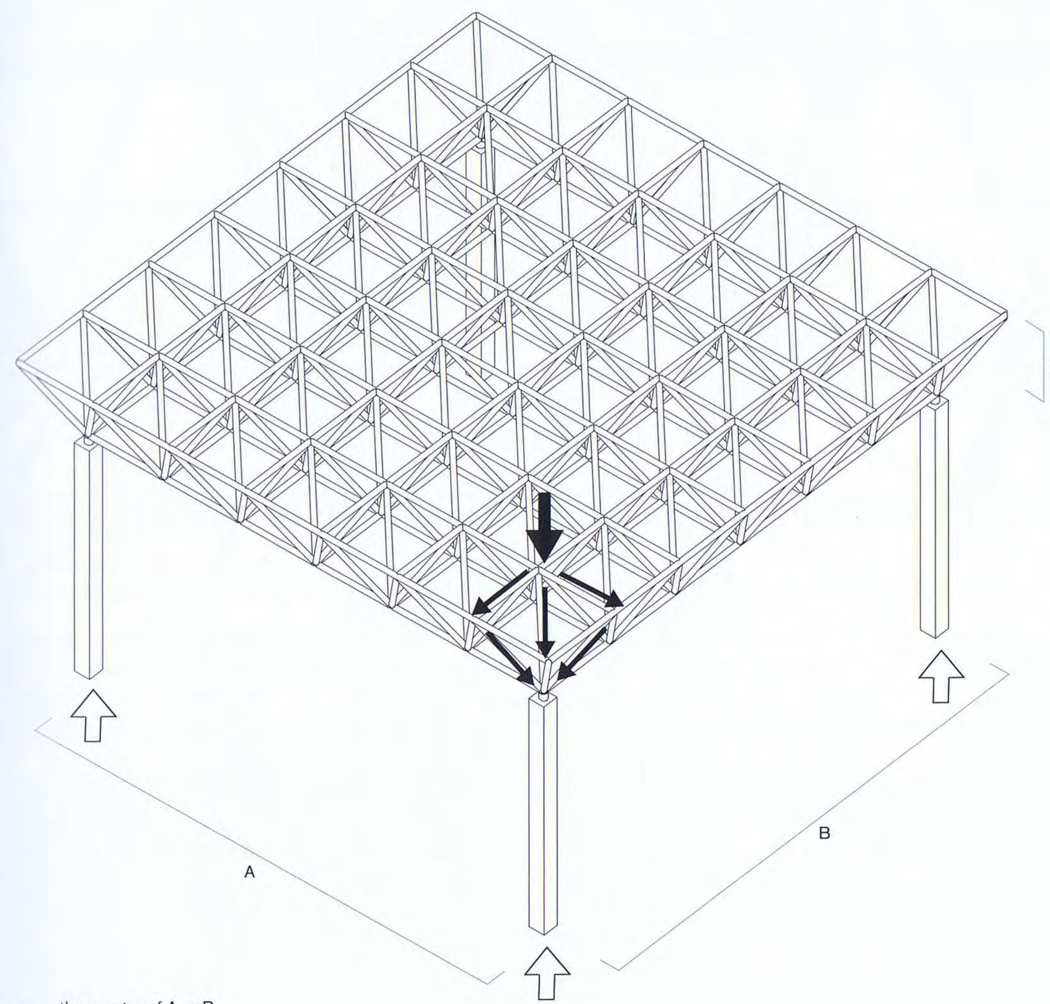




The Palazzetto dello Sport grid-slab frame is formed by the curved tessellation of a steel-reinforced concrete slab and a regular grid of beams in the lower part of the section, to produce a dome. The diamond grid arrayed radially from the center of the dome transmits an optical affect of concentricity, coffering and roundness, and an acoustical affect of diffusion.

The base unit of a double-layer-grid (space frame) is composed of two layers of triangular grids made of steel struts connected by diagonal struts to form a deep but lightweight structural unit. The struts in both the upper and the lower surfaces as well as in the diagonal dimension can be made of fiber-reinforced plastics and other metals such as aluminum rather than steel, when weight and spanning capacity do not need to be considered. The top and bottom horizontal members carry tension and compression along their length, related to the bending moment in the space frame overall, while the vertical (diagonal) members carry tension and compression alternately, in relation to the shear in the space frame, producing a lightweight rigid structure. This type of structure has the capacity to span long distances and to produce, independently of any additional walls or columns, complex forms by the tessellation of the triangular three-dimensional grid. The distribution of loads along the struts embeds the space frame with an optical affective property of lightness and continuity that remains consistent within any space it defines. A frame together with its overlaid surfaces can have an affect of specularity, focusing or diffusion, depending on the degree of its openness and lightness, and the contours of the surfaces.

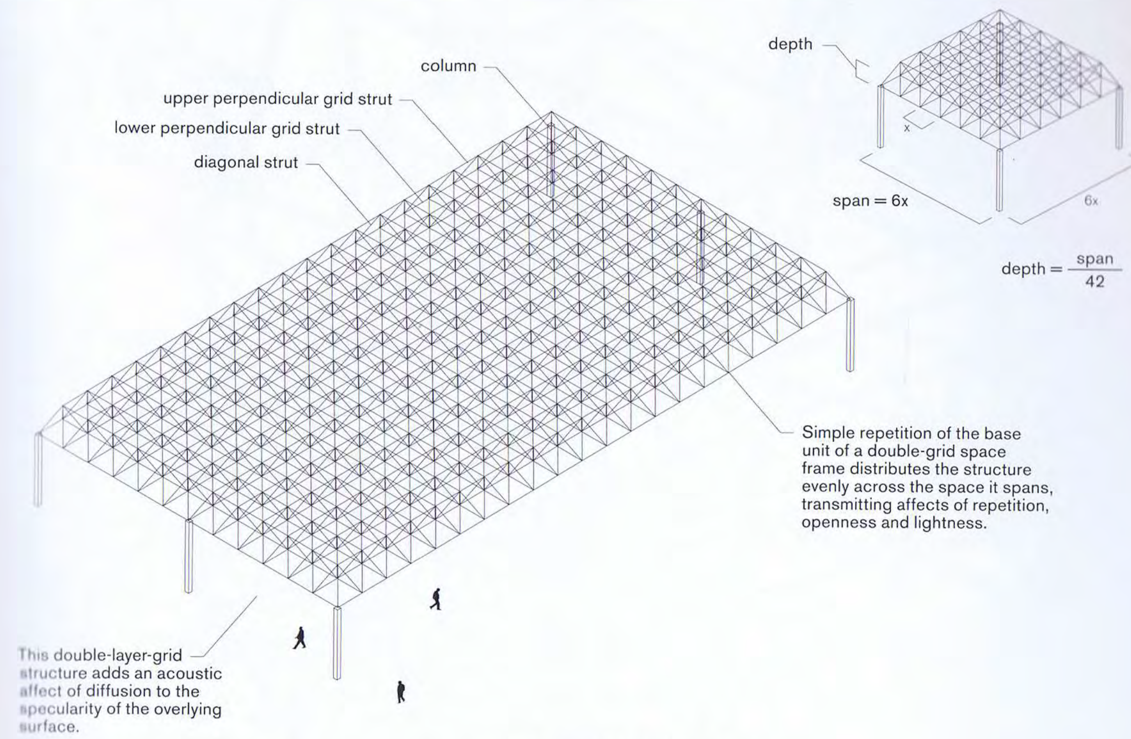
The protogeometry of gridded space frames is flexible in several ways:
Scale: Although the base units in a single assemblage are often kept at the same scale for economy of fabrication, other forms can use scales that are unique to each base unit, endowing them with specific scales of granularity.
Depth: The depth of the space-frame base unit in a simple enclosure is often kept consistent to maintain structural continuity and economy of fabrication, but the depth of the space frame can be varied to achieve a wide range of spans.
Profile: Space frames can tessellate horizontally or along curved lines of growth to produce structures that are horizontal (sheds) or curved (domes). The profile of the resulting structures can range from a horizontal slab of interlocking square-plan pyramids to a more complex isotropic form such as a barrel vault or a dome composed of interlocking tetrahedral pyramids in which all the struts have the same length.
Affect: The affective properties of a gridded space-frame can be multiplied when the base unit imbricates or intertwines with external factors, such as asymmetries that respond to the physical constraints of the site, environmental considerations, programmatic requirements, etc. As a result, in addition to lightness and continuity, a gridded space-frame can transmit other optical affects, including repetition, openness, unstructuredness, aggregation, boundlessness, enclosure. The grids can modify or dominate the acoustical affect of the overlaid slab by adding an affect of diffusion.

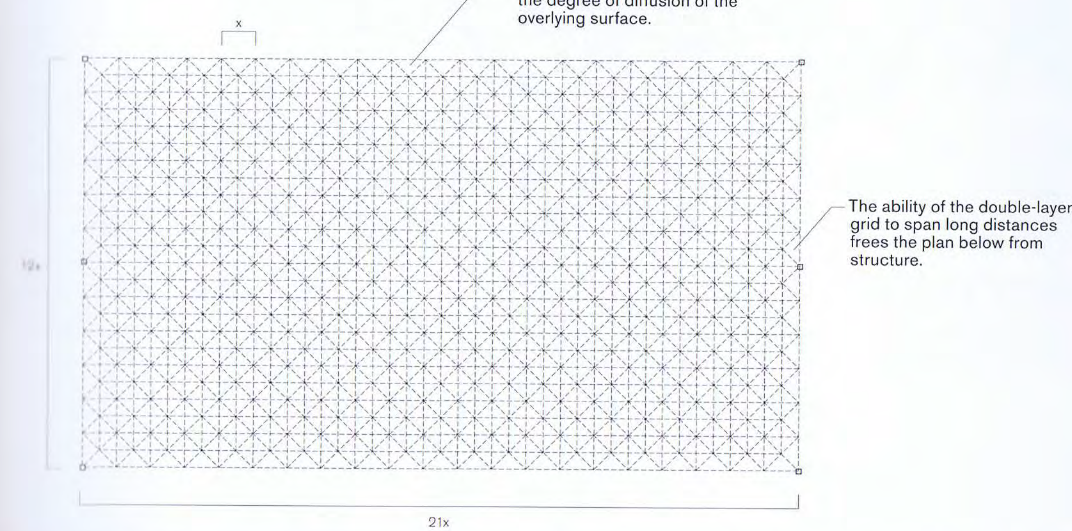


$$Z = \frac{\text{the greater of A or B}}{30\text{~}40}$$

Repetition, Openness, Lightness, Diffusion, Specularity

Horizontal / Double-Layer Grid



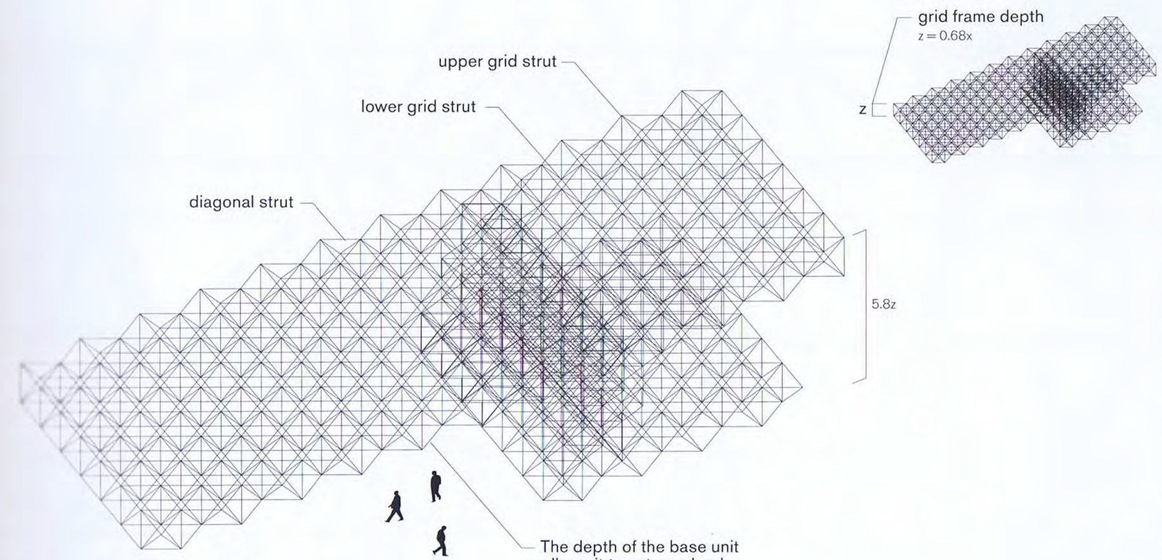


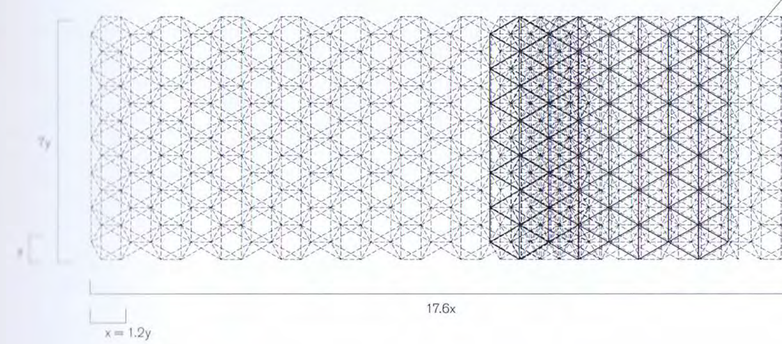
This horizontal form is produced by the tessellation of a base unit composed of a double grid of struts, tubular in section, which are interconnected by diagonal struts. The base unit simply repeats, but its depth and scale can vary, altering the rigidity and porosity of the structure. The struts can also be distributed regularly or irregularly along the double-layer grid to connect them at right angles or diagonally. This assembly transmits an optical affect of repetition, openness and lightness, and an acoustical affect of diffusion and specularity.

Cantilevering, Hovering, Openness, Lightness, Specularity

Horizontal / Double-Layer Grid

OCTET TRUSS PROJECT | R. BUCKMINSTER FULLER | 1959

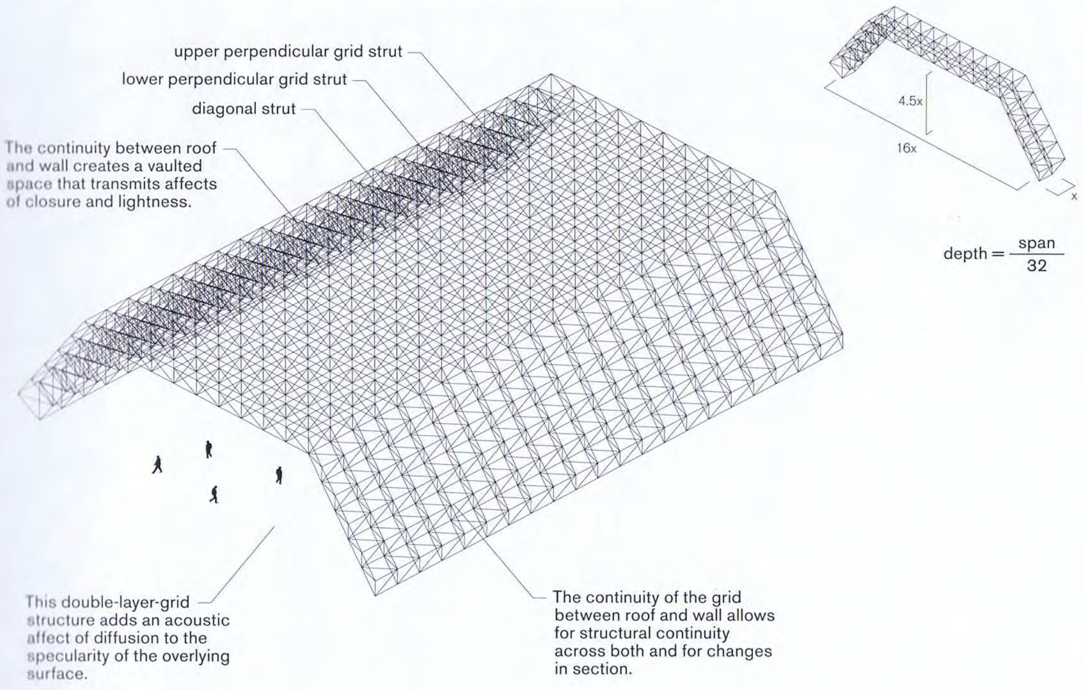


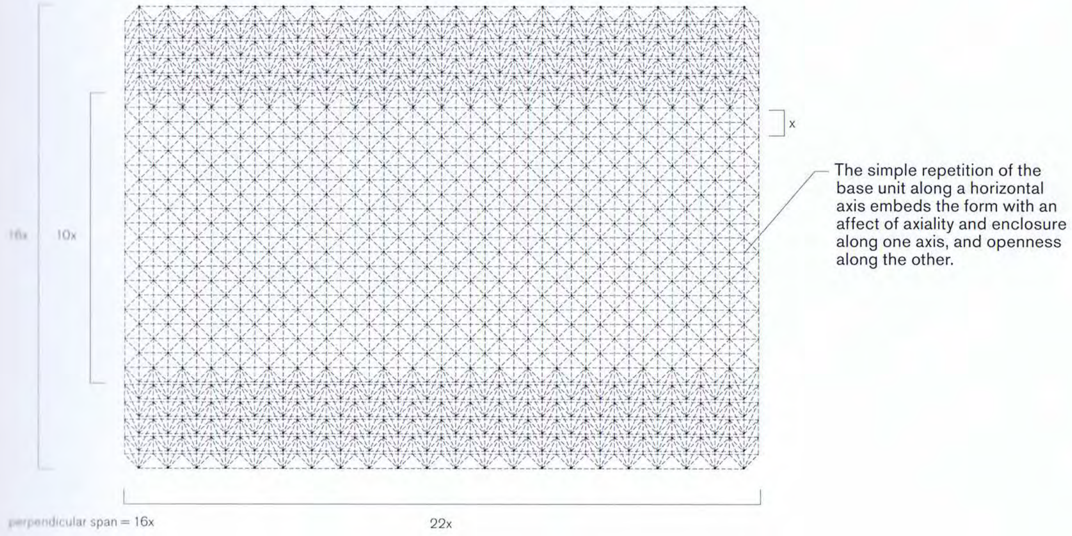


The octet truss is formed by the horizontal tessellation of a base unit composed of a double grid of struts, tubular in section, to produce a cantilevered roof and the supporting walls in a continuous surface. The base unit simply repeats along all its extensions, although its depth and scale can vary to produce a cantilevering form with irregular perimeters as well as varying degrees of porosity throughout the structure. The octet truss transmits an optical affect of cantilevering, hovering, openness and lightness, and an acoustical affect of specularity.

Vaulting, Enclosure, Lightness, Axiality, Diffusion, Specularity

Horizontal / Double-Layer Grid

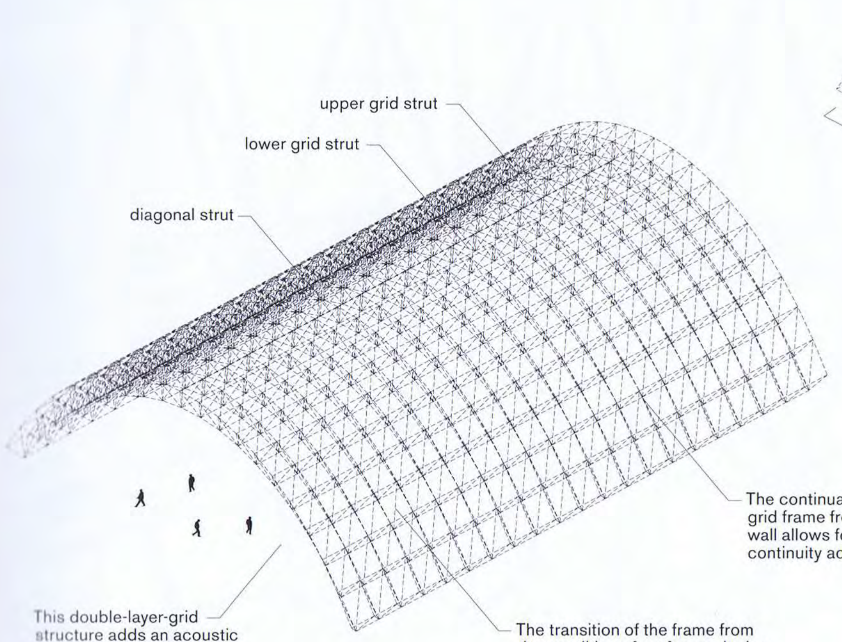


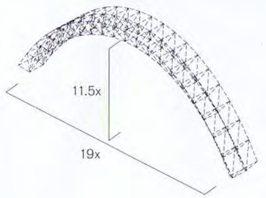


This horizontal form is produced by the tessellation of a base unit composed of a double grid of struts, tubular in section, which are interconnected by diagonal struts. The base unit in this case simply repeats, but its depth and scale can vary to change the rigidity and porosity of the structure. The struts can also be distributed regularly or irregularly along the double-layer grid to connect them at right angles or diagonally. This assembly transmits an optical affect of vaulting, enclosure, axiality and lightness, and an acoustical affect of diffusion and specularity.

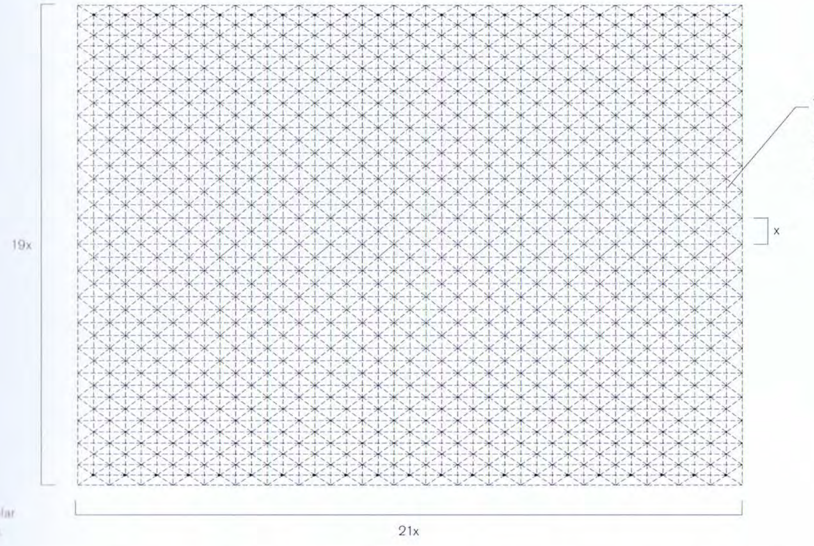
Arching, Enclosure, Lightness, Diffusion, Specularity

Horizontal / Double-Layer Grid





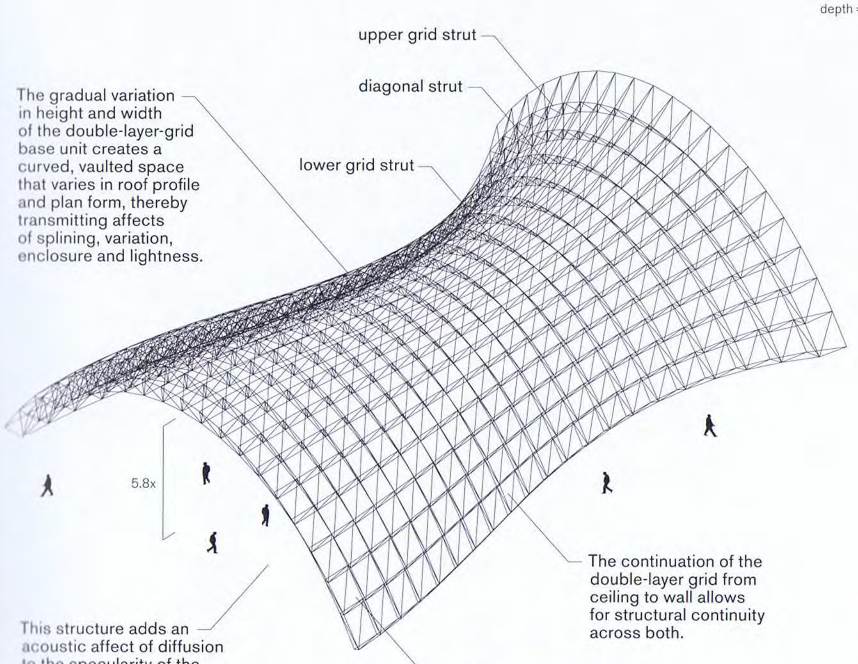
$$\text{depth} = \frac{\text{span}}{38}$$

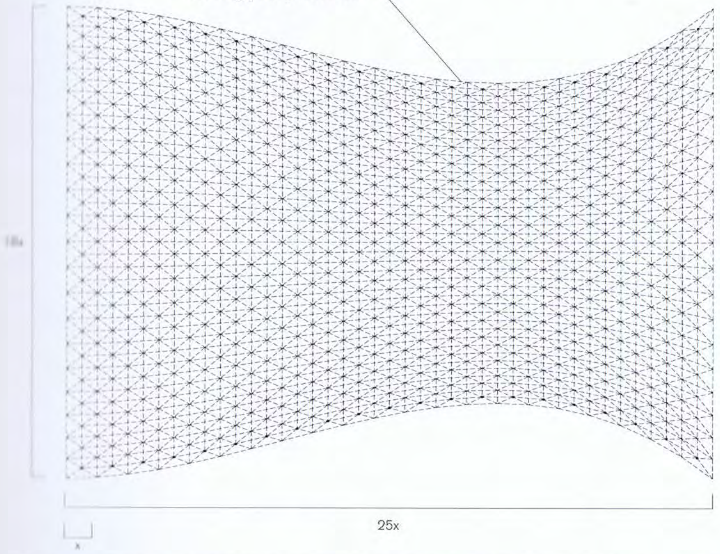


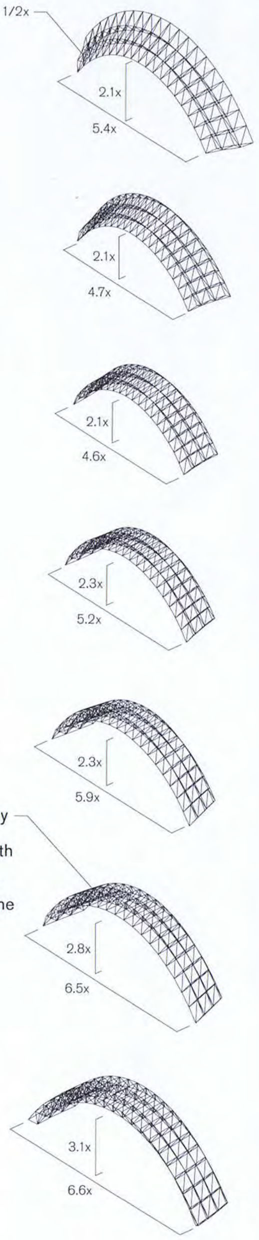
This horizontal form is produced by the tessellation of a base unit composed of a double grid of struts, tubular in section, which are interconnected by diagonal struts. The base unit in this case simply repeats, but its depth and scale can vary, altering the rigidity and porosity of the structure. The struts can also be distributed regularly or irregularly along the double-layer grid to connect them at right angles or diagonally. This assembly transmits an optical affect of arching, enclosure and lightness, and an acoustical affect of diffusion and specularity.

Splining, Variation, Enclosure, Lightness, Diffusion, Specularity

Horizontal / Double-Layer Grid





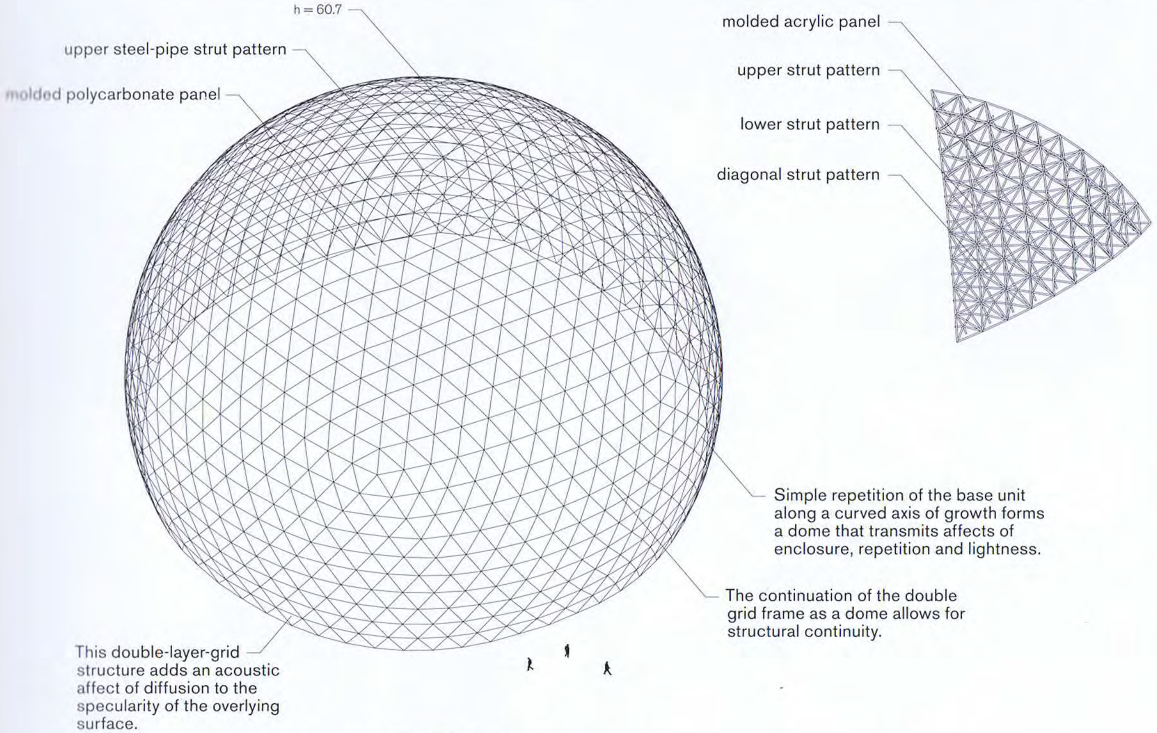


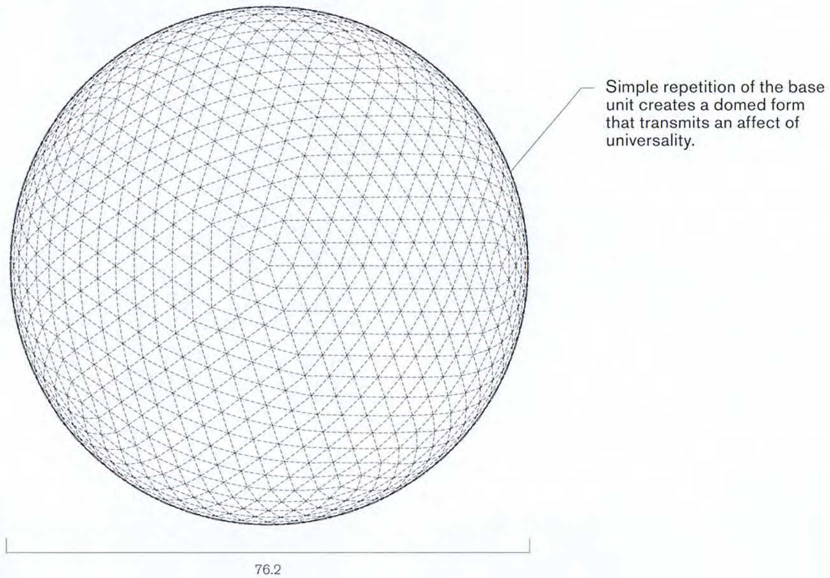
This horizontal form is produced by the tessellation of a base unit composed of a double grid of struts, tubular in section, which are interconnected by diagonal struts. The base unit repeats while changing in scale to adjust to the curvature in plan and section. However, the depth and scale of the base unit can vary, altering the rigidity and porosity of the structure. Furthermore, the struts can be distributed regularly along a perpendicular grid, or irregularly and diagonally, to introduce changes in the orientation of the structure. This assembly transmits an optical affect of splining, variation, enclosure and lightness, and an acoustical affect of diffusion and specularity.

Universality, Enclosure, Repetition, Lightness, Diffusion

Curved / Double-Layer Grid

US PAVILION, 1967 EXPO | R. BUCKMINSTER FULLER, S.SADAO | MONTREAL, CANADA | 1967





The US Pavilion is formed by the curved tessellation of a base unit of a double-layer grid composed of a pyramidal cell, repeated with no variations, to produce a regular curvature and enclose a spherical form. The pyramidal cells are regularly repeated to produce a spherical form. Since the cells are pyramidal, the external face of the sphere is triangulated, whereas the interior is hexagonal. Changes in the density and scale of the base unit can change the porosity and transparency of the form. The US Pavilion transmits an optical affect of universality, enclosure, repetition and lightness, and an acoustical affect of diffusion.