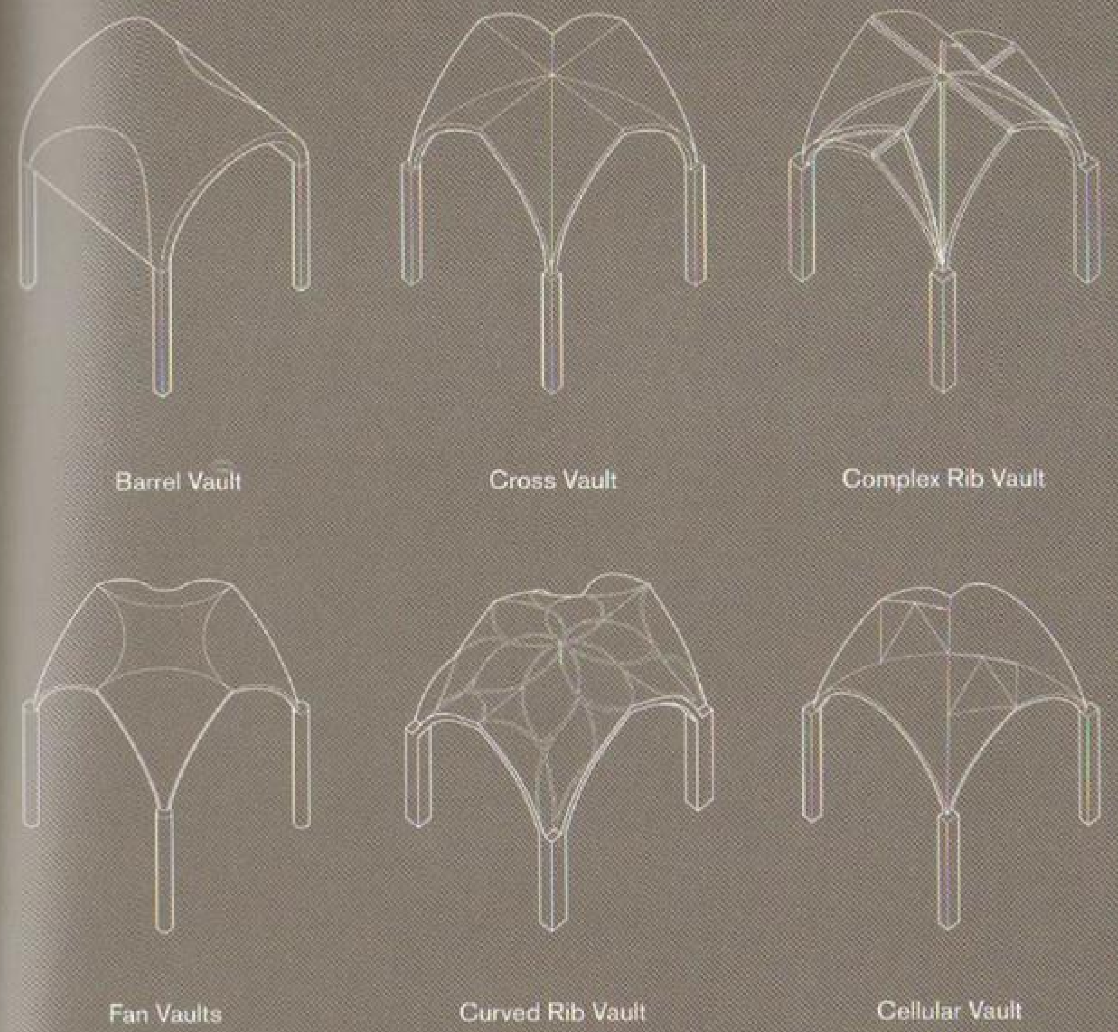
Vaults are structural systems which are composed of curved ribs and surface elements that distribute loads along ribs and planes, and have greatest efficiency when resisting evenly distributed loads. Vaults can be built of stone, masonry, thin grid-shell steel-reinforced concrete, lattice steel, or timber frames. Vaults vary in kind according to the arrangement of the columns and arches, and the degree of subdivision of the surfaces in between.

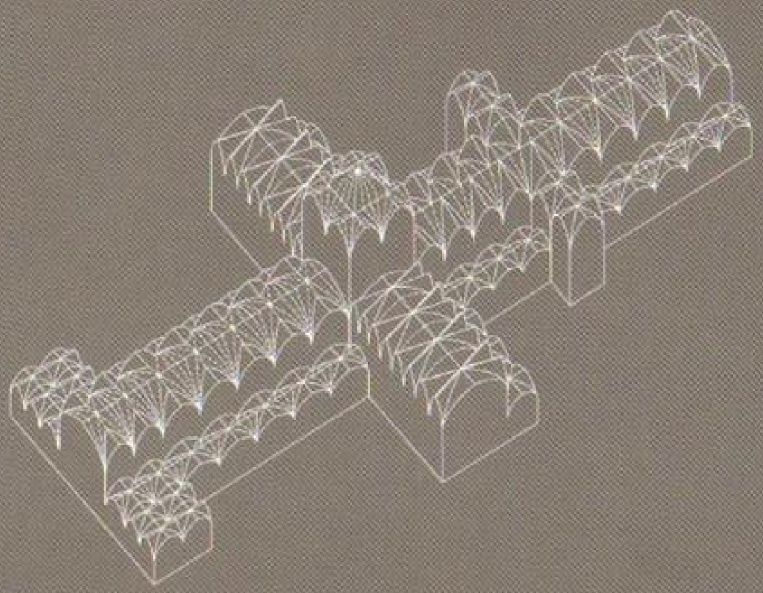
The system of vaults is divided into six primary subsystems: barrel vaults, cross vaults, complex rib vaults, fan vaults, curved rib vaults, and cellular vaults. These subsystems are defined by the degree of subdivision of the vault surfaces. Subdivision of the vault surface increases the overall structural strength by adding depth to the surface. It should be noted that system considerations have not specifically addressed resistance to lateral loads.

Barrel vaults distribute the lines of force along a continuous surface.
Cross vaults subdivide the surfaces by distributing the lines of force both along the surface and along the resulting ribs located at the seams of each subdivision. This subsystem is generated by the intersection of two perpendicular pointed arches extruded across to meet at a single apex.
Complex rib vaults further increase the degree of surface subdivision and the number of ribs by introducing ribs and apex points to a pointed arch configuration.
Fan vaults increase the subdivision of the vault's surface and the number of ribs by means of an array of pointed arches with differing profiles, with the ribs and surfaces between them forming a shell.
Curved rib vaults increase even further the degree of surface subdivision by replacing the ribs with a number of curves that distribute the lines of force.
Cellular vaults distribute the lines of force primarily along a highly subdivided surface that eliminates the need for ribs and distributes the loads along the surface of each facet.



Vaults tessellate along horizontal axes of growth to produce horizontal structural forms. The repetition of the vaults allows them to buttress one another to create more complex structural forms.

Horizontal tessellation can occur in all of the six primary subsystems, introducing difference as well as repetition in the resulting horizontal forms. The Gothic nave is characteristic of this type of complex repetition.
Vertical tessellation Vertical tessellation can occur in all of the six primary subsystems. The Palazzo della Civilta' del Lavoro in Rome (partly by Nervi), though not illustrated in this book, is an example.



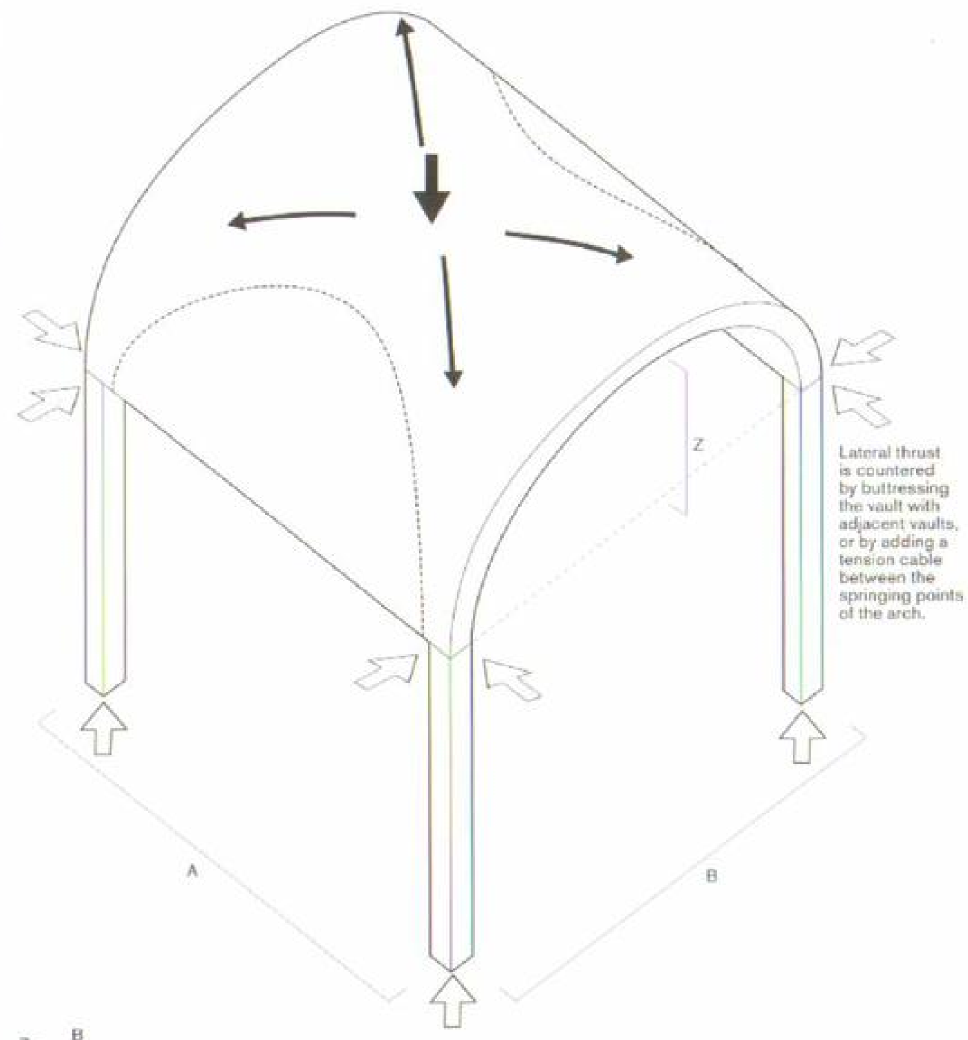
Horizontal Tessellation

Vertical Tessellation

Barrel Vault

The base unit of a barrel vault is formed by extruding a single arch in a straight line. The load in a barrel vault is distributed within its cross section. Ribbed arches forming bays are sometimes introduced to further stabilize the vault along its span. For any arch-based structure that resists load predominantly through axial compression, the barrel vault creates an outward needs to be resisted by an abutment or counteracted by adding parallel adjoining barrel vaults or by adding side vaults perpendicular to the main barrel vault to form a cross vault or by means of a tie at the spring points. The distribution of loads through masonry or steel-reinforced concrete surfaces produces a barrel vault form, the structural strength of which lies in its capacity to arch across a span onto load-bearing points in the form of columns or walls, and to resist the outward thrust generated by this arch. This embeds the barrel vault with an optical affect of ribbing and extrusion that remains consistent within any space it defines. The concave surface of a vault focuses sound near its center of curvature, but sound at a distance from the center can be diffused to an extent that depends upon the spectrum of the sound. Therefore, a barrel vault that is expansive and low can have an acoustical affect of focus, whereas one that is high and narrow can have an affect of diffusion. Ribs, facets and reticulation can modify the acoustical affect of a vault by adding diffusion, which may become dominant. Many vault subsystems
have a multiplicity of focal points. These can modify the acoustical affect of the vault by adding diffusion, which may become dominant.

The protogeometry of barrel vaults is flexible in several ways:
Scale: The scale of the barrel vault base unit can change to accommodate changes in plan such as an increase in the width of the bays.
Depth: The section of a barrel vault can vary according to the rise produced by the curvature of the arch.
Profile: The protogeometry of the barrel vault allows it to tessellate horizontally and vary, as the structural strength is proportional to the range of curvature of the initial arch determining the depth of its surface in section. Barrel vaults can tessellate horizontally along straight or curved lines of growth to produce structures that are horizontal (naves) or curved (naves in the shape of a half-torus).
Affect: The affective properties of a barrel vault can be multiplied when the base unit imbricates or intertwines with external factors, such as asymmetries in response to the physical constraints of the site, environmental considerations, programmatic requirements, etc. As a result, in addition to massiveness, solidity and orientedness, a barrel vault structure can transmit other optical affects, including non-orientedness, vaulting, extrusion, ribbing. An expansive and low barrel vault can have an acoustical affect of focusing, whereas one that is narrow or high can have an affect of diffusion.



$$Z = \frac{B}{2\text{–}12}$$

[A (span) : Z (rise) = 4–12].

For the case of a barrel vault on four supports, the sides of the vault are in tension (dotted area). If the vault were masonry it would require support to the area from below and a lateral thrust (shown thus "") to maintain stability. If it were reinforced concrete or steel it would have inherent tensile capacity in that zone and so no additional measures would be necessary.

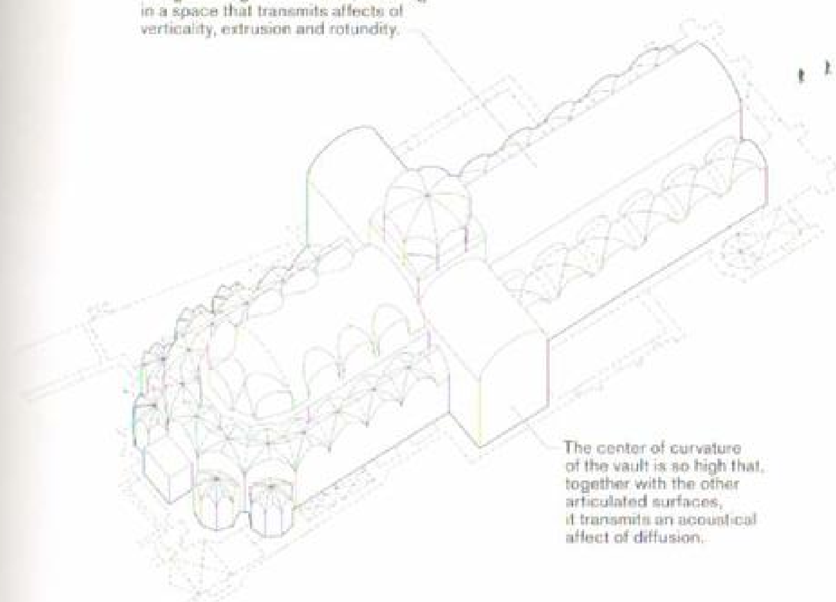
Verticality, Extrusion, Rotundity, Ribbing, Diffusion, Slowness

Horizontal / Barrel Vault

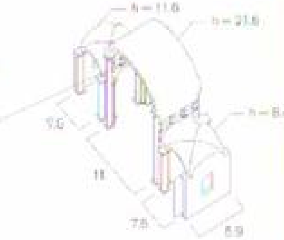
LISBON CATHEDRAL | LISBON, PORTUGAL | 1147

The nave of Lisbon cathedral is formed through the tessellation of a barrel vault base unit. The base unit varies to produce aisles, chapels and ambulatories while simply repeating along the length of the nave, resulting in a space that transmits affects of verticality, extrusion and rotundity.

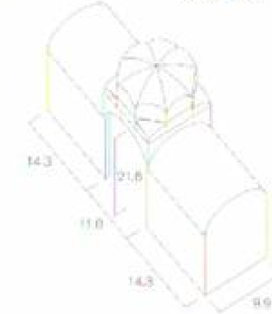
Transverse arch rings of cut stone brace the banded stone shell of the barrel vault making possible a general reduction in the thickness of the curved shell, and also allowing the stonemason to conceive of each bay as an isolated structural unit.



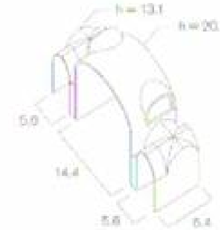
The center of curvature of the vault is so high that, together with the other articulated surfaces, it transmits an acoustical affect of diffusion.



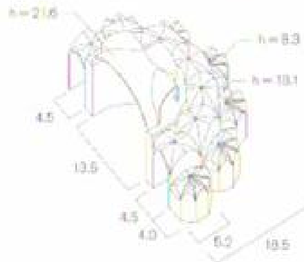
base unit a



base unit b



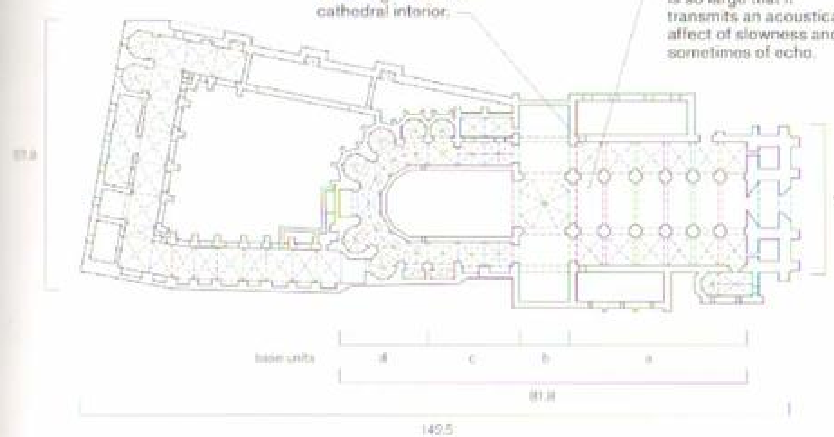
base unit c



base unit d

The tessellation of the base unit, which comprises a barrel vault and an arched rib, creates an affect of ribbing within the cathedral interior.

The cathedral interior is so large that it transmits an acoustical affect of slowness and sometimes of echo.



The ratio between the width of the bay and its height can be described as 1:3.

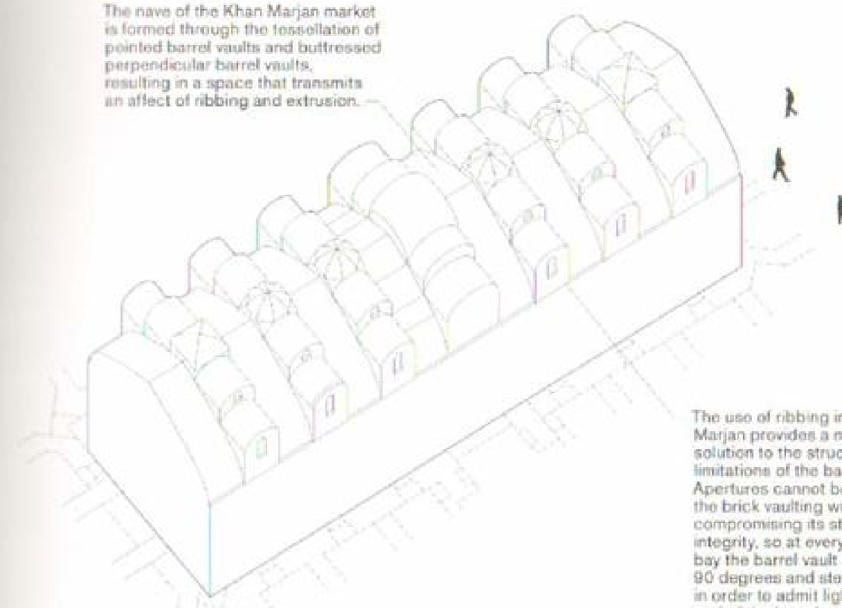
Lisbon cathedral is formed by the horizontal tessellation of a barrel vault base unit and ribs that reinforce the vaulted surface. Lisbon cathedral transmits optical affects such as ribbing and extrusion, and an acoustical affect of diffusion, slowness and echo.

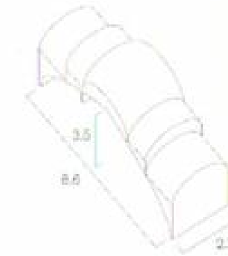
Ribbing, Stepping, Extrusion, Diffusion, Slowness

Horizontal / Barrel Vault

KHAN AL-MIRJAN | BAGHDAD, IRAQ | 1359

The nave of the Khan Marjan market is formed through the tessellation of pointed barrel vaults and buttressed perpendicular barrel vaults, resulting in a space that transmits an affect of ribbing and extrusion.



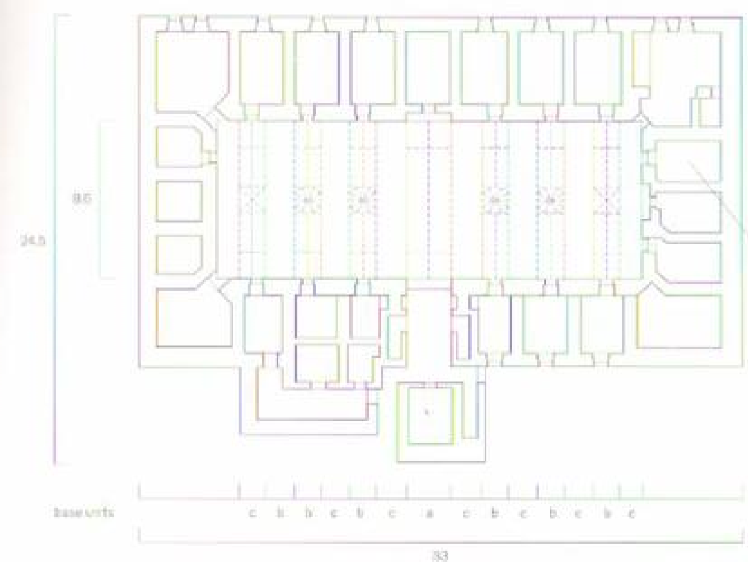


base unit a

The use of ribbing in Khan Marjan provides a novel solution to the structural limitations of the barrel vault. Apertures cannot be cut into the brick vaulting without compromising its structural integrity, so at every other bay the barrel vault is rotated 90 degrees and stepped, in order to admit light at the end of the barrel vault, where there is no structural action. This contributes to an affect of stepping.

base unit b

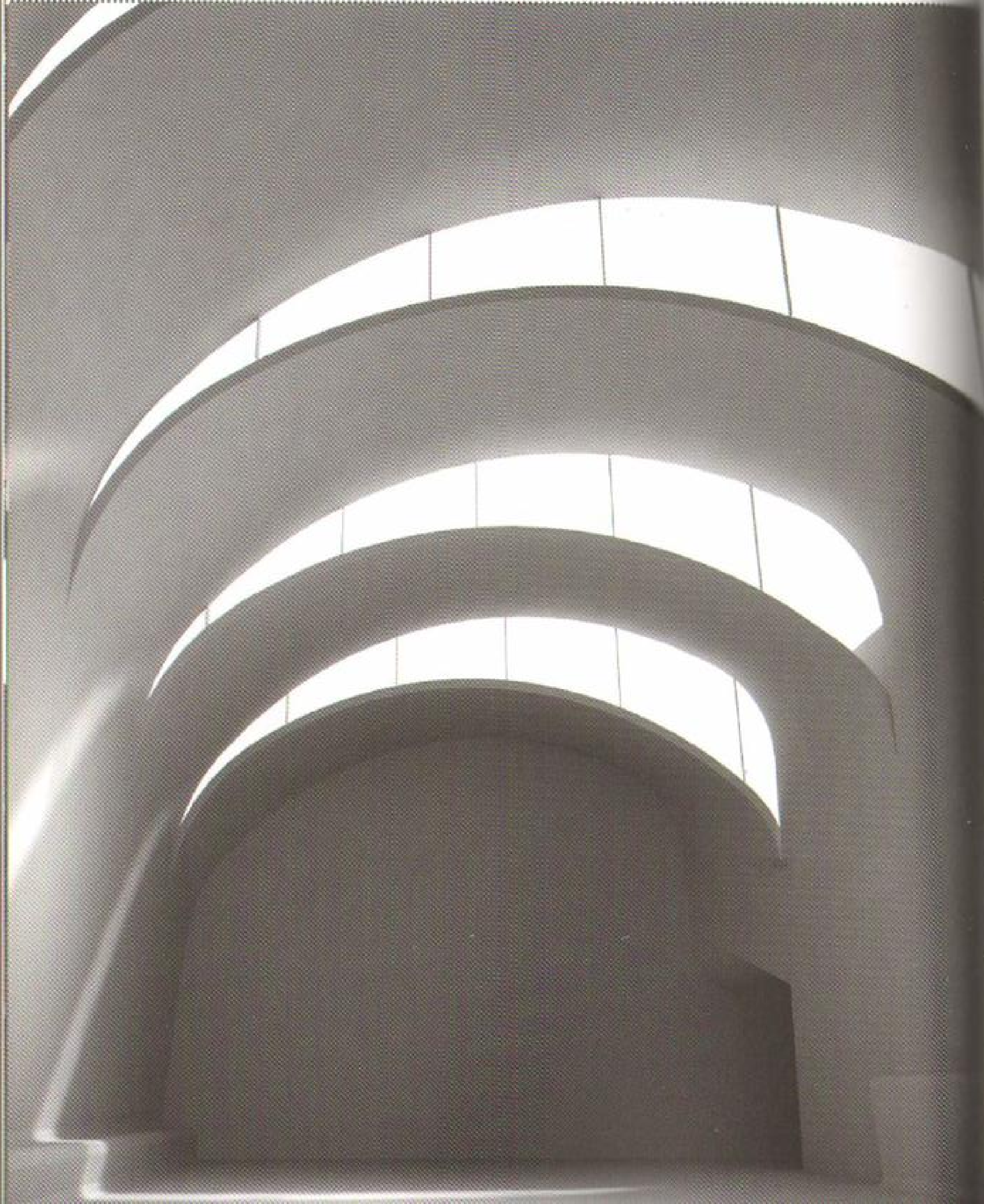
base unit c



The interior space transmits an acoustic affect of diffusion. The main vaults transmit an acoustic affect of focus but this is overwhelmed by the affect of diffusion transmitted by the series of small vaults, and the specularity transmitted by the walls. The interior, by virtue of its dimensions, transmits an affect of slowness.

Khan Marjan market is formed by the horizontal tessellation of a pointed-arch barrel-vault base unit and a series of smaller barrel vaults at right angles, which introduce light into the market space. Khan Marjan market transmits optical affects of ribbing, stepping and extrusion, and an acoustical affect of diffusion and slowness.

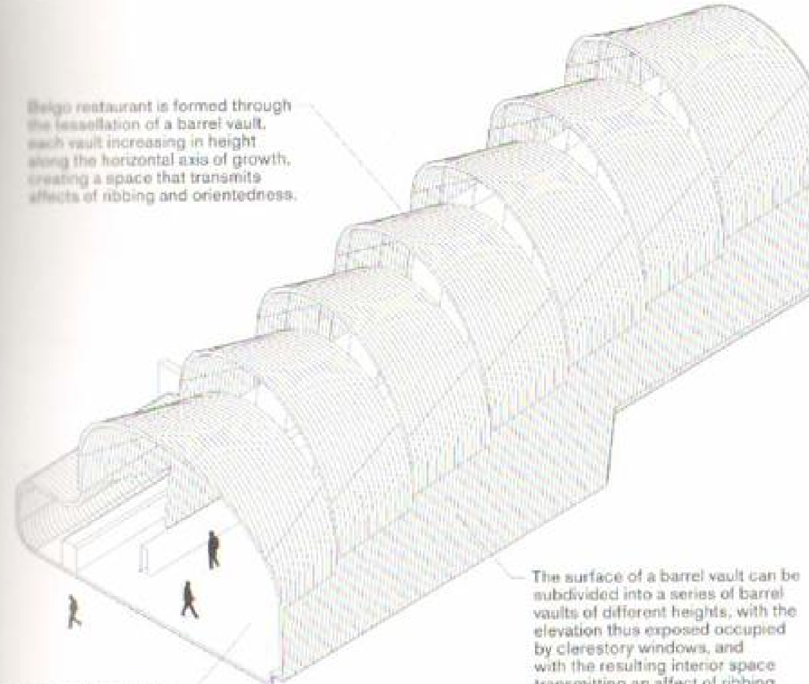
Ribbing, Orientedness, Asymmetry, Focusing, Specularity



Horizontal / Barrel Vault

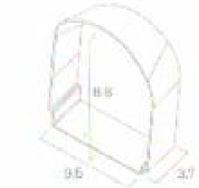
BELGO ZUID RESTAURANT | FOREIGN OFFICE ARCHITECTS; ADAMS KARA TAYLOR | LONDON, UK | 1999

Belgo restaurant is formed through the tessellation of a barrel vault, each vault increasing in height along the horizontal axis of growth, creating a space that transmits affects of ribbing and orientedness.

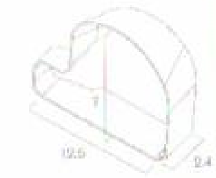


The surface of a barrel vault can be subdivided into a series of barrel vaults of different heights, with the elevation thus exposed occupied by clerestory windows, and with the resulting interior space transmitting an affect of ribbing.

The barrel vault transmits an acoustical affect of focusing near the center of the space, while the walls transmit specularity.

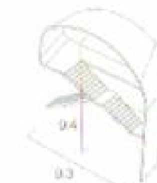


base unit a

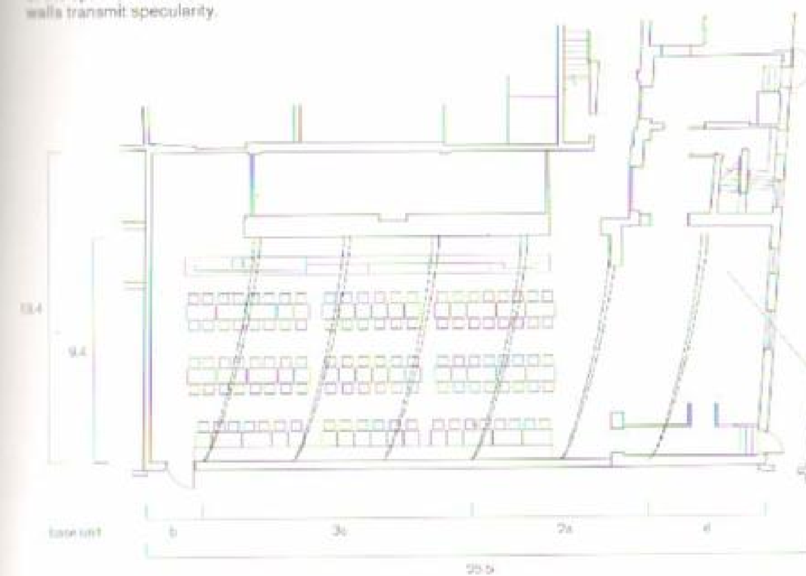


base unit b

base unit c



base unit d

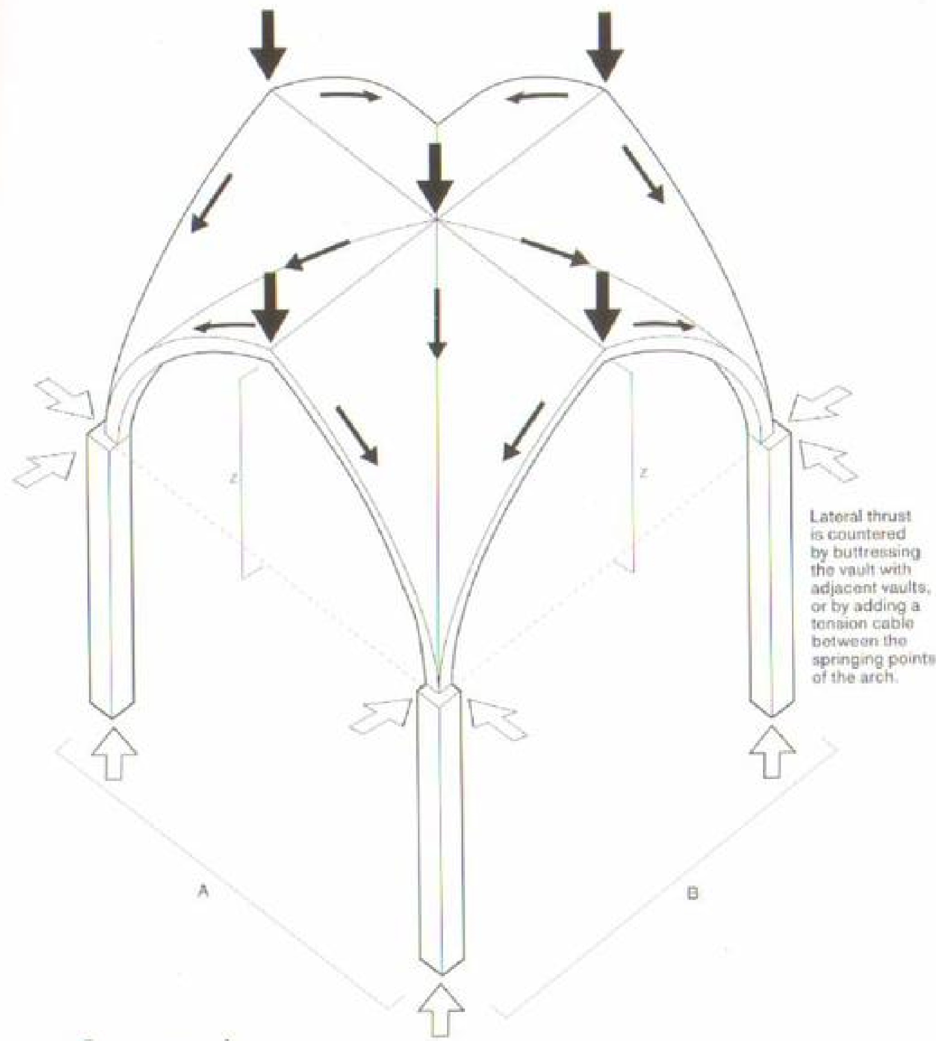


The diagonal placement of the vault in respect of the existing load-bearing walls contributes to an affect of asymmetry.

The Belgo restaurant building is formed by the horizontal tessellation of a barrel vault base unit, which is repeated to produce the restaurant space. Changes in the section height of each of those base units produce a series of elevational changes that allow clerestory windows to be introduced. Belgo restaurant transmits an optical affect of ribbing, asymmetry and orientedness, and an acoustical affect of focusing and specularity.

The base unit of a cross vault is composed of two pointed vaults intersecting. Cross vaults direct the primary forces along the principal axes of the arch surfaces, as they transfer the loads into columns. Vertical loads in a cross vault are distributed both along the lines of the ribs and along the infill surfaces, where the groins are often given a thicker section in the form of a rib in order to articulate and stabilize the intersection. This distribution of loads, through layers of masonry as well as reinforced concrete or a steel frame with infill panels of glass or timber, produces a thrust that is concentrated along the groins, or the four diagonal edges formed by the lines of intersection between the vaults, and embeds the cross vault with an optical affective property of verticality and cruciformity that remains consistent within any space it defines. The concave surface of a vault focuses sound near its center of curvature, but sound at a distance from the center can be diffused to an extent that depends upon the spectrum of the sound. Ribs, facets and reticulation can modify the acoustical affect of a vault by adding diffusion, which may become dominant. Many vault subsystems have a multiplicity of focal points. These can modify the acoustical affect of the vault by adding diffusion, which may become dominant.

The protogeometry of a cross vault allows it to be flexible in several ways:
Scale: The scale of the base unit of a cross vault can change to accommodate changes in plan such as an increase in the width of the bays, or asymmetries introduced to accommodate curvature.
Depth: The depth of the cross vault base unit can change according to the curvature of the intersecting arches.
Profile: The protogeometry of the cross vault allows flexibility with regard to the degree of steepness of the pointed section and the degree of asymmetry in the perpendicular alignment of the apexes as they form crossed or staggered configurations. Cross vaults can tessellate horizontally along straight or curved lines of growth to produce both horizontal structures (naves and apses) and vertical structures.
Affect: The affective properties of a cross vault 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 verticality and cruciformity, a barrel vault can transmit other optical affects, including structuredness, horizontality, openness, axiality, closure, roundness, rectangularity, asymmetry. The acoustical affect is diffusion.

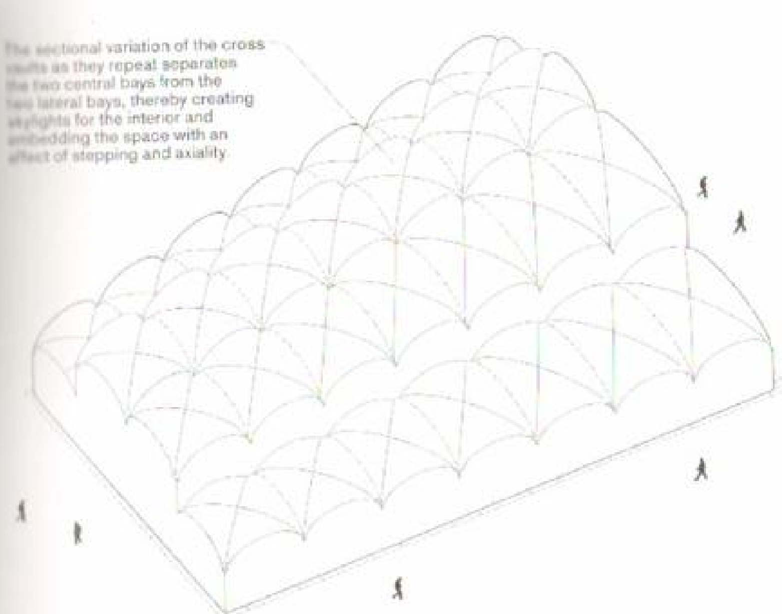


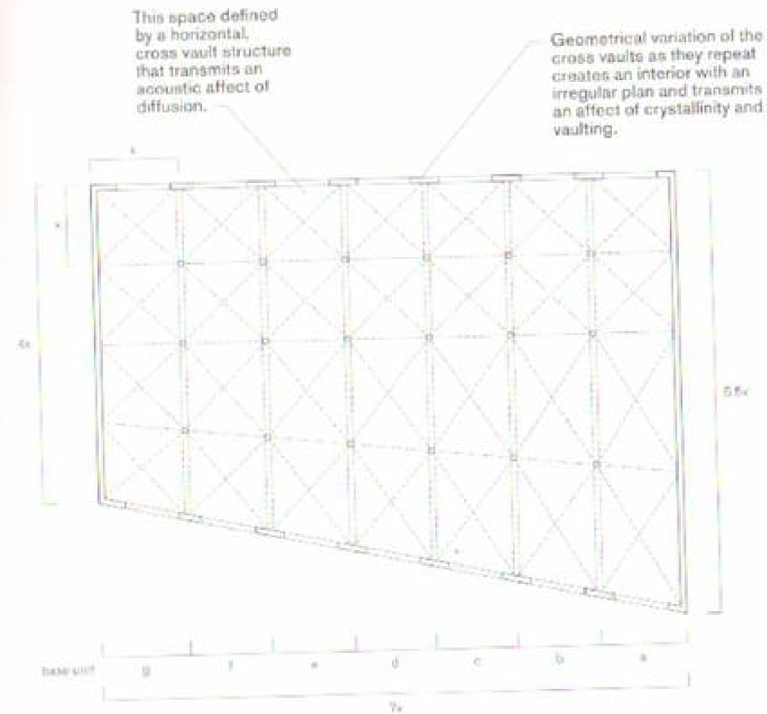
$Z = \frac{B}{2\text{-}12}$ $Y = \frac{A}{2\text{-}12}$

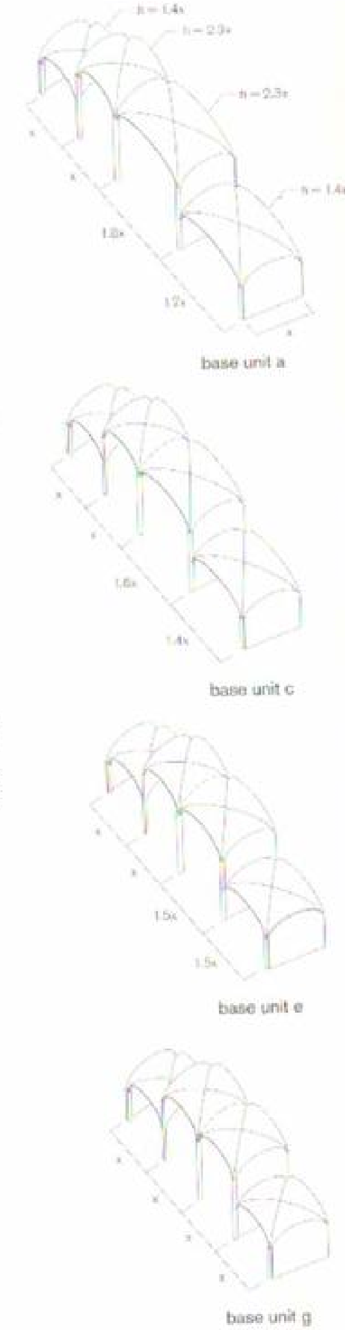
Initially, the ribs in groin vaults were thought of as covering for any unsightly irregularities in the groins, and only secondarily as aids to construction and potential stiffeners in the event of any weakness arising in the vault, but by the later twelfth and thirteenth centuries they had become indispensable. In addition to greatly reducing the need for centering, ribs simplified the process of setting-out and consequently increased freedom in planning by transferring the emphasis from the cross-sectional profiles of the intersecting vaults to the profiles of the bounding arches and the ribs, while the webs were left to accommodate themselves to these latter profiles in any way that was convenient. The structural significance of the rib has been much debated, partly because of evidence derived from ruins in which either the webs have fallen, leaving the ribs standing, or the webs have remained while the ribs have fallen. This can be explained by the fact that the vault is a statically indeterminate system in which the ribs and the web take loads in proportion to their stiffness. As the transfer of loads is highly dependent upon the particularities of the construction process, it is impossible to determine by visual inspection alone the degree to which, or even whether, the ribs are carrying a structural load.

Crystallinity, Vaulting, Stepping, Axiality, Diffusion

Horizontal / Cross Vault







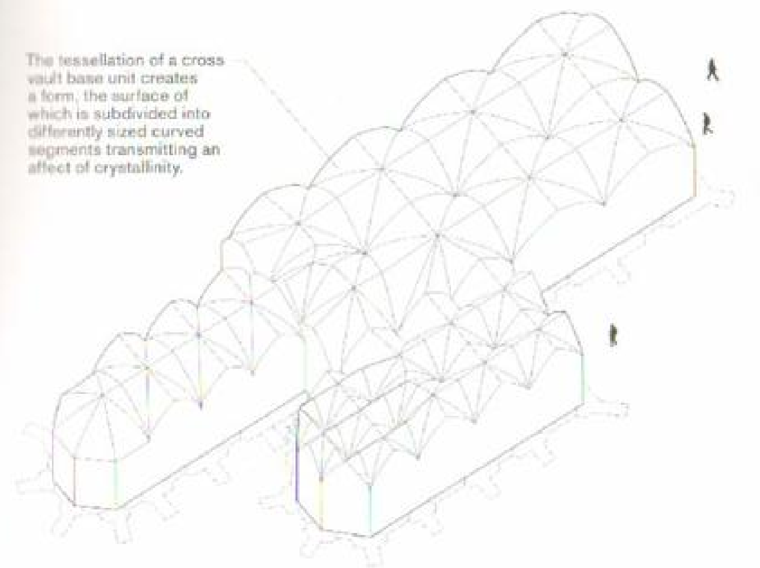
This horizontal form is produced by the horizontal tessellation of a series of cross vault base units repeated and interconnected to form a series of changing bays. The base unit repeats while gradually changing in width along one axis, increasing the width of the bays in plan as they grow. This assembly transmits an optical affect of crystallinity, vaulting, stepping and axiality, and an acoustical affect of diffusion.

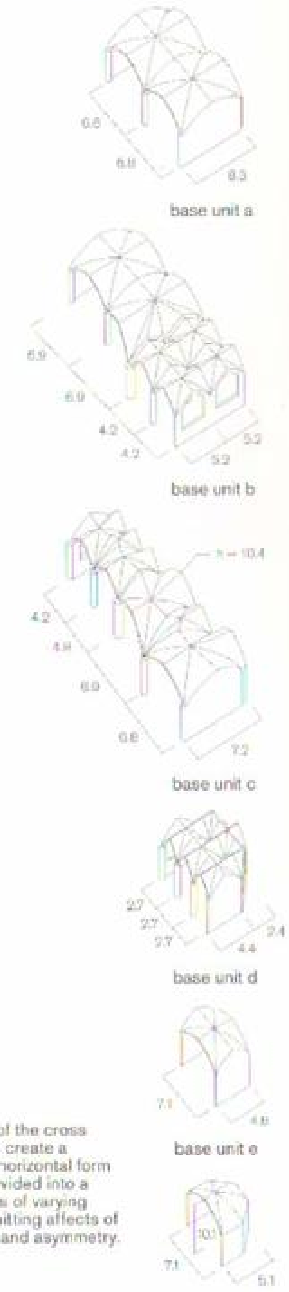
Rectangularity, Asymmetry, Crystallinity, Diffusion, Slowness

Horizontal / Cross Vault

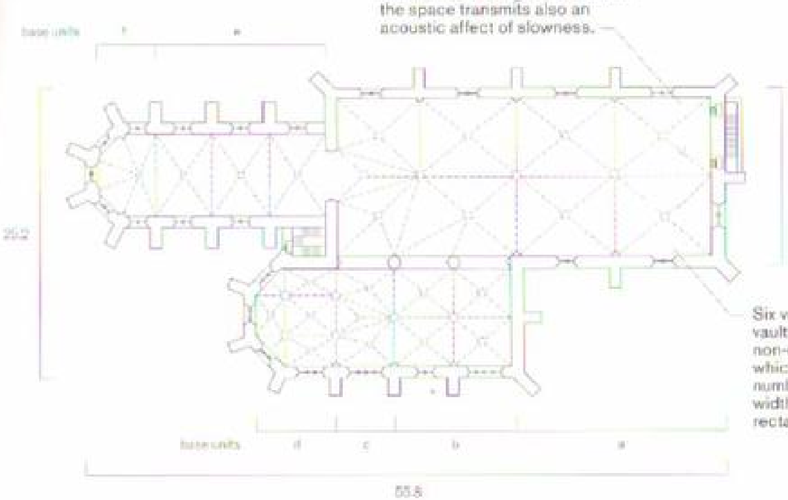
WALLSEE CHAPEL | REINPRECHT FRIEDRICH (FOUNDATIONS) | ENNS, AUSTRIA | 1343

The tessellation of a cross vault base unit creates a form, the surface of which is subdivided into differently sized curved segments transmitting an affect of crystallinity.



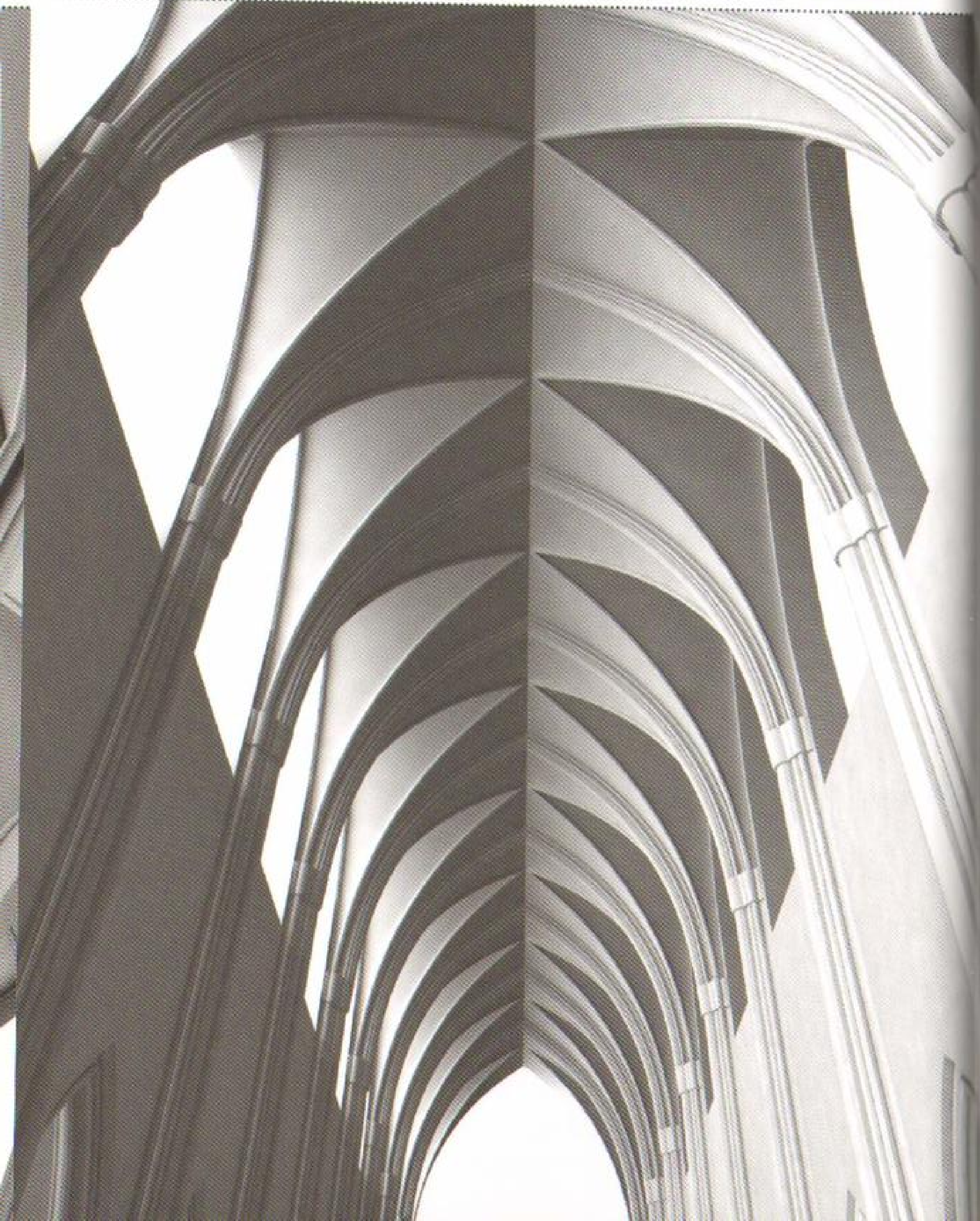


This space defined by a horizontal, cross vault structure transmits an acoustic affect of diffusion. Because of its large dimensions, the space transmits also an acoustic affect of slowness.



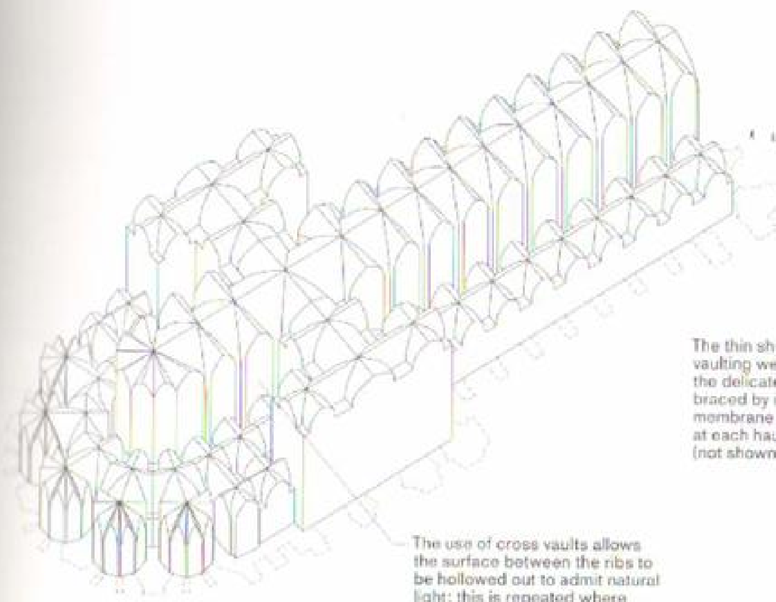
Six variations of the cross vault base unit create a non-extruded horizontal form which is subdivided into a number of bays of varying widths, transmitting affects of rectangularity and asymmetry.

The nave of Wallseer Kapelle is formed by the horizontal tessellation of a series of cross vault base units. Changes in their width in plan and in the number of bays, ranging from one to four, vary the profile of the nave along its length. In addition, changes to the number of arches that form the subdivision of the cross vault, ranging from four to eight, gradually vary the surface of the vault into different degrees of corrugation. The nave of Wallseer Kapelle transmits an optical affect of rectangularity, asymmetry and crystallinity, and an acoustical affect of diffusion and slowness.



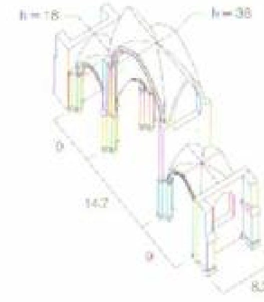
Horizontal / Cross Vault

REIMS CATHEDRAL | BEGUN BY J. D'ORBAIS | REIMS, FRANCE | 1210–1241

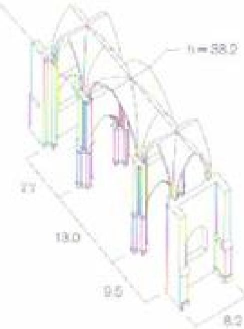


The use of cross vaults allows the surface between the ribs to be hollowed out to admit natural light; this is repeated where there are differences between the height of the bays.

The thin shell of the vaulting webs and the delicate ribs are braced by infill and membrane walls at each haunching (not shown).



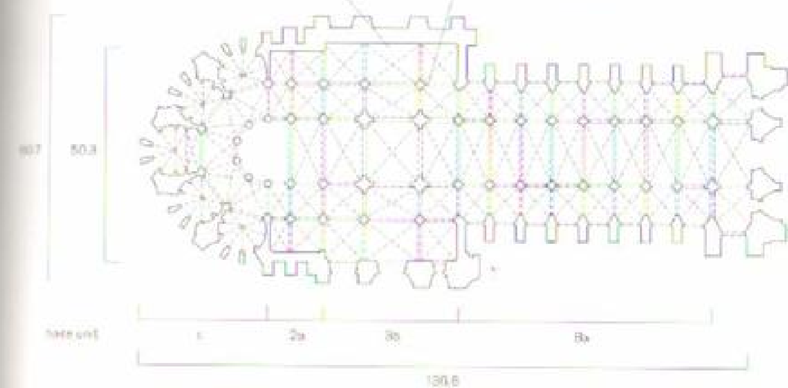
base unit a

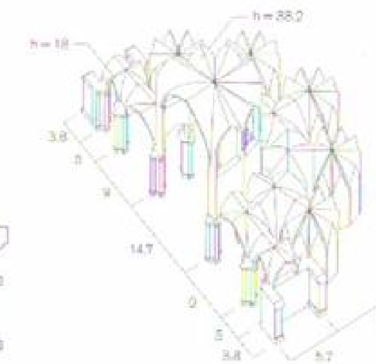


base unit b

This space defined by a horizontal cross-vault structure transmits an acoustical affect of diffusion and also, on account of its large dimensions, of slowness.

Construction of the nave uses the tessellation of three variations of a cross vault base unit to produce an axial rectangular form, rounded at one end and subdivided into three bays of varying heights and widths, transmitting an affect of axiality, verticality and pointedness.





base unit c

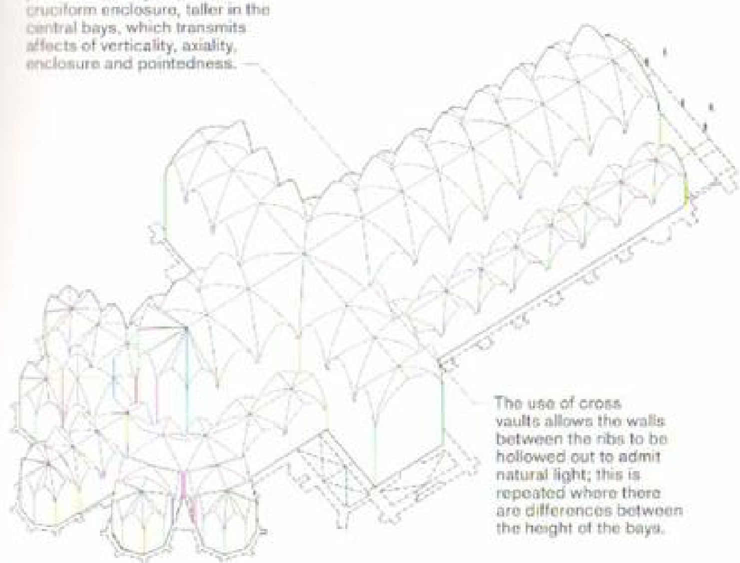
The nave of Reims cathedral is formed by the horizontal tessellation of a series of cross vault base units along the length of the nave. Changes in the height and width in plan, together with the orientation of the bays, from linear to curved, in plan, in the side chapels, vary the profile of the nave along its length. Significant changes in height between the nave and the side aisles allow for the introduction of large openings along the elevation. The nave of Reims cathedral transmits an optical affect of verticality, axiality, enclosure and pointedness, and an acoustical affect of diffusion and slowness.

Verticality, Axiality, Enclosure, Pointedness, Diffusion, Slowness

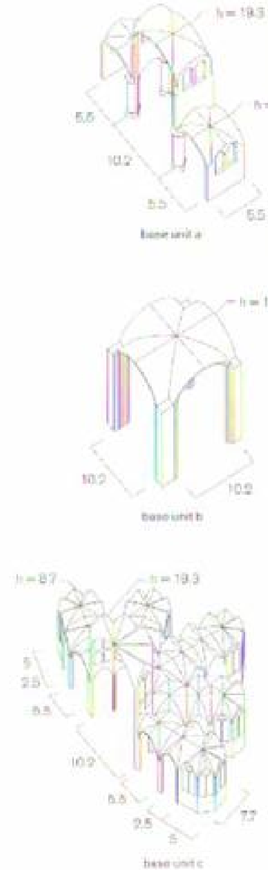
Horizontal / Cross Vault

SEEZ CATHEDRAL | SEEZ, FRANCE | 1210

Tessellation of three variations on the base unit of a cross vault made of columns and steeply pointed arches produces a cruciform enclosure, taller in the central bays, which transmits affects of verticality, axiality, enclosure and pointedness.

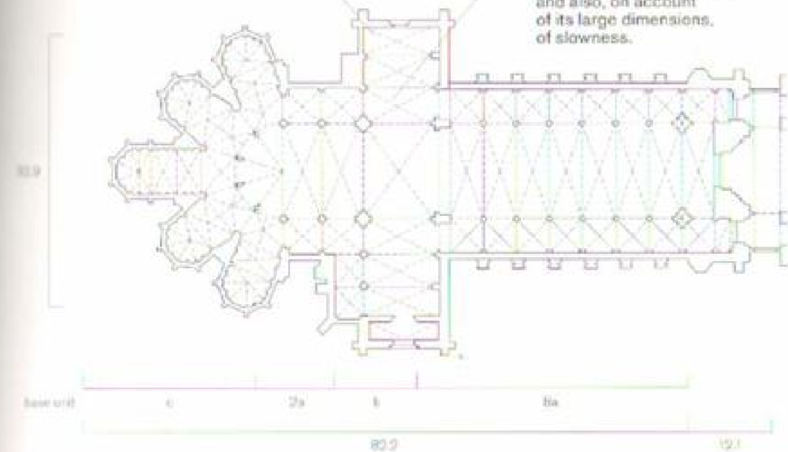


The use of cross vaults allows the walls between the ribs to be hollowed out to admit natural light; this is repeated where there are differences between the height of the bays.



The cross vault base unit changes to accommodate different bay widths in plan, differentiating the nave from the transept and the crossing between.

The horizontal cross-vault structure transmits an acoustical affect of diffusion and also, on account of its large dimensions, of slowness.

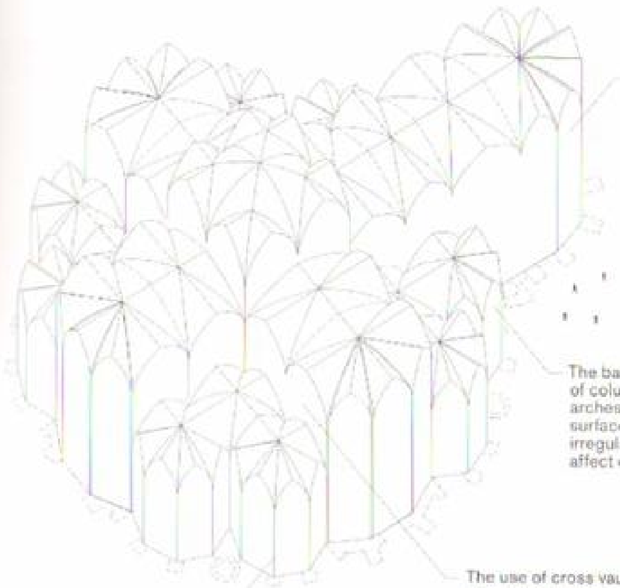


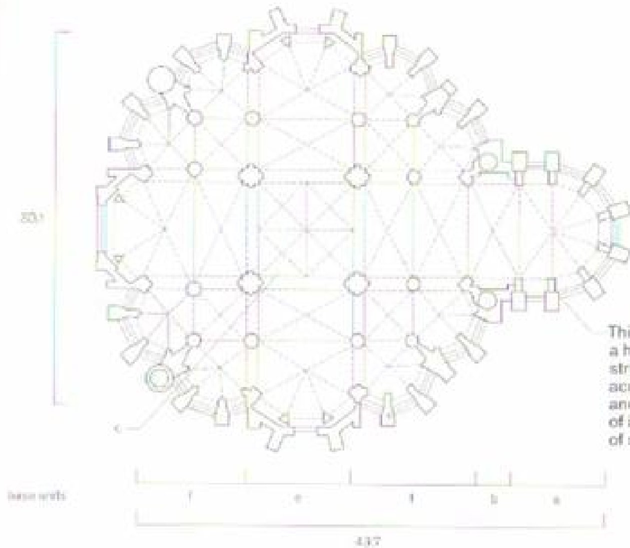
The nave of Seez cathedral is formed by the horizontal tessellation of a series of cross-vault base units that are repeated along the length of the nave. Changes in the height and width in plan, together with the orientation of the bays, from linear to curved in plan, in the side chapels, vary the profile of the nave along its length. The multiplication of a number of ribs that follow the profile of the pointed arches increases the surface corrugation between the ribs. Changes in height between the nave and the side aisles allow for the introduction of large openings along the elevation. The nave of Seez cathedral transmits an optical affect of verticality, axiality, enclosure and pointedness, and an acoustical affect of diffusion and slowness.

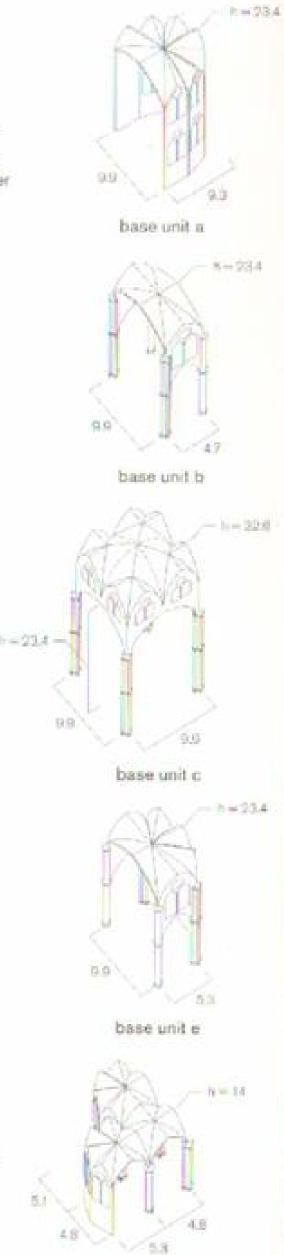
Roundness, Verticality, Symmetry, Crystallinity, Diffusion, Slowness

Horizontal / Cross Vault

CHURCH OF OUR DEAR LADY | ARCHBISHOP T. VON WIED | TRIER, GERMANY | 1180–1260





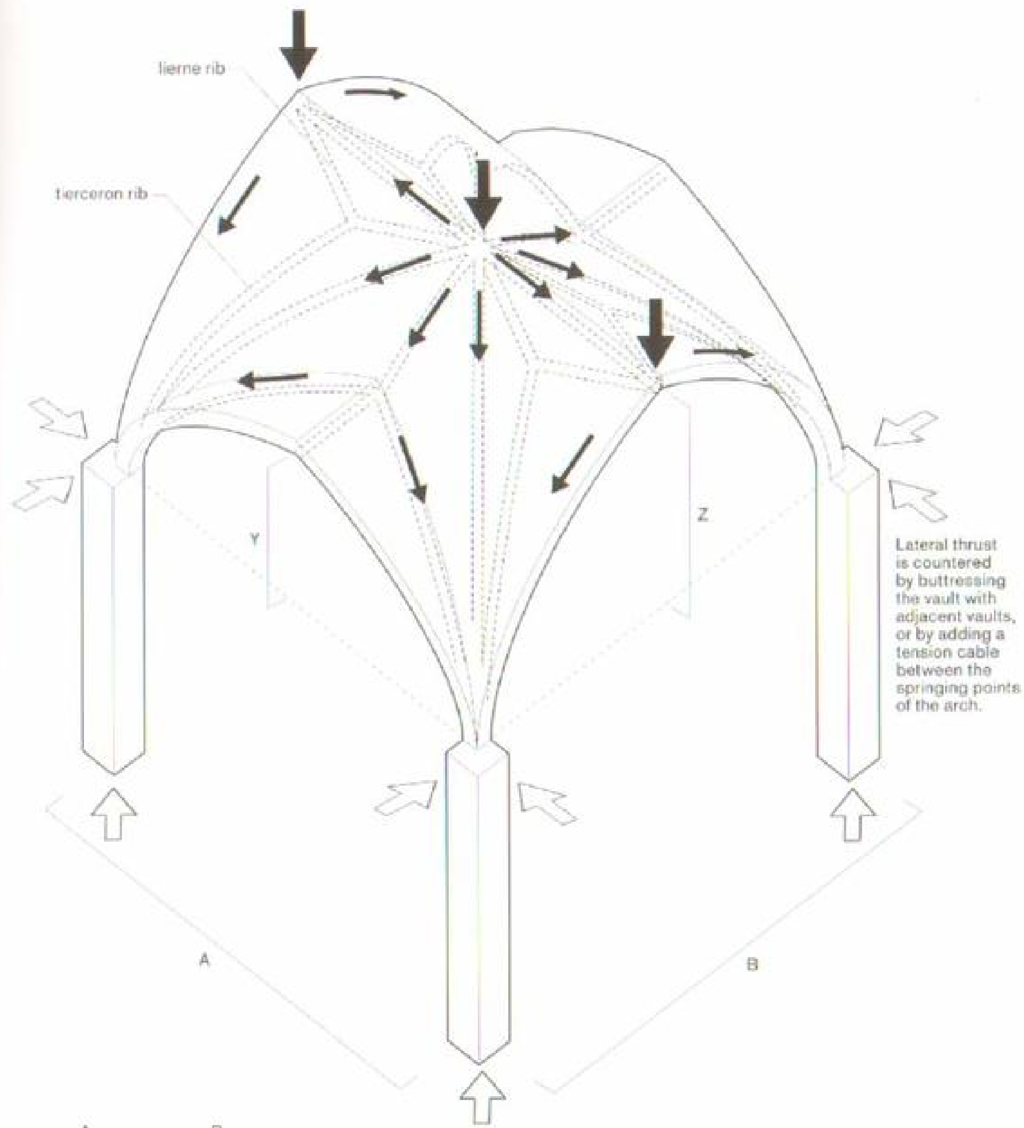


The nave of the Church of Our Dear Lady is formed by the horizontal tessellation of a series of cross-vault base units that are repeated along the length of the nave. Changes in the arrangement of the base units in plan, from linear in the center to curved along the edges, vary the profile of the nave to give it a mostly rounded plan. Changes in height between the nave and the side aisles allow for the introduction of openings along the elevation. The nave of the Church of Our Dear Lady transmits an optical affect of roundness, verticality, symmetry and crystallinity, and an acoustical affect of diffusion and slowness.

Complex Rib Vault

The base unit of a complex rib vault, a variation of the cross vault, introduces a series of ribs which further subdivide the cross vault surface. Ribs that originate from the vault spring line are called Tiercerons while those that do not are called Lierne ribs (from the French 'lier', to bind). The ribs can produce a wide range of geometric and reticulated patterns, the star shaped pattern is most common and in this case the vault is commonly referred to as a stellar vault. Complex rib vaults direct the primary forces along the lines of the ribs and along the infill surface. Complex rib vaults are made primarily of stone or masonry but can also be made of reinforced concrete, in which the degree of steel reinforcement would correspond to an increase in the overall number of ribs. The distribution of loads along the lines and surfaces of stone, masonry or steel-reinforced concrete embeds the complex rib vault with an optical affective property of verticality and stellatedness that remains consistent within any space it defines. The concave surface of a vault focuses sound near its center of curvature, but sound at a distance from the center can be diffused to an extent that depends upon the spectrum of the sound. Ribs, facets and reticulation can modify the acoustical affect of a complex rib vault by adding diffusion, which may become dominant. Many vault subsystems have a multiplicity of focal points. These can modify the acoustical affect of the vault by adding diffusion, which may become dominant.

Complex rib vaults are flexible in several ways:
Scale: The scale and span of a complex rib vault can be increased by introducing lierne and tierceron ribs, which further subdivide its surface.
Depth: Lierne and tierceron ribs follow the surface of the vaults, creating square and radial patterns, and this subdivision of the surface of the vault can increase its depth.
Profile: The protogeometry of complex rib vaults is flexible in the range of cross-bracing patterns created by the lierne and tierceron ribs, and also in the amount of subdivision that they introduce to the surface of the vault. In addition, a complex rib vault allows the apex of the primary vault to be placed higher than that of the secondary cross vaults, and also allows for an increase in the subdivision of the surfaces of the cross vaults and therefore a larger number of ribs.
Affect: The optical affective property of a complex rib vault 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 verticality and stellatedness, a complex rib vault can transmit other optical affects, including rectangularity, symmetry, diamonding, vaulting, horizontality, openness, cruciformity. The acoustical affect is diffusion.



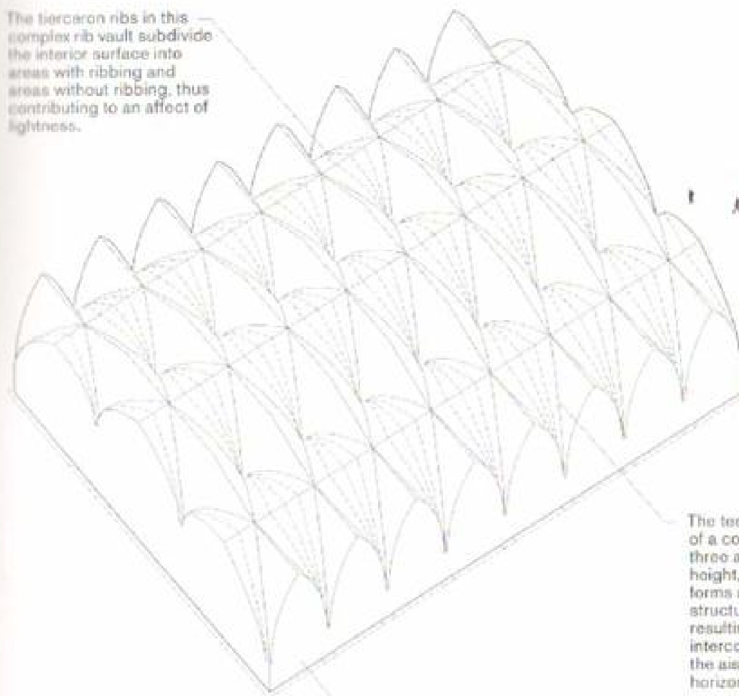
$$Y = \frac{A}{2-12} \quad Z = \frac{B}{2-12}$$

As the simple ribs of the groin vault gave way to increasingly complex patterns of liernes and tiercerons, the ribs were increasingly conceived of as a gridded mesh, curved to counter the forces of gravity. This freed the Gothic vault from the rigidity of the bay system. The ribs became a stiffening lattice, breaking the shell into manageable and comprehensible components, increasing geometric flexibility, and allowing the vault to span unusual plan shapes without creating twisted and structurally weak webbing. Gradually, the ribs began to assume the function of a brace or tie that could collect the diffuse pressures and thrusts of the vaults to carry them to the pier. Nodes, clusters or rib-fans gathered together the static forces of the shell to effect a smooth transition between vault and pier.

Ribbing, Horizontality, Bi-directionality, Lightness, Diffusion, Slowness

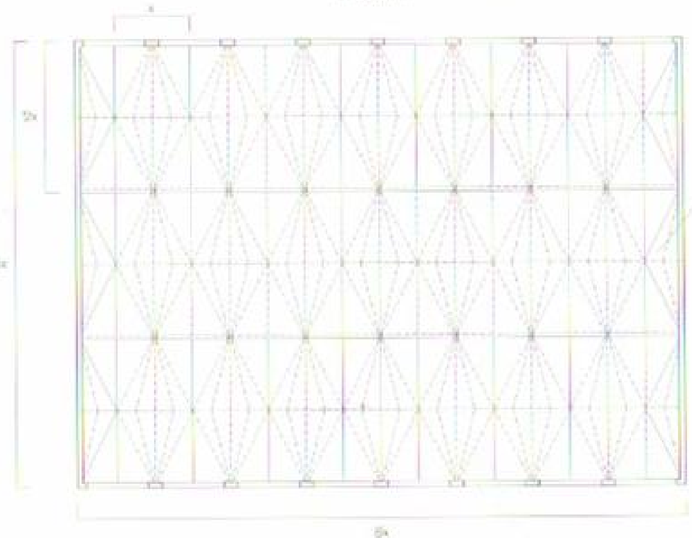
Horizontal / Complex Rib Vault

The tierceron ribs in this complex rib vault subdivide the interior surface into areas with ribbing and areas without ribbing, thus contributing to an affect of lightness.



The tessellation of the base unit of a complex rib vault, comprising three aisles of vaults equal in height, buttressing each other, forms a horizontal, shed-like structure in which the three resulting aisles are equally interconnected along and across the aisles, transmitting affects of horizontality and bi-directionality.

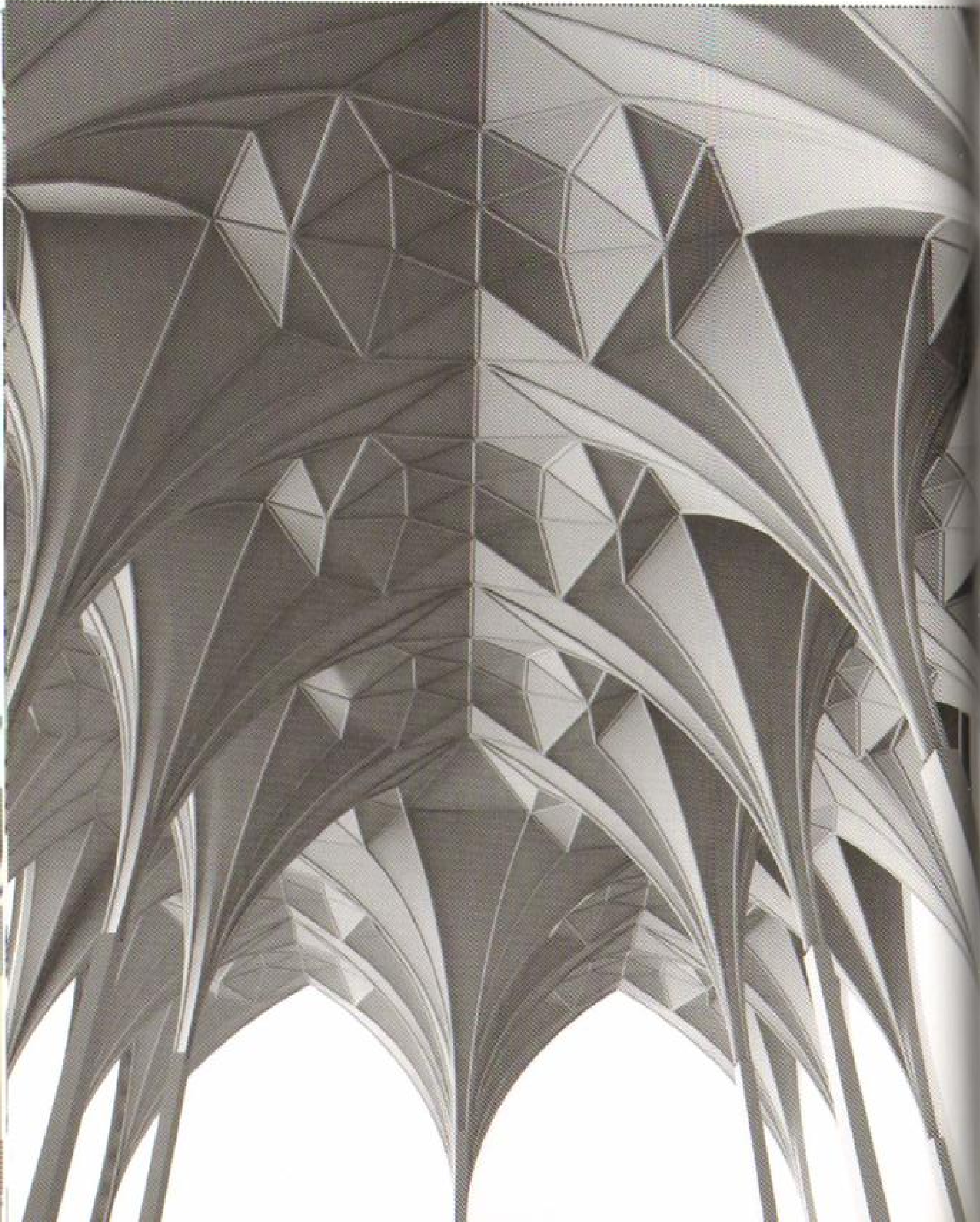
The regular distribution of the base unit creates a rectangular form with a repetitive perimeter condition.



This space defined by a horizontal complex rib vault structure transmits an acoustical affect of diffusion and also, on account of its large dimensions, of slowness.

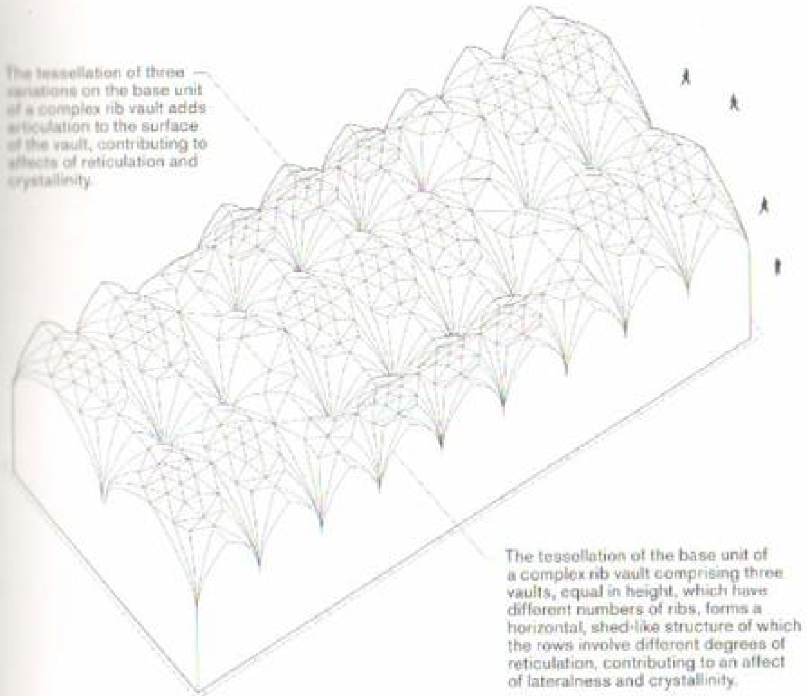
This horizontal form is produced by the horizontal tessellation of a complex rib vault base unit, repeated and interconnected to create three identical aisles. As the base unit repeats it introduces ribs on two sides of the four-sided surface of the cross vault in contrast to the other sides, which remain as plain surfaces. This assemblage transmits optical affects such as ribbing, horizontality and lightness, and an acoustical affect of diffusion and slowness.

Reticulation, Crystallinity, Lateralness, Diffusion, Slowness



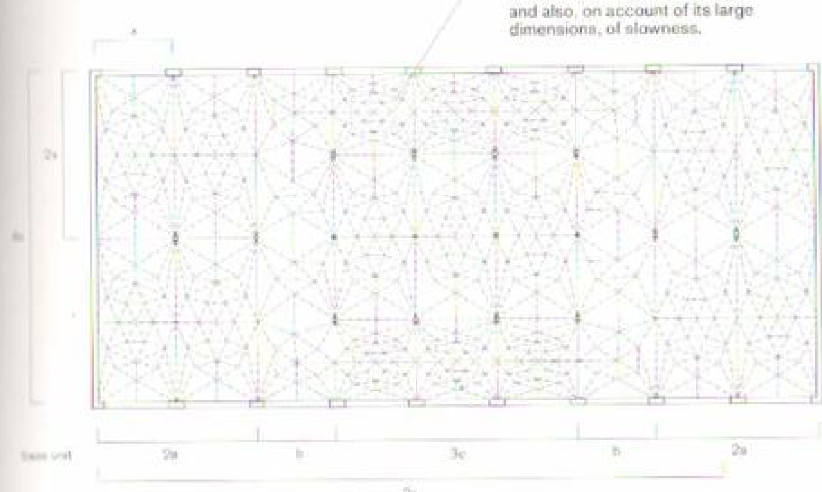
Horizontal / Complex Rib Vault

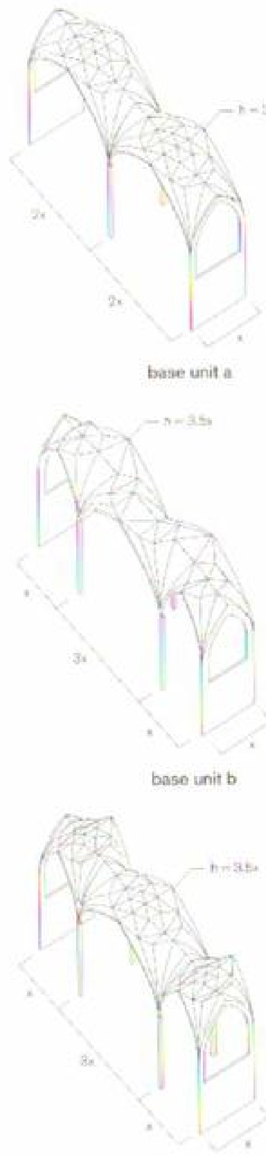
The tessellation of three variations on the base unit of a complex rib vault adds articulation to the surface of the vault, contributing to affects of reticulation and crystallinity.



The tessellation of the base unit of a complex rib vault comprising three vaults, equal in height, which have different numbers of ribs, forms a horizontal, shed-like structure of which the rows involve different degrees of reticulation, contributing to an affect of lateralness and crystallinity.

This space defined by a horizontal complex rib vault structure transmits an acoustical affect of diffusion and also, on account of its large dimensions, of slowness.





The introduction of liernes and tiercerons creates a web of arched ribs, which allows for a smooth transition from a three-bay to a two-bay vaulting system.

This horizontal form is produced by the horizontal tessellation of a complex rib vault base unit, repeated and interconnected to create a series of bays. The introduction of a large number of lierne and tierceron ribs subdivides the surface of the vault into a correspondingly large number of facets that together create a star-shaped pattern. In such cases the vault can be referred to as a stellar vault. Changes in the widths of the bays vary the scale of the subdivisions, although the degree of subdivision remains the same. This assemblage transmits an optical affect of reticulation, crystallinity and lateralness, and an acoustical affect of diffusion and slowness.

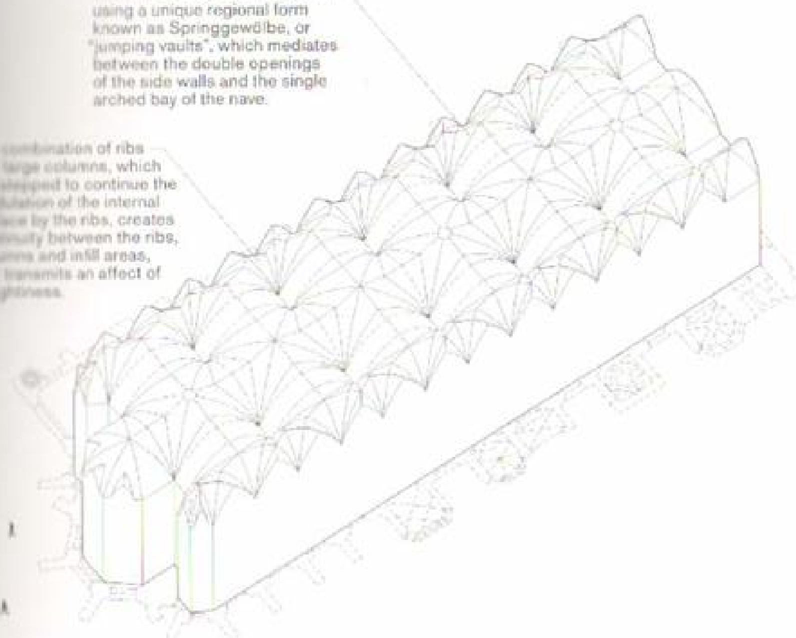
Stellatedness, Lateralness, Verticality, Diffusion, Slowness

Horizontal / Complex Rib Vault

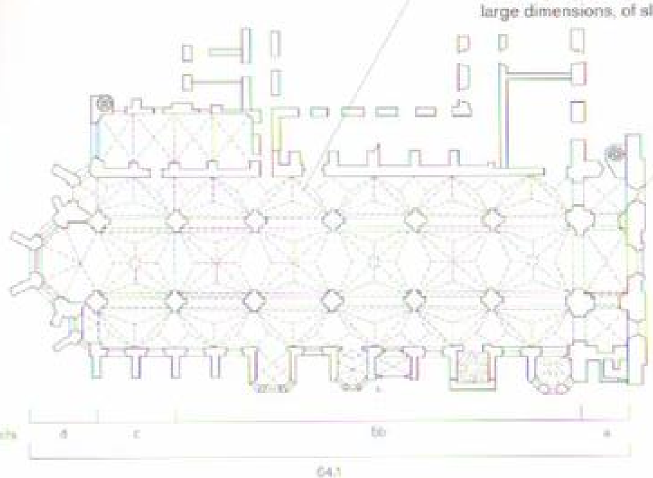
ST. MARY ON THE SANDS CHURCH | MASTER PIESZKO | WROCLAW, POLAND | 1334–1375

The side aisles are constructed using a unique regional form known as Springgewölbe, or "jumping vaults", which mediates between the double openings of the side walls and the single arched bay of the nave.

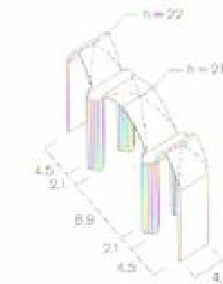
The combination of ribs and large columns, which are stepped to continue the modulation of the internal surface by the ribs, creates continuity between the ribs, columns and infill areas, and transmits an affect of weightiness.



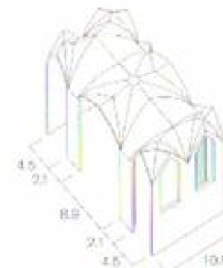
This space defined by a horizontal complex rib vault structure transmits an acoustical affect of diffusion and also, on account of its large dimensions, of slowness.



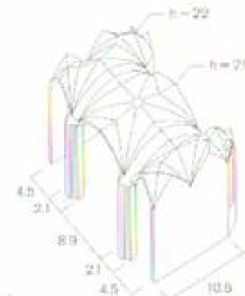
The tessellation of four base units of a complex rib vault which vary in ribbing but are equal in height creates a horizontal, shed-like form with affects, simultaneously, of stellatedness and lateralness.



base unit a



base unit b



base unit c

base unit d

The nave of St. Mary of the Sands is produced by the horizontal tessellation of a complex rib vault base unit, repeated and interconnected to form a main nave and two side naves. The base unit repeats longitudinally along the three aisles, while subdividing the surface of the vault into many facets by introducing numerous tierceron ribs. The degree of subdivision of the vaults' surfaces varies, with more facets occurring on the aisles. In these, one of the ribs of the vault is replaced by a central ridge point that constitutes a full cross vault, reduced in scale, resulting in a star-shaped pattern. In such cases the vault can be referred to as a stellar vault. The nave of St. Mary of the Sands transmits an optical affect of lateralness, stellatedness, and verticality, and an acoustical affect of diffusion and slowness.

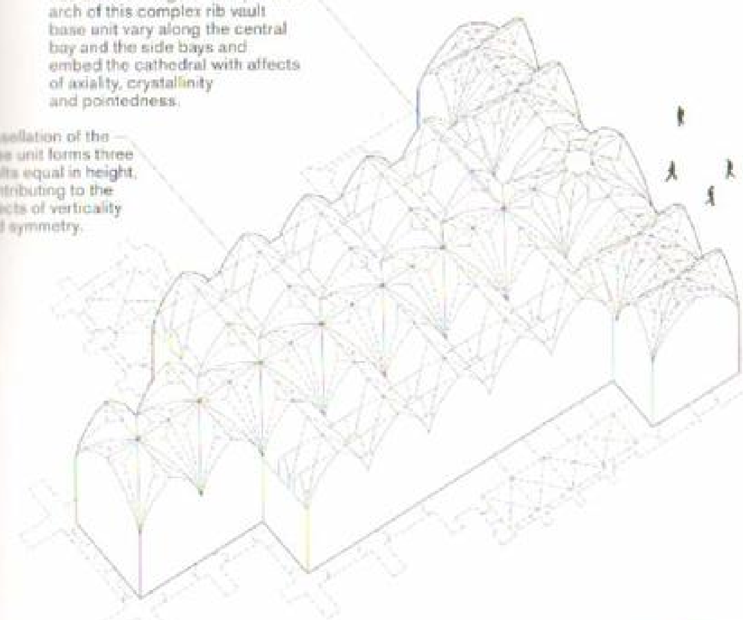
Verticality, Symmetry, Crystallinity, Pointedness, Diffusion, Slowness

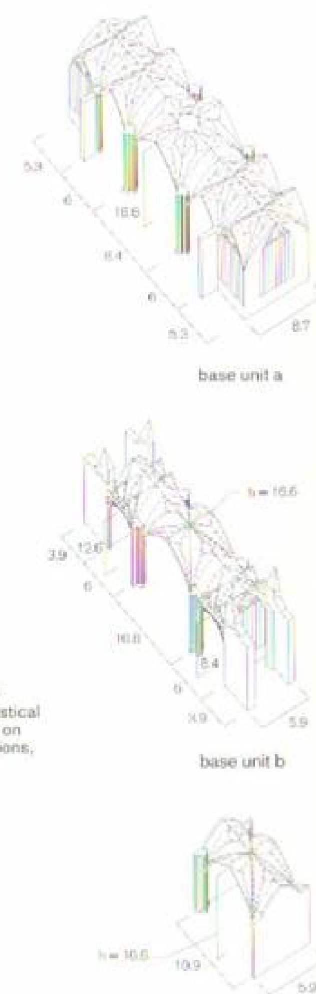
Horizontal / Complex Rib Vault

BRISTOL CATHEDRAL | A.E. KNOWLE | BRISTOL, UK | 1542

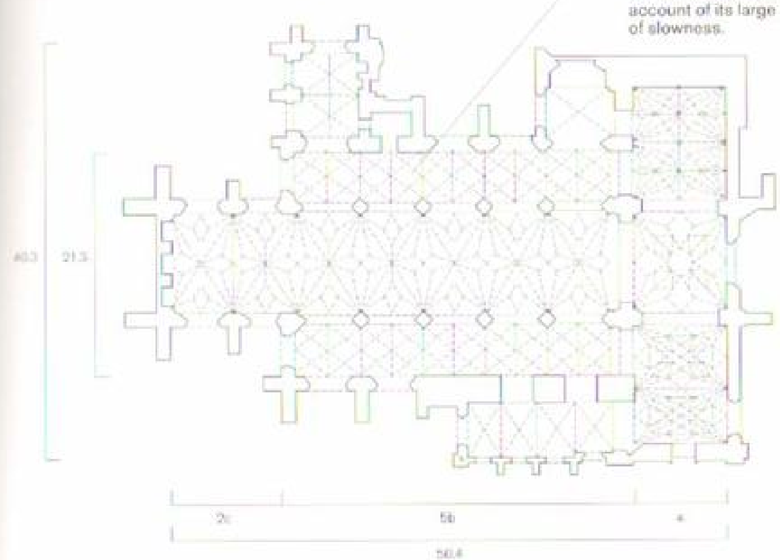
The number and pattern of the ribs that converge on the pointed arch of this complex rib vault base unit vary along the central bay and the side bays and embed the cathedral with affects of axiality, crystallinity and pointedness.

Tessellation of the base unit forms three vaults equal in height, contributing to the affects of verticality and symmetry.





This space defined by a horizontal complex rib vault structure transmits an acoustical affect of diffusion and also, on account of its large dimensions, of slowness.



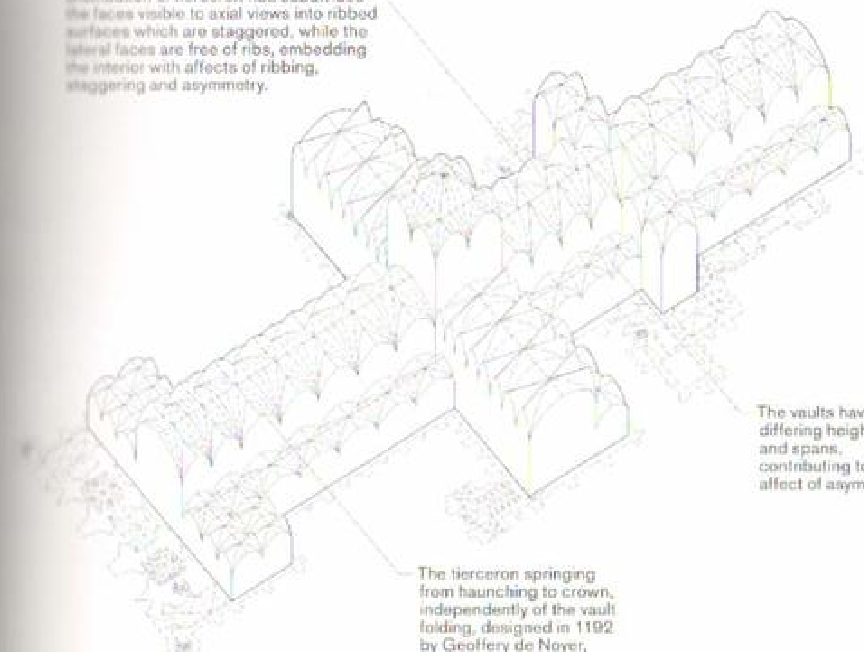
The nave of Bristol cathedral is formed by the horizontal tessellation of a complex rib vault base unit, repeated and interconnected to form a T-shaped plan composed of the nave and two side naves, and the transept. The base unit repeats along the nave and the aisles, while using a large number of lierne and tierceron ribs to introduce varying degrees of subdivision on the surface of the vault. There are more facets on the nave and the transept, where the liernes and tierceron ribs form a star-shaped pattern. Because of this pattern, this type of vault is commonly referred to as a stellar vault. The nave of Bristol cathedral transmits an optical affect of verticality, symmetry, crystallinity and pointedness, and an acoustical affect of diffusion and slowness.

Ribbing, Staggering, Asymmetry, Diffusion, Slowness

Horizontal / Complex Rib Vault

LINCOLN CATHEDRAL | BISHOP ST. HUGH | LINCOLN, UK | 1300-1549

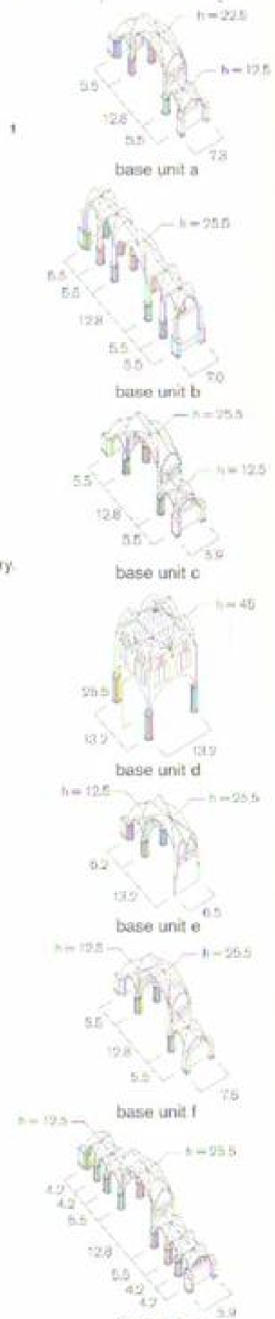
Distribution of tierceron ribs subdivides the faces visible to axial views into ribbed surfaces which are staggered, while the lateral faces are free of ribs, embedding the interior with affects of ribbing, staggering and asymmetry.



The vaults have differing heights and spans, contributing to an affect of asymmetry.

The tierceron springing from haunching to crown, independently of the vault folding, designed in 1192 by Geoffery de Noyer, makes its first appearance here as a deliberate effort to break the rigid bay system of the cross vault.

This space defined by a horizontal complex rib vault structure transmits an acoustical affect of diffusion and also, on account of its large dimensions, of slowness.



The nave of Lincoln cathedral is formed by the horizontal tessellation of a complex rib vault base unit, repeated and interconnected to form a double-cross-shaped plan. The nave and aisles constitute a triple bay, while the two transepts are the width of a double and a single bay. The base unit repeats along the nave and the aisles, with varying degrees of subdivision on the vault surfaces. These variations cause the orientation of some of the ridge lines to be changed from perpendicular to diagonal, and the alignment of the center points of the ridge lines to be staggered. The nave of Lincoln cathedral transmits an optical affect of ribbing, asymmetry, and staggering, and an acoustical affect of diffusion and slowness.

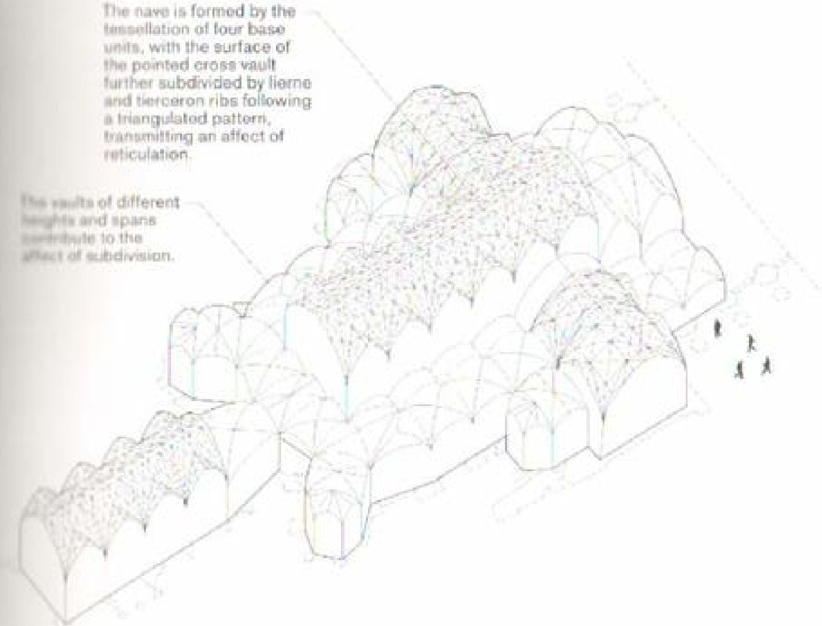
Verticality, Reticulation, Subdivision, Diffusion, Slowness

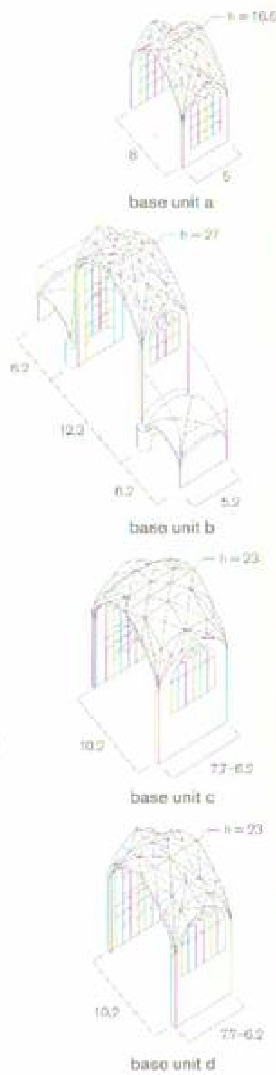
Horizontal / Complex Rib Vault

GLOUCESTER CATHEDRAL	ABBOT SERLO (FOUNDATIONS)	GLOUCESTER, UK	1072 FOUNDATIONS; 1242 NAVE; 1331 CHOIR; 1454–57 CENTRAL TOWER

The nave is formed by the tessellation of four base units, with the surface of the pointed cross vault further subdivided by lierne and tierceron ribs following a triangulated pattern, transmitting an affect of reticulation.

The vaults of different heights and spans contribute to the affect of subdivision.

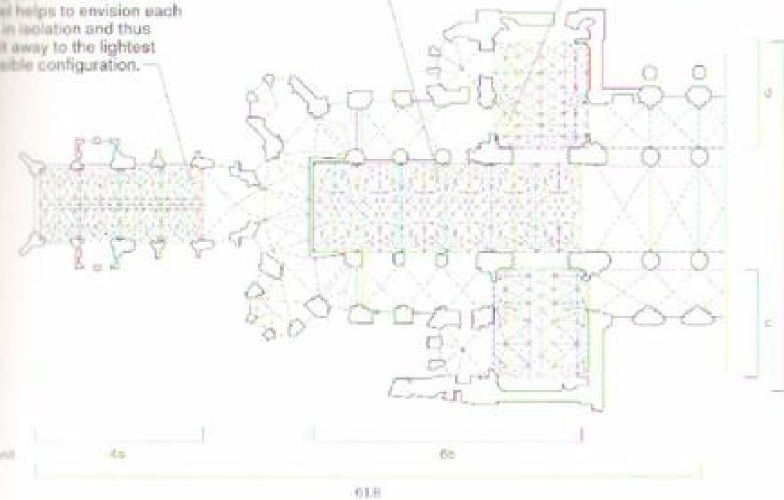




The triangulated pattern introduced by the lierne and tierceron ribs in plan follows the pointed cross vault surfaces, enhancing the affect of verticality transmitted by the pointed arch.

This space defined by a horizontal complex rib vault structure transmits an acoustical affect of diffusion and also, on account of its large dimensions, of slowness.

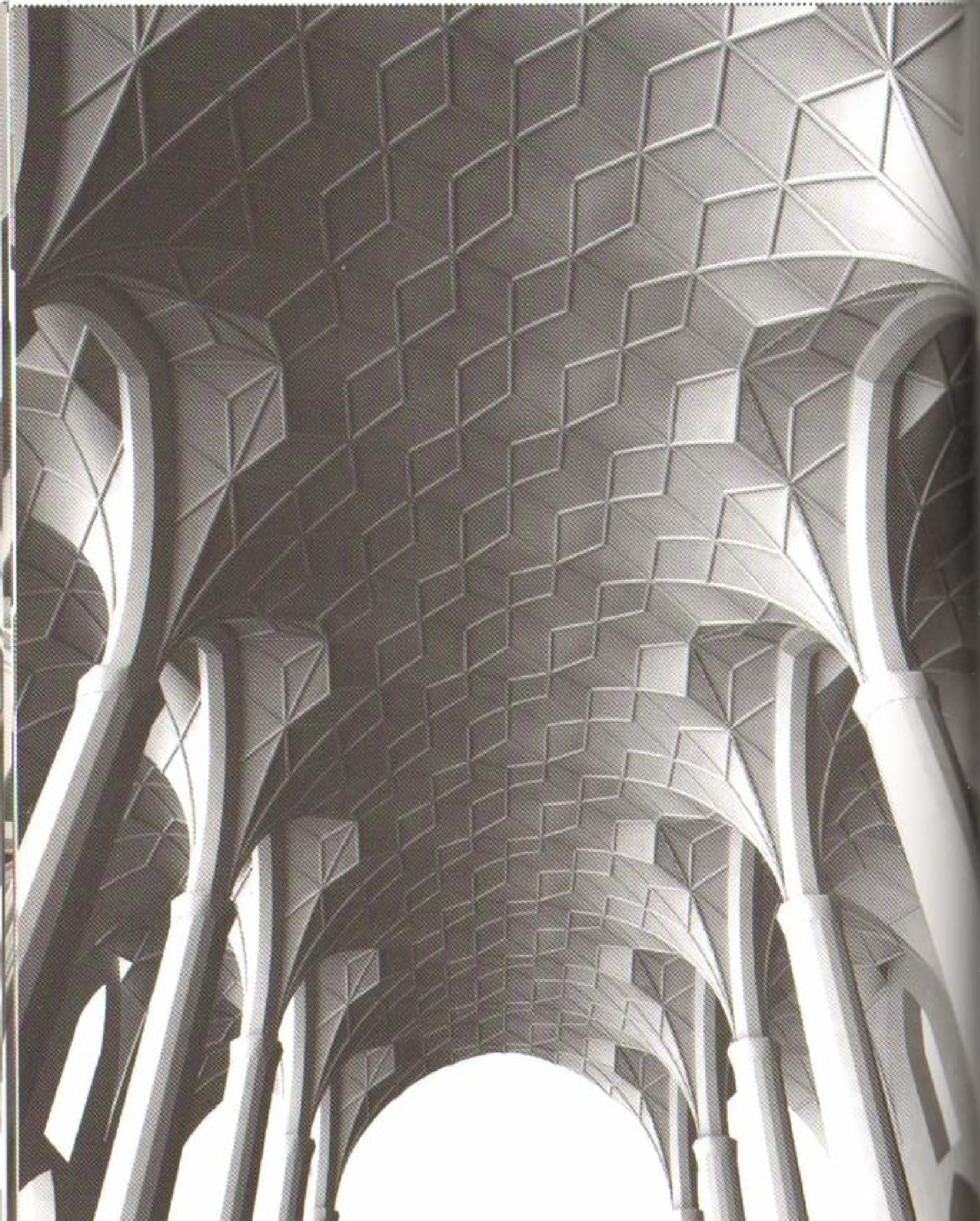
Breaking the smooth expanse of the curving shell into smaller, manageable components of rib and panel helps to envision each unit in isolation and thus cut it away to the lightest possible configuration.



The use of extensive ribbing allowed the cross vault to intersect the main vault at varying heights, as in base units a, b, and c.

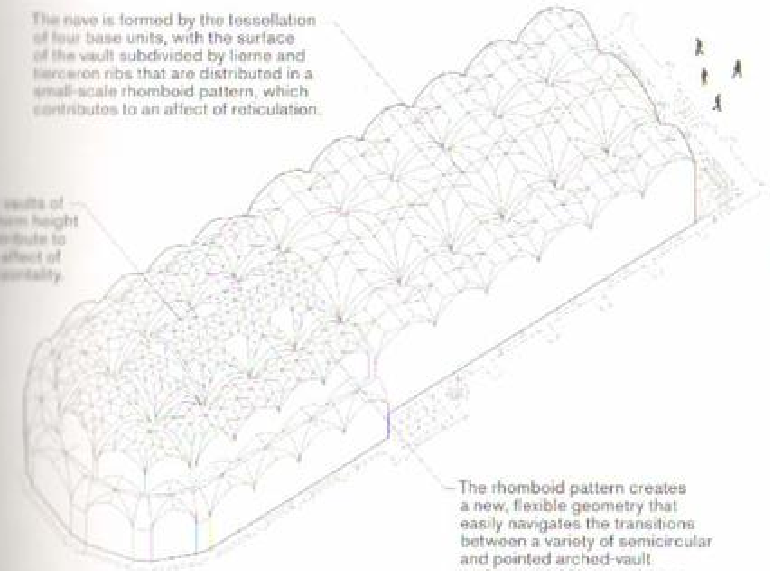
The nave of Gloucester cathedral is produced by the horizontal tessellation of a complex rib vault base unit, repeated and interconnected to form a T-shape. This assemblage consists of a triple bay composed of a nave with aisles, and a transept. The degree of subdivision of the vaults' surfaces varies, with considerably more facets occurring on the nave and the transept, where the lierne and tierceron ribs create a star-shaped pattern, on account of which this type of vault is commonly referred to as a stellar vault. The nave of Gloucester cathedral transmits an optical affect of verticality, subdivision and reticulation, and an acoustical affect of diffusion and slowness.

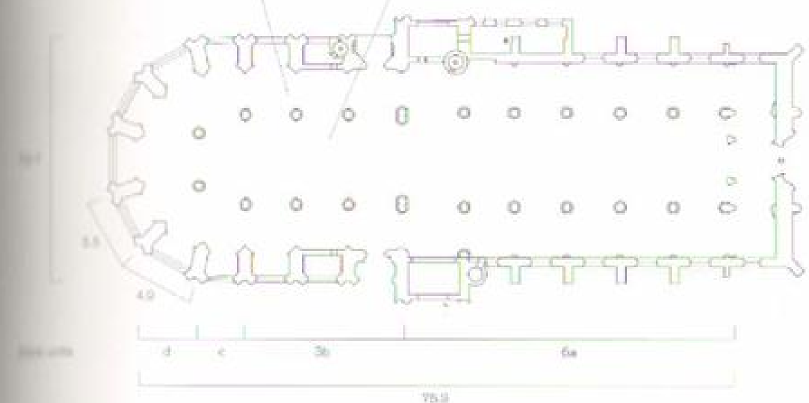
Horizontality, Reticulation, Diffusion, Slowness

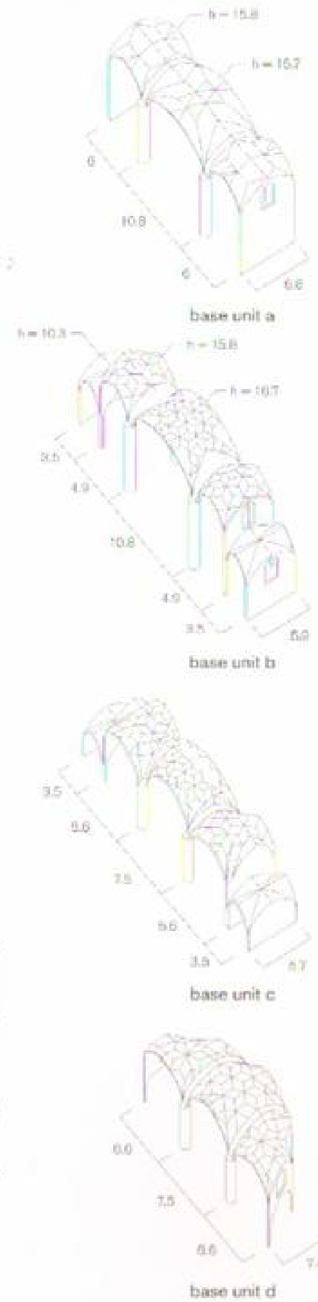


Horizontal / Complex Rib Vault

CATHEDRAL OF THE HOLY CROSS | H. PARLER, A. JORG, H. VON URACH | SCHWÄBISCH GMÜND, GERMANY | 1330–1552

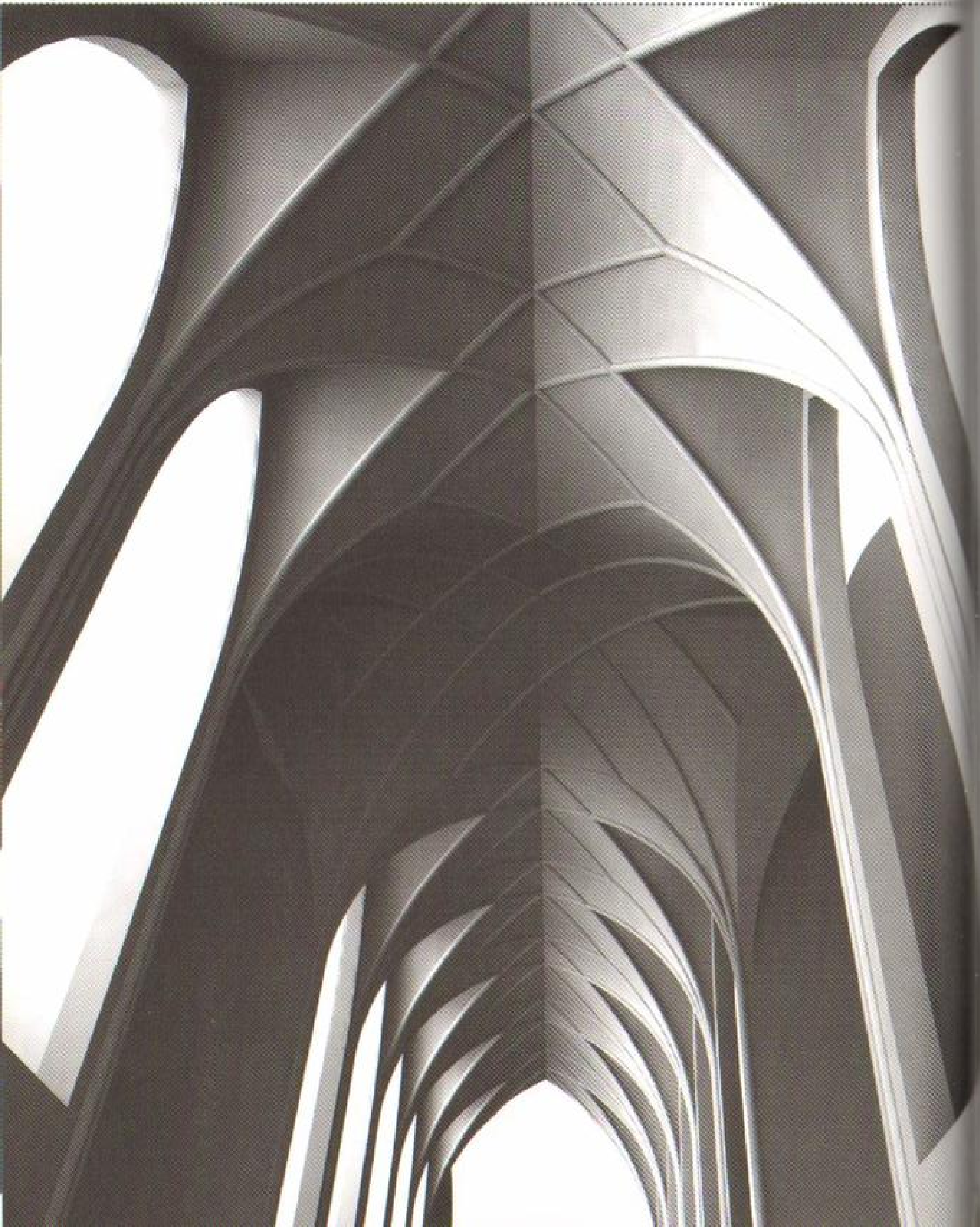






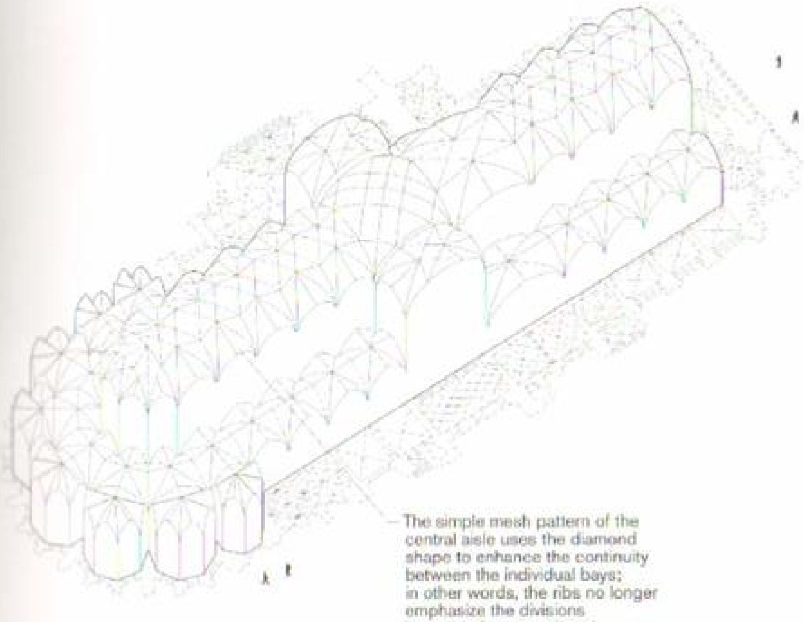
The nave of the Cathedral of the Holy Cross is formed by the horizontal tessellation of a complex rib vault base unit, repeated and interconnected. This assemblage consists of a triple-bayed nave, the width of which increases halfway towards the apse to include extra bays, composed of side vaults spanning side buttresses. Repetition of the base unit results in vault surfaces that are highly subdivided by lierne and tierceron ribs, and the number of facets in the wider part of the nave is considerably greater than elsewhere. Here, the lierne and tierceron ribs create a rhomboid-shaped pattern. The nave of the Cathedral of the Holy Cross transmits an optical affect of horizontality and reticulation, and an acoustical affect of diffusion and slowness.

Continuity, Asymmetry, Pointedness, Verticality, Diffusion, Slowness

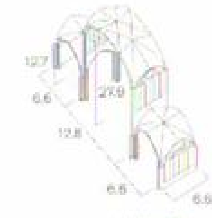


Horizontal / Complex Rib Vault

ST. VITUS CATHEDRAL | M. OF ARRAS, P. PARLER | PRAGUE, CZECH REPUBLIC | 1334–1352

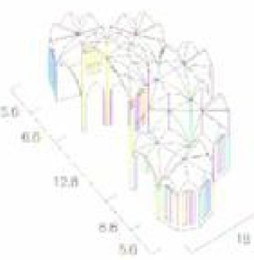


The simple mesh pattern of the central aisle uses the diamond shape to enhance the continuity between the individual bays; in other words, the ribs no longer emphasize the divisions between the repeating elements, contributing to an affect of continuity, pointedness and verticality.



base unit a

base unit b



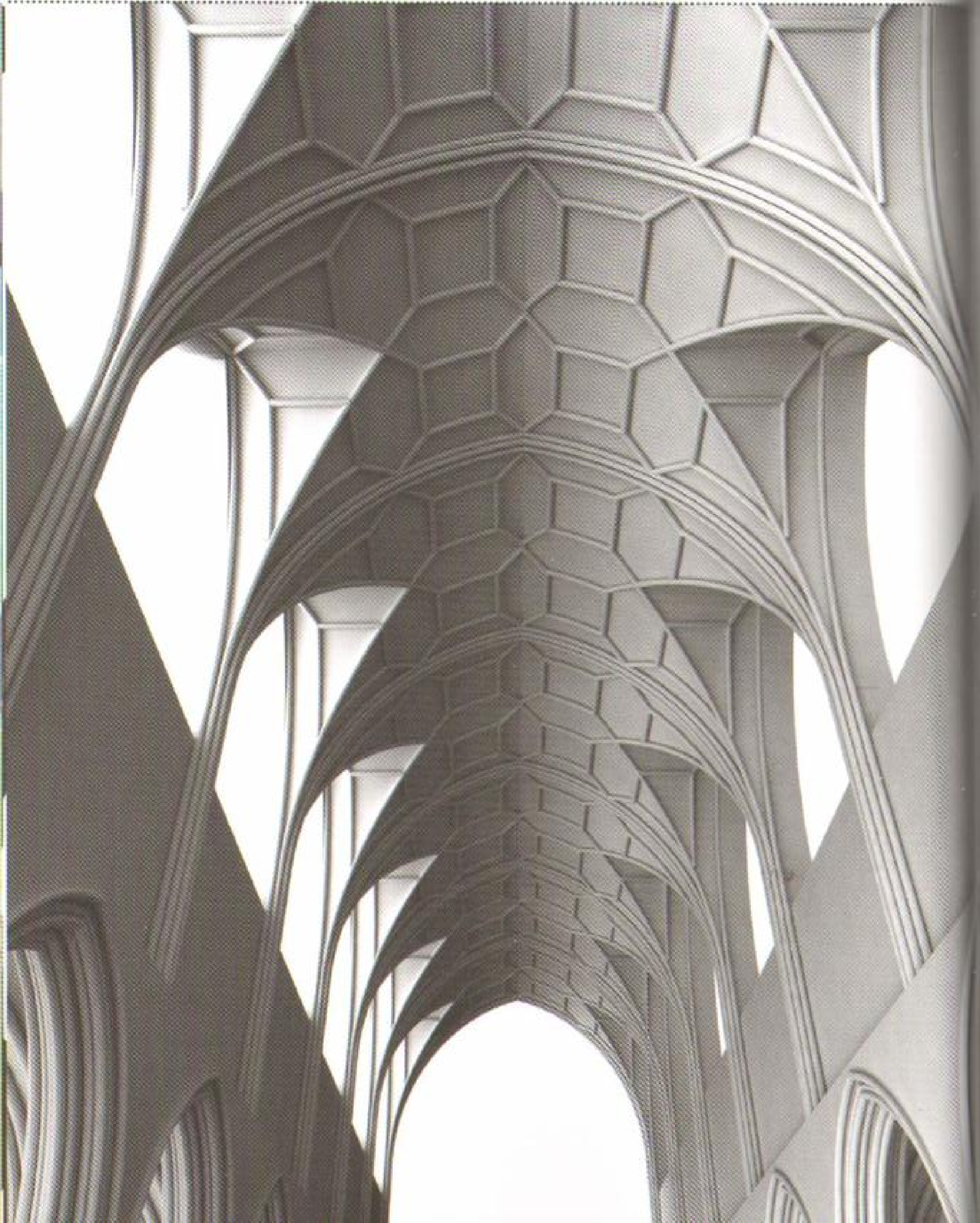
base unit c

The use of three different complex rib vault base units composed of different numbers and patterns of ribs contributes to the affect of differentiation and asymmetry.

This space defined by a horizontal complex rib vault structure transmits an acoustical affect of diffusion and also, on account of its large dimensions, of slowness.

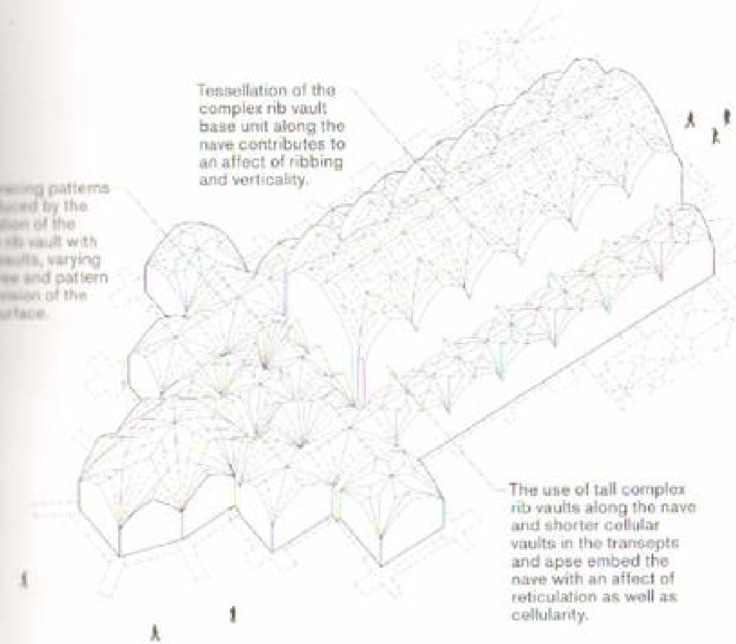
The nave of St. Vitus cathedral is formed by the horizontal tessellation of a complex rib vault base unit, repeated and interconnected. This assemblage comprises a nave and two aisles. Halfway between the transept and the apse the width of the nave increases to include extra bays composed of side vaults spanning side buttresses. Repetition of the base unit results in vault surfaces that are more or less regularly subdivided by a series of tierceron and lierne ribs resulting in a star-shaped pattern. Because of this resulting pattern, this type of vault is commonly referred to as a stellar vault. The difference in height between the nave and the side aisles increases the surface of the elevations, introducing a higher ratio of openings. The nave of St. Vitus cathedral transmits an optical affect of continuity, pointedness, asymmetry and verticality, and an acoustical affect of diffusion and slowness.

Cellularity, Reticulation, Verticality, Ribbing, Diffusion, Slowness



Horizontal / Cellular and Complex Rib Vault

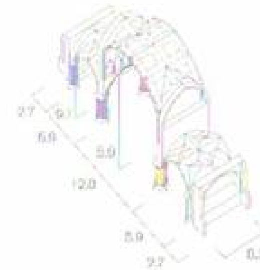
WELLS CATHEDRAL | W. J. MASON | WELLS, UK | 1175–1490



Tessellation of the complex rib vault base unit along the nave contributes to an affect of ribbing and verticality.

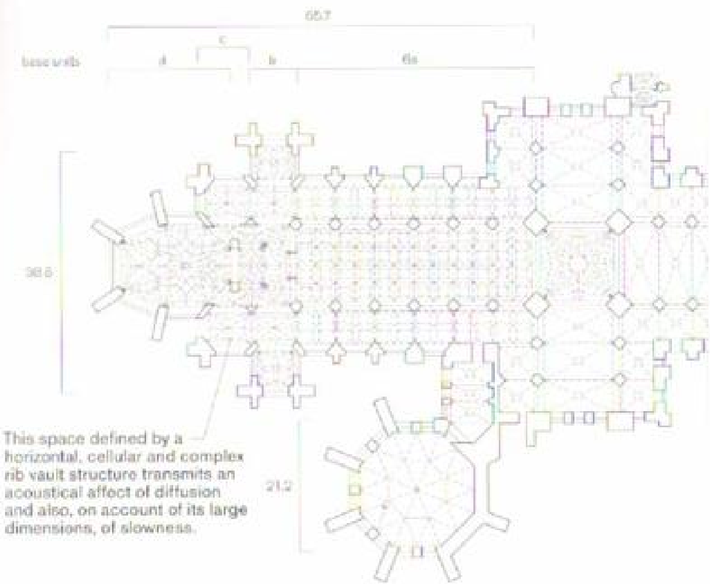
[illegible] bracing patterns [illegible] produced by the [illegible] of the [illegible] rib vault with [illegible] vaults, varying [illegible] degree and pattern [illegible] subdivision of the [illegible] surface.

The use of tall complex rib vaults along the nave and shorter cellular vaults in the transepts and apse embed the nave with an affect of reticulation as well as cellularity.

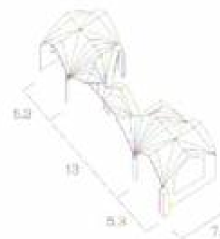


base unit a

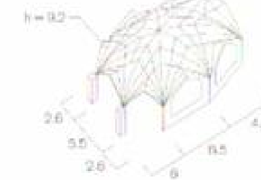
base unit b



This space defined by a horizontal, cellular and complex rib vault structure transmits an acoustical affect of diffusion and also, on account of its large dimensions, of slowness.



base unit c



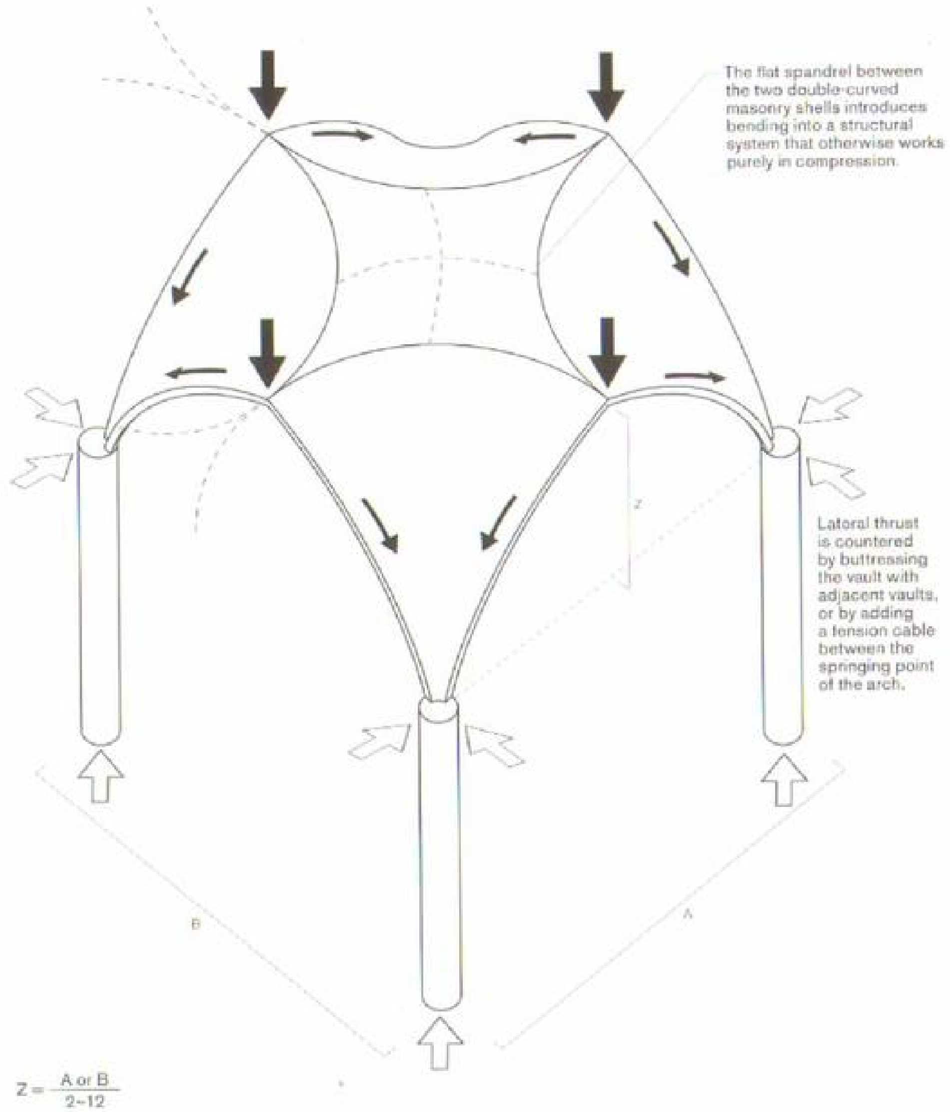
base unit d

The nave of Wells cathedral is a hybrid assemblage formed by the horizontal tessellation of a base unit that combines cellular vaults with complex rib vaults. The cellular vaults are situated along the nave, and the complex rib vaults along the side aisles. The combination of base units introduces different degrees of subdivision of the vaults' surfaces as well as a range of patterns, from a triangulated pattern on the complex rib vaults to one that is square-based on the cellular vaults. The difference in height between the nave and the side aisles increases the surface of the elevation, introducing a higher ratio of openings. The nave of Wells cathedral transmits an optical affect of cellularity, reticulation, verticality and ribbing, and an acoustical affect of diffusion and slowness.

Fan Vault

The base unit of a fan vault is assembled from a set of curved ribs – all with the same curve and spaced equidistantly in a radial pattern – that describe a curved shell surface, or conoid. These are butted together tangentially to form a spandrel, a flat surface between them which ensures their rigidity. Vertical loads in a fan vault are distributed along both its ribs and its surface, following the contours of the conoids. Fan vaults can be made of stone or masonry. The distribution of loads along the lines and surfaces of stone and masonry embeds the fan vault with an optical affective property of ribbing and striatedness that remains consistent within any space it defines. Whilst the fan vault has a concave radial section it also has convex horizontal sections with varying radiuses. The resulting profile has a complex curvature that transmits much diffusion.

Fan vaults are flexible in several ways:
Scale: The number and density of the curved ribs can change the scale of the subdivision of the vault's surface.
Depth: The surfaces spanning between the curved ribs can be formed to fit flush between them, or they can be deepened to create a corrugated surface that increases the overall surface.
Profile: The protogeometry of the fan vault allows for flexibility in the range of curvature of the ribs and in the tangential distribution of the conoids, increasing or decreasing accordingly the surface of the spandrel. Fan vaults can tessellate horizontally along straight or curved lines of growth to produce horizontal forms.
Affect: The distribution of loads along the lines of the ribs and the conoids' surfaces embeds fan vaults with a curved and ribbed affective property that remains consistent within any shape they define. The affective property of a fan vault 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 ribbing and striatedness, the fan vault can transmit other optical affects, including hyper-curving, ribbing, closure, vaulting. The acoustical affect is diffusion.

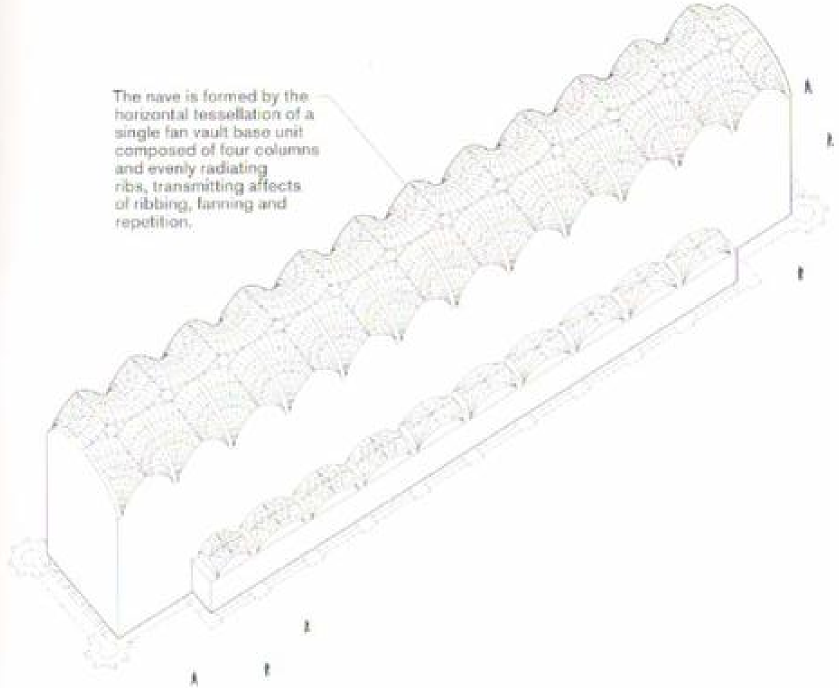


In adopting the fan vault, English masons turned away from two centuries of folding and ribbing to experiment once again with curved shell surfaces. The intersection of reversed curvatures in the flaring conoids of the fan vaults ensured the rigidity of the shell surface.

Axiality, Fanning, Repetition, Diffusion, Slowness

Horizontal / Fan Vault

KINGS COLLEGE CHAPEL | R. ELY | CAMBRIDGE, UK | 1441–1515

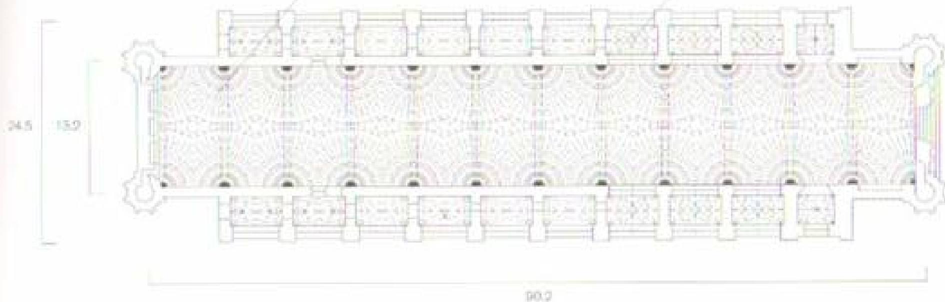


The nave is formed by the horizontal tessellation of a single fan vault base unit composed of four columns and evenly radiating ribs, transmitting affects of ribbing, fanning and repetition.

The spaces between the columns of the fan vault are pierced to embed it with lightness.

Fan vaults transmit an acoustical affect of diffusion and, on account of its large dimensions, the space transmits an affect of slowness.

The repetition of the base unit twelve times produces a form with aspect ratios that embed it with an affect of axiality.



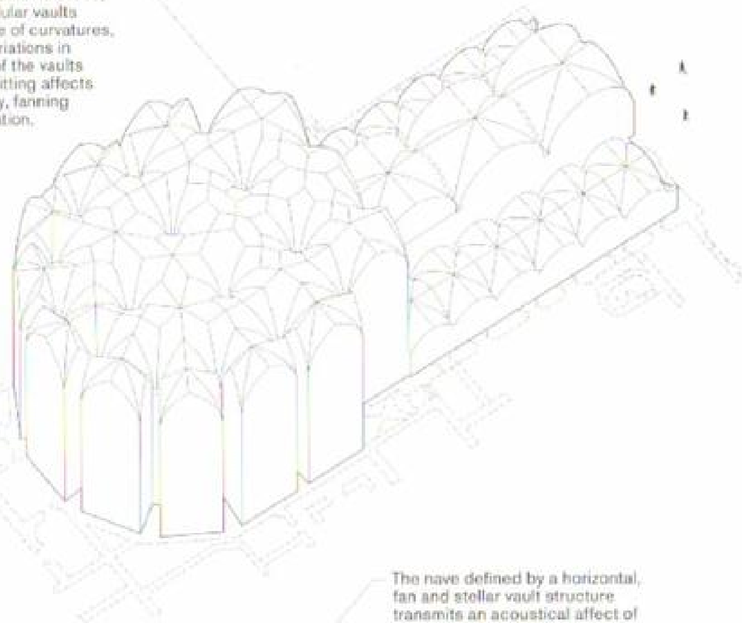
The nave of King's College Chapel is produced by the horizontal tessellation of a fan vault base unit, repeated and interconnected, to form a tall nave and two lower side aisles. The base unit repeats regularly to subdivide the surface of the fan vault regularly. The difference in height between the nave and the aisles increases the surface of the elevation, allowing openings to be introduced. The nave of King's College Chapel transmits an optical affect of axiality, fanning and repetition, and an acoustical affect of diffusion and slowness.

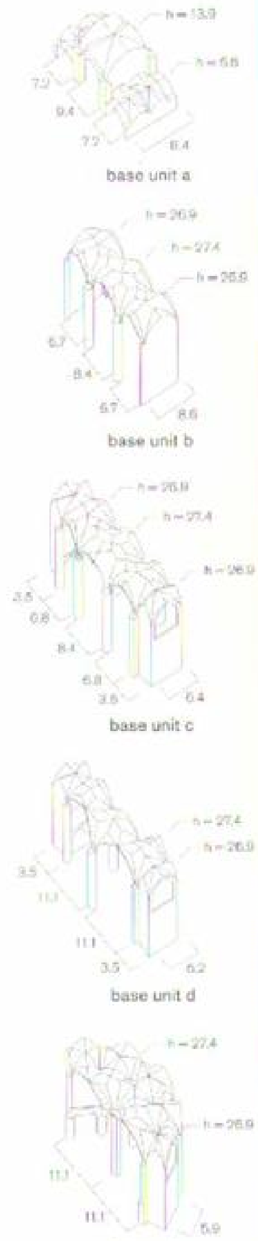
Fanning, Cellularity, Variegation, Diffusion, Slowness

Horizontal / Cross, Fan and Cellular Vaults

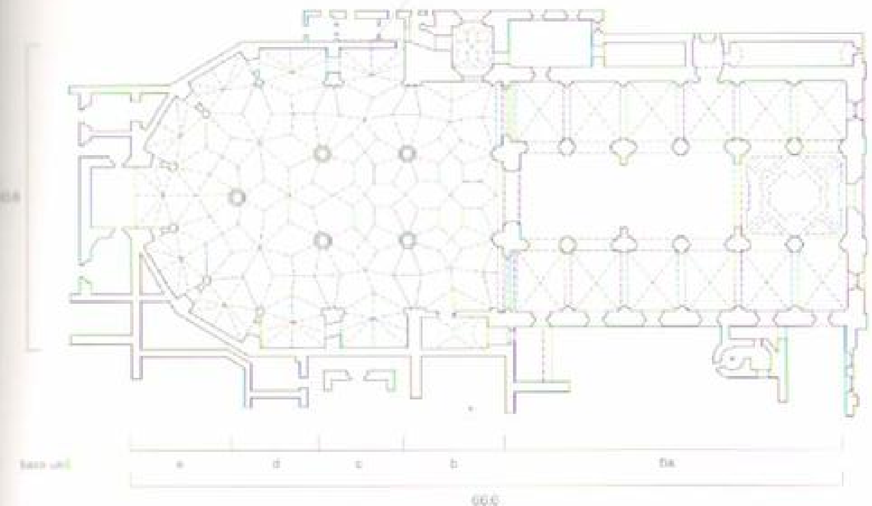
FRANCISCAN CHURCH | H. STETHEIMER | SALZBURG, AUSTRIA | 1498

The nave is formed by the tessellation of five base units that combine cross, fan and cellular vaults with a range of curvatures, allowing variations in the spans of the vaults and transmitting affects of cellularity, fanning and variegation.





The nave defined by a horizontal, fan and stellar vault structure transmits an acoustical affect of diffusion and also, on account of its large dimensions, an affect of slowness.

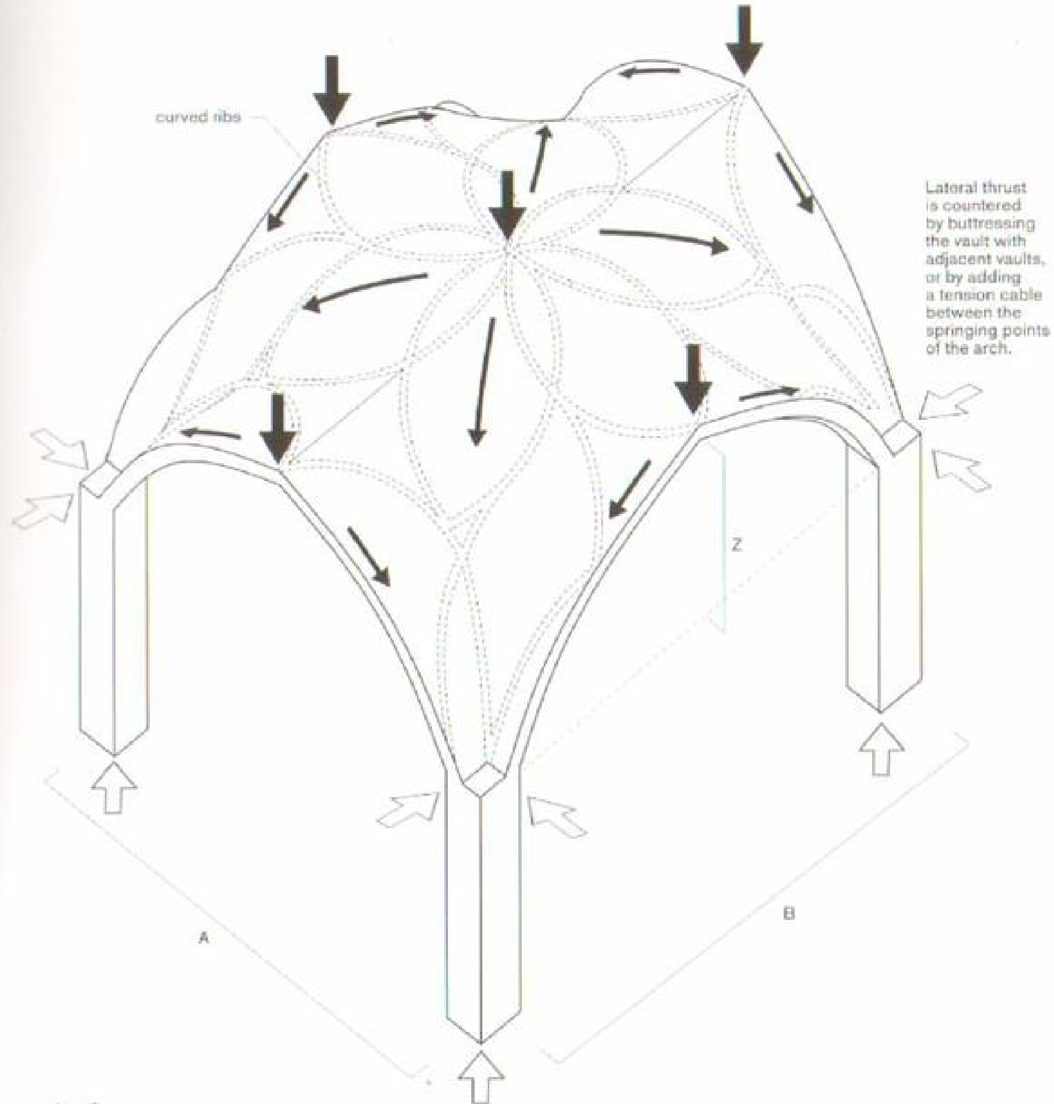


The nave of the Franciscan Church is a hybrid formed by the horizontal tessellation of cross, fan and cellular vaults' base units. This assemblage is composed of a tall nave, the first half of which is formed by regular cross vaults, and the second by a hybrid of both fan and cellular vaults springing from a set of five columns to span from the edges of the nave to its center. The meeting of the ribs at the top of the vault creates a diamond-shaped pattern that accommodates the introduction of the fifth column, which is not aligned with the other four, located along the side edges of the nave. A change in height along the aisles increases the surface of the elevation, introducing openings along side perimeter walls. The nave of the Franciscan Church transmits an optical affect of cellularity, fanning and variegation, and an acoustical affect of diffusion and slowness.

Curved Rib Vault

The base unit of a curved rib vault is composed of a cross vault with an additional set of curved ribs, some of which are derived from the intersection of the surface of the vault with that of a projected sphere. Vertical loads in curved rib vaults are distributed along the lines of the ribs and along the contours of the infill surface. Curved rib vaults can be made of stone or masonry, but can also be made of reinforced concrete, or a mixture of the two. The distribution of loads along the lines and surfaces of stone, masonry or steel-reinforced concrete embeds the curved rib vault with an optical affective property of hyper-curving and ribbing that remains consistent within any space it defines. The concave surface of a vault focuses sound near its center of curvature, but sound at a distance from the center can be diffused to an extent that depends upon the spectrum of the sound. Variations in the radius and direction of curvature of the curved rib vault create a multiplicity of focal points. Together with the ribs, facets and reticulation, these transmit diffusion as the dominant affect.

Curved rib vaults are flexible in several ways:
Scale: The protogeometry of curved rib vaults is flexible in the number of ribs and in the variations of the patterns they form as well as the scale of the subdivisions in relation to the surface of the vault.
Profile: The range of overall curvature can vary, whether in the ribs themselves or in the surfaces between them, which can be shaped individually where the ribs are detached from the vault's surface. In addition, the curvilinear ribs form petal-like subdivisions that can gradually increase the curvature of the vault surface.
Depth: The petal-like surface subdivisions can be inscribed flush with the ribs, or they can be deepened to increase the overall area of the surface.
Affect: The affective property of a curved rib vault 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 hyper-curving and ribbing, a curved rib vault can transmit other optical affects, including ribbing, closure, axiality, verticality, pointedness. The acoustical affect can be focusing or diffusion.



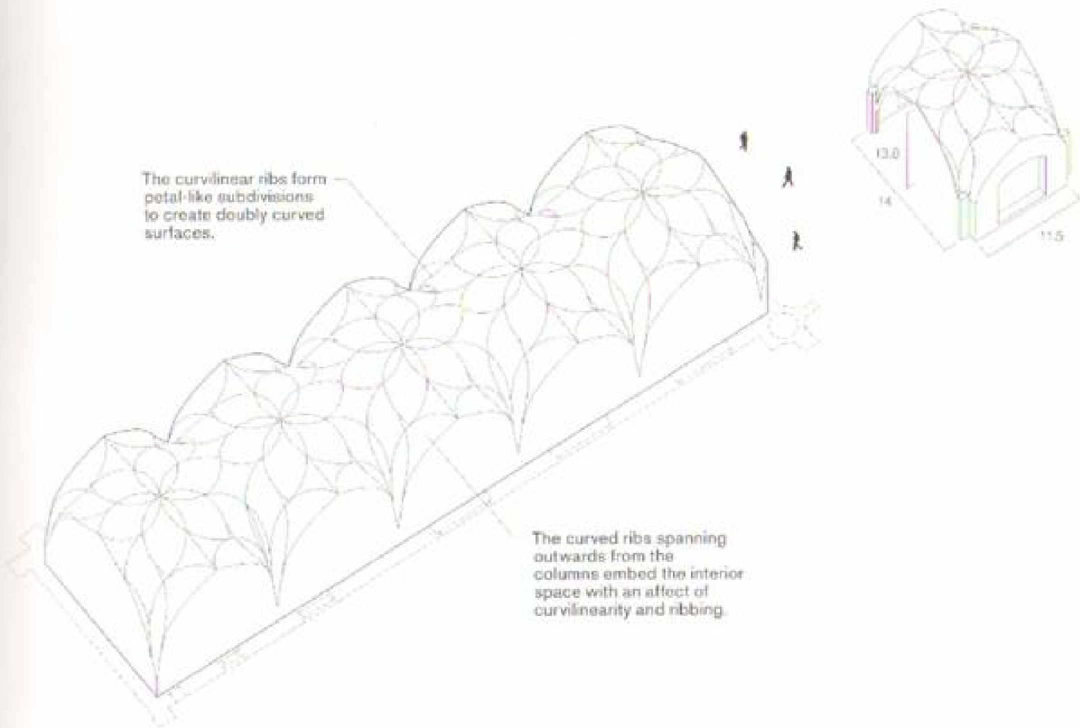
$$Z = \frac{A \text{ or } B}{2\text{–}12}$$

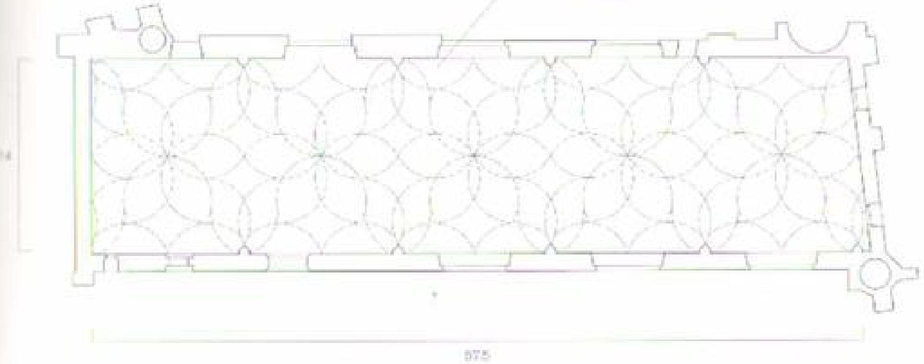
Predating lamella shells, curved rib vaults respond to load-bearing forces similarly, where the load is shared between the ribs and the surface of the vault. In addition, the curvature of the ribs allows them to have an increased resistance to lateral forces. In some cases, the radial and floral patterns created by the ribs results from the intersection of an inscribed sphere and the surface of a cross vault.

Curvilinearity, Ribbing, Diffusion

Horizontal / Curved Rib Vault

VLADISLAV HALL | B. REID | PRAGUE, CZECH REPUBLIC | 1493–1500



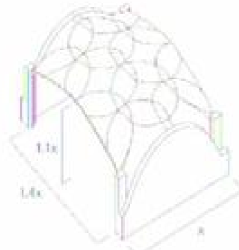


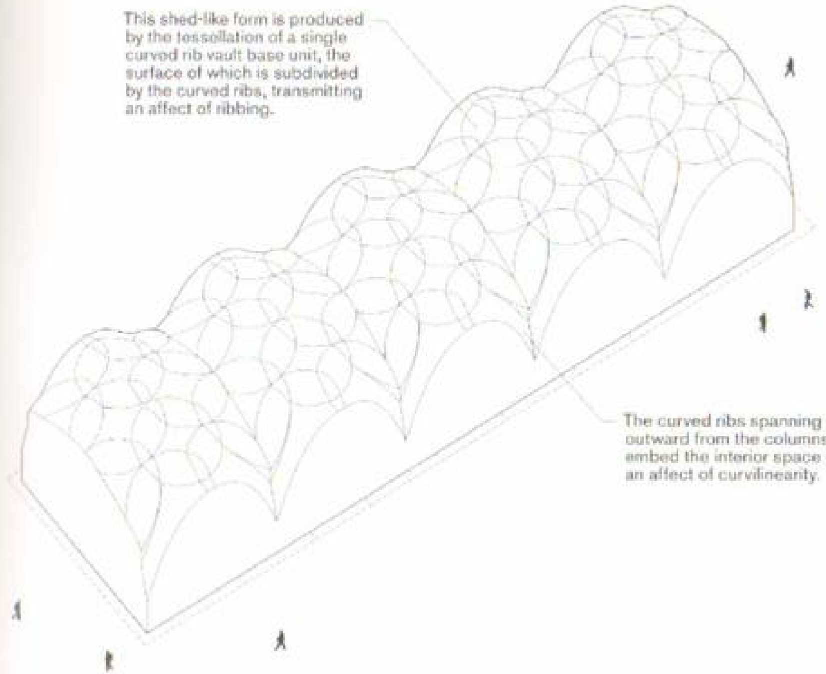
The Vladislav Hall is produced by the horizontal tessellation of a curved rib vault base unit, repeated and interconnected. The base unit introduces curved ribs which radiate from the apex of a cross vault. The degree of subdivision of the vault surface is determined by the number of curved ribs. Even though some of these curved ribs approximate to the load-bearing lines of a cross vault, the majority of the load bearing forces are distributed along the surface of the vault rather than along the seams, as in the case of a cross vault. The Vladislav Hall transmits an optical affect of curvilinearity and ribbing, and an acoustical affect of diffusion.

Curvilinearity, Ribbing, Diffusion

Horizontal / Curved Rib Vault

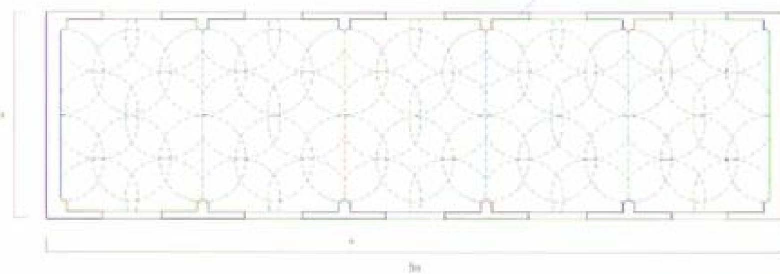
This shed-like form is produced by the tessellation of a single curved rib vault base unit, the surface of which is subdivided by the curved ribs, transmitting an affect of ribbing.



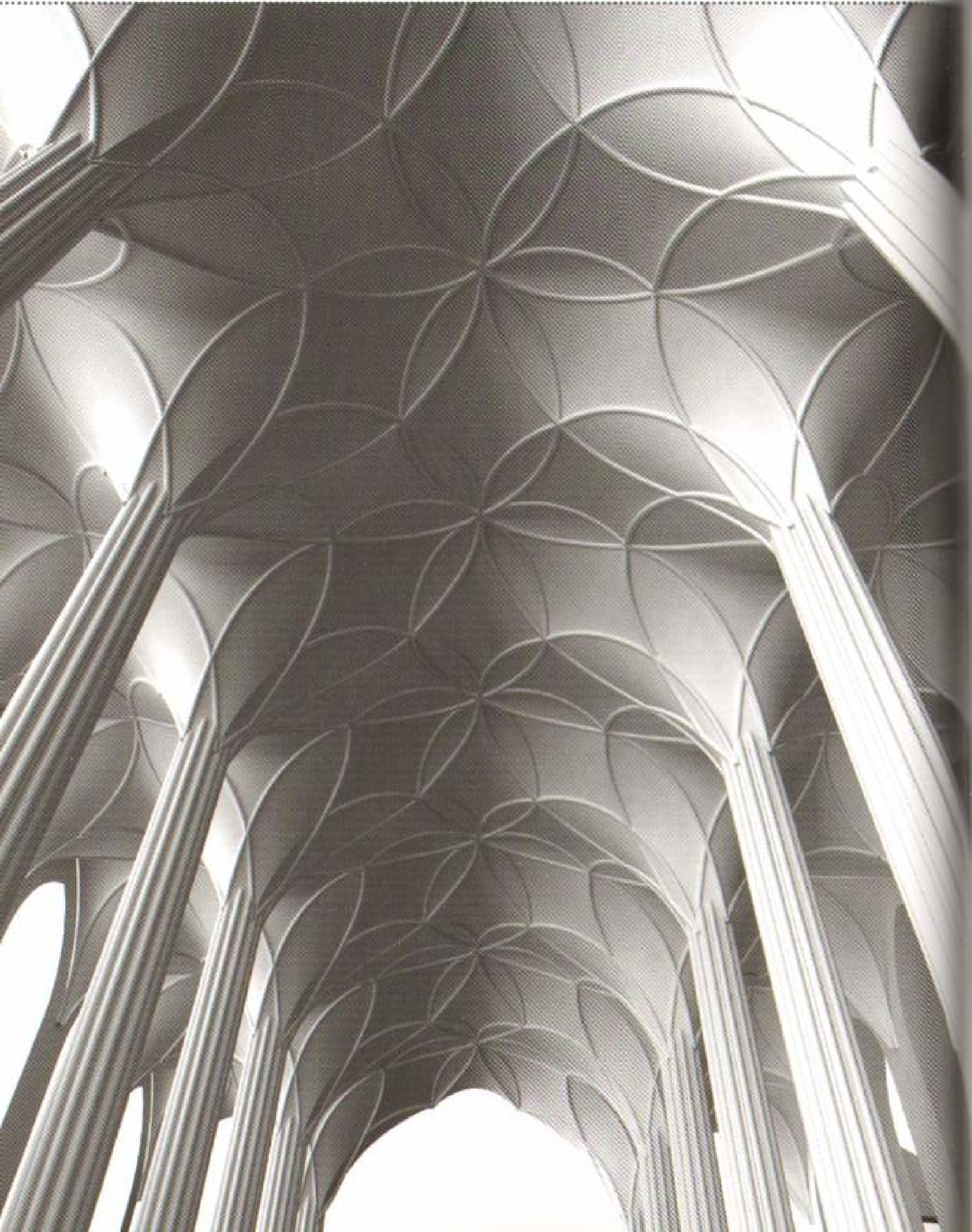


The curved ribs spanning outward from the columns embed the interior space with an affect of curvilinearity.

This curved rib vaulted space transmits an acoustic affect of diffusion.

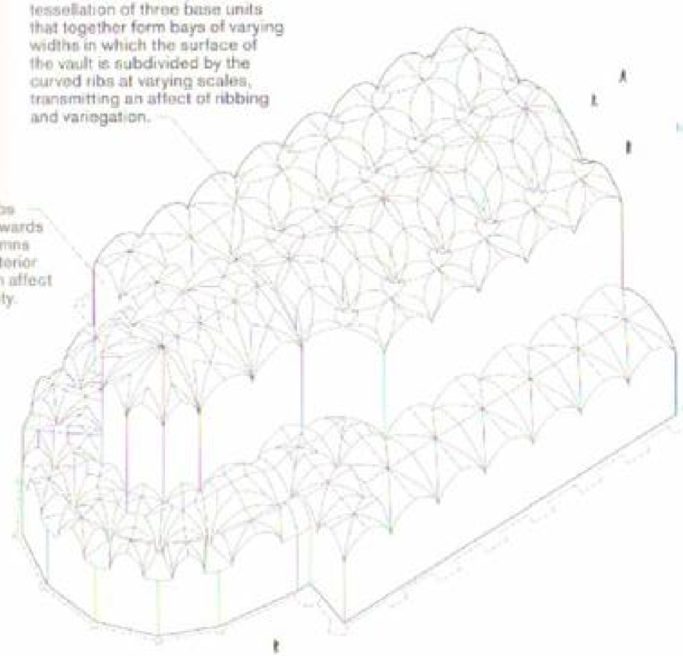


This form is produced by the horizontal tessellation of a curved rib vault base unit, repeated and interconnected to form a series of bays. The base unit subdivides the surface of the vault into facets by introducing a number of curved ribs. These ribs are derived from circles arrayed in plan, and projected onto the surface of the vault. The degree of subdivision of the vault surface is determined by the number of curved ribs that are introduced. Some of these ribs approximate to the load-bearing lines of a cross vault, while the majority of them distribute the forces along the contours of the vault surface rather than following the seams of the surface, as in the case of a cross vault. This assemblage transmits an optical affect of curvilinearity and ribbing, and an acoustical affect of diffusion.



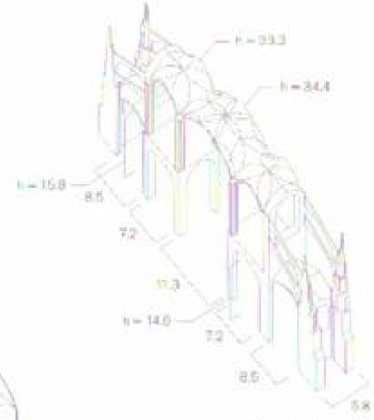
Horizontal / Curved Rib Vault

THE CATHEDRAL OF ST. BARBARA | P. PARLER | KUTNA HORA, CZECH REPUBLIC | 1420



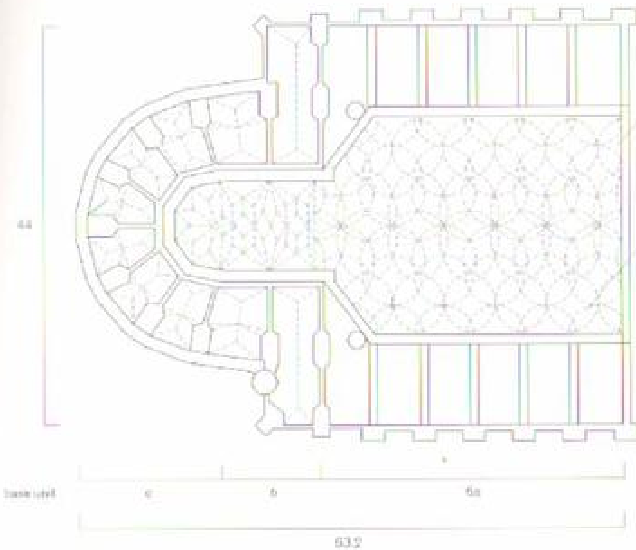
The nave is formed by the tessellation of three base units that together form bays of varying widths in which the surface of the vault is subdivided by the curved ribs at varying scales, transmitting an affect of ribbing and variegation.

The curved ribs spanning outwards from the columns imbue the interior space with an affect of curvilinearity.



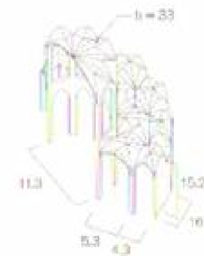
base unit a

base unit b



The variation possible in the pattern of ribs allows the vaulted form to adjust to an irregular perimeter.

This space defined by a curved rib and lierne vaulted structure transmits an acoustical affect of diffusion and also, on account of the large dimensions of the enclosed space, of slowness.



base unit c

Curved ribs can pick up stress caused by lateral forces, which Benedict Reid intuited and gave form to in this complex interweaving of isostatic forces through the curved ribs.

The nave of St. Barbara is produced by the horizontal tessellation of a curved rib vault base unit of a curved rib vault, repeated and interconnected to form its naves. The base unit subdivides the surface of the vault into facets by introducing curved ribs, the number of which determines the degree of subdivision of the surface. Some of these ribs approximate to the natural load-bearing lines of the cross vault, while the majority of them distribute the forces along the contour of the vault rather than following the seams of the surface, as in the case of a cross vault. The difference in height between the nave and the aisles increases the surface of the elevation, allowing openings to be introduced. The nave of St. Barbara transmits an optical affect of curvilinearity, ribbing and variegation, and an acoustical affect of diffusion and slowness.

Cellular Vault

The base unit of a cellular vault is composed of vaults made of pointed arches, with the ribs eliminated, which are formed by the infill surfaces of the vault and subdivided into prismatic surfaces. Cellular vaults direct the primary forces along the surfaces of the prisms, which spring from the side walls toward the apex, generating a crystalline trace which in plan remains a regular diagonal grid. Cellular vaults can be made of bricks covered on the underside with a thick layer of plaster to form a smooth surface. The possibility of building these in folded steel plates could be explored. The distribution of loads through brick shells – or folded steel plates – allows for different degrees of subdivision on the surface. This distribution of loads along the lines and surfaces of a masonry shell, steel-reinforced concrete, or folded steel plates embeds cellular vaults with an optical affective property of cellularity and pointedness that remains consistent within any space they define. The concave surface of a vault focuses sound near its center of curvature, but sound at a distance from the center can be diffused to an extent that depends upon the spectrum of the sound. However, this focusing is overwhelmed by the diffusion created by the curvature variations and prismatic surfaces.

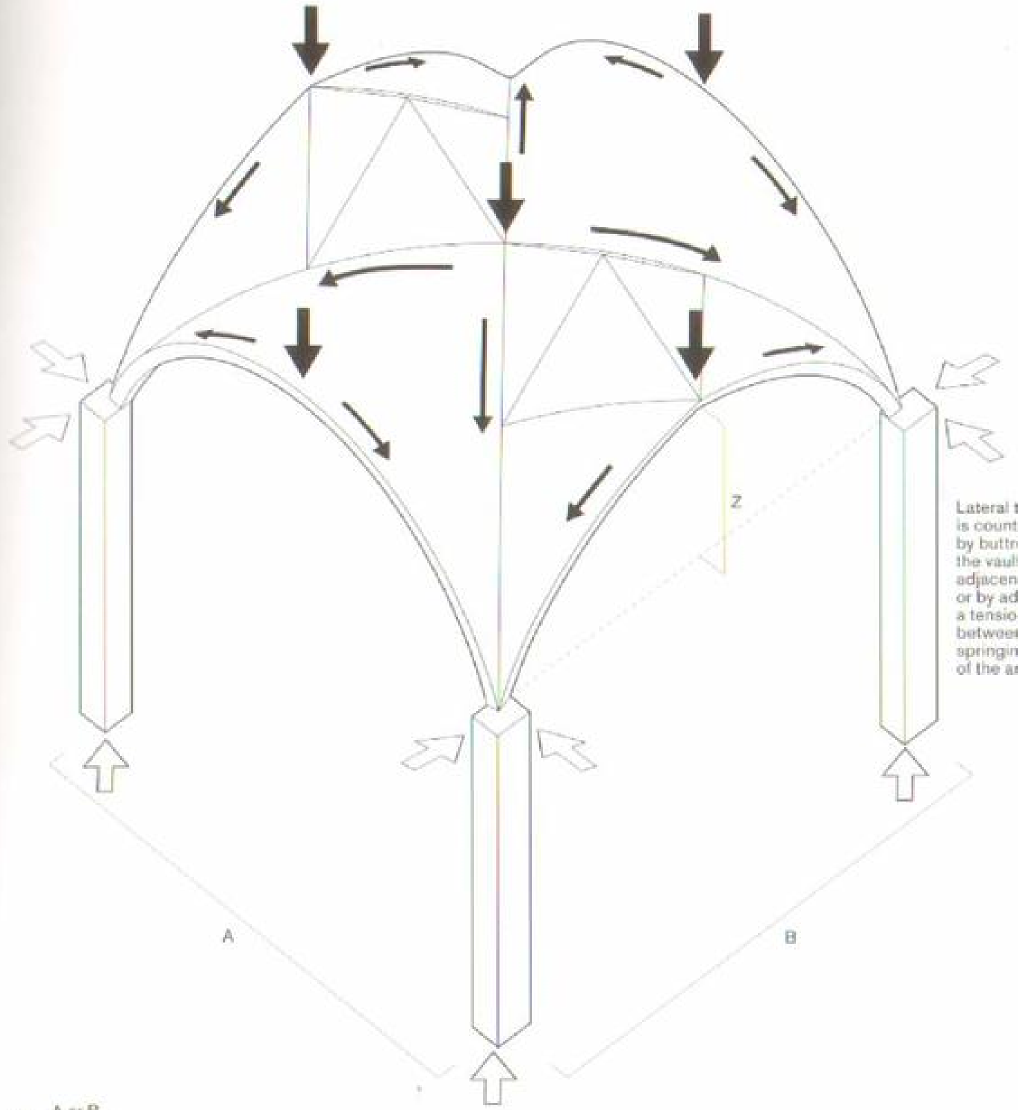
Cellular vaults are flexible in several ways:

Scale: The protogeometry of cellular vaults is flexible in the number of surface subdivisions it allows as well as the range of scales in subdivision.

Depth: The degree of surface corrugation corresponds to the degree of subdivision of the vault's surface. The depth of the overall surface can be increased by increasing the subdivision of the surface as well as the depth of each of the surface folds.

Profile: Changes in the curvature of each of the surfaces also increases or decreases the crystalline character of the vault's surface. Cellular vaults can tessellate horizontally along straight or curved lines of growth to produce horizontal or curved structures.

Affect: The affective property of a cellular vault 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. In addition to cellularity and pointedness, a cellular vault can transmit other optical affects, including verticality, asymmetry, vaulting, horizontality, symmetry, cruciformity, centeredness, rectilinearity. The acoustical affect is diffusion.



Lateral thrust is countered by buttressing the vault with adjacent vaults, or by adding a tension cable between the springing points of the arch.

$$Z = \frac{A \text{ or } B}{2\text{–}12}$$

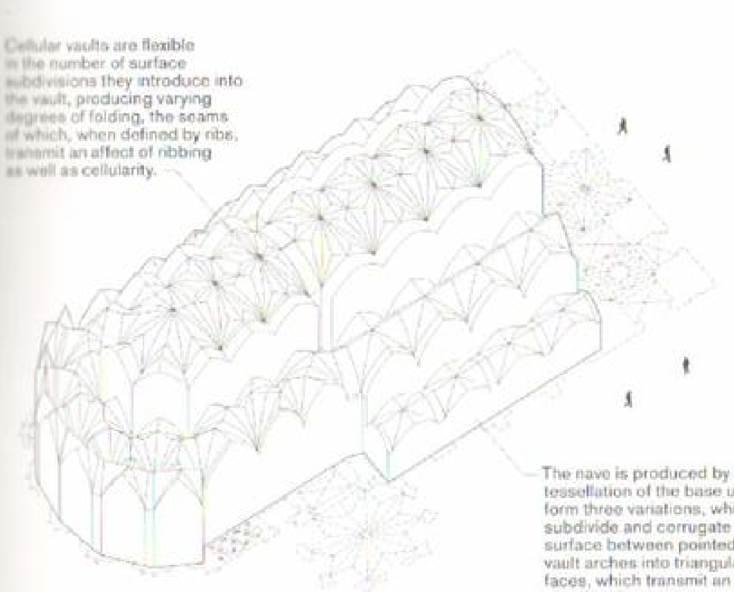
In comparison to complex rib vaults, the surface of the vault in the cellular vault, which has been subdivided into a series of discrete manageable components, invites the introduction of further vaulting within these segments. Most of the cellular vaults were made of brick. The ribless, curving cells were stabilized by the combined forces of thrust, gravity and the mechanical interlocking of bricks. The folding produced by the cells add the necessary stiffness which the ribs would have provided. Generally, cellular vaults cover smaller spans than do complex rib or cross vaults.

Cellularity, Ribbing, Pointedness, Diffusion, Slowness

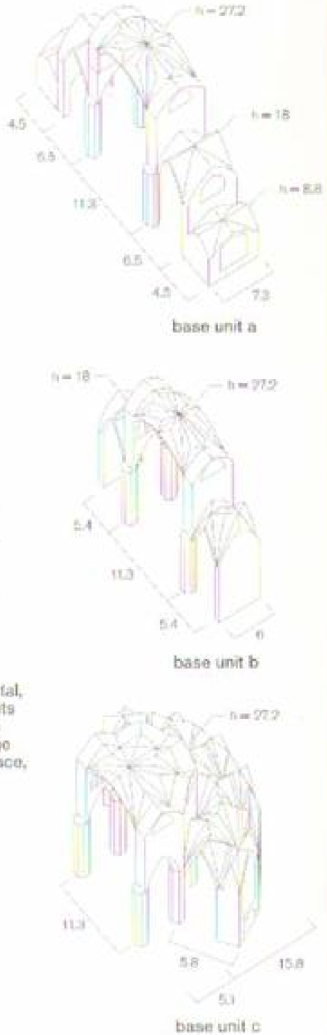
Horizontal / Cellular Vault

ST. MARY'S CHURCH | H. BRUNSBERG, CHOIR | STARGARD SZCZECINSKI, POLAND | 1292–1350

Cellular vaults are flexible in the number of surface subdivisions they introduce into the vault, producing varying degrees of folding, the seams of which, when defined by ribs, transmit an affect of ribbing as well as cellularity.

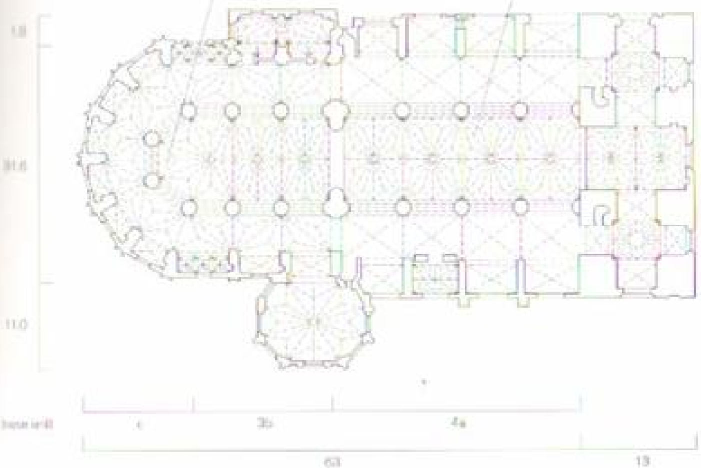


The nave is produced by the tessellation of the base unit to form three variations, which subdivide and corrugate the surface between pointed cross vault arches into triangulated faces, which transmit an affect of pointedness.



The range of possible surface subdivisions of a cellular vault allows it to have a range of spans, which in turn enables it to adjust to an irregular plan.

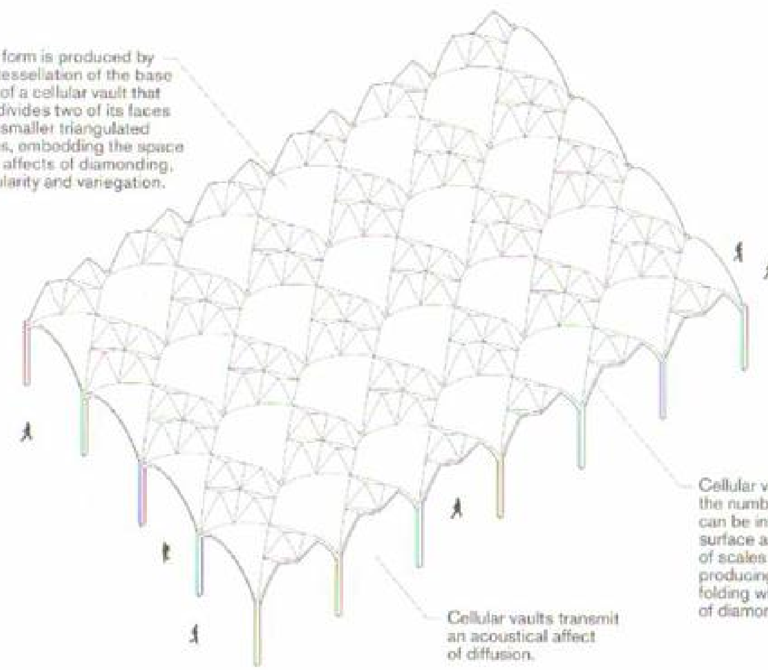
This space defined by a horizontal, stellar-vaulted structure transmits an acoustical affect of diffusion and also, on account of the large dimensions of the enclosed space, of slowness.

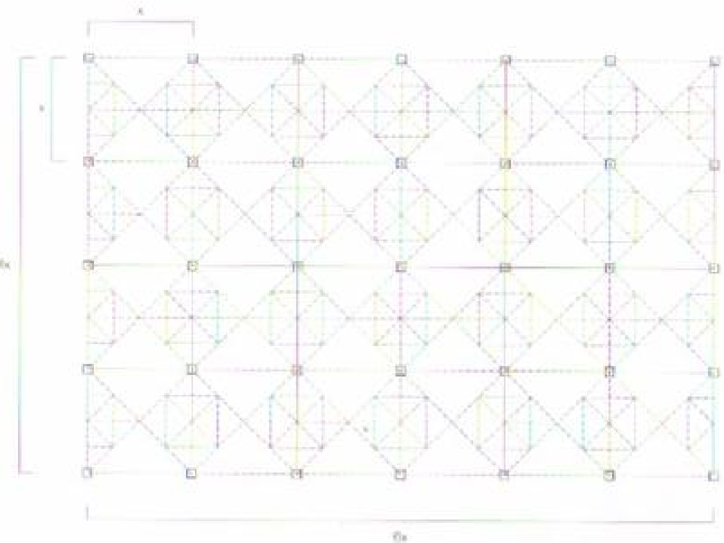


St. Mary's Church demonstrates the transition from lierne to cellular vaults. The segments of the star-shaped vault are further subdivided into a series of tripartite, shallow, concave vaulted surfaces. It is quite possible that early experiments with vaulted surfaces for aesthetic means lead to innovation in structure later on with deeper cellular vaults.

The nave of St. Mary's Church is produced by the horizontal tessellation of a cellular vault base unit of a cellular vault, repeated and interconnected to form a series of bays. As the base unit repeats it subdivides the surface of the vault into facets. The degree of subdivision of the vault's surface is determined by the number of surface folds that are introduced. The seams forming the surface folds are star-shaped in plan, and they approximate to the force lines of a complex rib vault with lierne ribs. The difference in height between the nave and the aisles increases the surface of the elevation, allowing openings to be introduced. The nave of St. Mary's Church transmits an optical affect of ribbing, cellularity and pointedness, and an acoustical affect of diffusion and slowness.

Horizontal / Cellular Vault

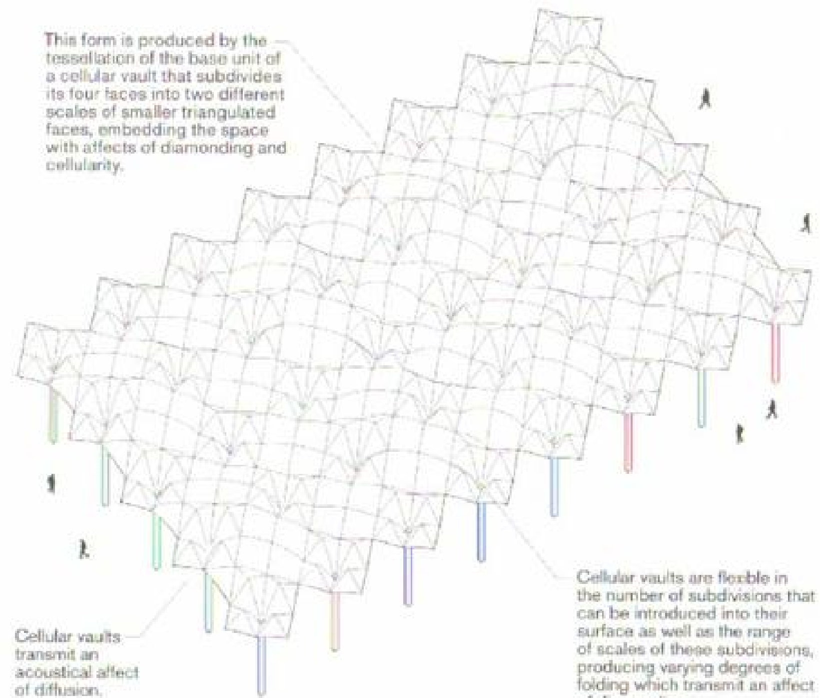




This form is produced by the horizontal tessellation of a cellular vault base unit, repeated and interconnected to create a series of bays. The base unit repeats regularly to subdivide the surface of the vault into facets. The degree of subdivision is determined by the number of facets, which are evenly distributed. The seams forming the surface folds are distributed in such a way that they approximate to the force lines of a cross vault. This vault frame assemblage transmits an optical affect of diamonding, cellularity and variegation, and an acoustical affect of diffusion.

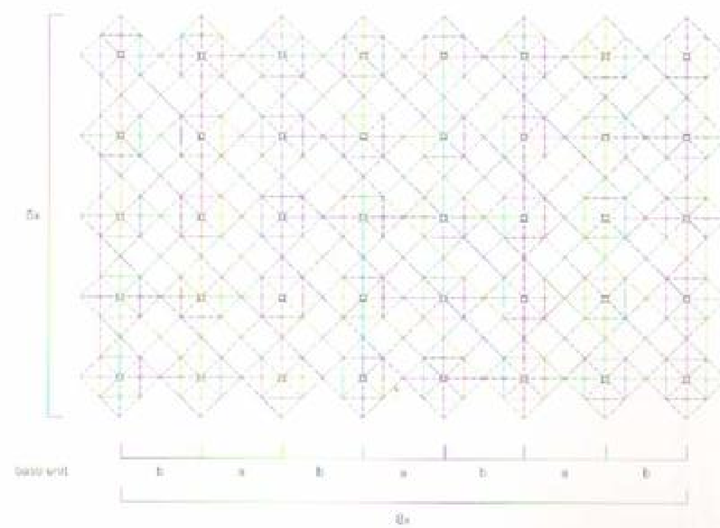
Diamonding, Cellularity, Differentiation, Diffusion

Horizontal / Cellular Vault



base unit a

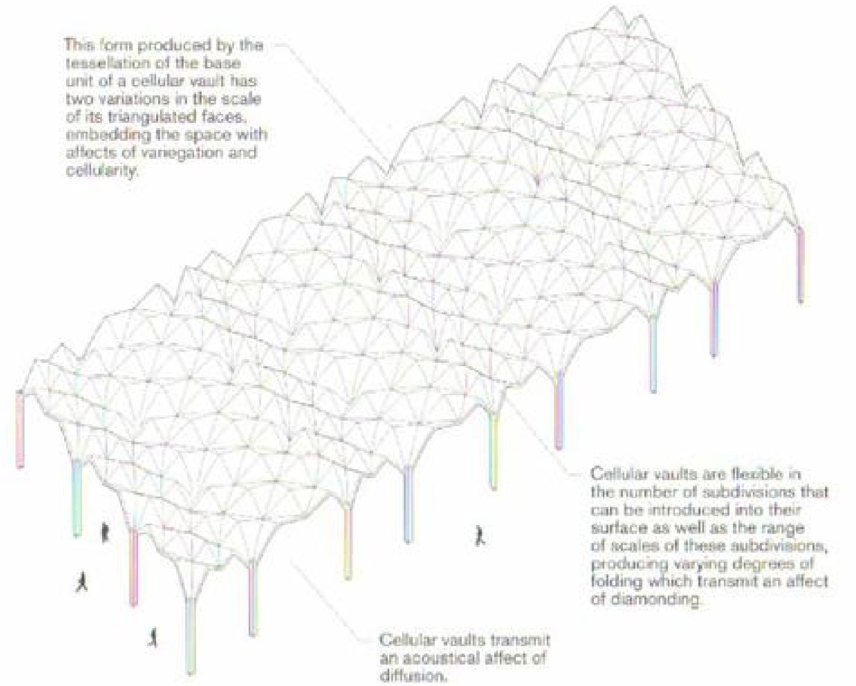
base unit b

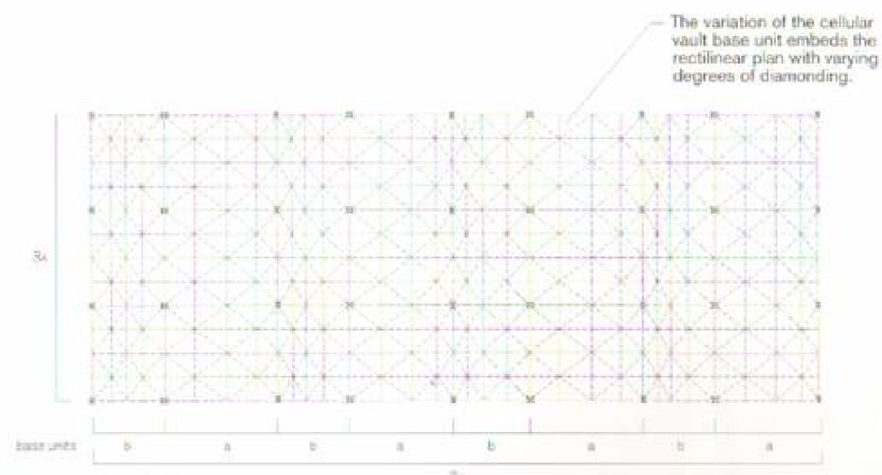


This form is produced by the horizontal tessellation of a cellular vault base unit, repeated and interconnected to create a series of bays. As the base unit repeats to subdivide the surface of the vault, it introduces irregularities, which are clustered around the supporting columns, where the depth of each of the surfaces also increases. This vaulted assemblage transmits an optical affect of diamonding, cellularity and differentiation, and an acoustical affect of diffusion.

Diamonding, Cellularity, Variegation, Diffusion

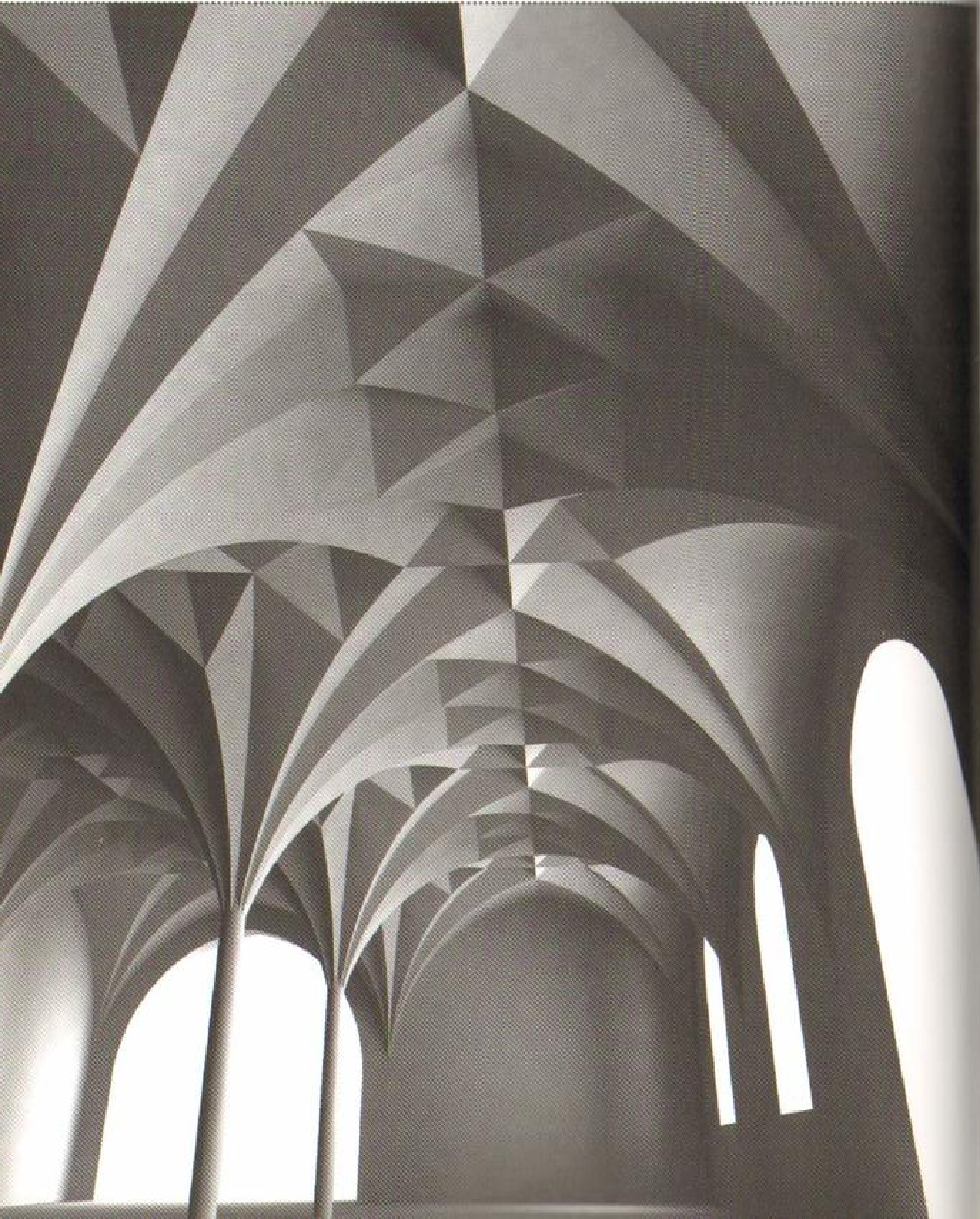
Horizontal / Cellular Vault





This form is produced by the horizontal tessellation of a cellular vault base, repeated and interconnected to create a series of bays. The base unit repeats irregularly to subdivide the surface of the vault into facets. The degree of subdivision is determined by the number of surface folds, which in this case are distributed irregularly along the bays to form an undulating surface. The seams forming the surface folds are distributed in such a way that they approximate to the force lines of a cross vault. This vault frame assemblage transmits an optical affect of diamonding, cellularity and variegation, and an acoustical affect of diffusion.

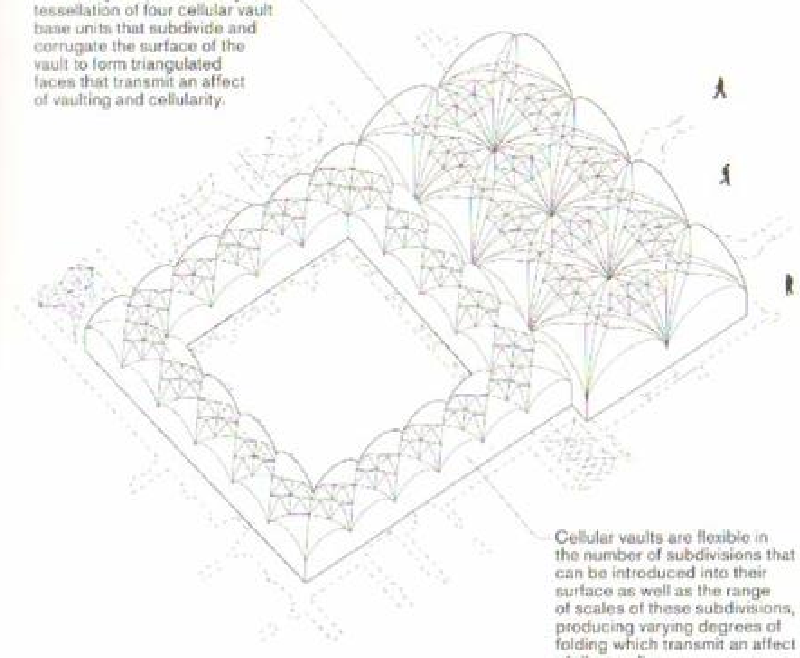
Diamonding, Cellularity, Vaulting, Diffusion



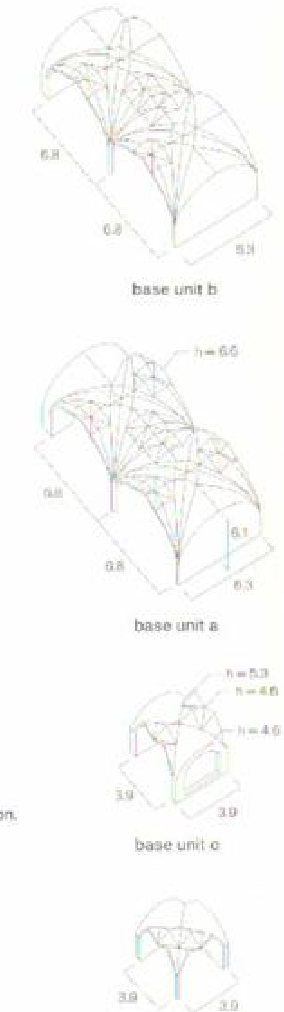
Horizontal / Cellular Vault

CHURCH OF THE ASSUMPTION | Z. VON STEMBERK | BECHYNE, CZECH REPUBLIC | 1490

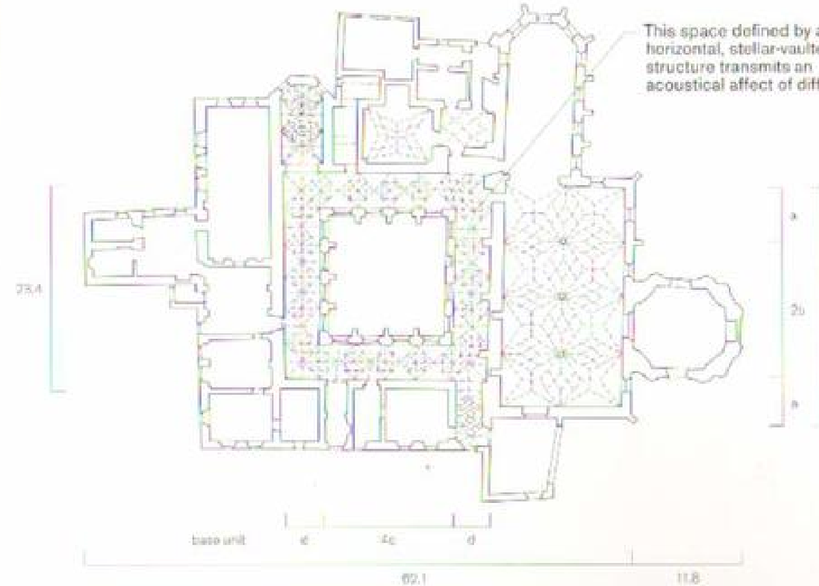
The nave and courtyard of the monastery are produced by the tessellation of four cellular vault base units that subdivide and corrugate the surface of the vault to form triangulated faces that transmit an affect of vaulting and cellularity.



Cellular vaults are flexible in the number of subdivisions that can be introduced into their surface as well as the range of scales of these subdivisions, producing varying degrees of folding which transmit an affect of diamonding.



This space defined by a horizontal, stellar-vaulted structure transmits an acoustical affect of diffusion.



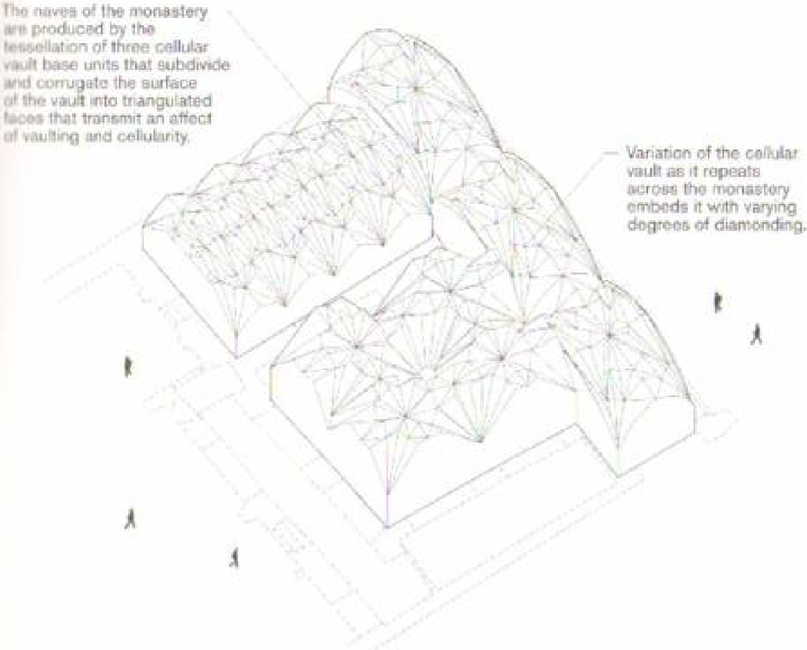
Cellular vaults were built by first laying out the primary structural ribs, made of brick, with a wooden framework, and the other cells were then built, freehand, with reference to these primary ribs.

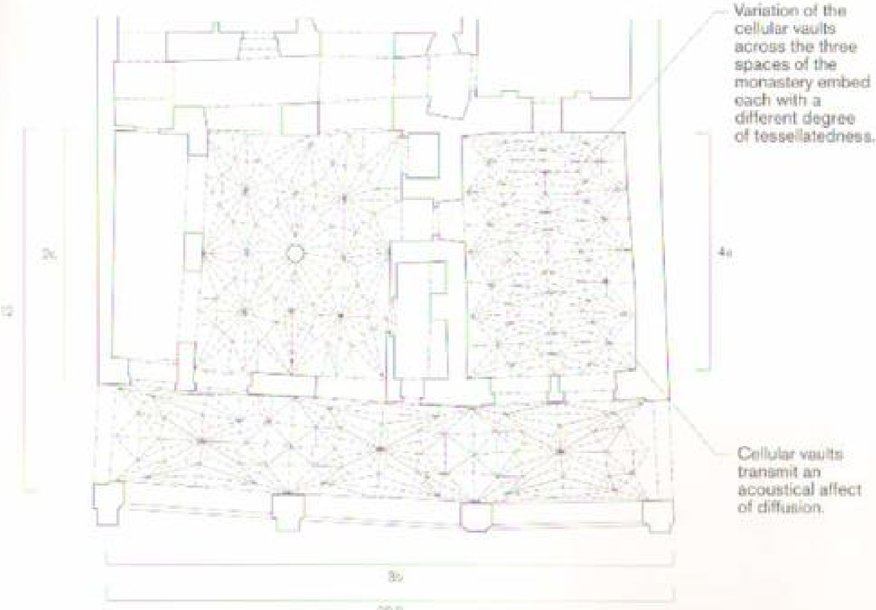
The nave the Church of the Assumption is produced by the horizontal tessellation of a cellular vault base unit, repeated and interconnected to form a series of bays. As the base unit repeats, it forms folds on the surface of the vault and introduces subdivisions at differing scales. The degree of subdivision of the vault's surface is determined by the number of surface folds, which increase as the distance from the supporting columns increases. The seams of the surface folds form a star-shaped plan, and approximate to the force lines of a fan vault. The nave of the Church of the Assumption transmits an optical affect of diamonding, cellularity and vaulting, and an acoustical affect of diffusion.

Diamonding, Cellularity, Stellatedness, Diffusion

Horizontal / Cellular Vault

COLLIN-LUTHER HOUSE | A. VON WESTFALEN | CHOMUTOV, CZECH REPUBLIC | 1500

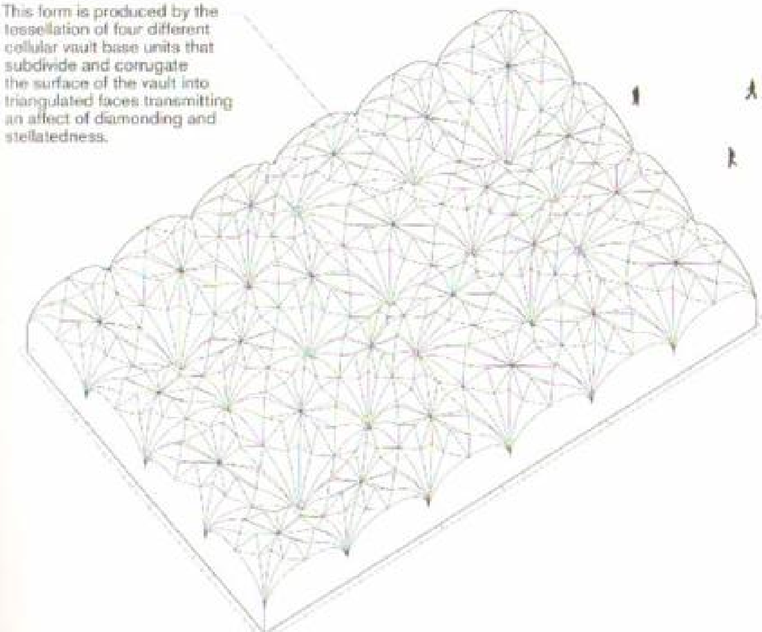


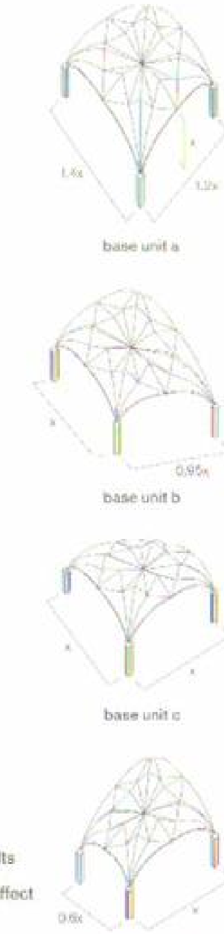


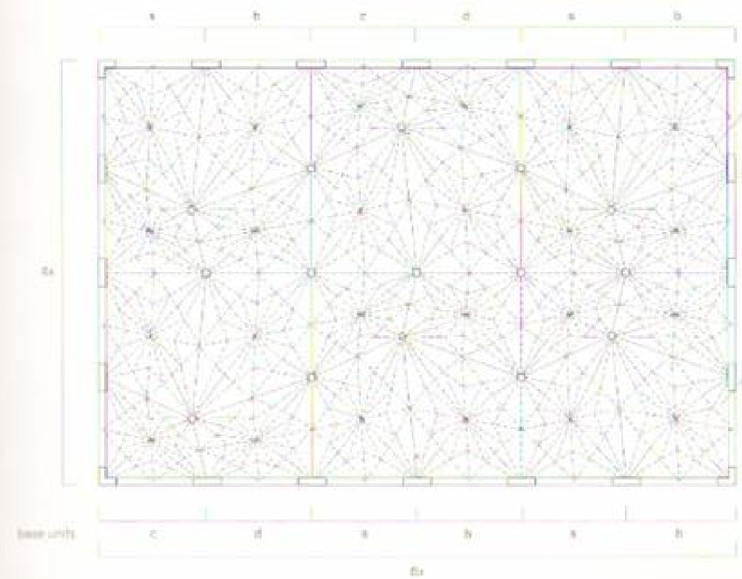
The naves of Collin Luther House are produced by the horizontal tessellation of a cellular vault base unit, repeated and interconnected irregularly to form a series of transversal and longitudinal bays. As the base unit repeats, it forms folds on the surface of the vault and introduces facets at different scales. The degree of subdivision is determined by the number of surface folds, which increases or decreases in certain bays. The seams of the surface folds form a star-shaped pattern and approximate to the force lines of a fan vault. The naves of Collin Luther House transmit an optical affect of diamonding, cellularity and stellatedness, and an acoustical affect of diffusion.

Diamonding, Cellularity, Stellatedness, Diffusion

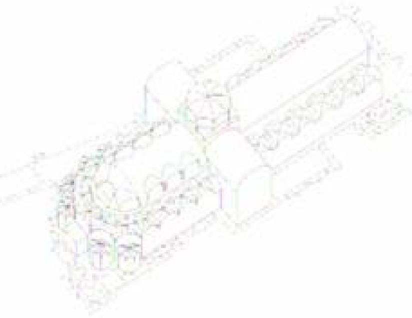
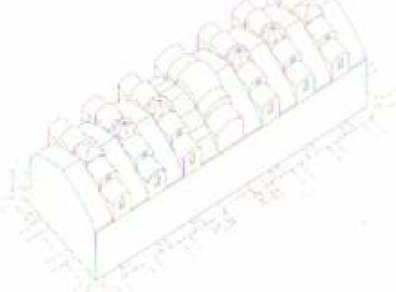
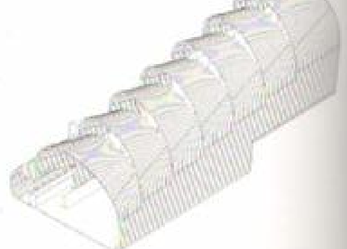
Horizontal / Cellular Vault

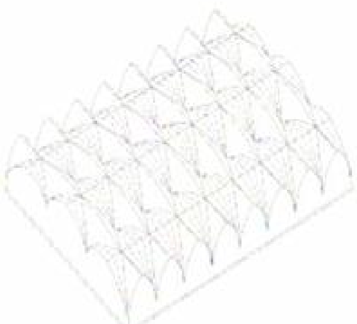
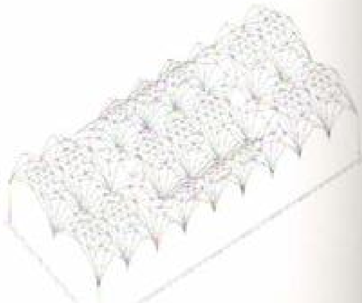
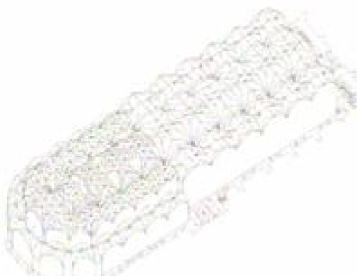
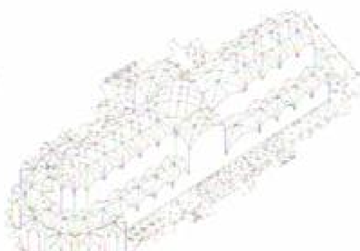
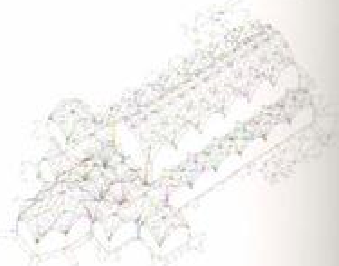


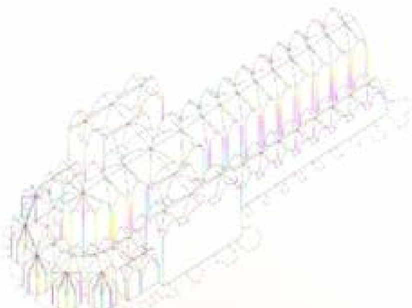
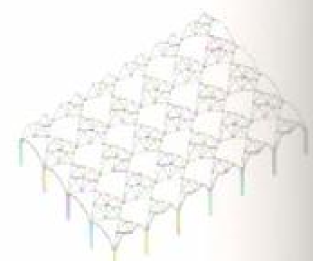


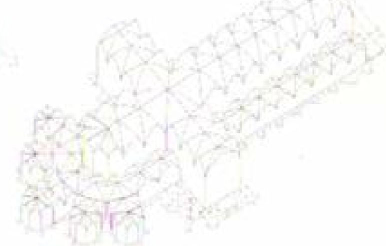
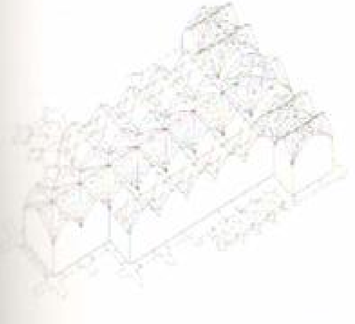
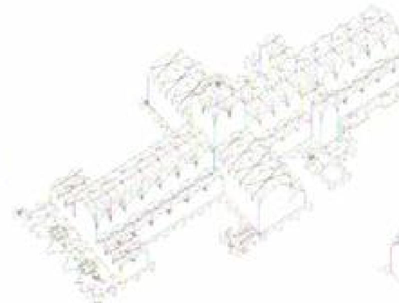
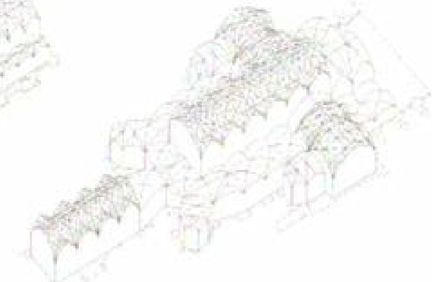
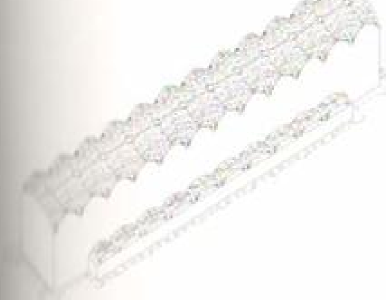
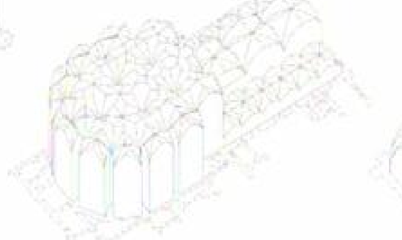


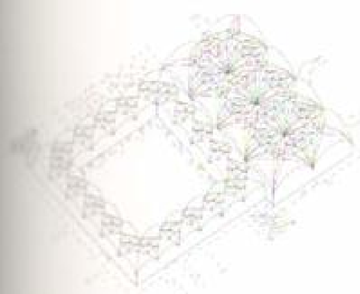
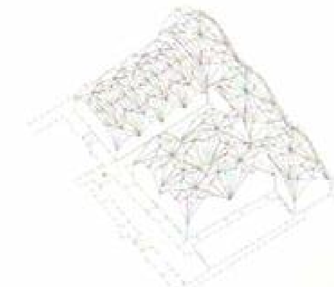
This form is produced by the horizontal tessellation of a cellular vault base unit, repeated and interconnected to create a series of irregular bays. The base unit repeats to subdivide the surface of the vault into facets. The degree of subdivision of the vault's surface is determined by the number of surface folds, which span from the supporting columns and are irregularly distributed. The seams of the surface folds approximate to the force lines of a fan vault. This vault frame assemblage transmits an optical affect of diamonding, cellularity and stellatedness, and an acoustical affect of diffusion.

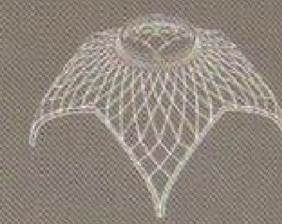

Domes are composed of surfaces or surfaces and ribs that distribute loads in plane or along the ribs. Surface domes have greatest efficiency when resisting evenly distributed loads. Ribbed domes have a greater capacity to resist asymmetrical loading. Domes can vary in kind according to the way they direct loads toward the ground. Accordingly, the system of domes is divided into seven primary subsystems: surface domes, ribbed domes, stacked arch domes, yazdi-bandi domes, kar-bandi domes, kaseh-sazi domes and muqarnas domes. These subsystems are determined by the way loads are distributed along the surfaces or lines of the domes, and the degree of subdivision of their surfaces. This analysis has not specifically addressed resistance to lateral loads.

Surface domes distribute loads along a continuous surface.
Ribbed domes distribute loads along the ribs and along the infill surfaces between them.
Stacked arched domes distribute loads along their corbelled arches.
Yazdi-bandi domes distribute loads along a surface which is composed of interlocking diamond-shaped modules.
Kar-bandi domes distribute loads along a surface which is formed by cross vaults and pendentives. A small dome is often used to cover the oculus produced by the combination of cross vaults and pendentives.
Kaseh-sazi domes distribute loads along a surface which is formed by shallow domes resting on a set of pendentives and pointed arches.
Muqarnas domes distribute loads along a highly subdivided surface, formed by the stacking of a series of horizontal tracks which are in turn composed of four repeating corbelled elements.

Surface Dome

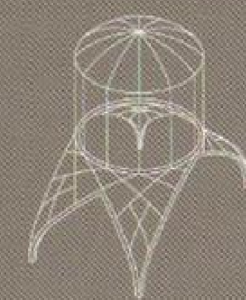
Ribbed Dome

Stacked Arch Dome

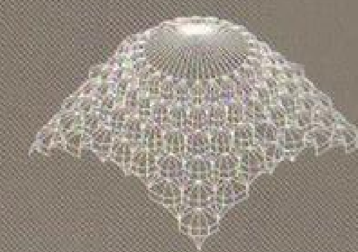


Yazdi-Bandi Dome

Kar-Bandi Dome



Kaseh-Sazi Dome

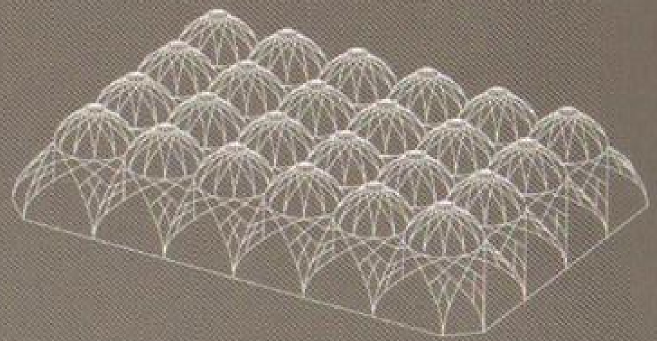


Muqarnas Dome

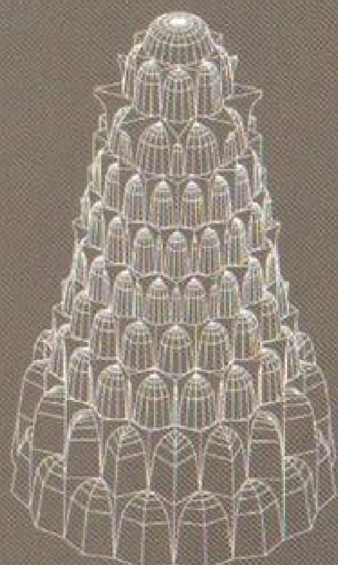
Domes tessellate along horizontal and vertical axes of growth to produce horizontal and vertical structural forms.

Horizontal tessellation can occur in all seven of the subsystems, since the protogeometry allows loads to be distributed along the horizontal axis. This is achieved by distributing structural forces along lines and surfaces to create horizontal assemblages. All horizontal tessellations form shed-like structures that may vary in section or ground plan according to variations in the domes as they grow along the horizontal axis. Changes in section which are caused by the intersection of base units composed of multiple domes allow flexibility in the shape of the ground plan and can generate a range of complex forms.

Vertical tessellation can occur in all seven of the subsystems, given that the protogeometry of a dome is able to respond to the three-dimensional bending moment which is characteristic of a vertical structure. The vertical tessellation of domes can result in structural forms that vary in plan and profile along the vertical axis of growth.



Horizontal Tessellation



Vertical Tessellation

The base unit of a surface dome consists of an arch rotated around its vertical axis to form a smooth surface. Vertical loads are carried by a combination of arching (in-plane forces) and bending moments within the shell. Surface domes are circular in plan, and additional arches and pendentives are required to integrate them with a square or polygonal plan. Surface domes can be made of masonry or reinforced, thin-shell concrete. The distribution of loads along the lines and surfaces embeds domes with an optical affective property of enclosure and non-orientedness that remains consistent within any space they define. Near its center of curvature, the concave surface of a basic dome focuses sound. At a distance from the center, sound can be diffused. The extent to which sound is diffused depends upon its spectrum. A dome that is large and low has an acoustical affect of focusing, whereas a dome that is small or high has one of diffusion. The acoustical affect of focusing of a dome is much stronger than that of a vault but, like the vault, the affect can be modified by ribbing, pleating and scalloping. This adds diffusion, which may become the dominant affect. Other dome subsystems can have a multiplicity of focal points. These add diffusion, which may become the dominant affect.

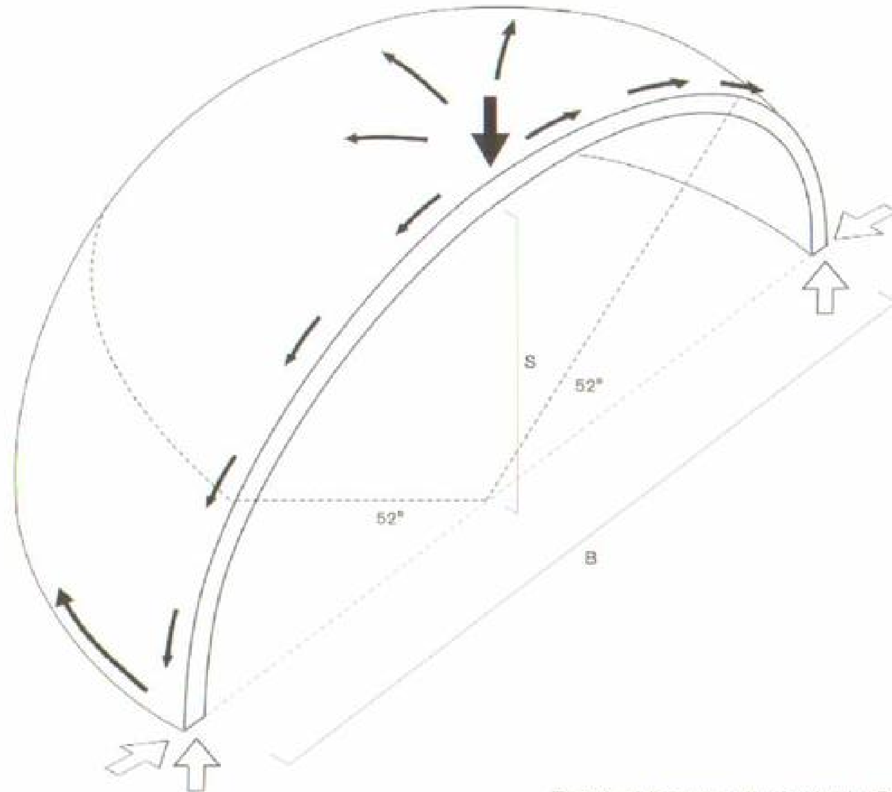
Surface domes are flexible in several ways:

Scale: The protogeometry of the surface dome can be flexible in the range of curvature of its section and in the variety of plan forms that can be generated by its aggregation with smaller half-domes, side arches, or pendentives.

Depth: The range of curvature of the dome's section can vary its overall depth, ranging from shallow to steep.

Profile: Surface domes can tessellate concentrically and horizontally along straight or curved lines of growth to produce horizontal or curved structures.

Affect: The optical affective property of a surface dome 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 enclosure and non-orientedness, a surface dome can transmit other optical affects, including axiality, cruciformity, scalloping, faceting, multi-scaling. The acoustical affect is focusing, although at a distance from the center it can become diffusion.



The ratio of these two actions is related to B/S.

As B/S goes to 12, bending predominates;

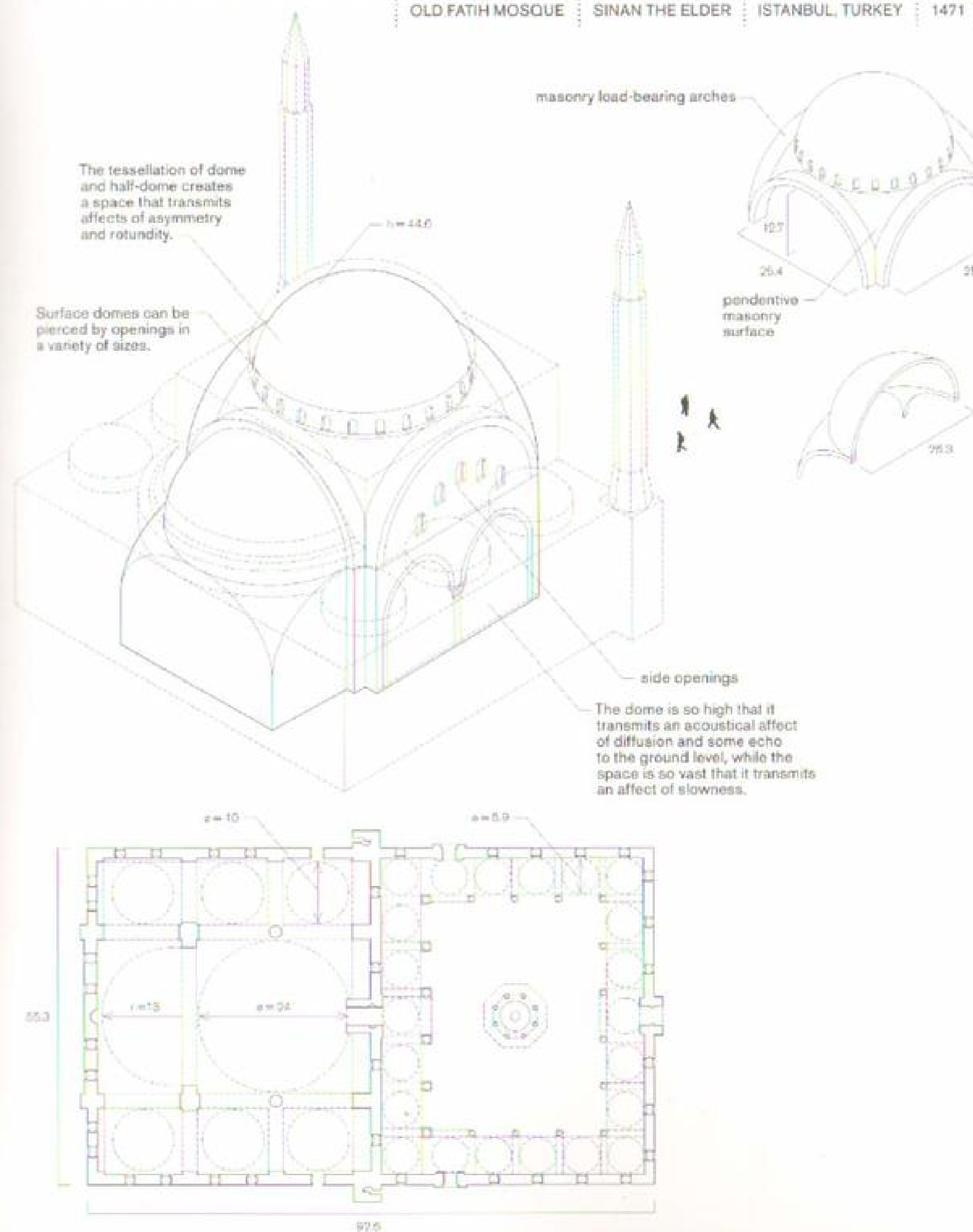
as B/S goes to 4, arching predominates.

The geometry of a shell tends to be governed by the self weight of the unit and the distribution of external loads to be carried by the unit. The aim is to alter the geometry to achieve predominantly axial internal forces and minimize bending moments.

Asymmetry, Rotundity, Diffusion, Slowness

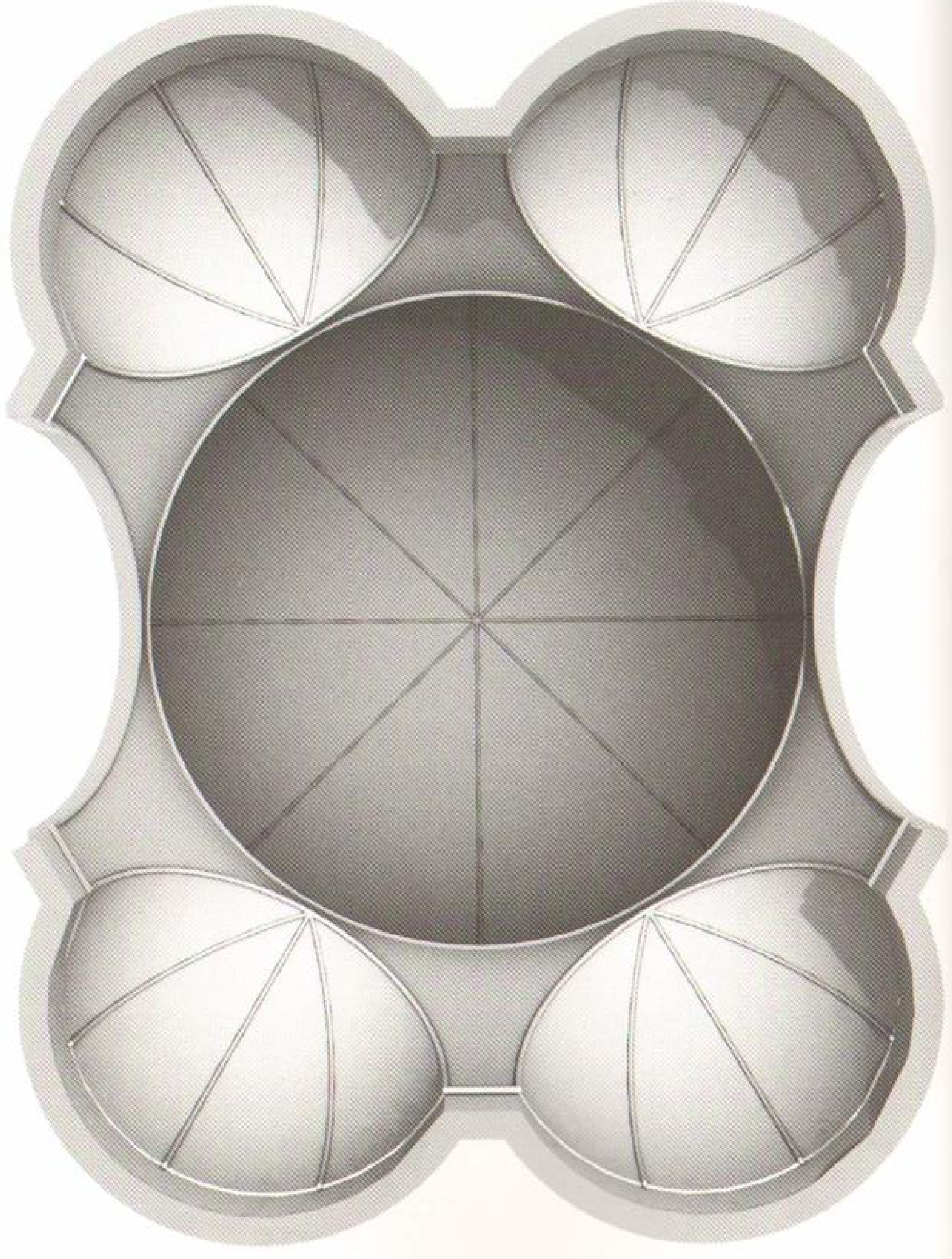
Horizontal / Surface Dome

OLD FATIH MOSQUE | SINAN THE ELDER | ISTANBUL, TURKEY | 1471



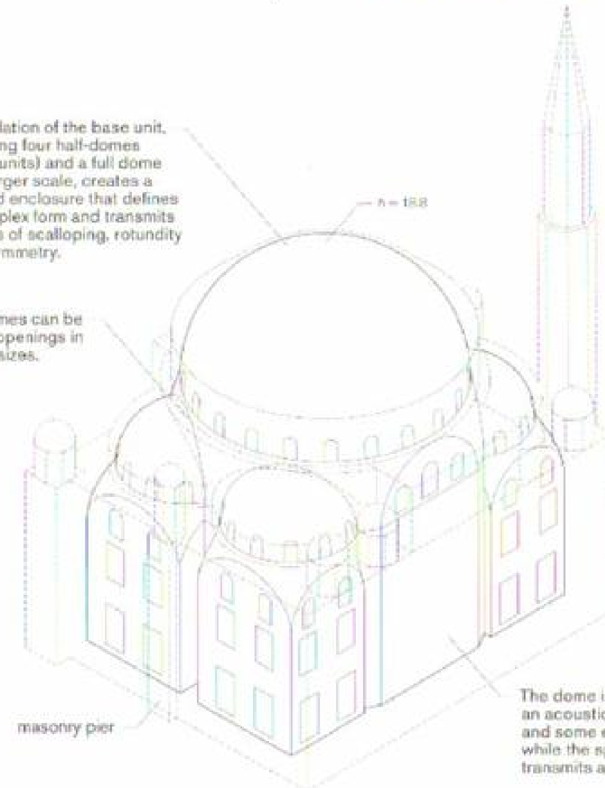
Old Fatih mosque is formed by the horizontal tessellation of a surface dome base unit, repeated, scaled and interconnected by arches and pendentives. The base unit is scaled down as it repeats, starting from the space under the full dome in the center and subdividing into a combination of a half-dome with smaller domes along the perimeter. The degree to which the main dome scales and subdivides varies. The scale decreases towards the bays along the perimeter, where the half-domes and smaller domes are interconnected by pendentives and arches. This assemblage transmits an optical affect of asymmetry and rotundity, and an acoustical affect of diffusion, echo and slowness.

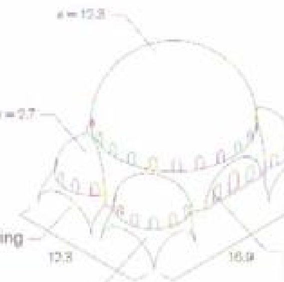
Scalloping, Rotundity, Symmetry, Diffusion, Slowness

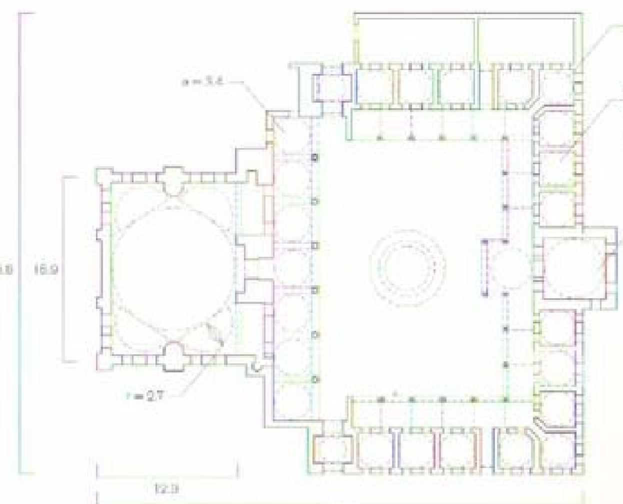


Horizontal / Surface Dome

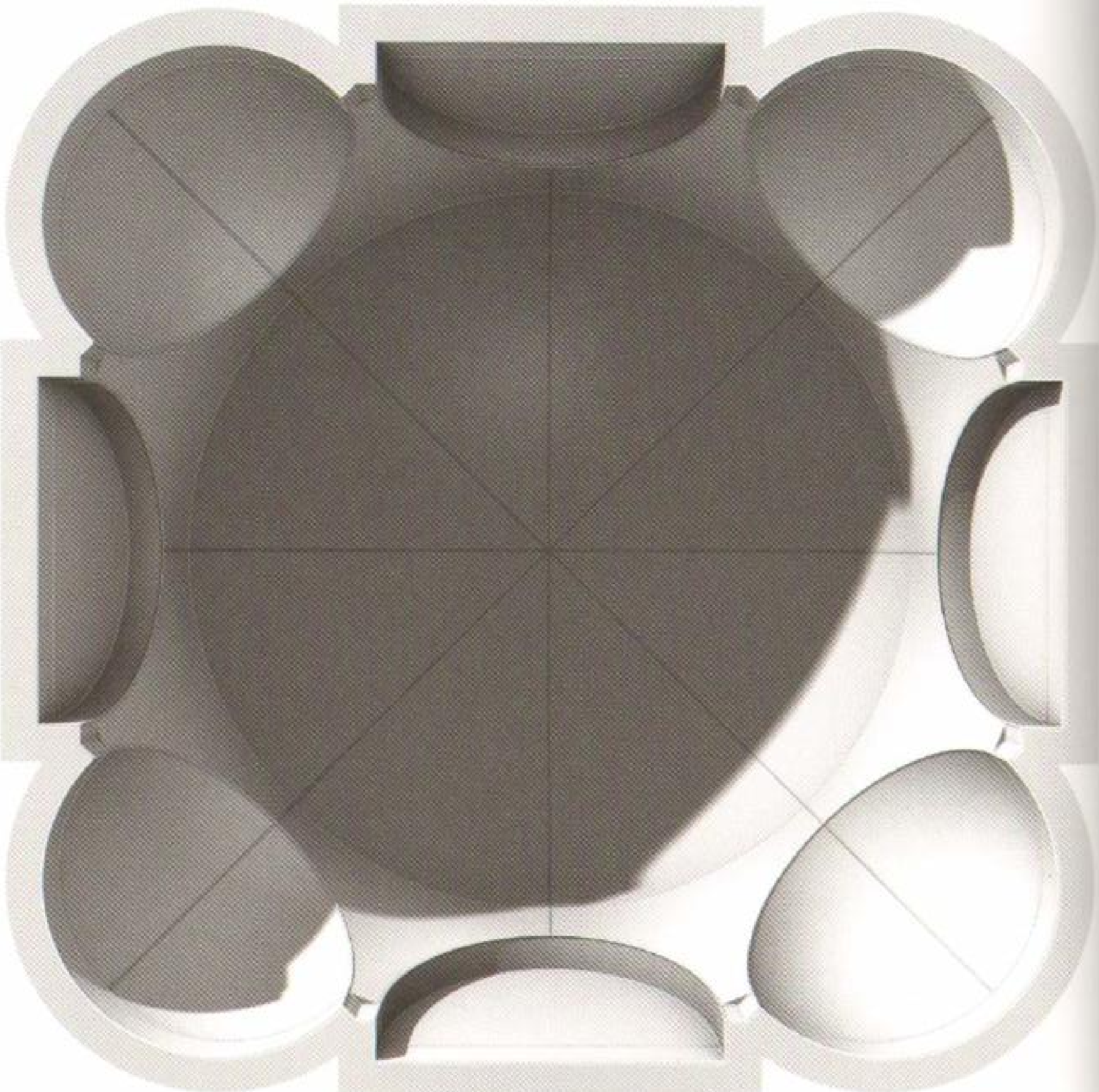
SOKULLU MEHMET PASHA MOSQUE | SINAN | ISTANBUL, TURKEY | 1571



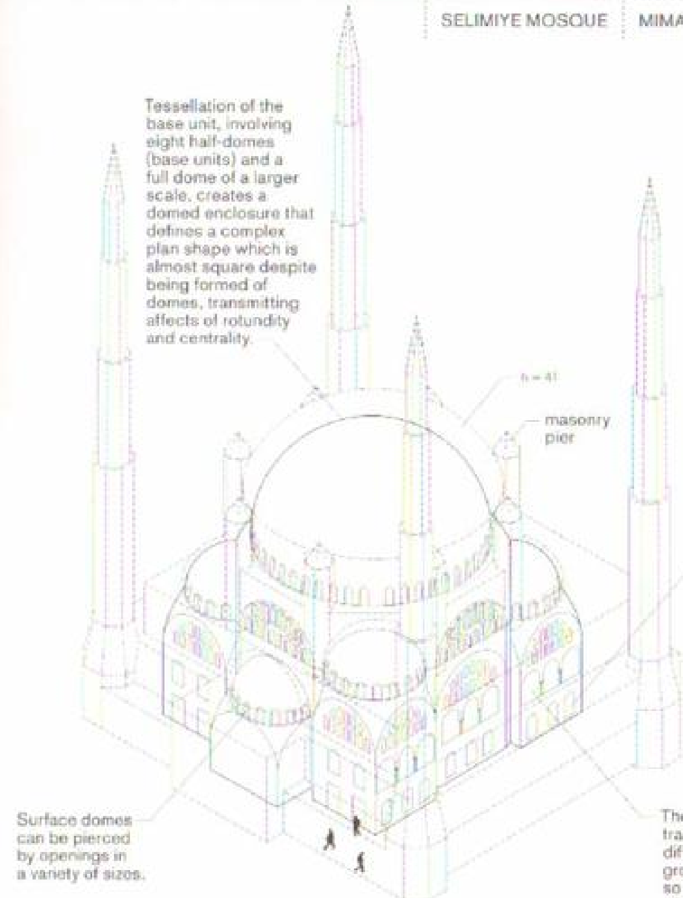


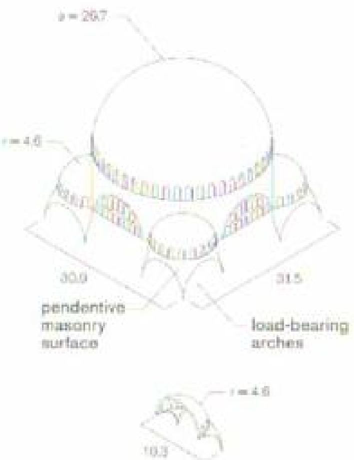


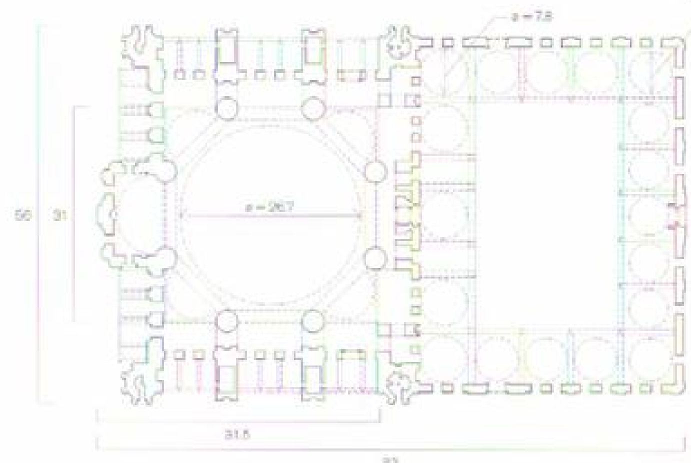
Sokullu Mehmet Pasha is formed by the horizontal tessellation of a surface dome base unit, repeated, scaled and interconnected by arches and pendentives. The base unit is scaled down as it repeats. The transition from the circular plan of the main dome to the square plan of the perimeter is achieved by four smaller half-domes located at the corners of the square plan. The degree to which the main dome scales down determines the transition between the circular and the square plans, with the central dome interconnected with the half-domes by a set of four arches and six pendentives. Sokullu Mehmet Pasha transmits an optical affect of scalloping, rotundity and symmetry, and an acoustical affect of diffusion and slowness.



SELIMIYE MOSQUE | MIMAR SINAN | EDIRNE, TURKEY | 1568–74

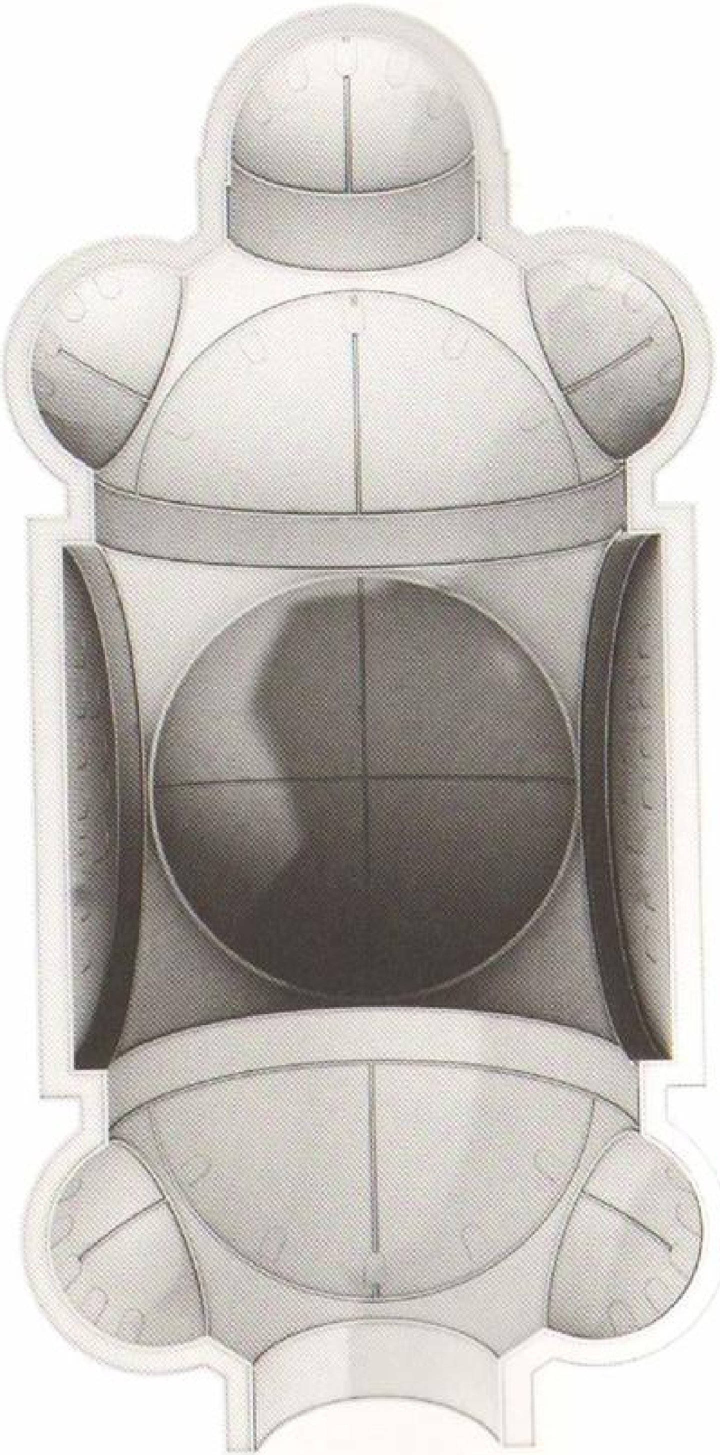






Selimiye mosque is formed by the horizontal tessellation of a surface dome base unit, repeated, scaled and interconnected by arches and pendentives. As the base unit repeats and is scaled down, it divides into five half-domes which are situated at the perimeter of the main dome to serve as a transition from the circular plan of the dome to the square plan of the perimeter. The main dome rests on a set of eight columned arches and pendentives, which give way to the five half-domes along the perimeter. Both the main dome and the half-domes are given narrow openings along their bases in order to introduce natural light into the interior. Selimiye mosque transmits an optical affect of rotundity and centrality, and an acoustical affect of diffusion and slowness.

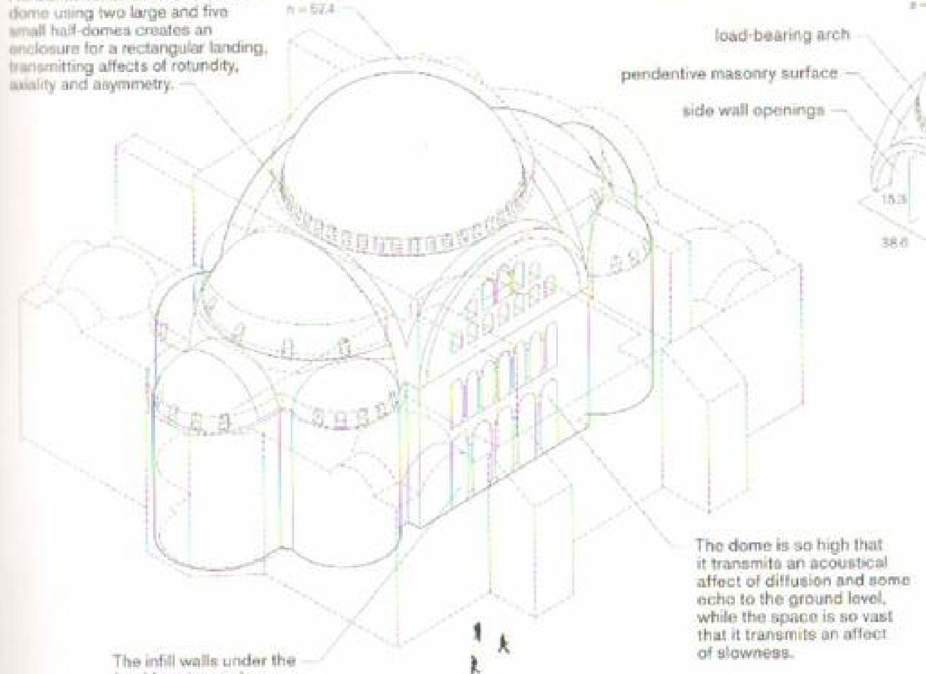
Rotundity, Axiality, Asymmetry, Diffusion, Slowness

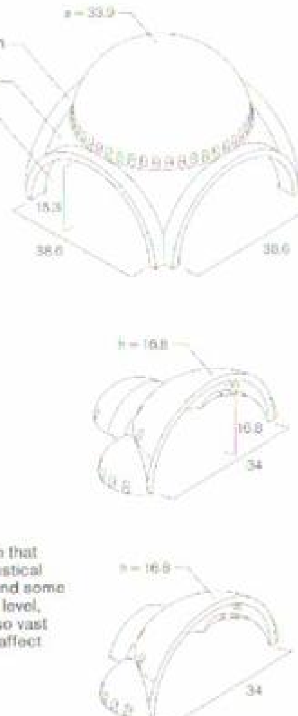


Horizontal / Surface Dome

HAGIA SOPHIA | ISIDORE, ANTHEMIUS | ISTANBUL, TURKEY | 532–37

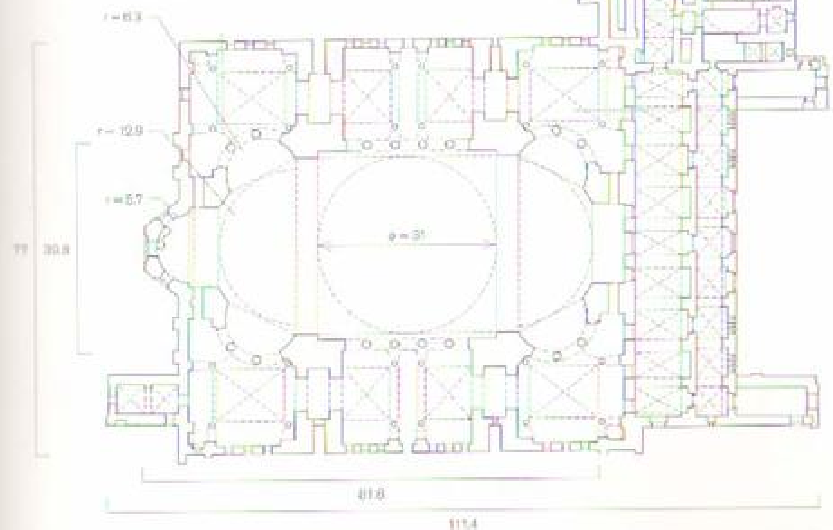
Horizontal tessellation of a surface dome using two large and five small half-domes creates an enclosure for a rectangular landing, transmitting affects of rotundity, axiality and asymmetry.



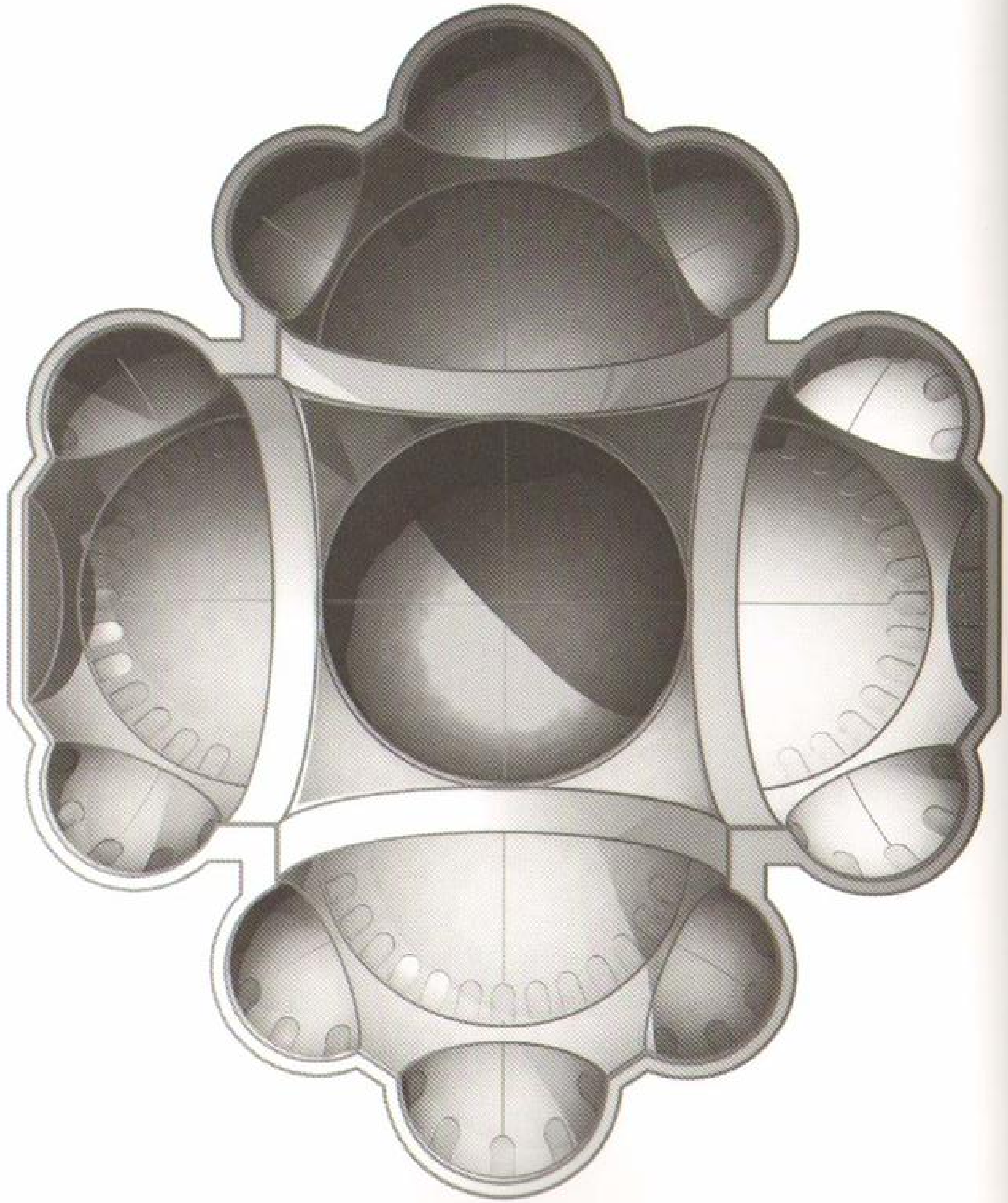


The dome is so high that it transmits an acoustical affect of diffusion and some echo to the ground level, while the space is so vast that it transmits an affect of slowness.

The infill walls under the load-bearing arches are not load-bearing and can therefore be pierced to incorporate windows and entryways.

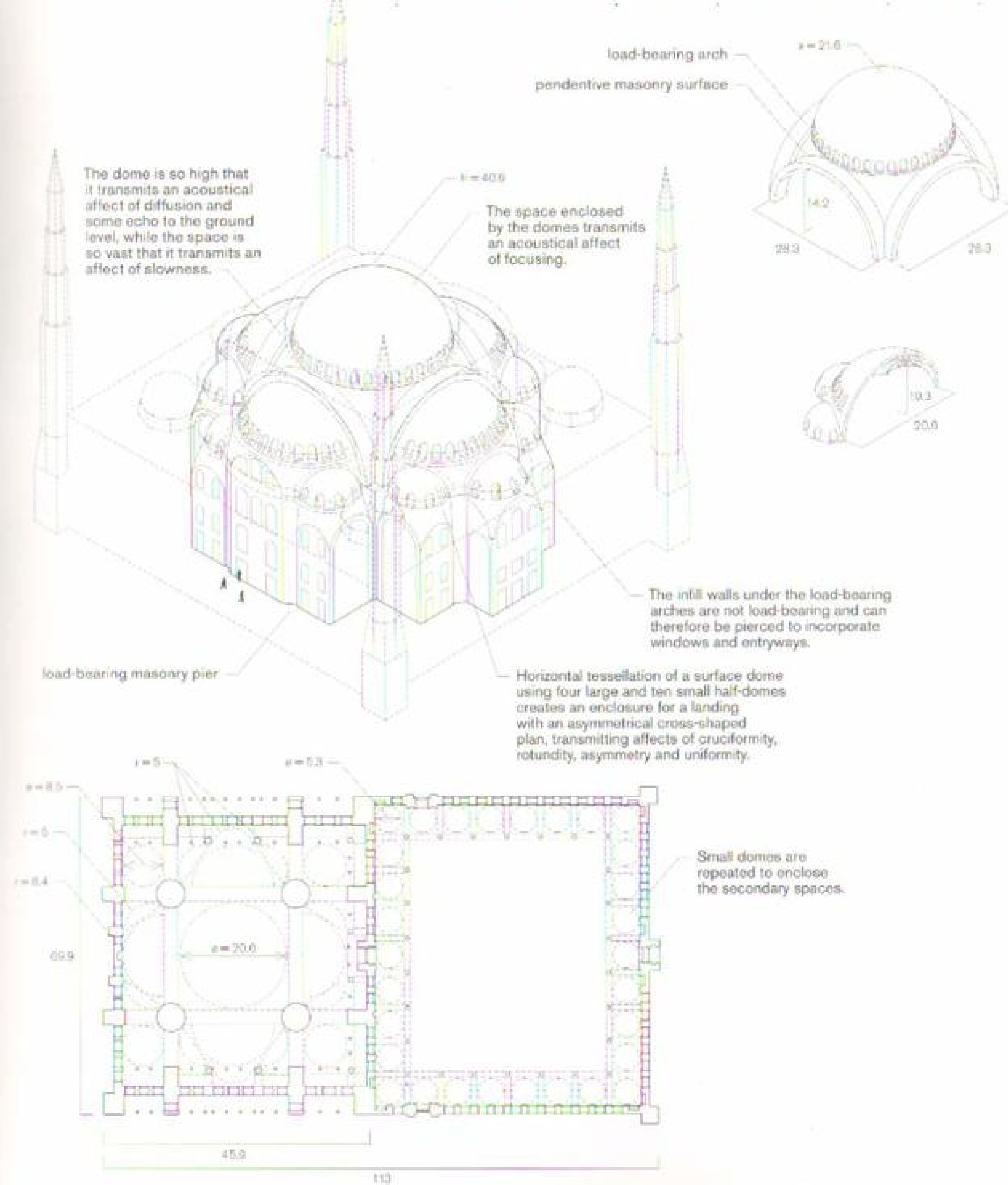


Hagia Sophia is formed by the horizontal tessellation of a surface dome base unit, repeated, scaled and interconnected by arches and pendentives. The base unit is composed of a full dome in the center, which is then repeated in the form of half-domes on two of its sides longitudinally. These two half-domes are further subdivided into two smaller half-domes each. The main dome rests on a set of four columns, arches, and pendentives, which give way to the two half-domes on two sides, and two arched elevations pierced by a large number of openings on the other two. Both the main dome and the half-domes are given narrow openings along their base in order to introduce natural light into the interior. Hagia Sophia transmits an optical affect of rotundity, asymmetry, and axiality, and an acoustical affect of diffusion and slowness.



Horizontal / Surface Dome

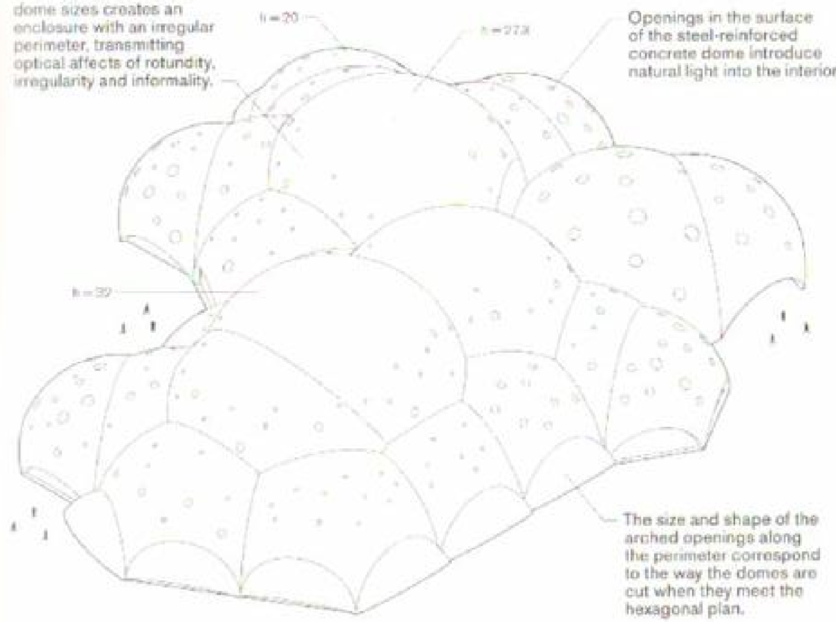
SULTAN AHMED MOSQUE | S. M. AGA | ISTANBUL, TURKEY | 1609–16

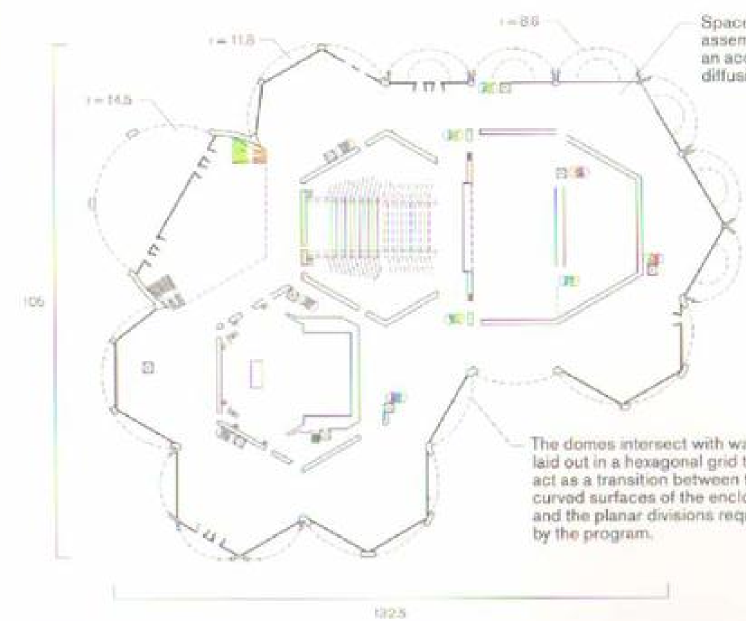


Sultan Ahmed mosque is formed by the horizontal tessellation of a surface dome base unit, scaled and interconnected by arches and pendentives. The base unit is composed of a full dome in the center, which is then repeated on the four sides as half-domes which are further subdivided into three half-domes each, in two cases, and two in the other two. The main dome rests on a set of four columned arches and pendentives that give way to the four half-domes and the smaller half-domes, which consist of one-third of their surface. Both the main dome and the half-domes are given narrow openings along their bases in order to introduce natural light into the interior. Sultan Ahmed mosque transmits an optical affect of cruciformity, rotundity, asymmetry and uniformity, and an acoustical affect of diffusion and slowness.

Horizontal / Surface Dome

NICOSIA CULTURAL CENTER | FOREIGN OFFICE ARCHITECTS | NICOSIA, CYPRUS | 2007





Nicosia Cultural Center is formed by the horizontal tessellation of a surface dome base unit, scaled and interconnected. Arches are formed by the intersections of the domes. The base unit begins as a single dome which is sectioned to fit a hexagonal plan at its base, forming six arches as the dome surface is transferred to the ground. The plan distributes and combines a series of these domes to fill a hexagonal grid. The grid is then scaled in plan to span larger or smaller areas according to the requirements of the program, and the surfaces of the domes are also scaled accordingly. Nicosia Cultural Center transmits an optical affect of rotundity, irregularity and informality, and an acoustical affect of diffusion.

Ribbed Dome

The base unit of a ribbed dome consists of a hemispherical form composed of ribs which are connected by infill surfaces. Ribbed domes direct the loads along the lines of the ribs and the infill surfaces between them. Ribbed domes can be built of masonry covered by plaster to achieve a smooth surface, but they can also be built of reinforced concrete. As with surface domes, the amount of bending to arch action varies with the geometry of the dome. Ribs are much more effective at resisting bending moments and are therefore more efficient at greater plan depth to section height (B/S) ratios. The distribution of loads along the lines of the ribs and the infill surfaces between them embeds ribbed domes with an optical affect of pleating and scalloping that remains consistent within any space they define. Near its center of curvature, the concave surface of a basic dome focuses sound, while the ribs add diffusion, the extent of which depends upon the spectrum of the sound.

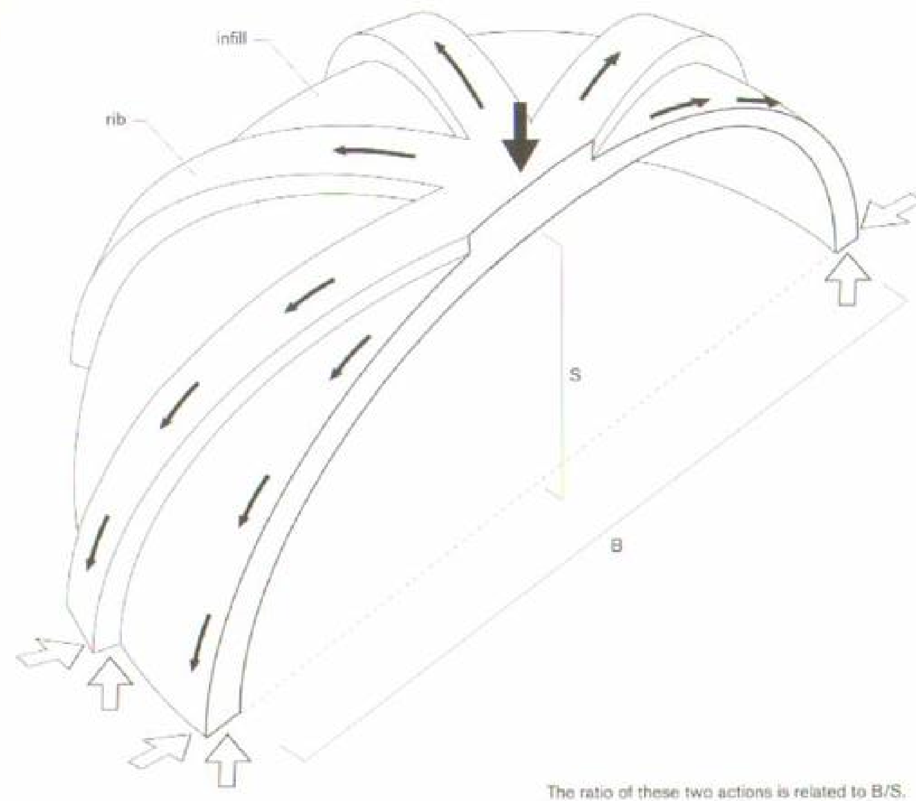
Ribbed domes can be flexible in several ways:

Scale: Different scales of apertures can be introduced on the surface of the dome, in the sections between the arches.

Depth: The protogeometry of the ribbed dome is flexible in the capacity of the corrugation to generate varied plan shapes each with different shapes.

Profile: The ribs allow the infill surfaces between to assume shapes that fall outside the curve without affecting the structural integrity of the dome. The surfaces between ribs can range from concave to convex, according to the type of plan. When the shape of the infill section departs from that of a catenary curve, the load-bearing forces of the main span are no longer shared between the ribs and the infill, and the ribs take on the primary load-bearing role.

Affect: The optical affect of a ribbed dome 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 pleating and scalloping, ribbed domes can transmit other optical affects, including verticality, rotundity, pleating, faceting, squareness, triangularity. The acoustical affect is focusing and diffusion.

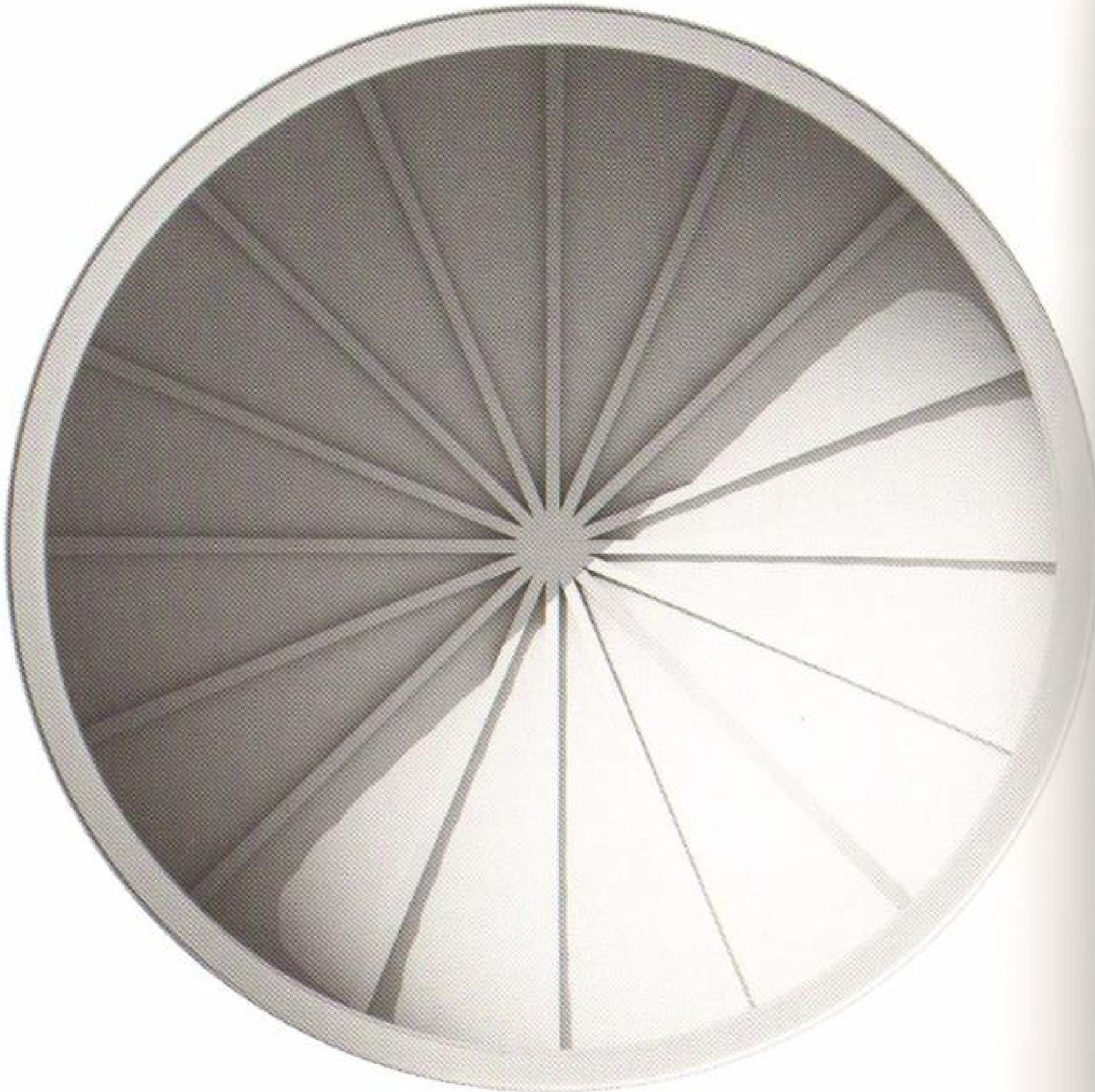


The ratio of these two actions is related to B/S.

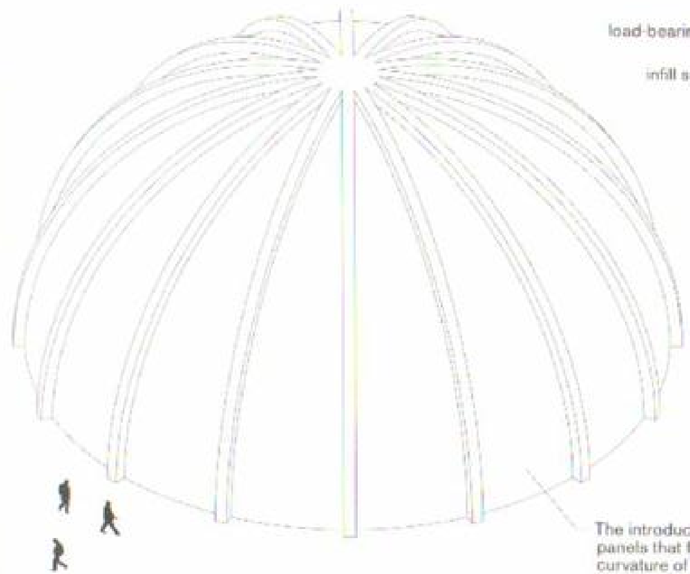
As B/S goes to 12, bending predominates;

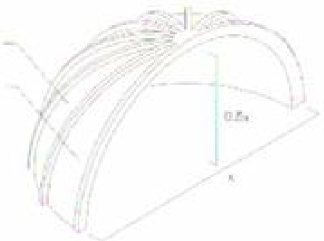
as B/S goes to 4, arching predominates.

Ribbing, Roundness, Uniformity, Focusing

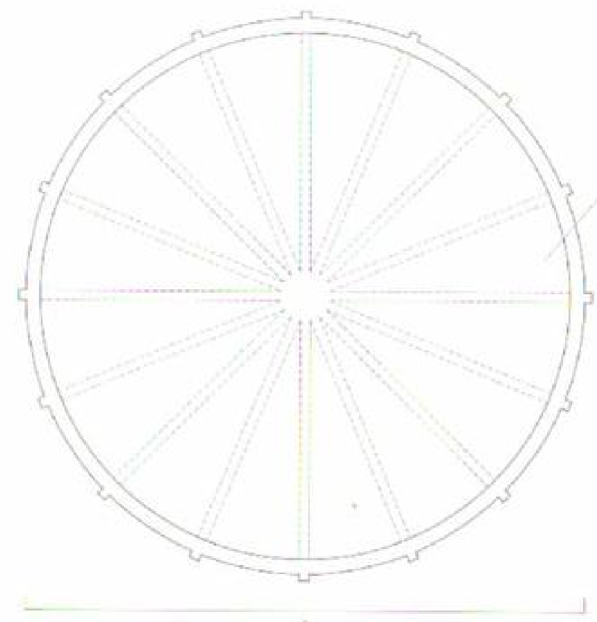


Horizontal / Ribbed Dome





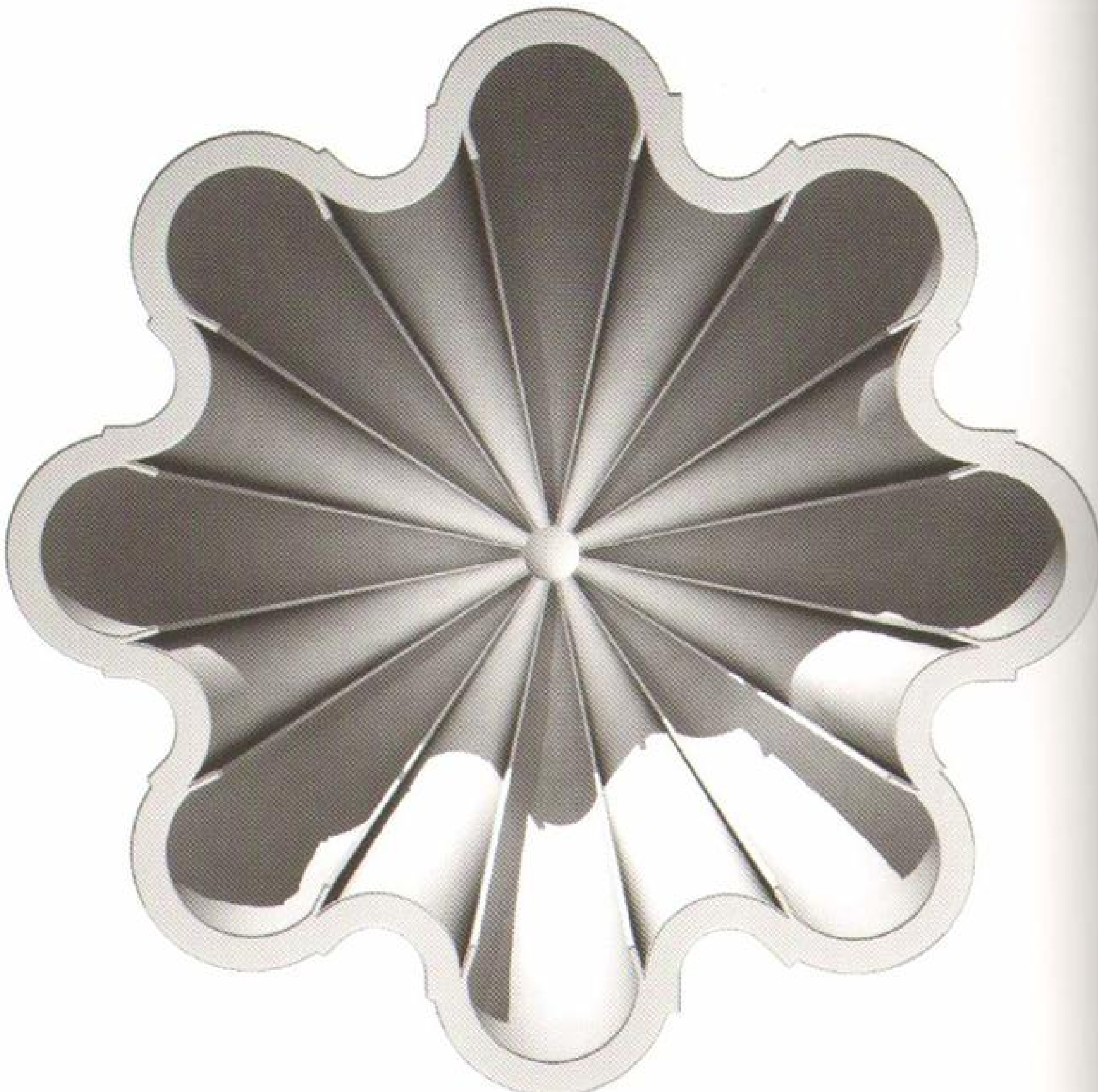
The introduction of infill panels that follow the curvature of the ribs creates a dome perimeter that transmits an affect of roundness and uniformity.

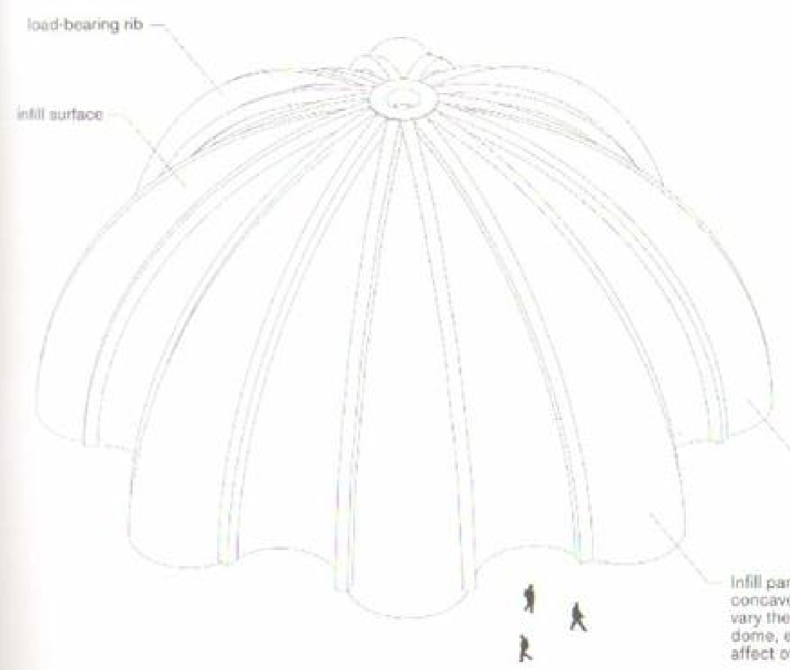


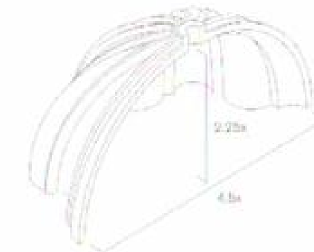
Space enclosed by this ribbed dome transmits an acoustical affect of focusing.

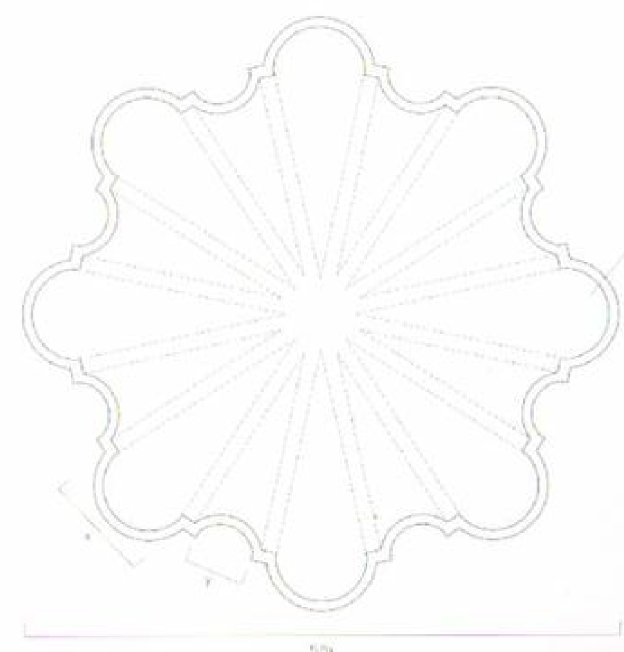
This ribbed dome is formed by the horizontal tessellation of a ribbed dome base unit, composed of nine arched ribs radiating from a central point and infill surfaces. A single repetition of the half-dome creates a full dome that transmits an optical affect of ribbing, roundness and uniformity, and an acoustical affect of focusing.

Horizontal / Ribbed Dome



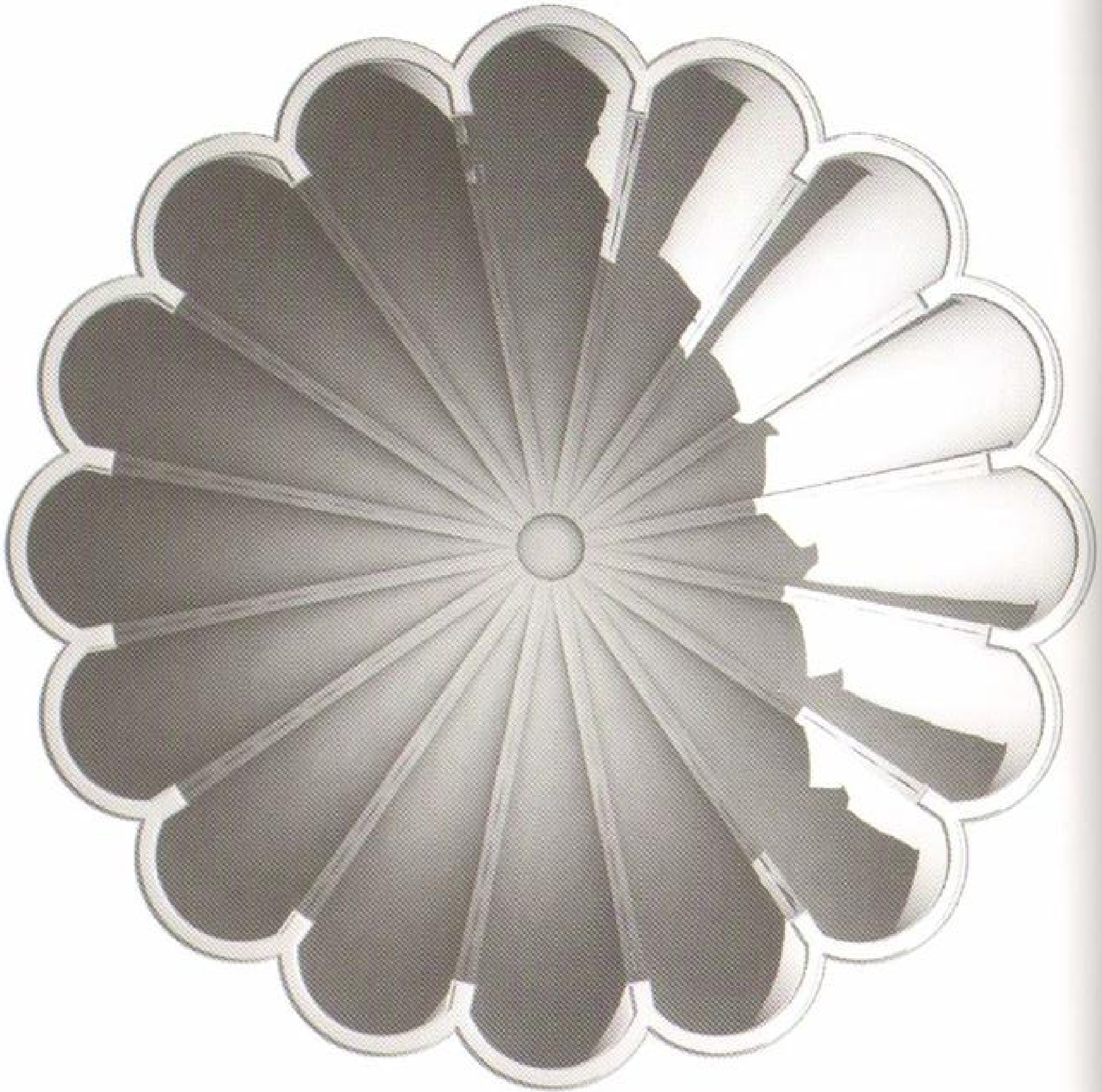




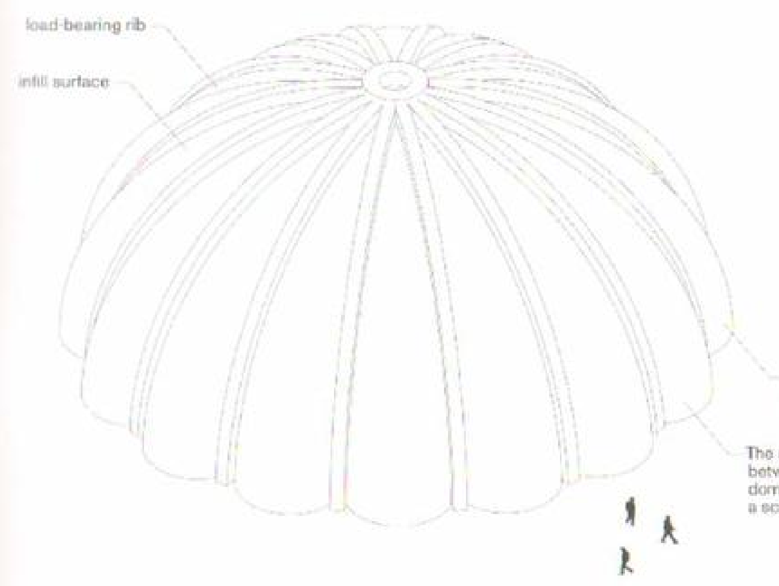


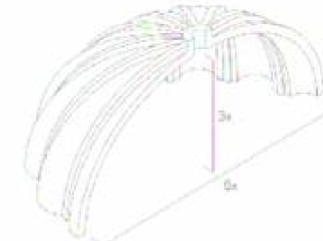
This ribbed dome is formed by the horizontal tessellation of a ribbed dome base unit, formed by nine arched ribs, equally spaced, and curved infill surfaces. A single repetition of the base unit creates a full dome that transmits optical affects of pleating and undulation, and an acoustical affect of focusing and diffusion.

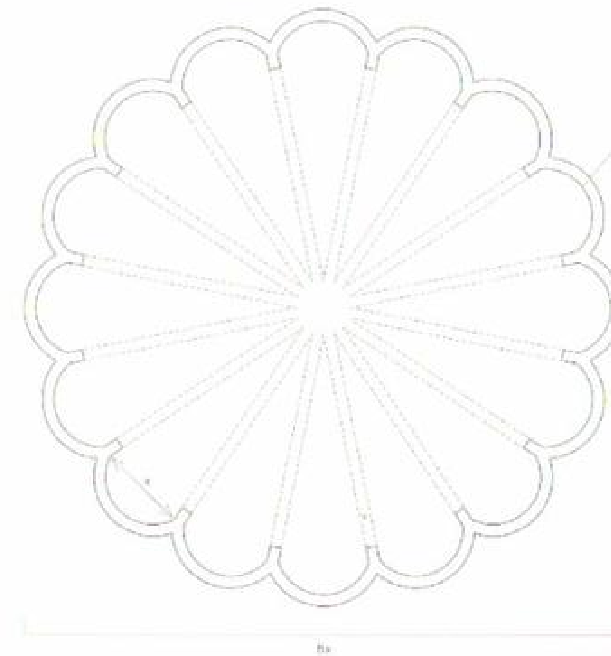
Pleating, Scalloping, Diffusion, Focusing



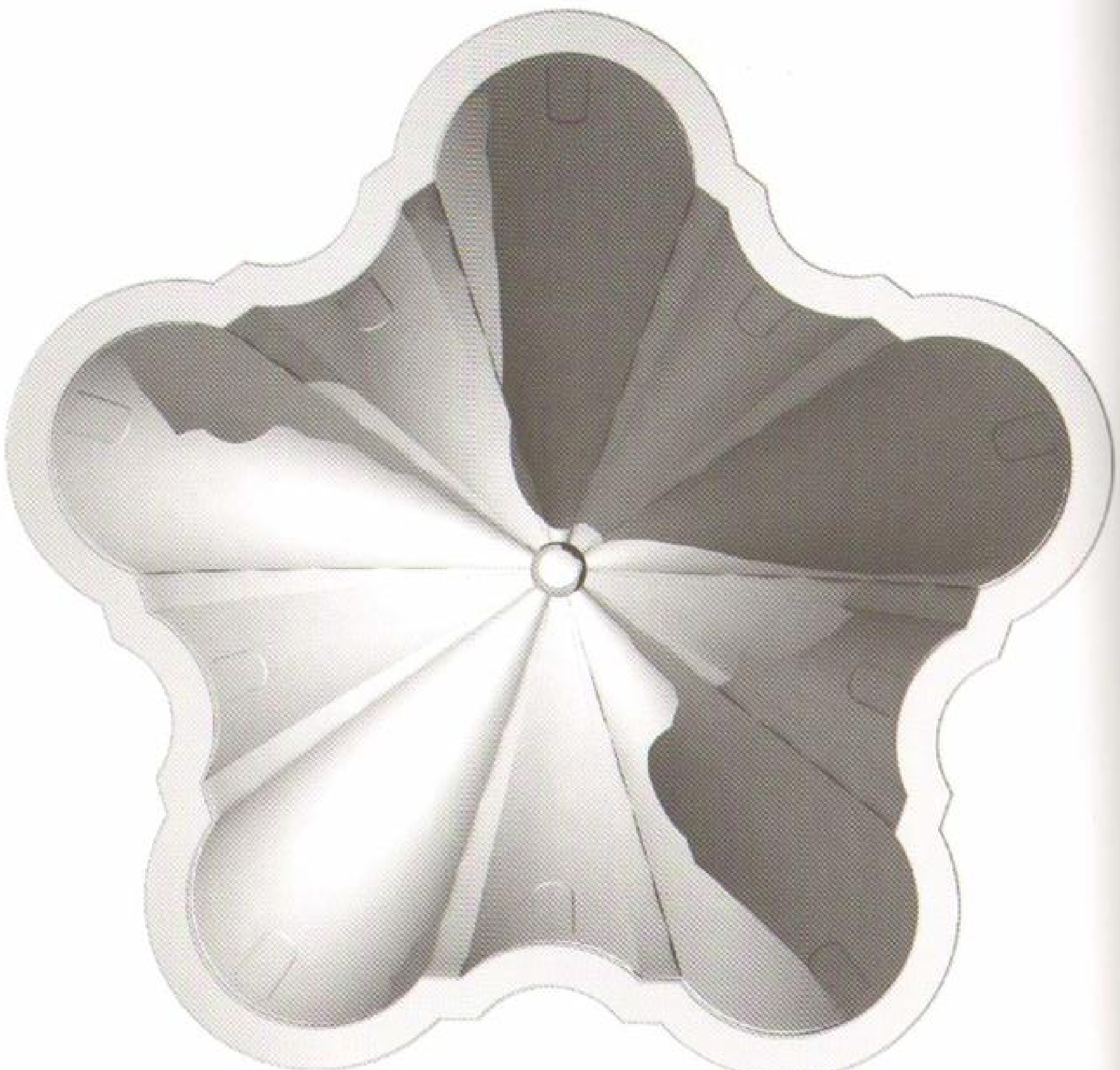
Horizontal / Ribbed Dome

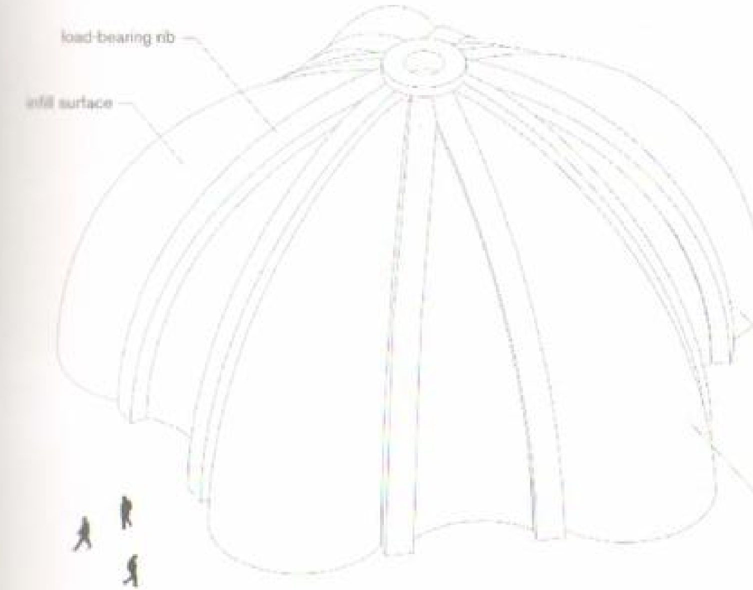


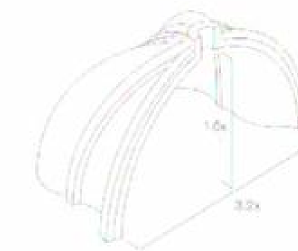




This ribbed dome is formed by the horizontal tessellation of a ribbed dome base unit, composed of nine arched ribs, equally spaced, and infill surfaces which are concave in section. A single repetition of the base unit creates a full dome that transmits optical affects of pleating and scalloping, and an acoustical affect of diffusion and focusing.

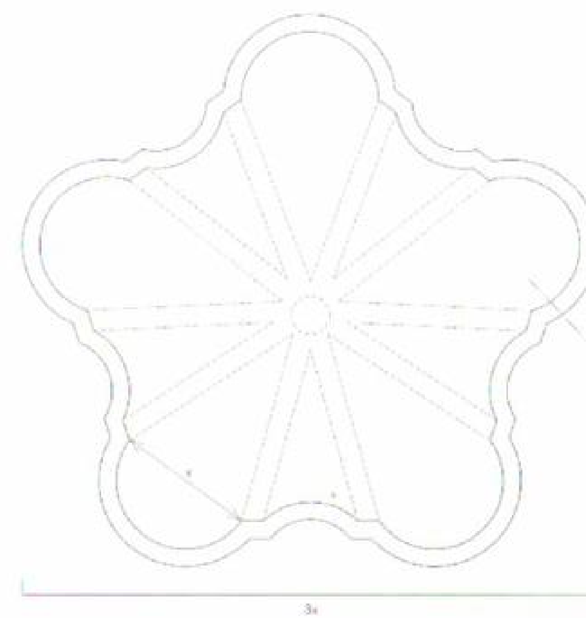






Primary loads are concentrated on the ribs, liberating the infill panels.

Infill panels alternating between concave and convex curvatures vary the perimeter of a simple dome, embedding it with an affect of pleating and scalloping.

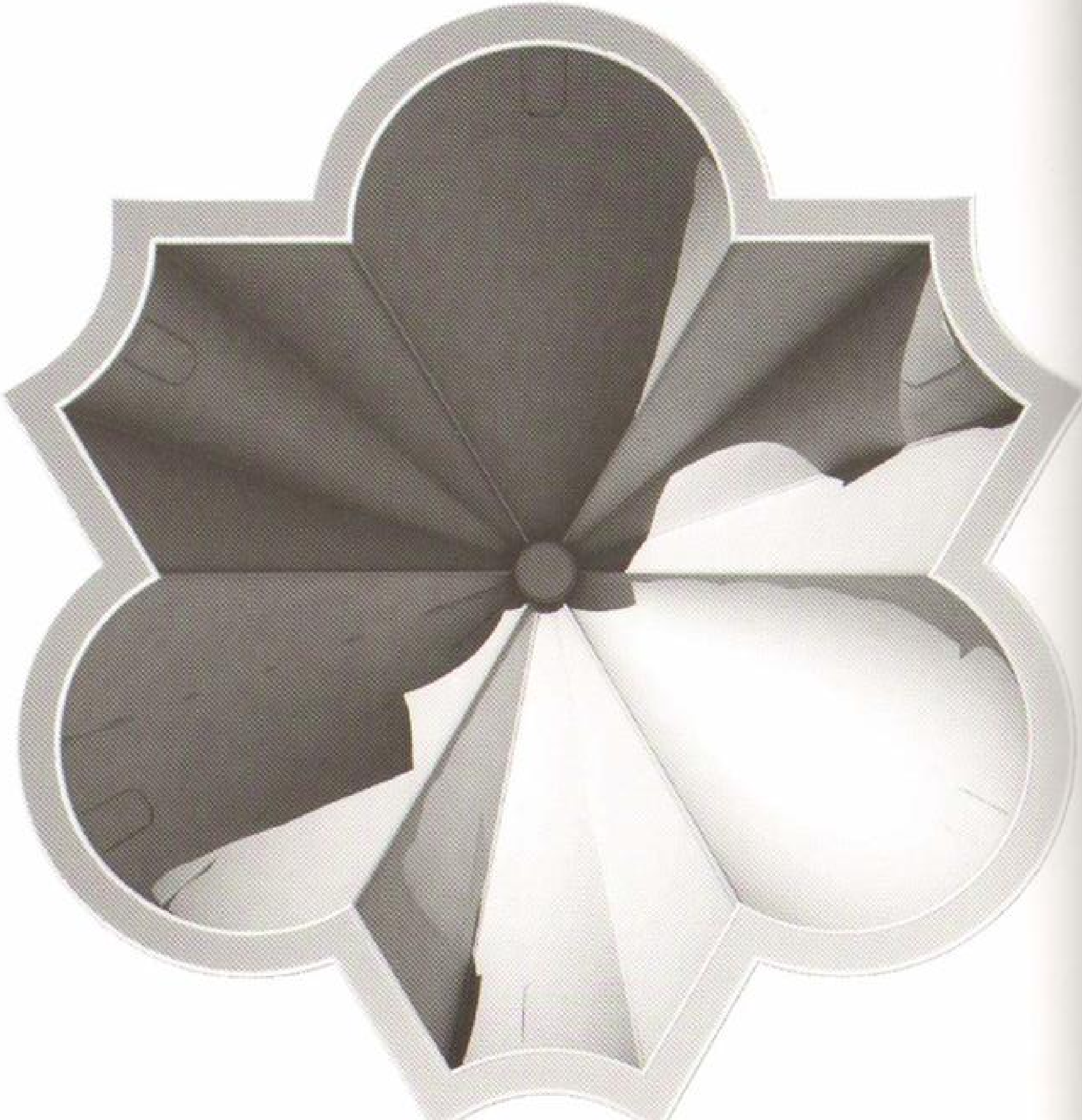


Unequal spacing of the ribs together with the use of concave and convex infill panels creates a star-shaped dome with a perimeter that transmits a scalloping affect.

Space enclosed by a ribbed dome transmits an acoustical affect of focusing or diffusion, depending upon the spectrum of the sound.

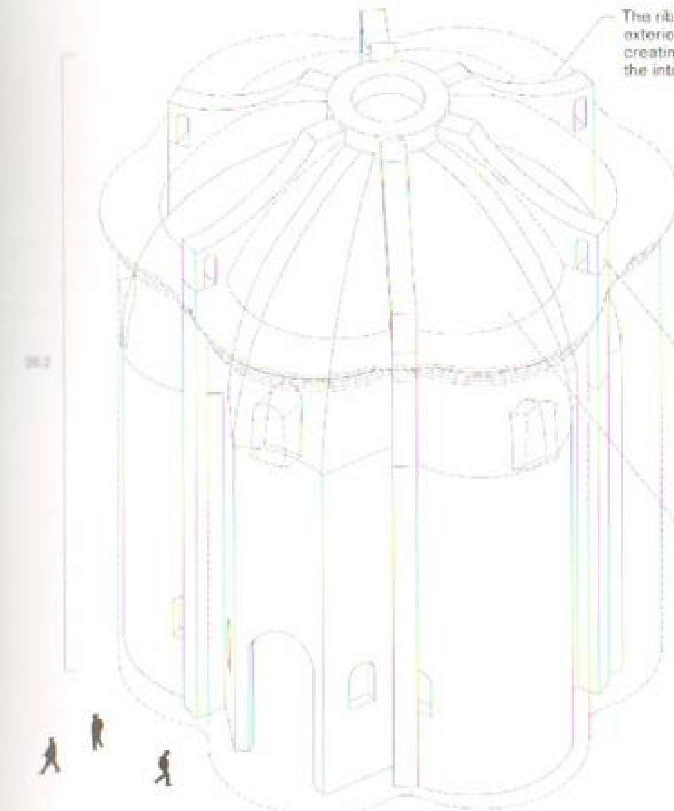
This ribbed dome is formed by the horizontal tessellation of a ribbed dome base unit, composed of six arched ribs, unequally spaced, and infill panels which are alternately concave or convex in section, deepening the curvature of the dome surface. A single repetition of the base unit creates a full dome that transmits optical affects of pleating and scalloping, and an acoustical affect of diffusion.

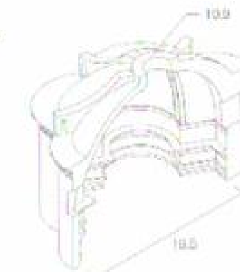
Pleating, Scalloping, Diffusion

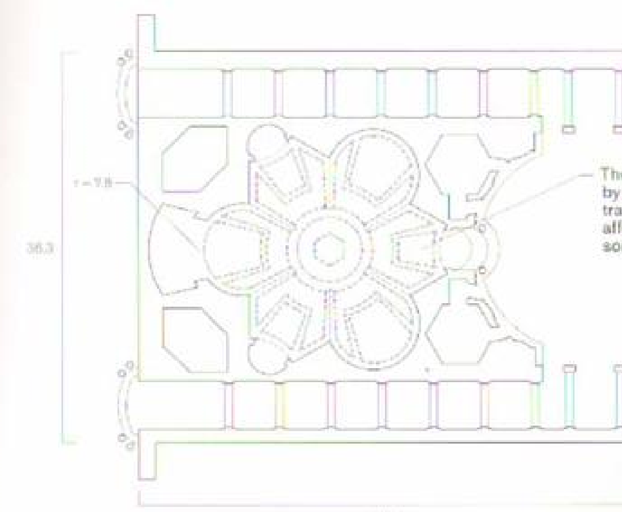


Horizontal / Ribbed Dome

CHURCH OF SANT'IVO ALLA SAPIENZA | F. BORROMINI | ROME, ITALY | 1642–50





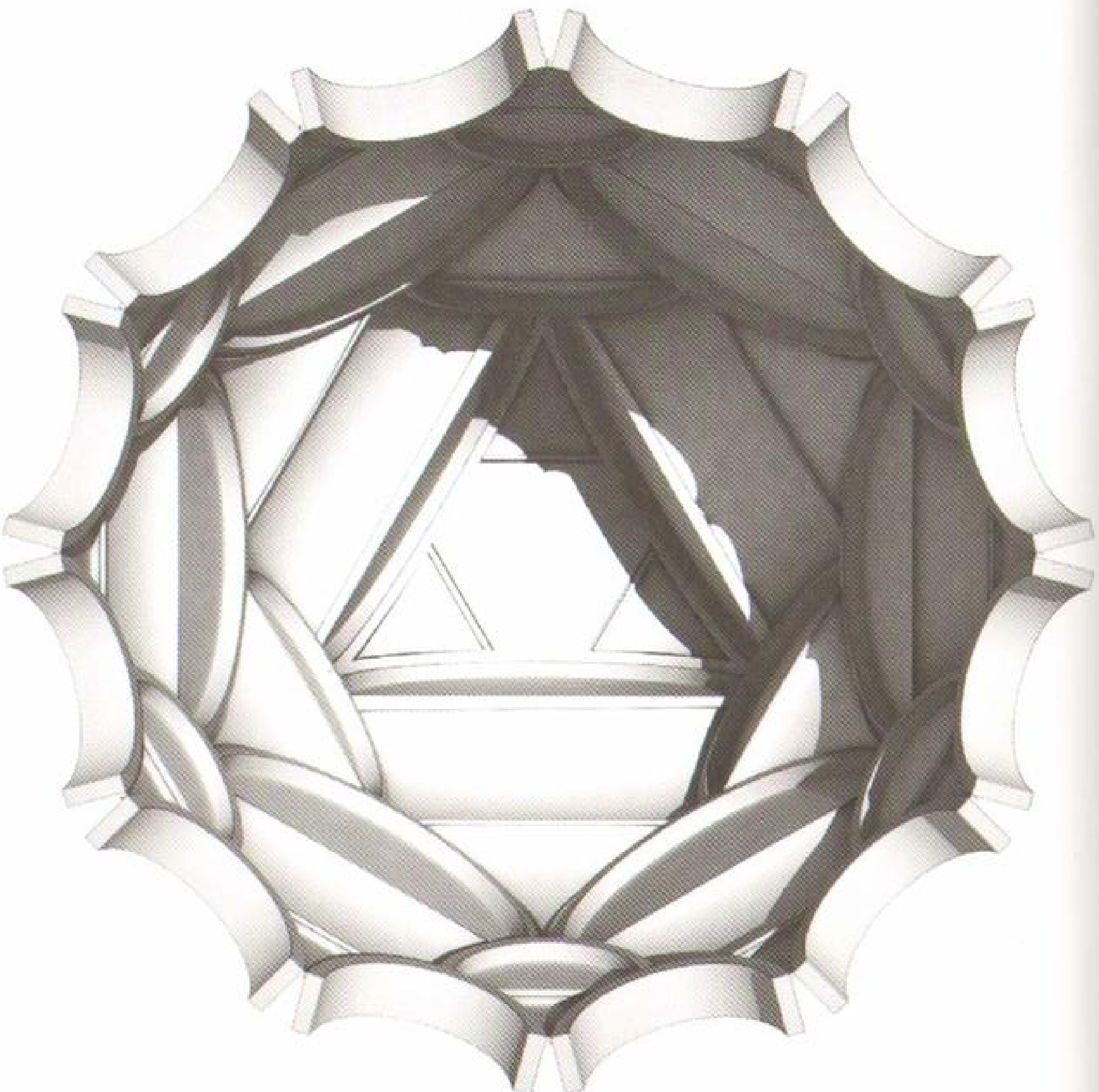


The dome of the Church of St. Ivo is formed by the horizontal tessellation of a ribbed dome base unit, a half-dome composed of four arched ribs, unequally spaced, and infill panels which are alternately concave or convex in section, deepening the curvature of the dome surface. A single repetition of the base unit creates a full dome that transmits optical affects of pleating and scalloping, and an acoustical affect of diffusion.

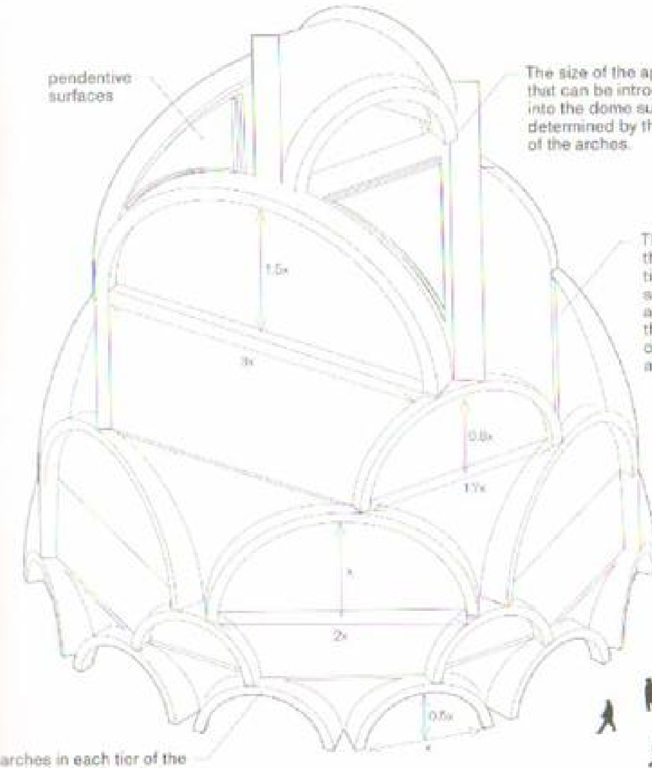
The base unit of a stacked arch dome is composed of a tier of corbelled arches that form a regular polygon in plan. Similarly to a kar-bandi dome, a stacked arch dome is composed of an open-top ring around which the first tier of arches is arrayed. The arches grow in size progressively toward the base, transferring the loads downward to the braced keystones of the nested arches. Each polygon is rotated so that its vertices touch the mid-point of each side of the polygon beneath, resulting in a lattice-like structure that allows for a far greater number of apertures than a masonry shell dome. Stacked arch domes direct the loads along the lines of the arches, from one conic section to another. A stacked arch dome can be made of masonry, but also of reinforced-concrete rib-and-infill. The distribution of loads along the lines of the arches embeds the stacked arch dome with an optical affective property of asymmetry and twisting that remains consistent within any space it defines. The stacked arch dome transmits an acoustical affect of diffusion which tends to overwhelm any affect of focusing of the dome shape.

Stacked arch domes are flexible in several ways:
Scale: The protogeometry of the stacked arch dome is flexible in the combination it allows of differently scaled polygonal plan forms across different tiers, most commonly pentagons, and in the range of the radii of the arches as they move upward that stack upon one another, creating different dome profiles.
Depth: The infill surfaces under the arches and in the pendentives between them can vary in depth, altering the overall depth of the dome surface and therefore its environmental performance. In addition, given that the infill surfaces are not load-bearing, they can be removed to act as openings and vary the porosity of the dome surface.
Profile: Stacked arch domes can tessellate concentrically and horizontally along straight or curved lines of growth to produce horizontal or curved structures.
Affect: The optical affective property of a stacked arch dome 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 asymmetry and twisting, a stacked arch dome can transmit other optical affects, including enclosure, stacking, arching, rotundity, faceting, stellatedness and conicality. The acoustical affect of stacked arch domes is diffusion.

Conicality, Stacking, Arching, Rotundity, Diffusion



Vertical / Stacked Arch Dome

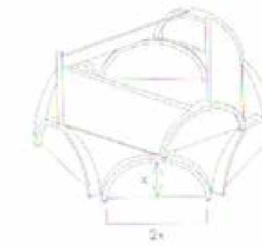


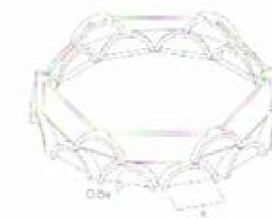
pendentive surfaces

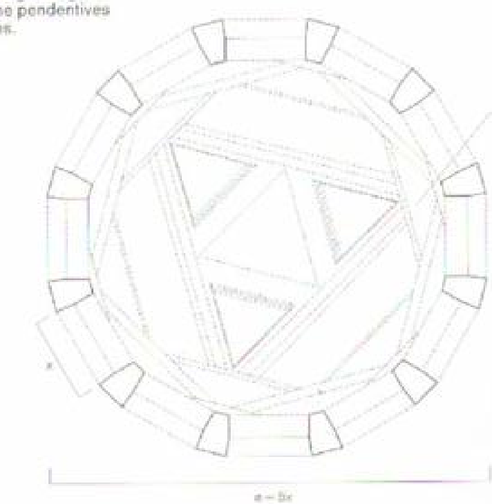
The size of the apertures that can be introduced into the dome surface is determined by the scale of the arches.

The construction of the dome surface by tiers of increasingly smaller stacked arches creates a form that transmits affects of conicality, stacking and arching.

The arches in each tier of the dome subdivide its surface into differently sized segments, with corresponding changes in the scale of the pendentives and infill surfaces.



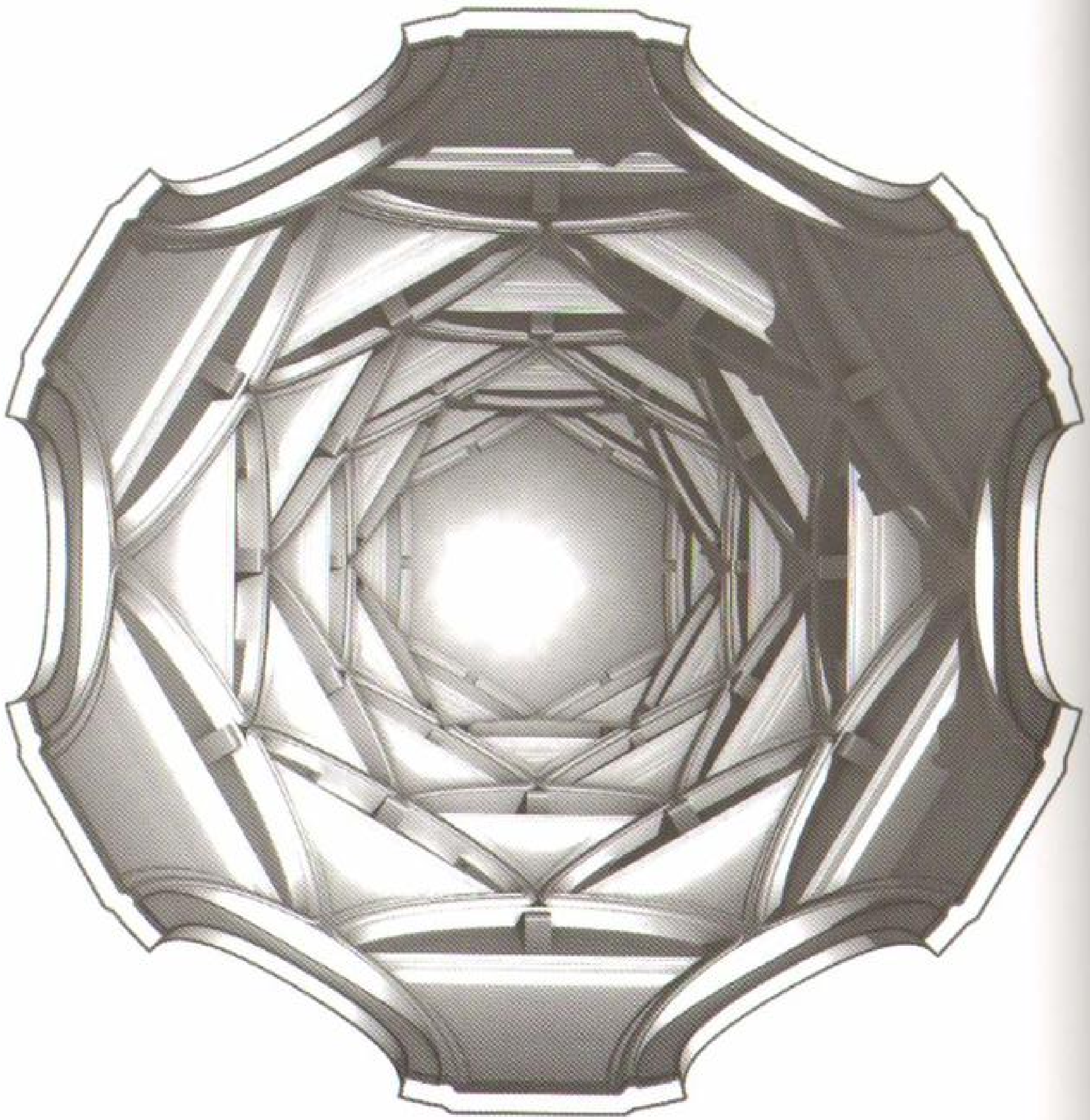




Stacked tiers of arches, with each tier gradually diminishing in size, create a dome form with a polygonal plan and transmits an acoustical affect of diffusion.

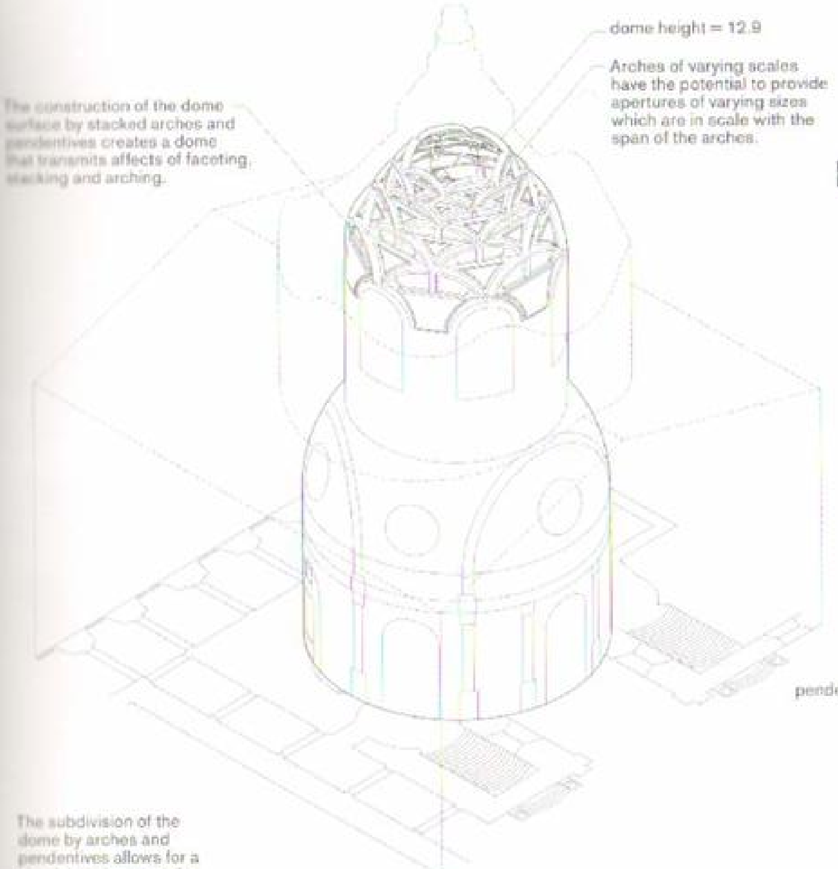
This dome is formed by the vertical tessellation of the base unit, composed of a tier arches. The first tier is a twelve-sided polygon in plan. The second and third tiers are six-sided, and the top tier is a triangle. As the assemblage grows taller, the number of sides of each tier is reduced. This results in an increase in the span of the arches that make up each tier as the dome gets taller, and in the height of the arches as they span longer distances. The combination of arches and pendentives forms a domed structure. This assemblage transmits an optical affect of conicality, stacking, arching and rotundity, and an acoustical affect of diffusion.

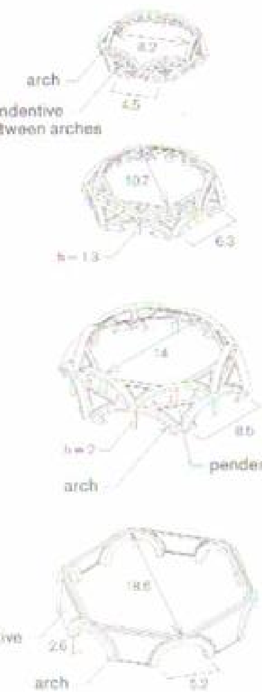
Faceting, Stacking, Arching, Rotundity, Diffusion

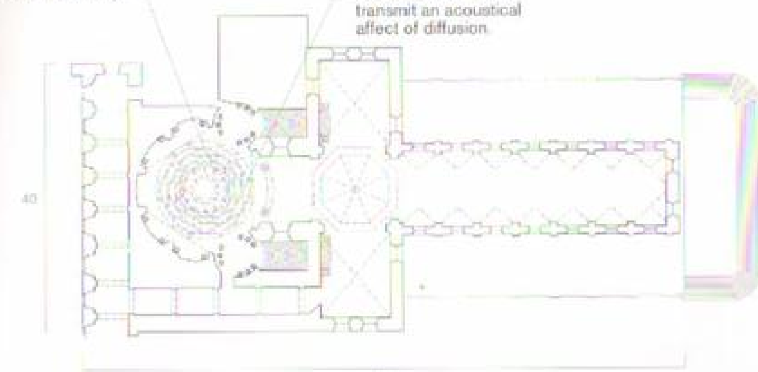


Vertical / Stacked Arch Dome

SS. SINDONE CHAPEL | G. GUARINI | TURIN, ITALY | 1667–90

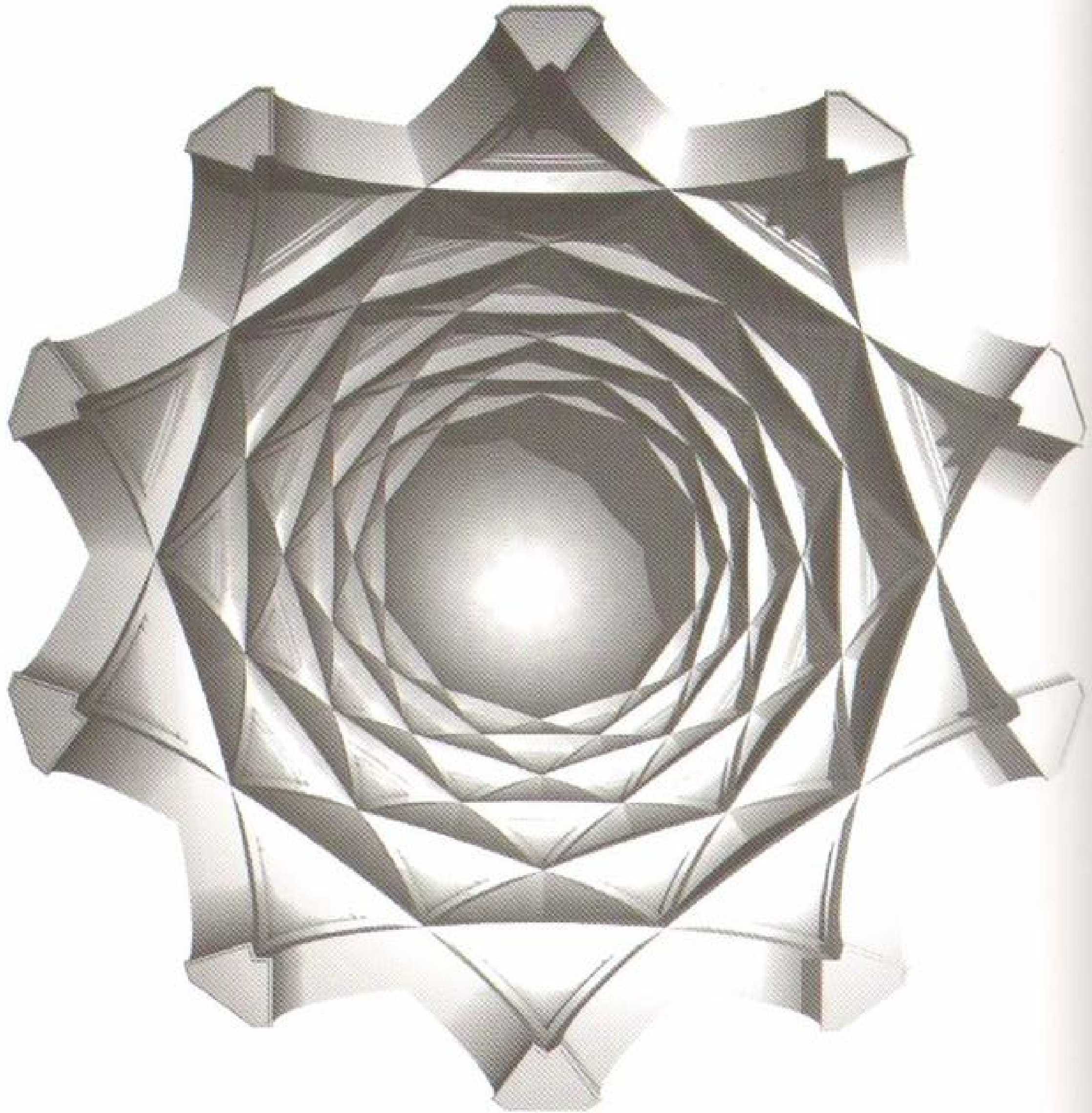




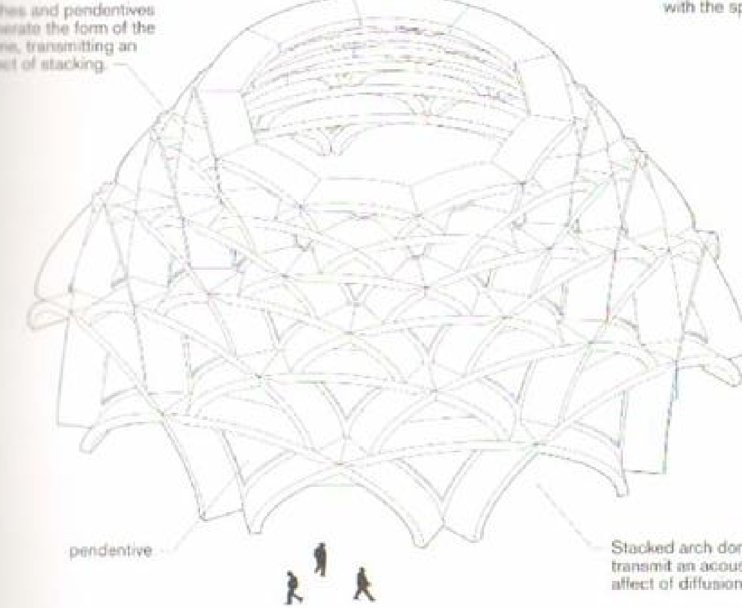


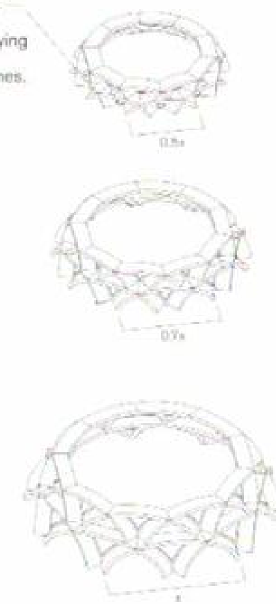
The dome of SS. Sindone chapel is formed by the vertical tessellation of a tier of crossed arches. The arches that form each tier rest at the center point of the arches in the tier below. The number of arches, their scale, and the resulting pendentives determine the plan as well as the profile of the dome in section. The combination of arches and pendentives results in a domed structure which is round in plan. The scale of subdivision is determined by the total number of tiers, in this case seven, the number of faces of the polygons in plan for each, and the scale of the arches forming the tiers. The dome of SS. Sindone chapel transmits an optical affect of faceting, stacking, arching and rotundity, and an acoustical affect of diffusion.

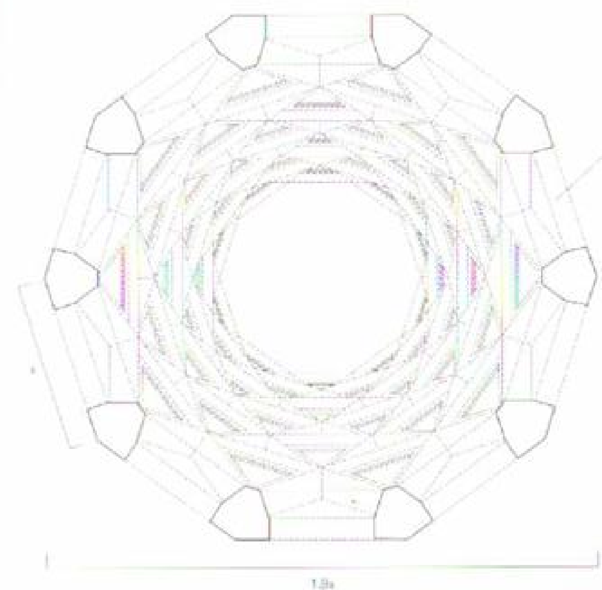
Enclosure, Stacking, Arching, Rotundity, Diffusion



Vertical / Stacked Arch Dome

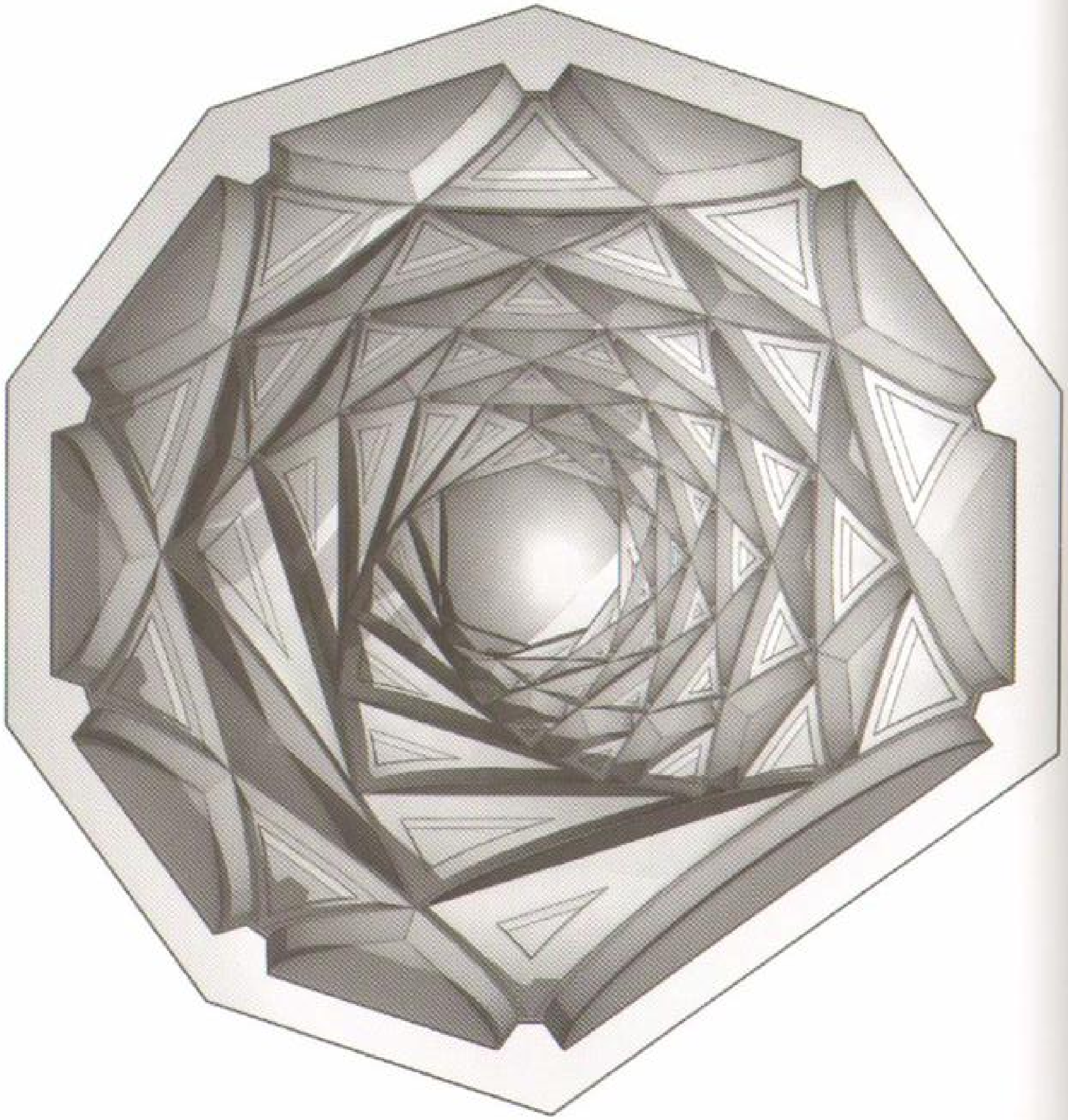




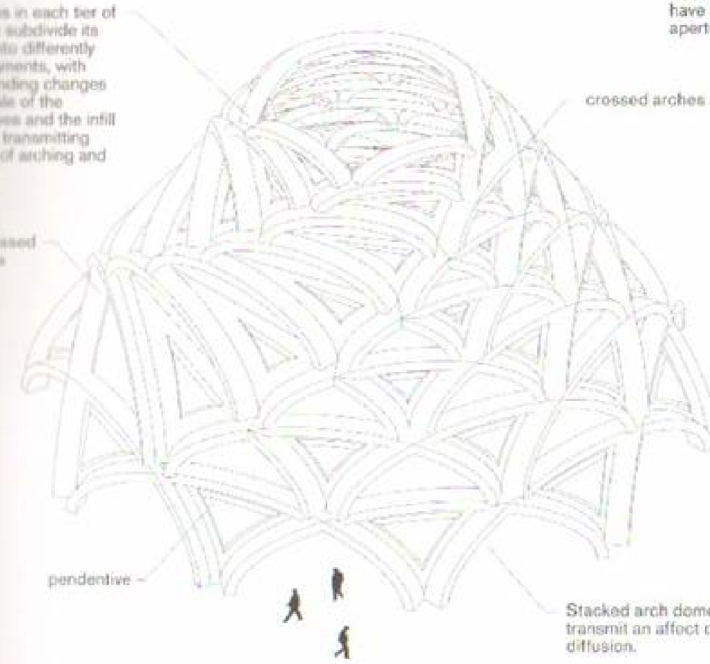


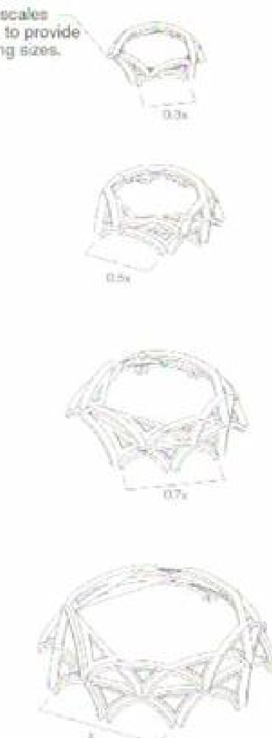
This dome is formed by the vertical tessellation of a tier of crossed arches which originates in a ten-sided polygon in plan. As the tiers move upward, the polygon rotates so that its vertices align with the middle of the face of the lower polygon of the previous tier. This results in a decrease in the scale of the faces of the polygons in plan, and also a decrease in scale of the arches. The arches that form each tier intersect one another at two points along the curvature of each arch, at approximately one-third of their length. The combination of cross arches and the infill surfaces between them forms a domed structure. The scale of subdivision is determined by the total number of tiers, in this case six, the number of faces of the polygons in plan for each, in this case ten, and the scale of the crossed arches forming the tiers. This assemblage transmits an optical affect of enclosure, stacking, arching, and rotundity, and an acoustical affect of diffusion.

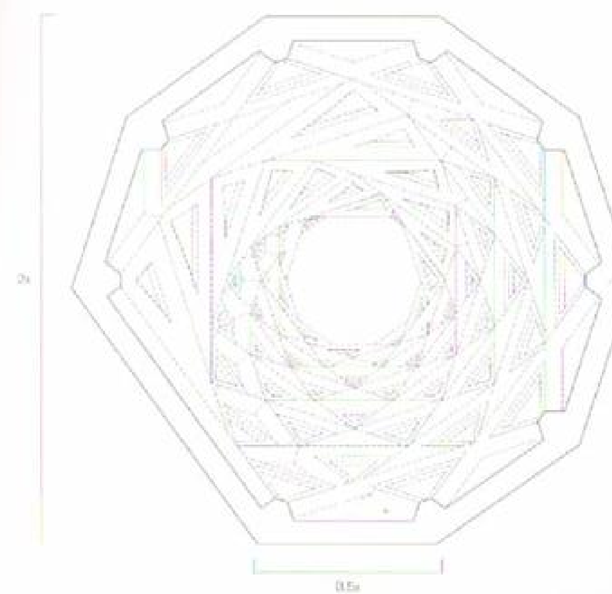
Stellatedness, Stacking, Arching, Rotundity, Diffusion



Vertical / Stacked Arch Dome

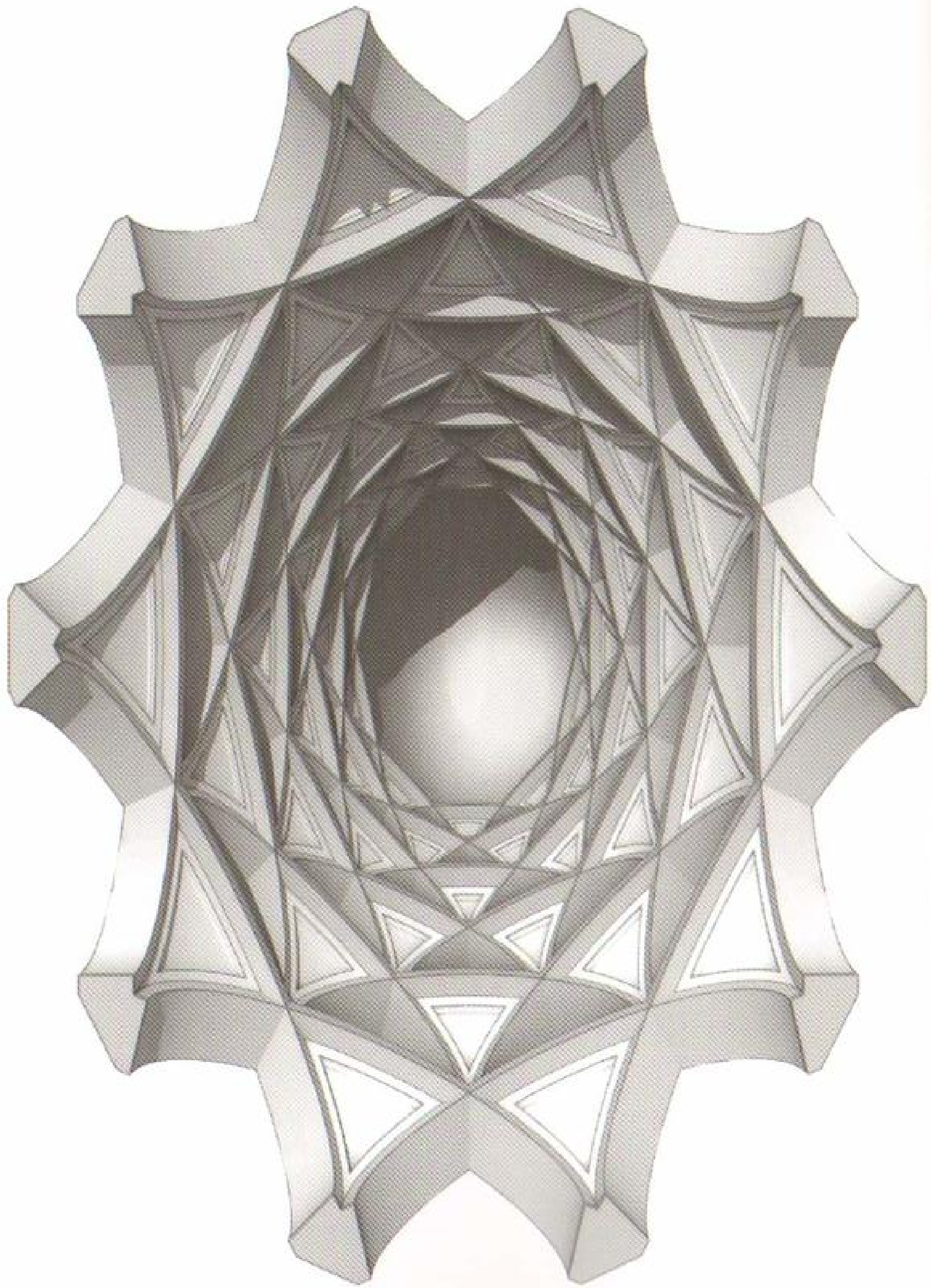




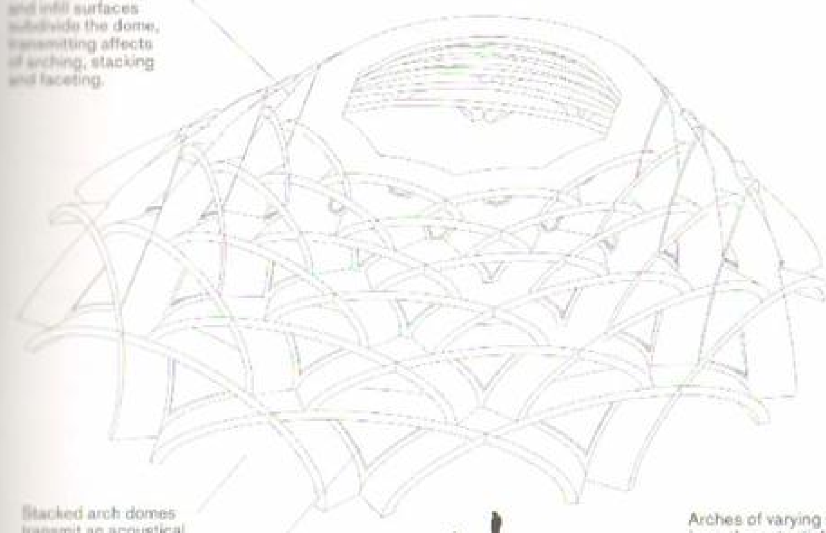


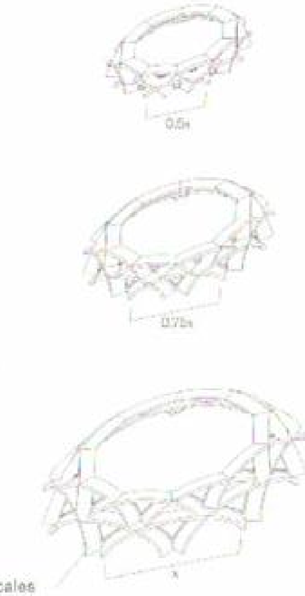
This dome is formed by the vertical tessellation of a tier of crossed arches in one-half of its volume, and buttressed arches in the other. The tier of arches originates in a ten-sided polygon in plan. As they move upward, the polygon rotates so that its vertices land in the middle of the polygon of the tier below. This results in a diminution of the scale of the faces of the polygons in plan for each tier, and also a diminution in scale of the resulting arches. On half of the dome, the arches that form each tier intersect one another at two points along the curvature of each arch, at approximately one-third of their length. On the other half of the dome, the arches do not intersect, but rest on one another. This produces an asymmetry in both volume and plan. The combination of cross arches, buttressed arches, and the infill surfaces between them forms a domed structure and transmits an optical affect of stellatedness, stacking, arching, and rotundity, and an acoustical affect of diffusion.

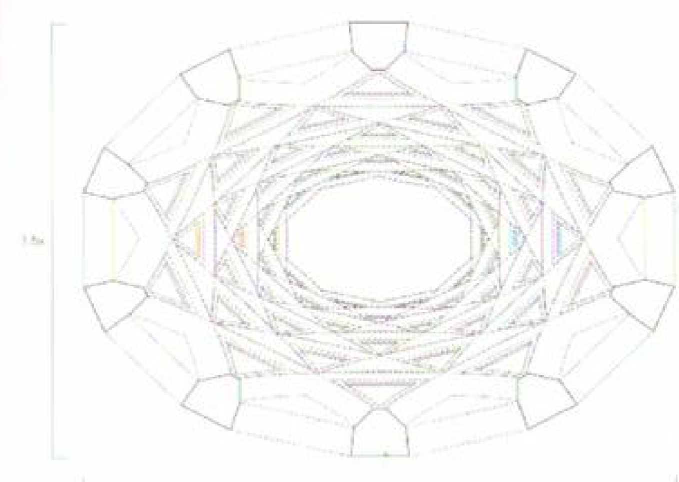
Faceting, Stacking, Arching, Rotundity, Axiality, Diffusion



Vertical / Stacked Arch Dome



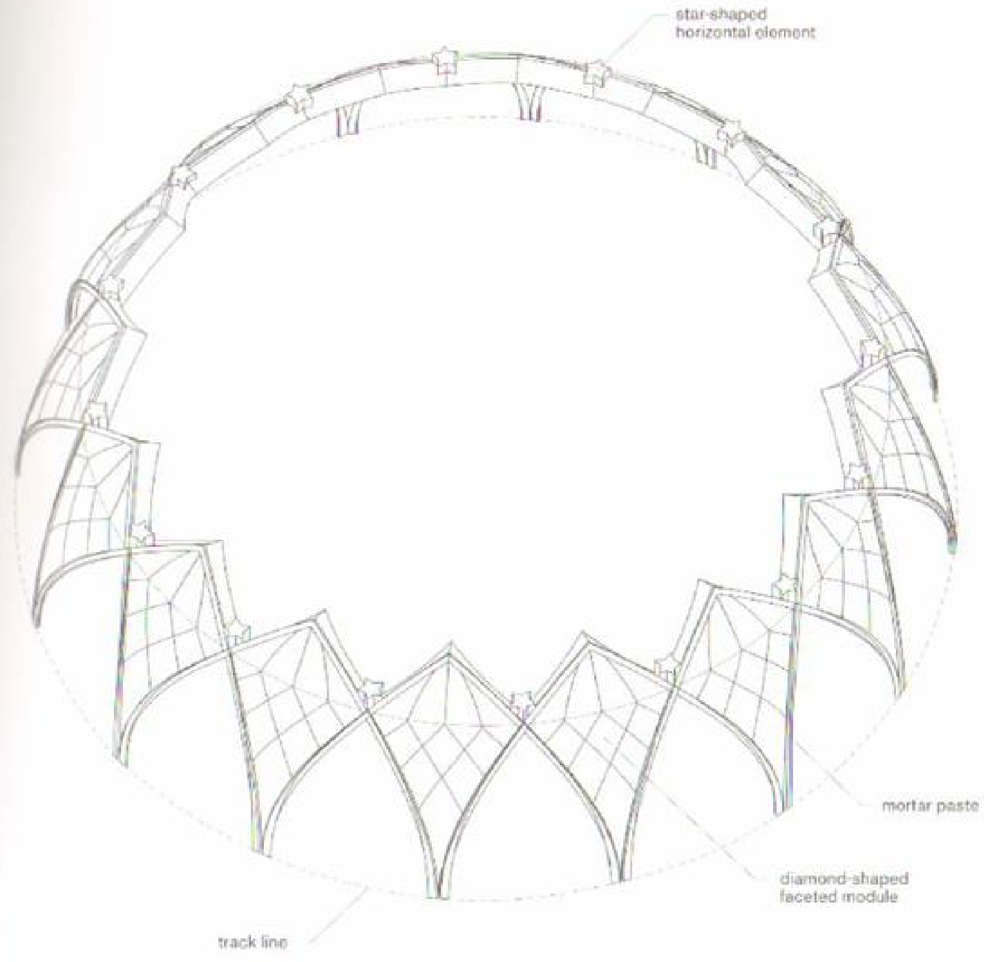




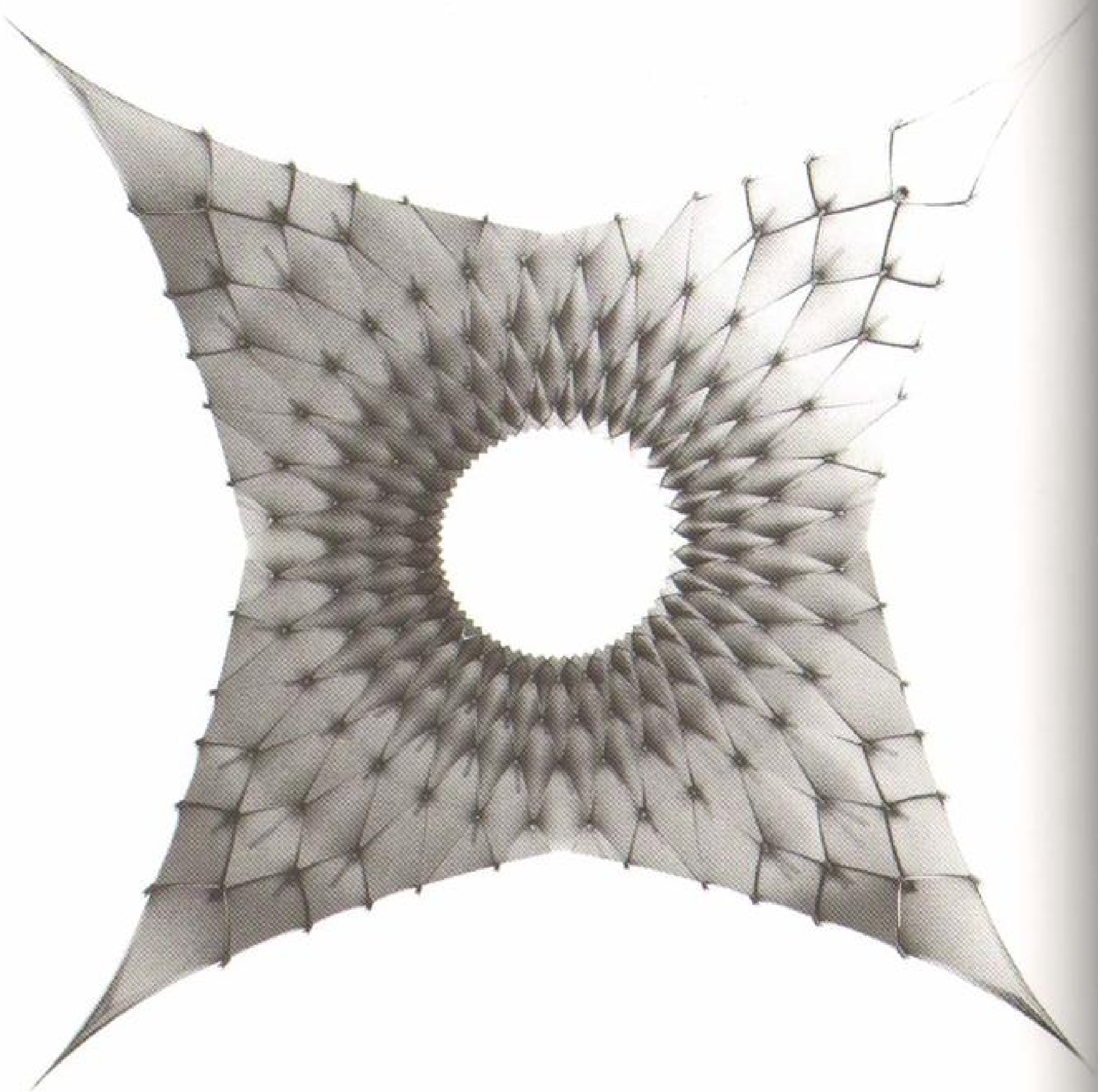
This dome is formed by the vertical tessellation of a tier of crossed arches which originates as a ten-sided polygon in plan. Although the faces of the polygon are equal in length, their angles are different, resulting in a figure that approximates to an ellipse. As the tiers move upward, the polygon rotates, so that its vertices land in the middle of the face of the polygon below. This results in a diminution of the scale of the faces of the polygons in each tier, as well as a decrease in scale of the resulting arches. The arches that form each tier intersect one another at two points along their curvatures, at approximately at one-third of their length. The combination of cross-arches and the infill surfaces between them forms a domed structure that transmits an optical affect of faceting, stacking, arching and rotundity, and an acoustical affect of diffusion.

The yazdi-bandi dome base unit is a tier, or track, composed of smooth, finely grained, diamond-shaped modules of differing sizes, with very small flat and horizontal star-shaped pieces in between.
Each tier interlocks with the tiers above and below. Yazdi-bandi domes direct the loads along the diagonal borders between the diamond modules, and along the surfaces between these lines. The yazdi-bandi dome historically has been an ornament added to underlying structural elements to introduce granularity to an otherwise smooth surface. A yazdi-bandi dome can be made of reinforced concrete, with the steel reinforcement following the diamond pattern subdividing its surface. The distribution of loads along the lines and surfaces of the yazdi-bandi dome embeds it with an optical affective property of diamonding and gradation that remains consistent within any space it defines. The variation of curvature of yazdi-bandi domes creates an acoustical affect of diffusion that dominates any focusing from the overall dome shape. This diffusion is enhanced by any diamonding of the surface.

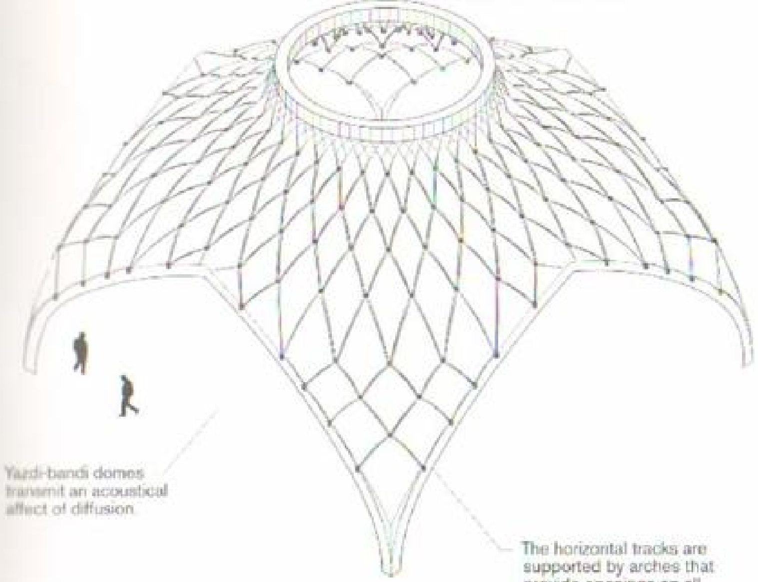
Yazdi-bandi domes are flexible in several ways:
Profile: The protogeometry of the yazdi-bandi dome can be flexible in the degree of corrugation that is achieved by the granulation of the dome's surface, based on the degree of its subdivision by diamond-shaped modules.
Plan: The yazdi-bandi dome system can tessellate using varying numbers of pointed arches at its base. From the round plan of the oculus at the top, the yazdi-bandi dome can tessellate into a polygonal plan form, often rectangular, and a series of arches at ground level, which facilitates its combination with other types of base unit in order to allow for horizontal growth.
Depth: The number of tracks forming a yazdi-bandi dome as well as the diameter of the tracks can be varied to achieve different sections to the dome which in turn determine the depth of its plan.
Affect: The optical affective property of the yazdi-bandi dome 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 diamonding and gradation, a yazdi-bandi dome can transmit other optical affects, including conicality, rotundity, orthogonality, asymmetry, cruciformity, orientedness. The acoustical affect is diffusion, although sometimes it is focusing

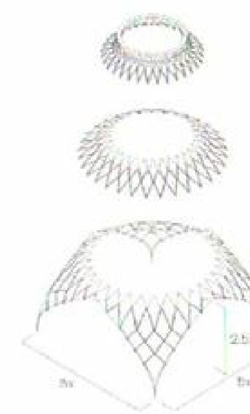


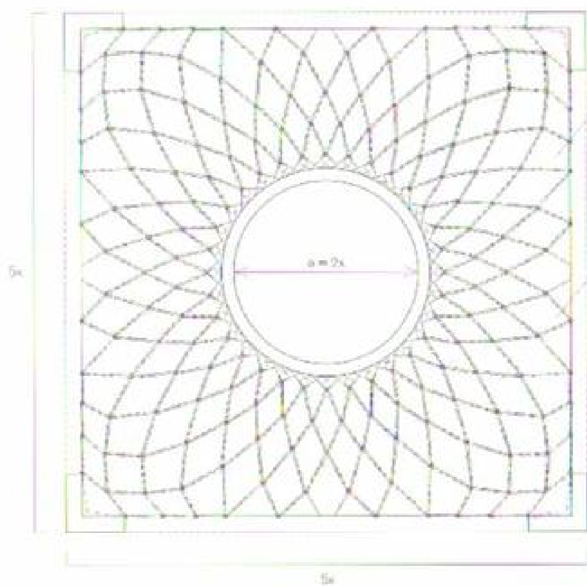
Orthogonality, Rotundity, Gradation, Diamonding, Diffusion



Vertical / Yazdi-Bandi Dome



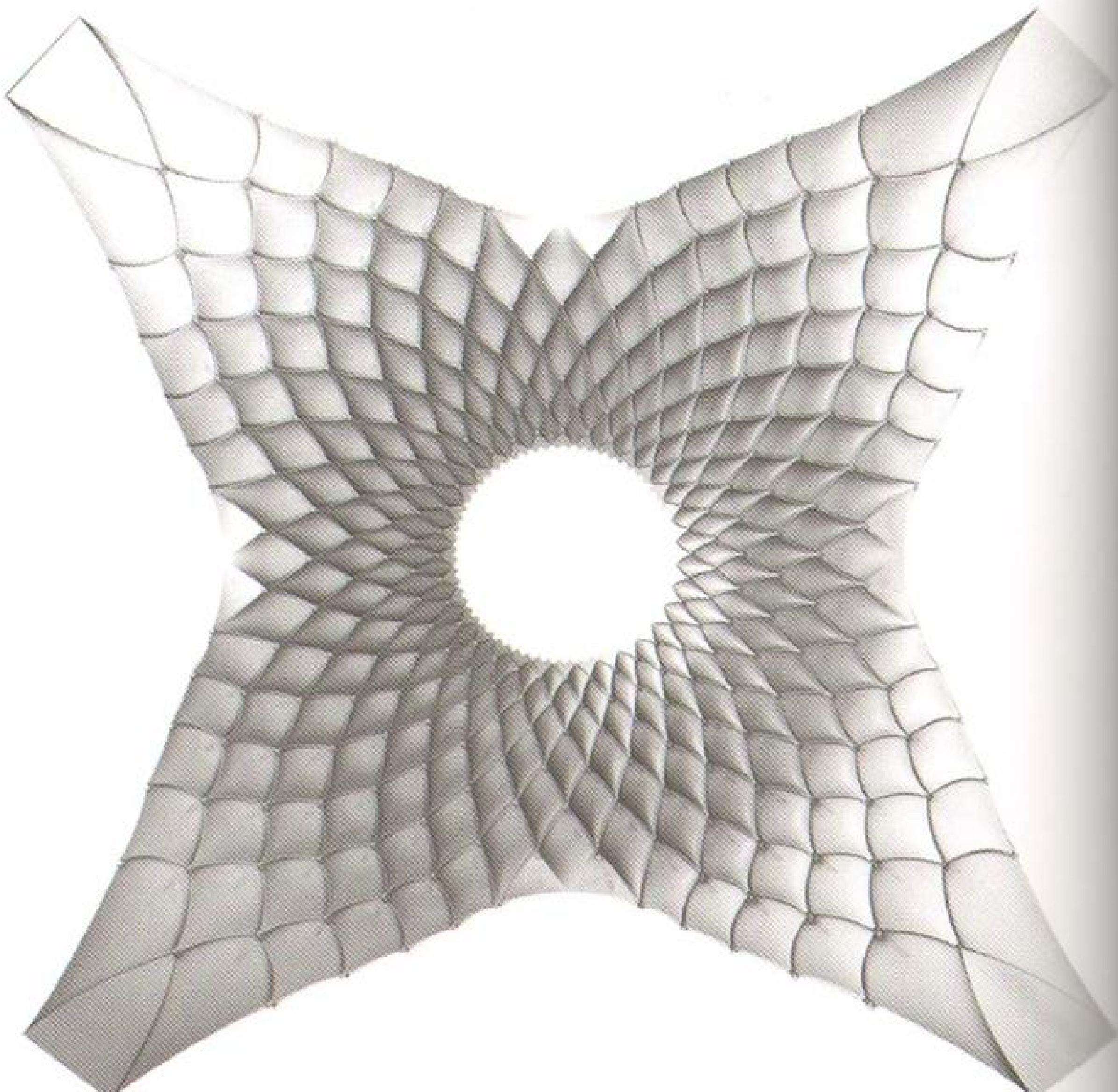




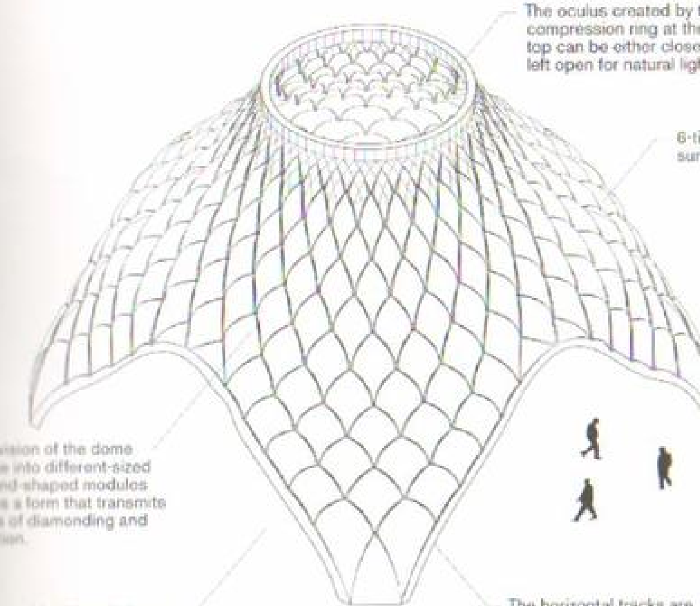
square plan

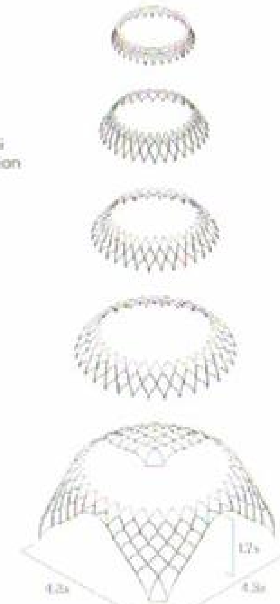
This dome is formed by the vertical tessellation of a horizontal tier composed of a pendentive-like surface that spans from a square plan with four pointed arches on the perimeter to a circular top in the form of a compression ring. The resulting surface is subdivided into a diamond grid in which each of the facets gradually diminishes in size towards the top. This yazdi-bandi dome assemblage transmits an optical affect of orthogonality, rotundity, gradation and diamonding, and an acoustical affect of diffusion.

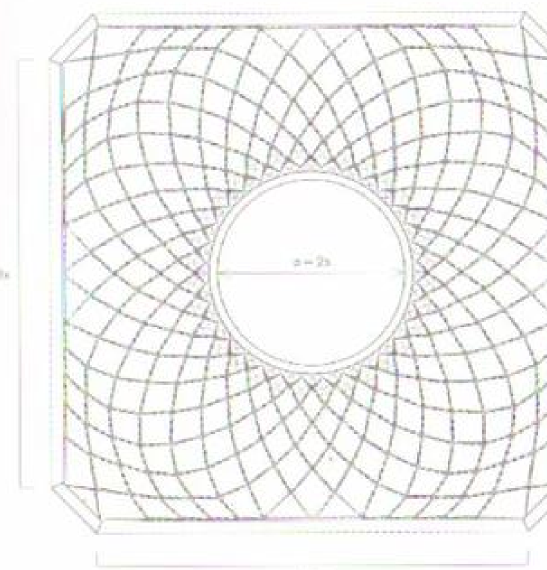
Orthogonality, Rotundity, Gradation, Diamonding, Diffusion



Vertical / Yazdi-Bandi Dome



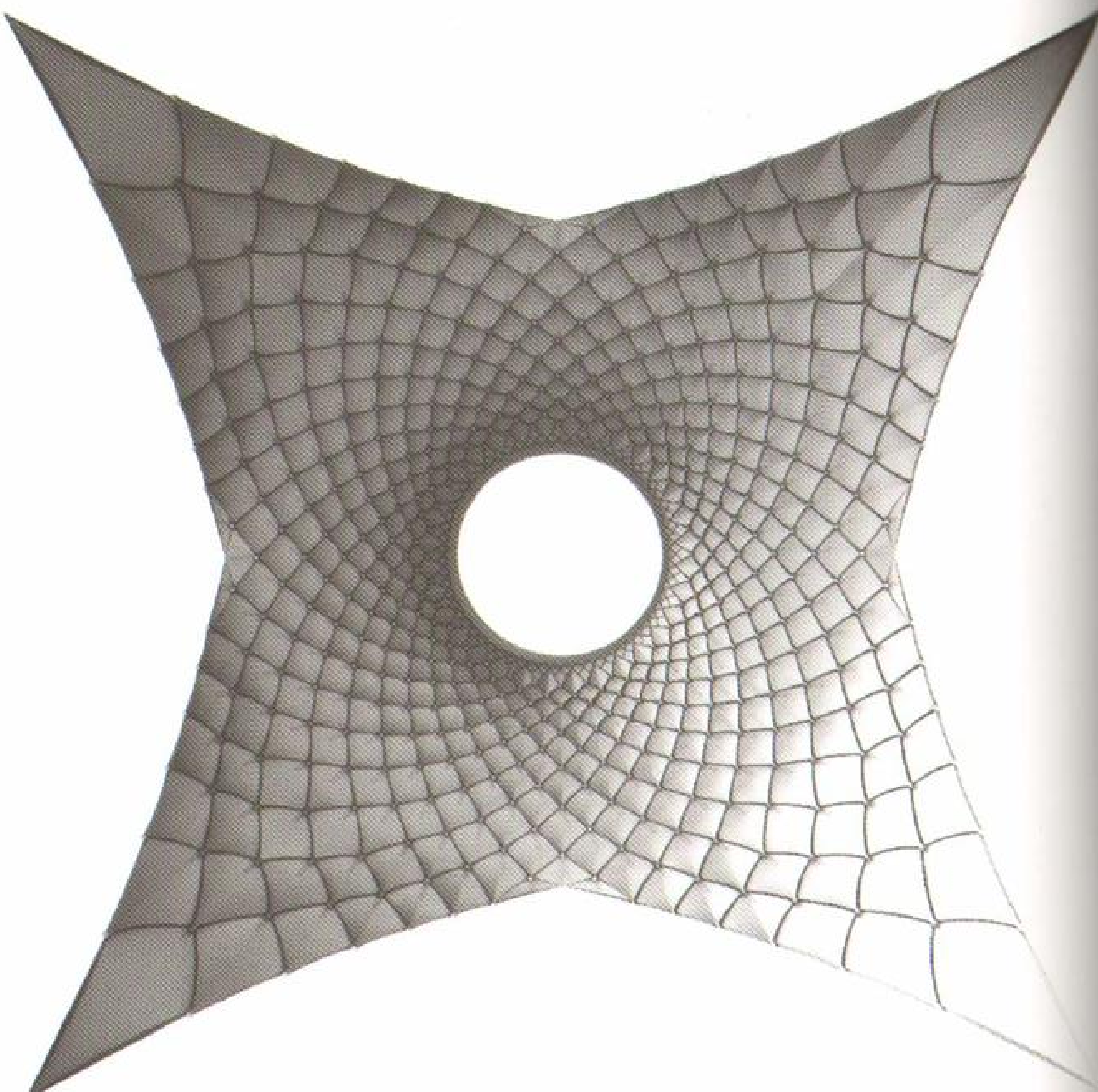




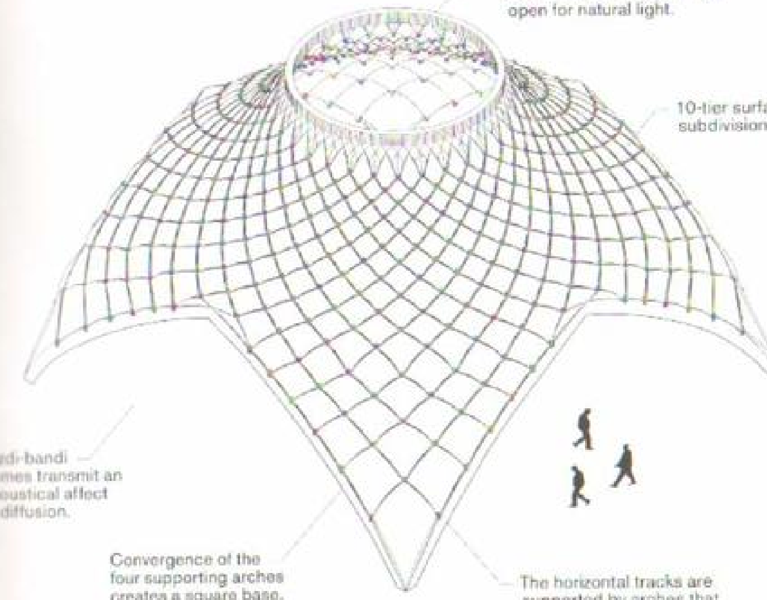
octagonal plan

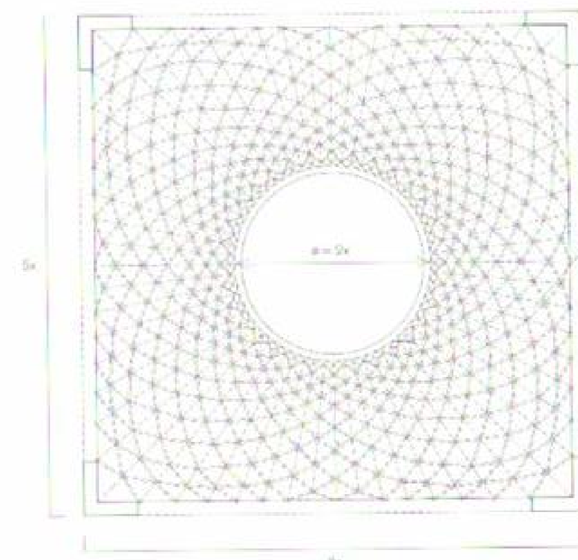
This dome is formed by the vertical tessellation of a horizontal tier composed of a pendentive-like surface that spans from an octagonal plan with four pointed arches on the perimeter to a circular top in the form of a compression ring. The resulting surface is subdivided into a diamond grid in which each of the facets gradually diminishes in size towards the top. This yazdi-bandi dome assemblage transmits an optical affect of orthogonality, rotundity, gradation, and diamonding, and an acoustical affect of diffusion.

Orthogonality, Rotundity, Gradation, Diamonding, Diffusion



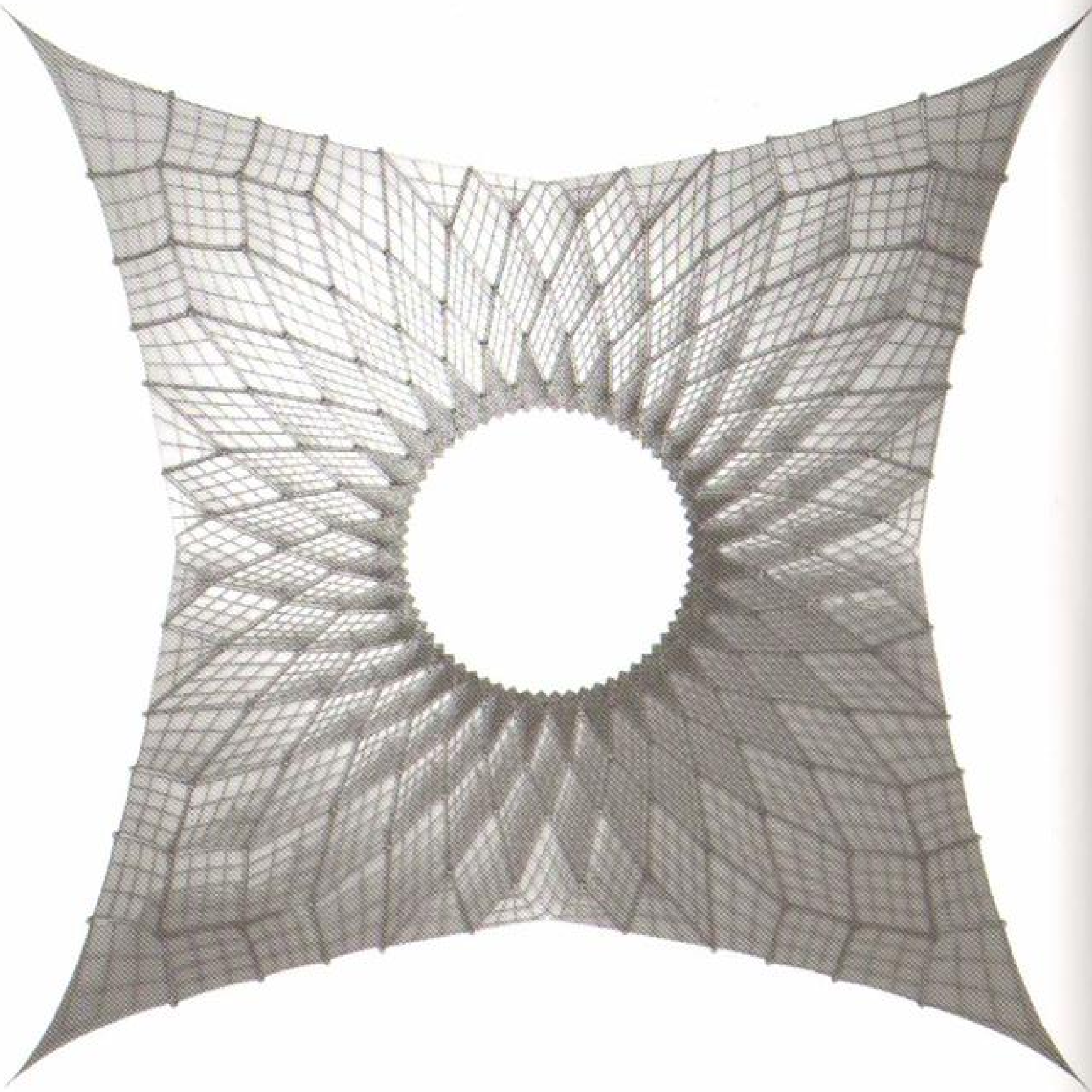
Vertical / Yazdi-Bandi Dome



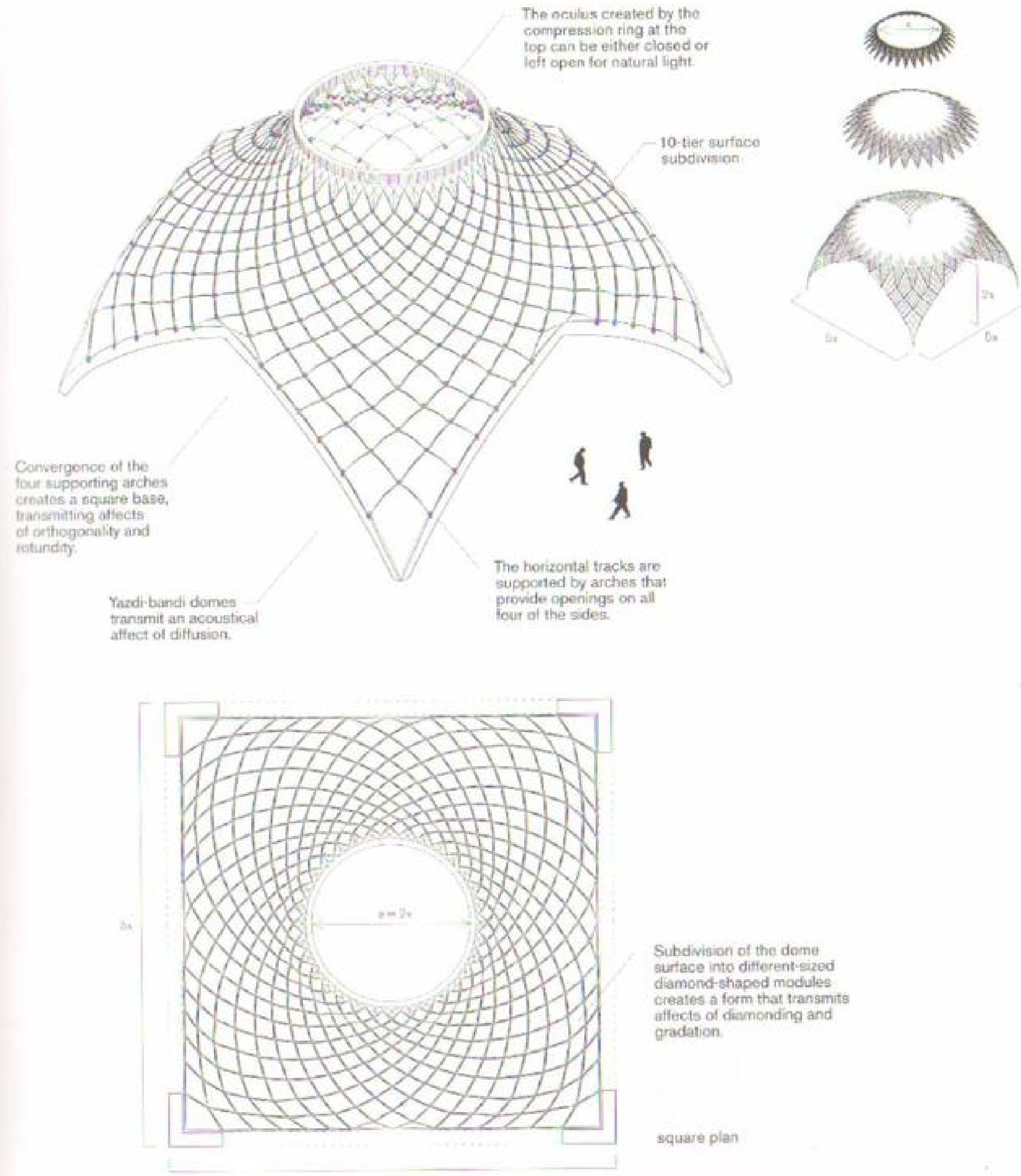


This dome is formed by the vertical tessellation of a horizontal tier composed of a pendentive-like surface that spans from a square plan with four pointed arches on the perimeter to a circular top in the form of a compression ring. The resulting surface is subdivided into a diamond grid in which each of the facets gradually diminishes in size towards the top. This yazdi-bandi dome assemblage transmits an optical affect of orthogonality, rotundity, gradation and diamonding, and an acoustical affect of diffusion.

Orthogonality, Rotundity, Gradation, Diamonding, Diffusion

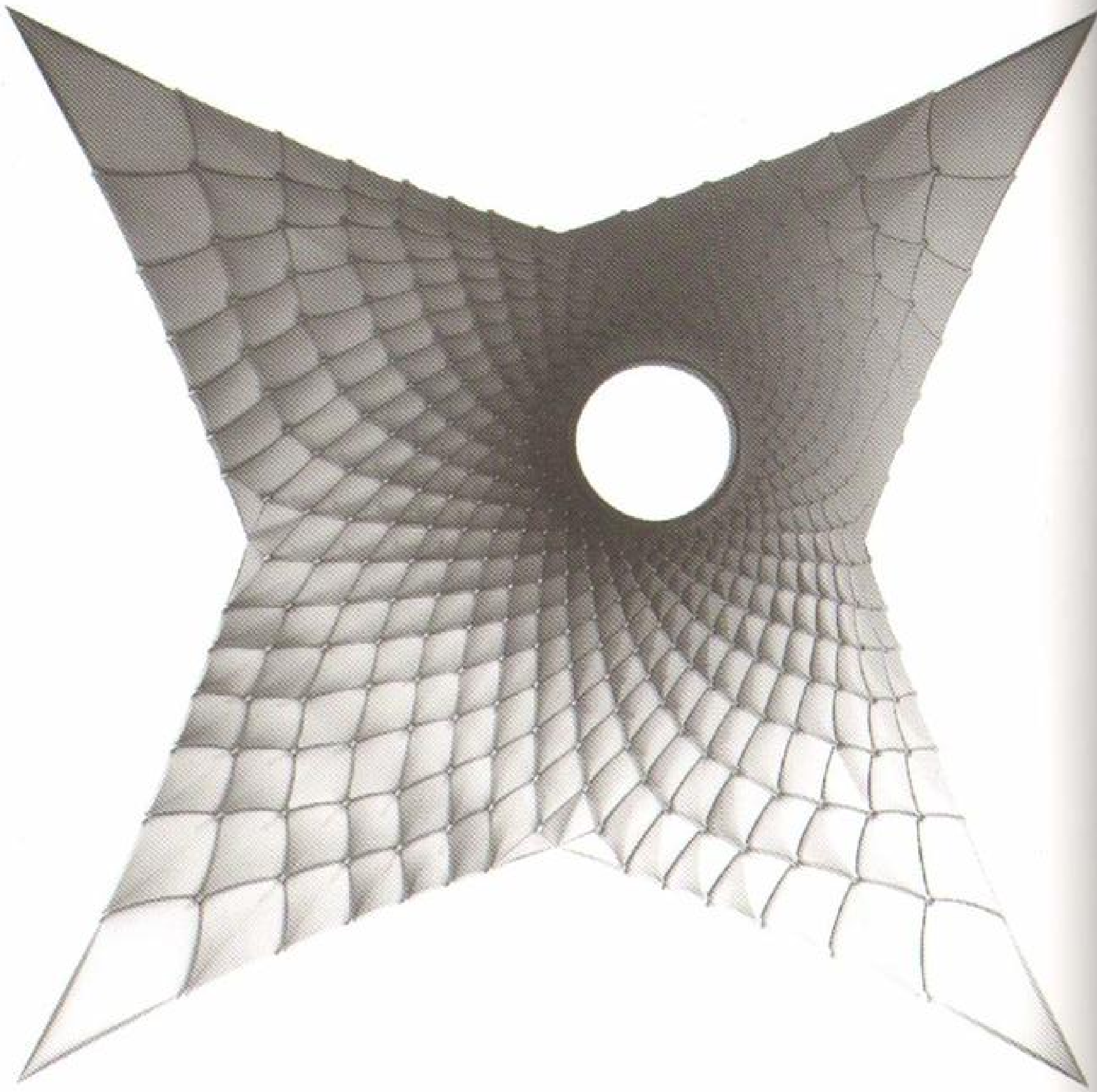


Vertical / Yazdi-Bandi Dome

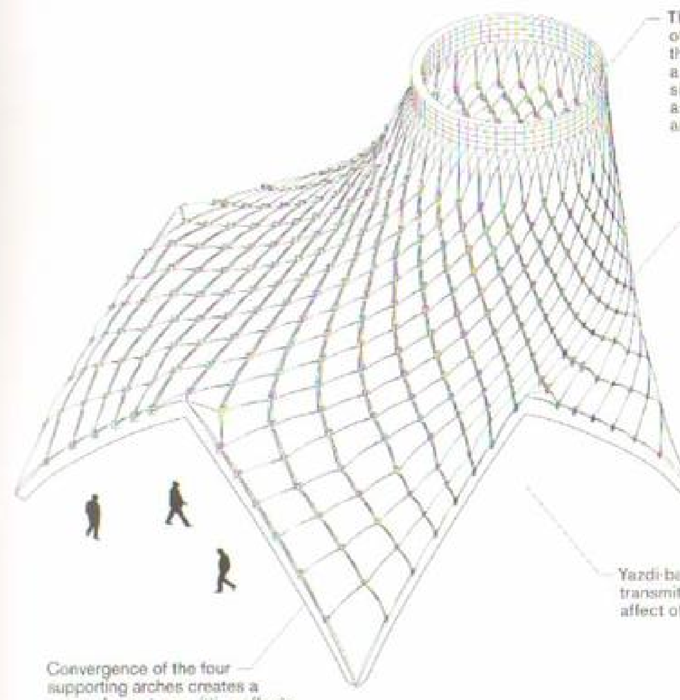


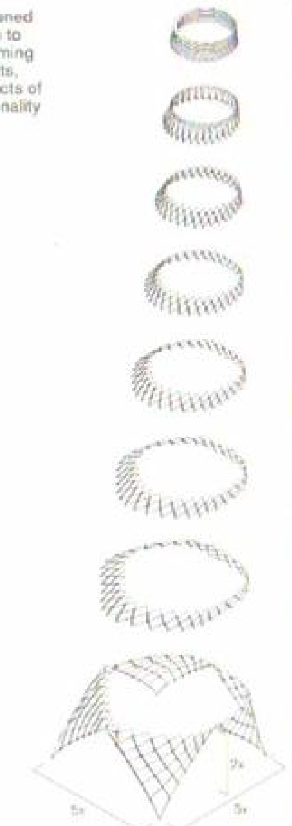
This dome is formed by the vertical tessellation of a horizontal tier composed of a pendentive-like surface that spans from a square plan with four pointed arches on the perimeter to a circular top in the form of a compression ring. The resulting surface is subdivided into a diamond grid in which each of the facets gradually diminishes in size towards the top. Each of these diamonds is further subdivided into smaller diamonds. The scale of subdivision of the pendentive surface is set by the diamond grid, the scale and density of which changes gradually, through a series of horizontal tiers, to adapt to the contours of the surface. This yazdi-bandi dome assemblage transmits an optical affect of orthogonality, rotundity, gradation and diamonding, and an acoustical affect of diffusion.

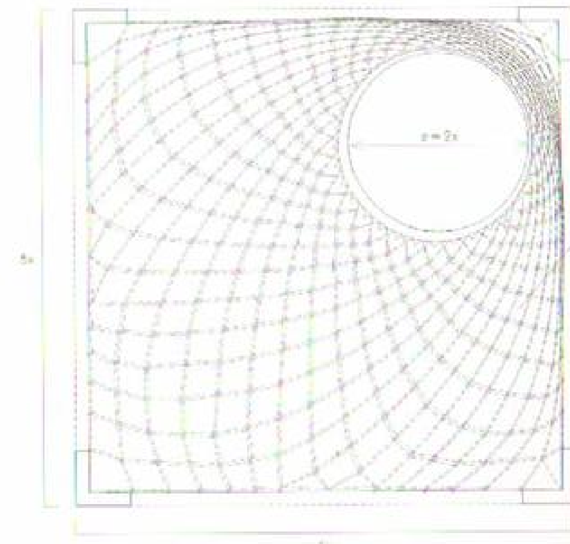
Asymmetry, Rotundity, Gradation, Diamonding, Diffusion



Vertical / Yazdi-Bandi Dome

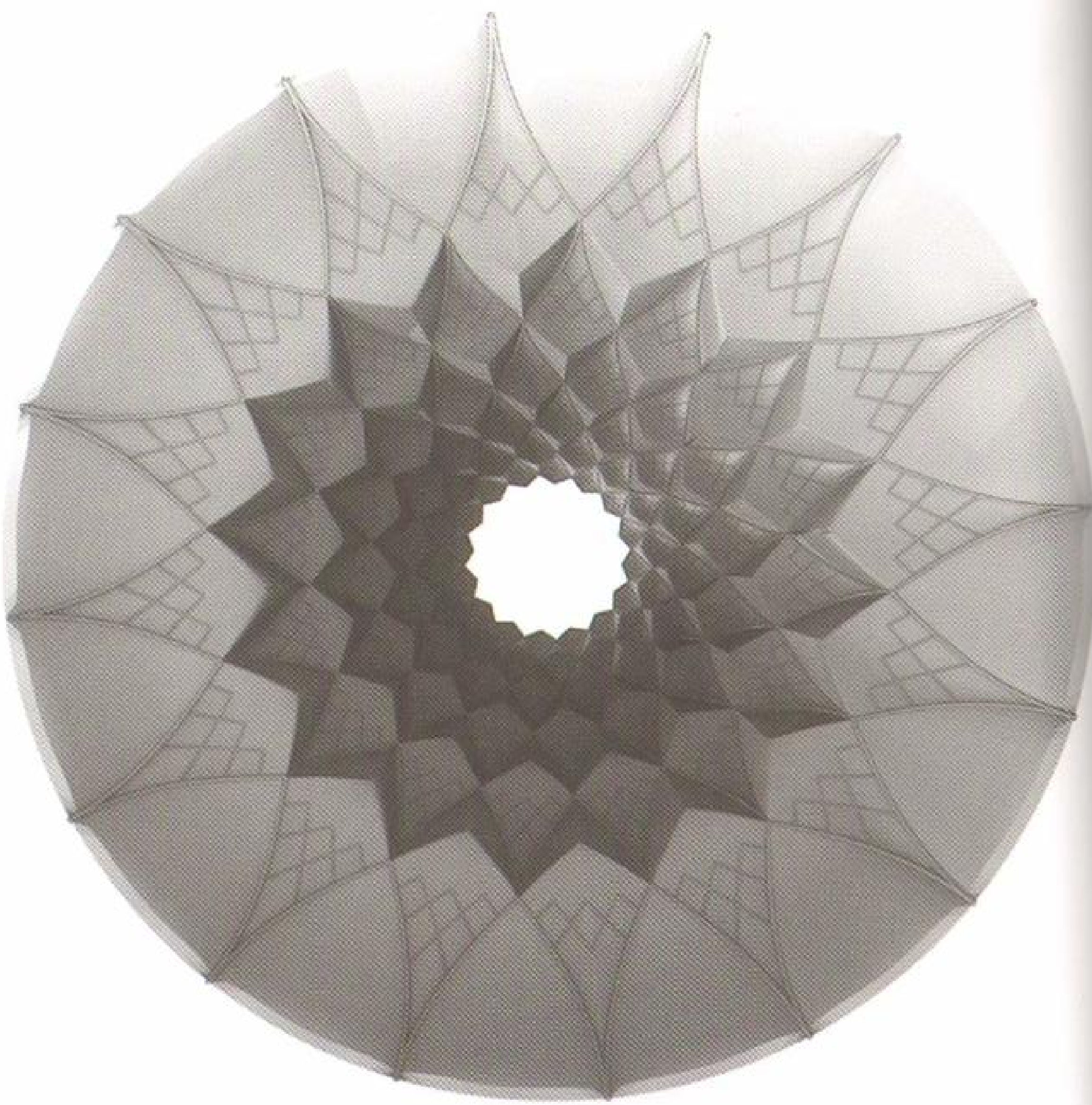




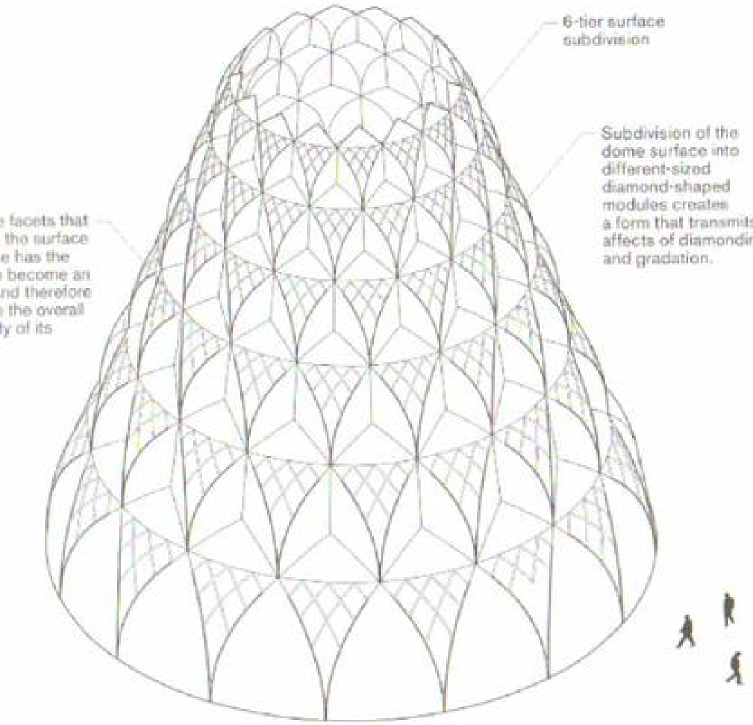


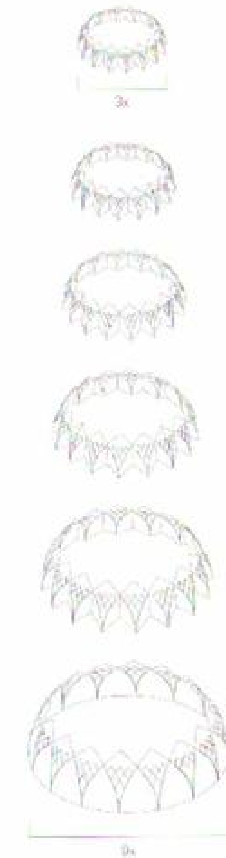
This dome is formed by the vertical tessellation of a horizontal tier composed of a pendentive-like surface that spans from a square plan with four curved arches on the perimeter to a circular top in the form of a compression ring which is off-center. The resulting surface is subdivided into a scalloped diamond grid in which each of the facets gradually diminishes in size towards the top. The scale of subdivision of the pendentive surface is set by the diamond grid, the scale and density of which changes gradually, through a series of horizontal tiers, to adapt to the contours of the surface. This yazdi-bandi dome assemblage transmits an optical affect of asymmetry, rotundity, gradation and diamonding, and an acoustical affect of diffusion.

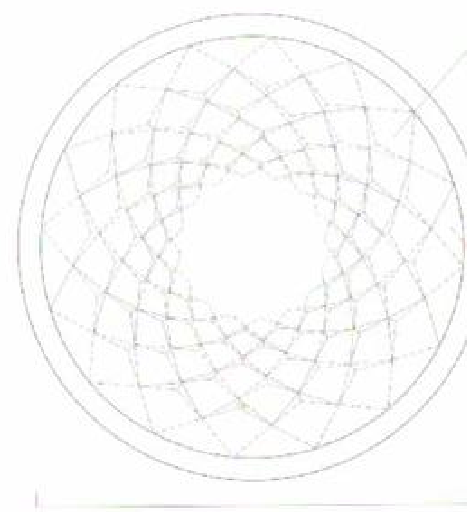
Conicality, Rotundity, Gradation, Diamonding, Diffusion



Vertical / Yazdi-Bandi Dome





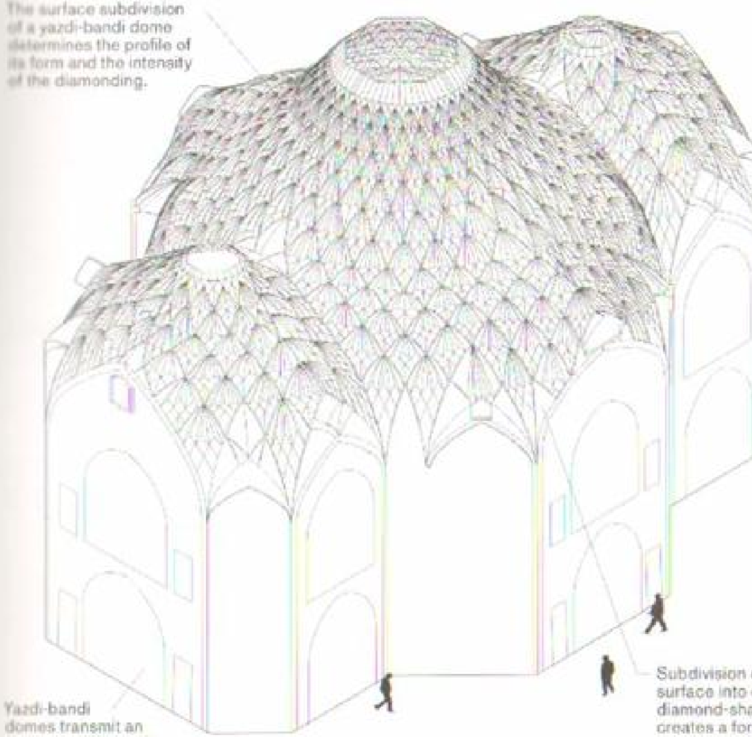


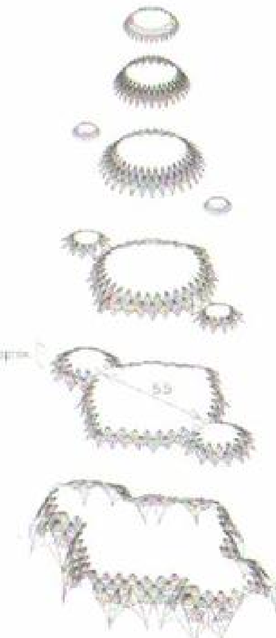
This dome is formed by the vertical tessellation of a horizontal tier composed of a surface that spans symmetrically from a round plan with sixteen pointed arches on the perimeter to a circular top in the form of a compression ring. The resulting surface is subdivided into a triangulated diamond grid in which each of the facets gradually diminishes in size towards the top. The scale of subdivision of the pendentive surface is set by the diamond grid, the scale and density of which changes gradually, through a series of horizontal tiers, to adapt to the contours of the surface. This yazdi-bandi dome assemblage transmits an optical affect of conicality, rotundity, gradation and diamonding, and an acoustical affect of diffusion.

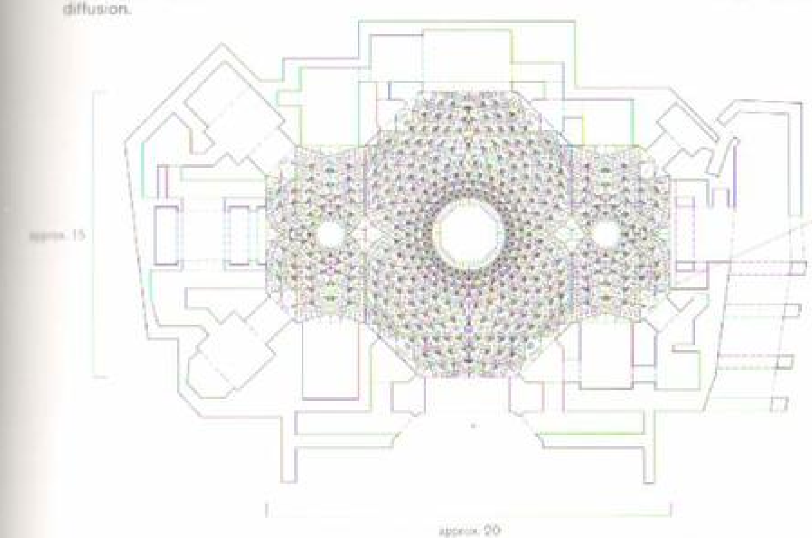
Diamonding, Cruciformity, Gradation, Rotundity, Diffusion

Vertical / Yazdi-Bandi Dome

AMIN AL DOLLEH BAZAAR TIMCHEH (ARCADE) | OSTAD ALI MARYAM | KASHAN, IRAN | 1900







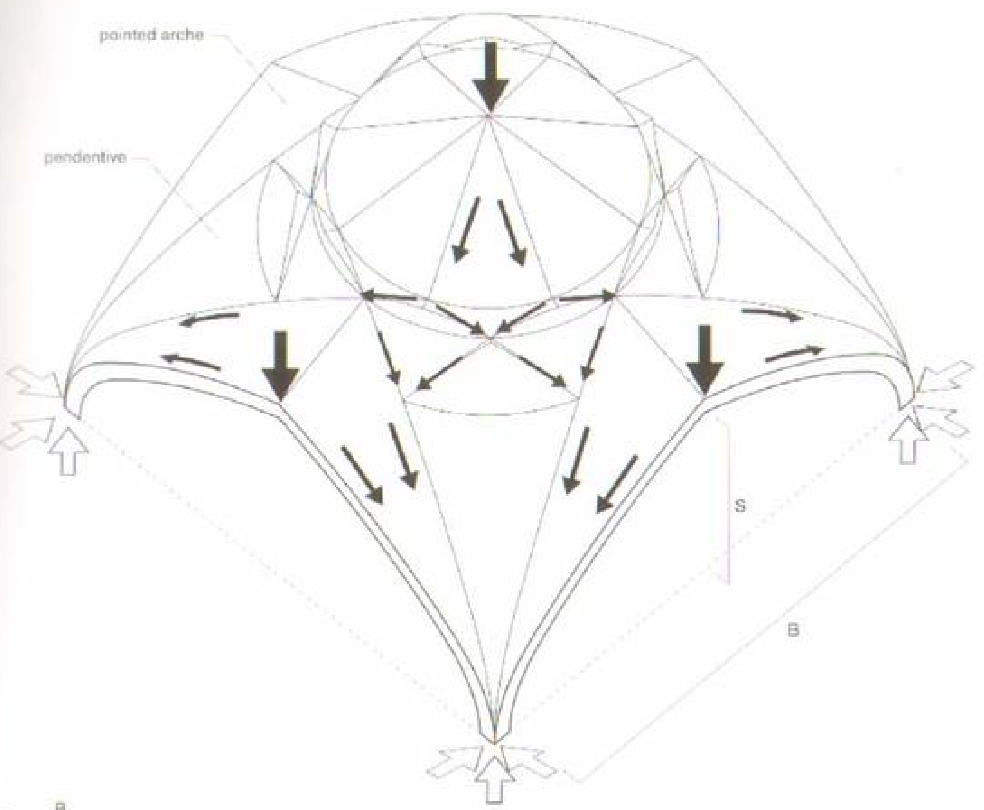
sixteen-sided plan

The nave of Amin Al Dolleh arcade is formed by the vertical tessellation of a horizontal tier composed of a pendentive-like surface that spans from an octagonal plan with eight pointed arches of differing scales on the perimeter to a hexagonal top in the form of a compression ring. The surface is subdivided into a triangulated diamond grid in which each of the facets is kept at approximately the same scale. The scale of subdivision of the pendentive surface is set by the diamond grid, the scale and density of which changes gradually, through a series of horizontal tiers, to adapt to the contours of the surface. The nave of Amin Al Dolleh arcade transmits an optical affect of diamonding, cruciformity, gradation, and rotundity, and an acoustical affect of diffusion.

Kar-Bandi Dome

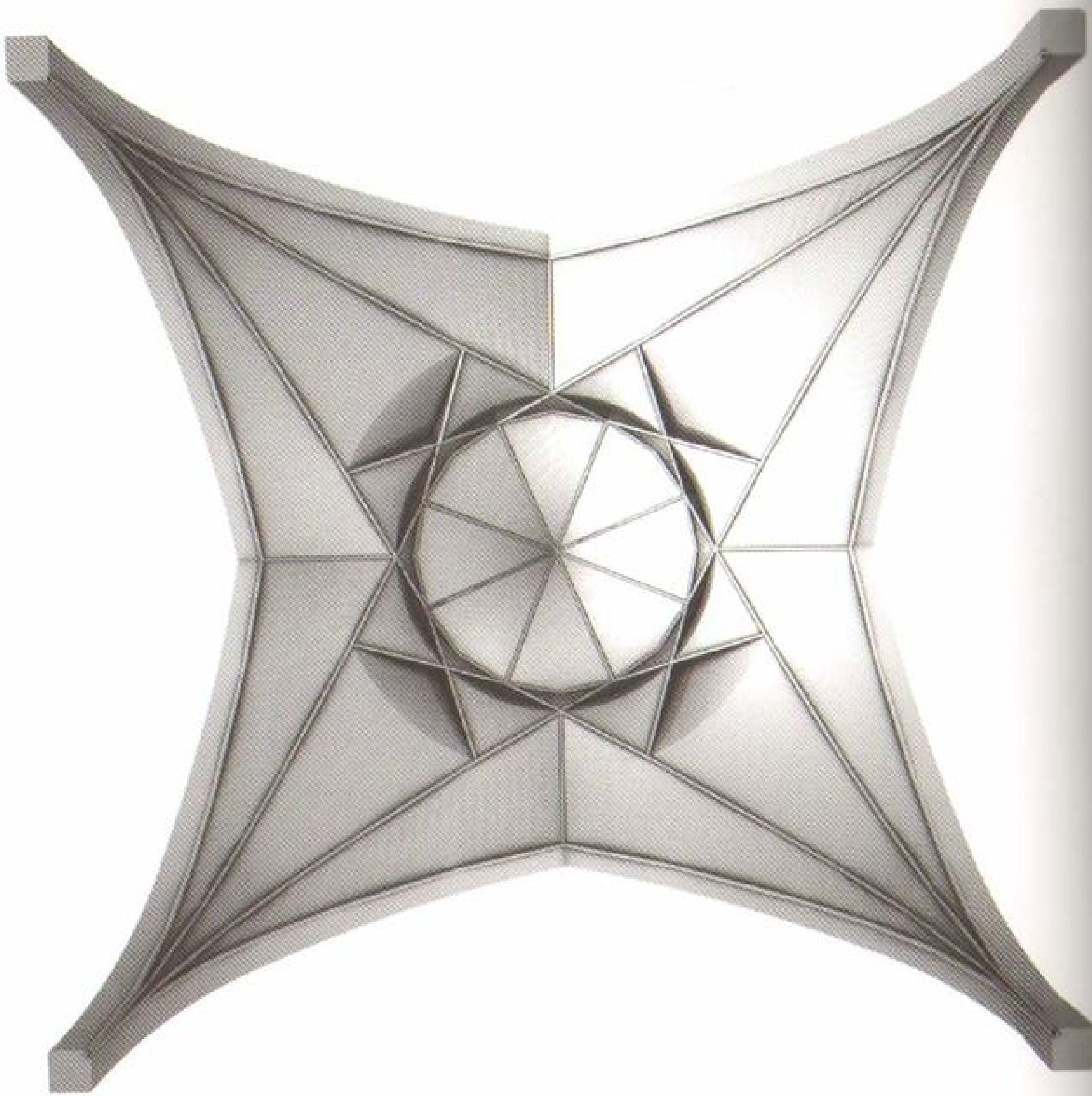
The base unit of a kar-bandi dome, a variation of the ribbed dome, is composed of a series of arches infill surfaces (pendentives) arranged around a compression ring, or oculus. This compression ring can serve as a support for a smaller dome, which is a special feature of the kar-bandi system, or it can be left open. Kar-bandi domes direct the loads along their surface, starting from the compression ring at the top through the set of pointed arches at the base. Kar-bandi domes can be made of masonry covered with plaster to achieve a continuous surface, and they can also be made of reinforced concrete. The distribution of loads along the surface of a kar-bandi dome embeds it with an optical affective property of crystallinity and stalactiformity that remains consistent within any space it defines. The variations in curvature, faceting and ribbing all add diffusion which often dominates focusing.

Kar-bandi domes are flexible in several ways.
Depth: The protogeometry of a kar-bandi dome can be flexible both in the degree of corrugation of the dome's surface and in the resulting plan.
Profile: The variability of the top aperture also contributes to the flexibility of this system. Kar-bandi domes can tessellate horizontally to produce horizontal structures. Traditionally, it has been used in Bazaar intersections, as it is able to transition many sided intersections to create a uniform structural ceiling.
Affect: The affective property of a kar-bandi dome 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 crystallinity and stalactiformity, a kar-bandi dome can transmit other optical affects, including ribbing, stellatedness, symmetry, faceting, diagonality pleating, asymmetry, rectangularity, orientedness, rotundity, non-orientededness, cellularity, non-repetition. The acoustical affect is diffusion.

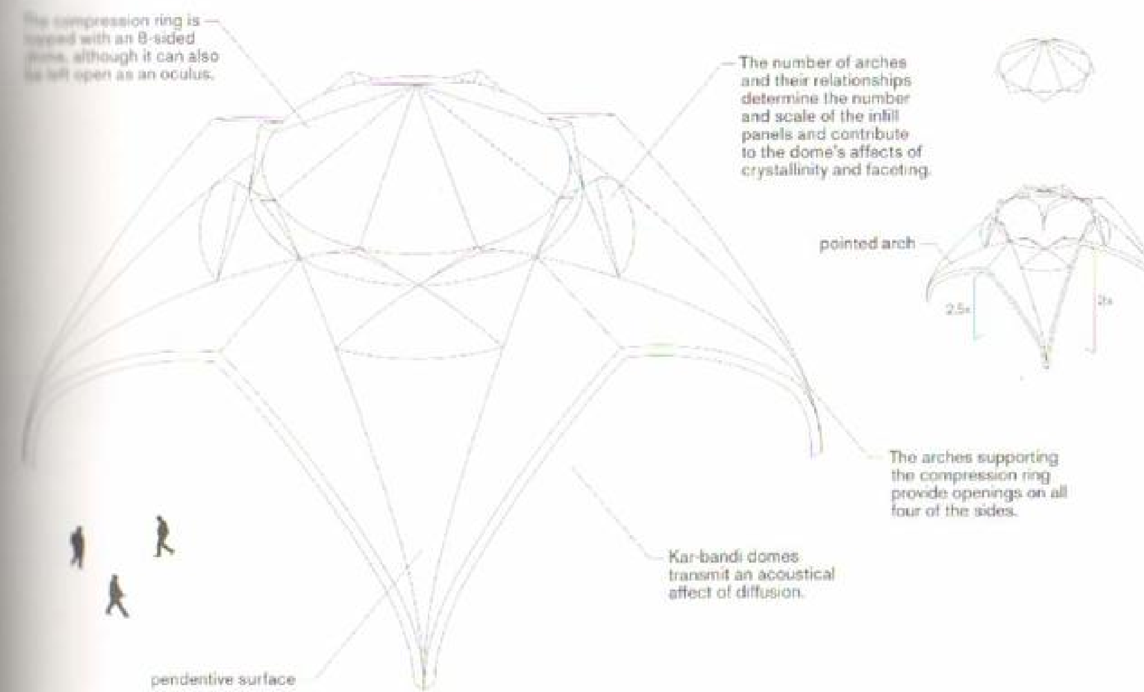


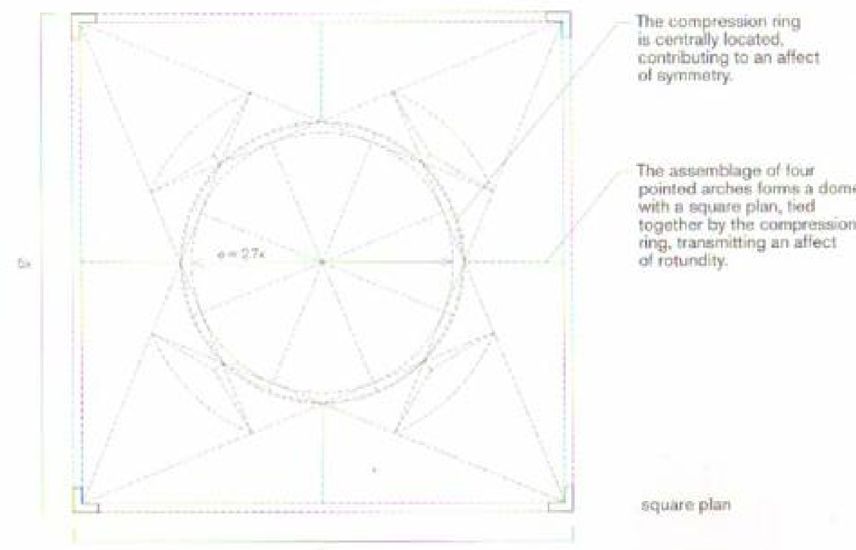
$$S = \frac{B}{2\text{–}12}$$

Crystallinity, Faceting, Rotundity, Symmetry, Diffusion



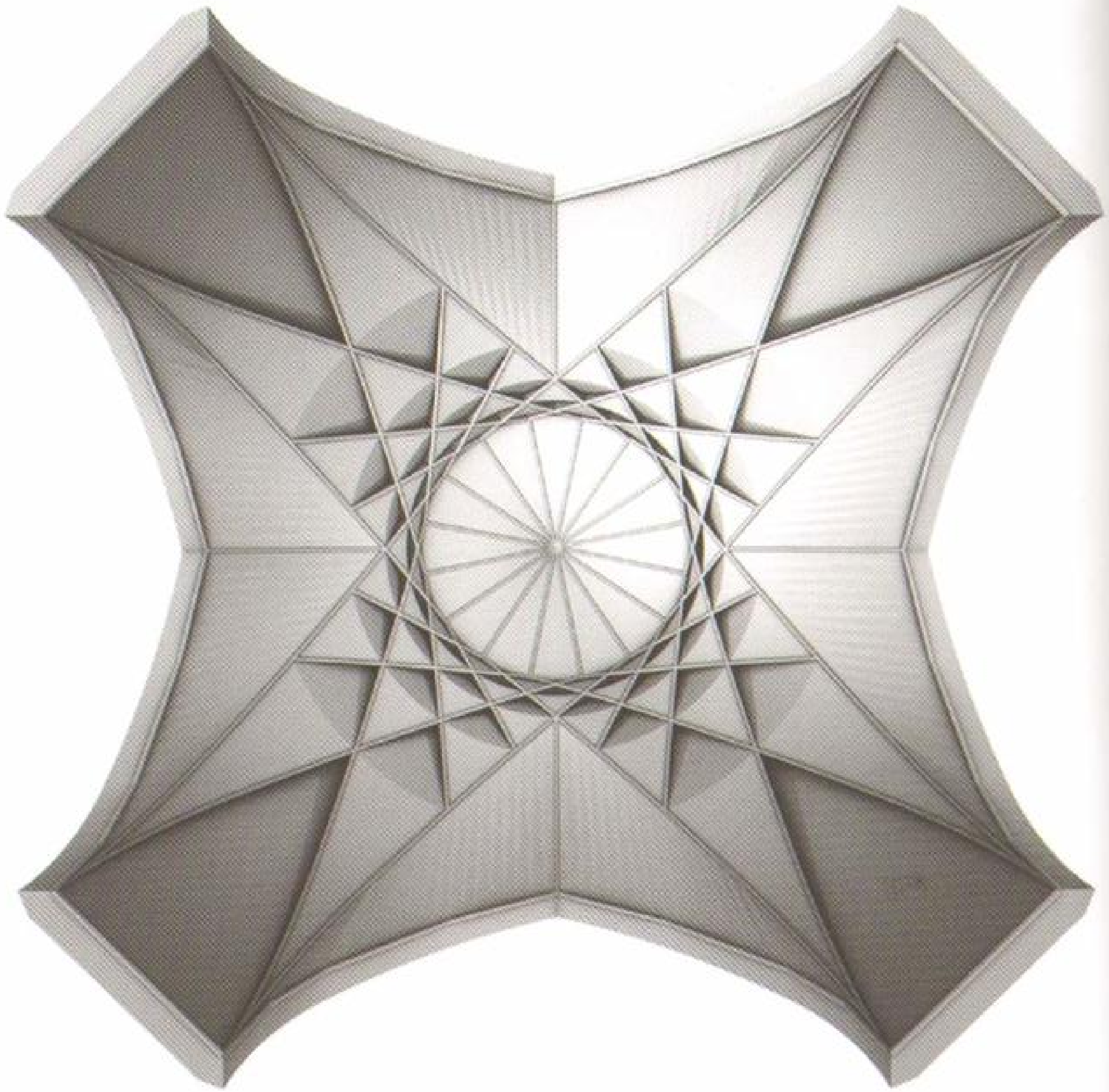
Horizontal / Kar-Bandi Dome



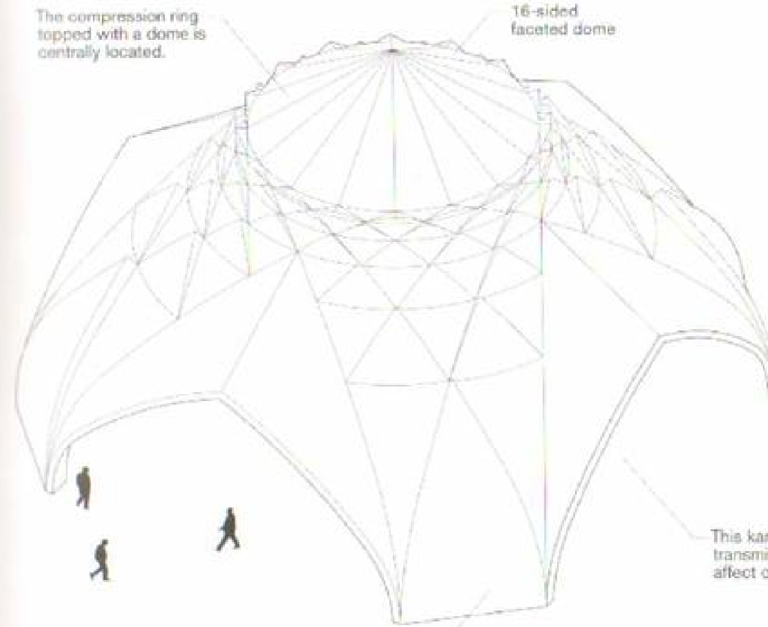


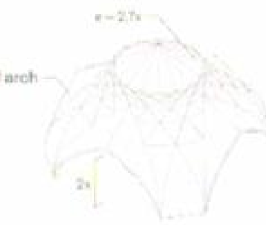
This dome is formed by a base unit composed of two pointed arches and four pendentives arrayed twice around a central compression ring. The dome form is a transition from the circular compression ring at the top to a square plan with four pointed arches at its base. The degree of subdivision of the kar-bandi's surface is determined by the number of arches and infill surfaces that are introduced, with the pendentives further subdivided into a diamond grid that produces triangulated facets. This kar-bandi dome assemblage transmits an optical affect of crystallinity, faceting and rotundity, and an acoustical affect of diffusion.

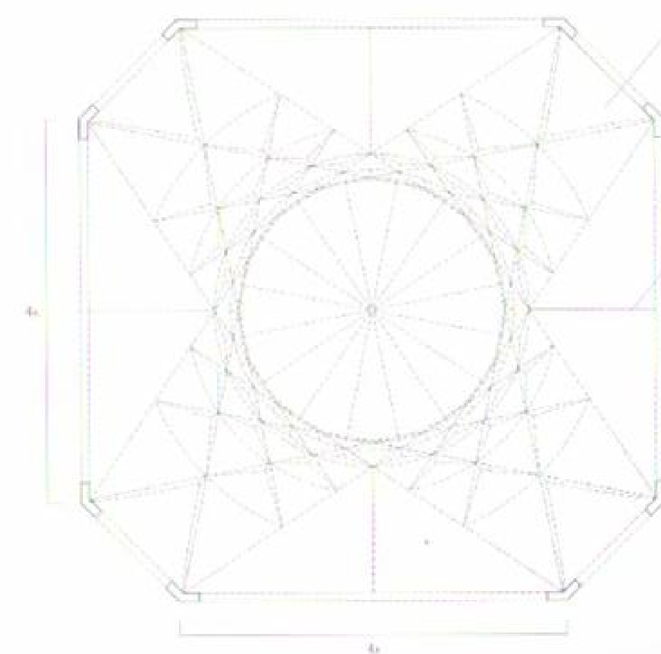
Crystallinity, Faceting, Rotundity, Focusing, Diffusion



Horizontal / Kar-Bandi Dome



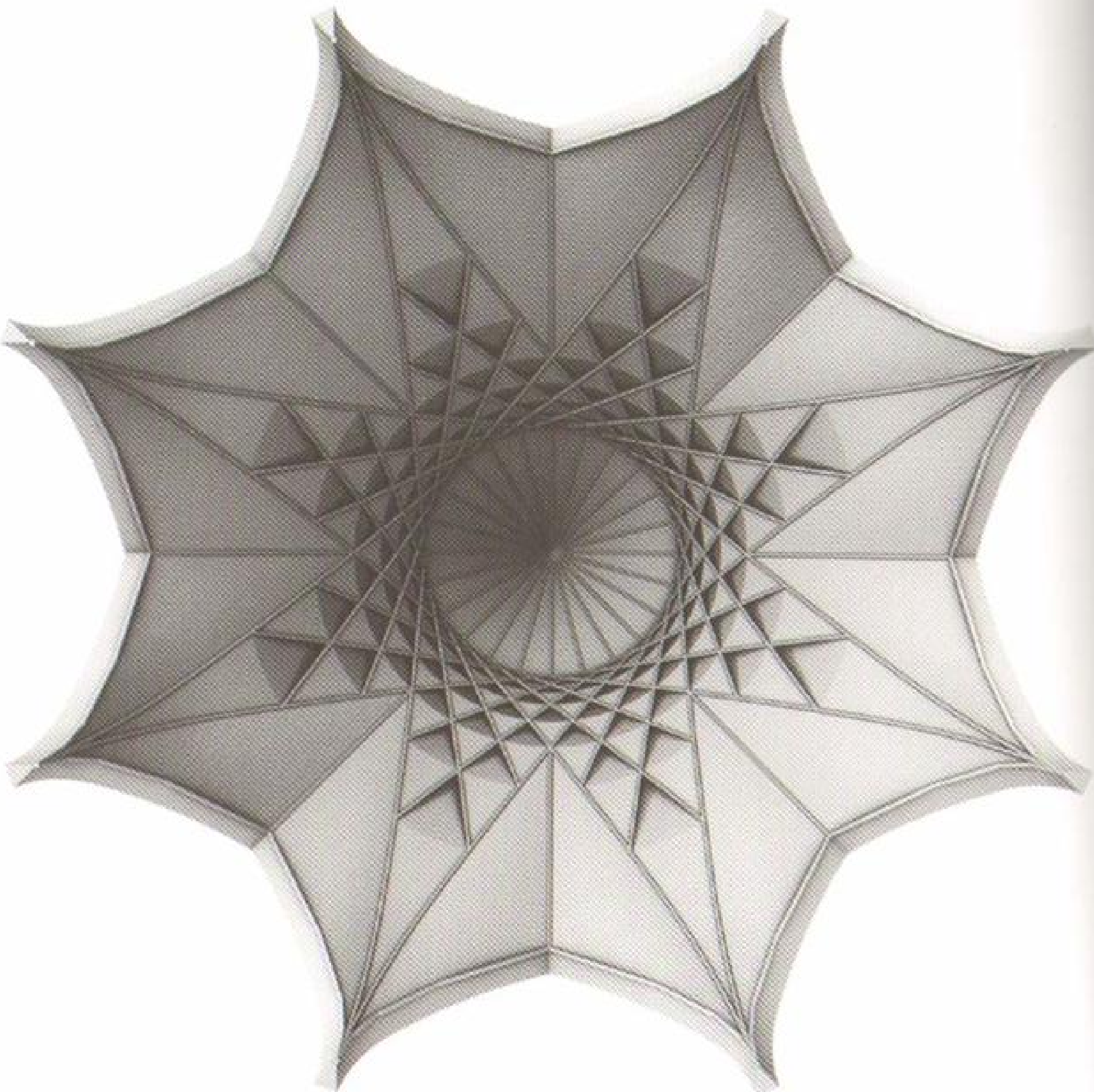




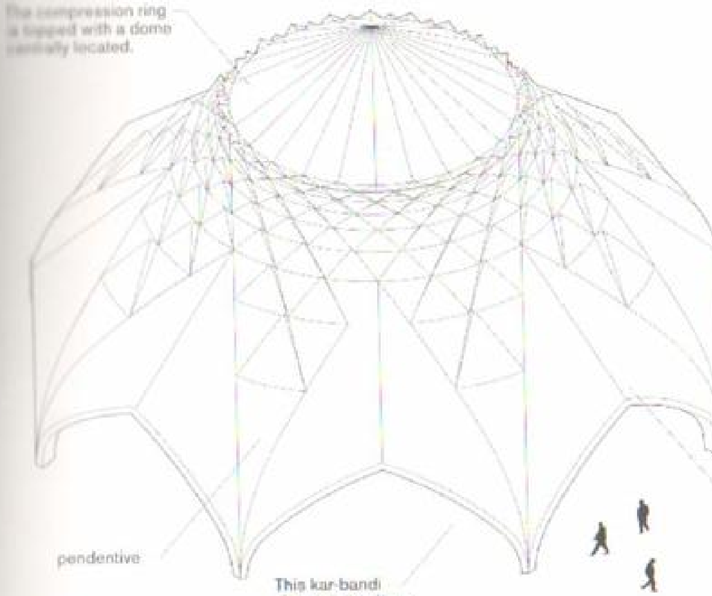
octagonal plan

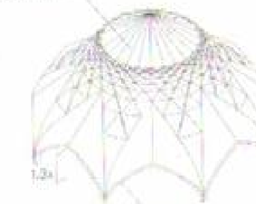
This dome is formed by a base unit composed of two pointed arches and four pendentives, which is repeated twice. The dome form is a transition from the circular compression ring at the top to an octagonal plan, and has four pointed arches at its base. The degree of subdivision of the kar-bandi's surface is determined by the number of arches and infill surfaces which are introduced, with the pendentives further subdivided into a diamond grid that produces triangulated facets. This kar-bandi dome assemblage transmits an optical affect of crystallinity, faceting and rotundity, and an acoustical affect of focusing and diffusion.

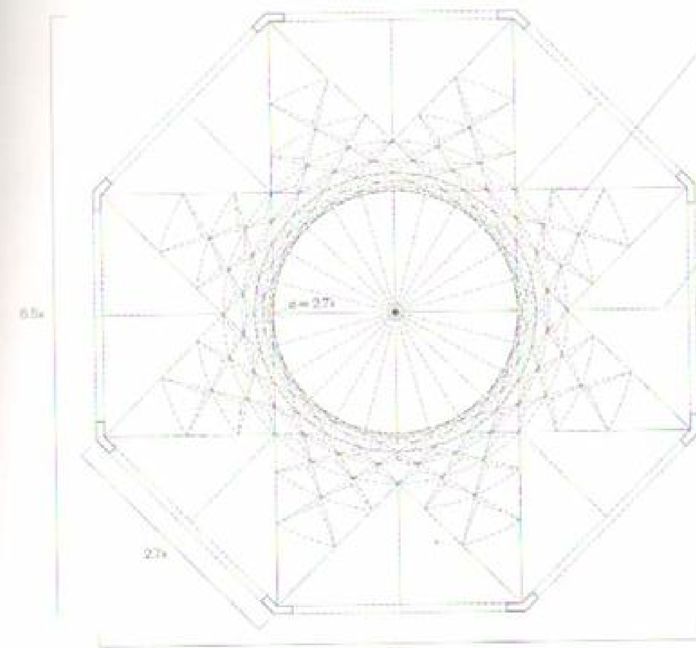
Crystallinity, Faceting, Rotundity, Focusing, Diffusion



Horizontal / Kar-Bandi Dome

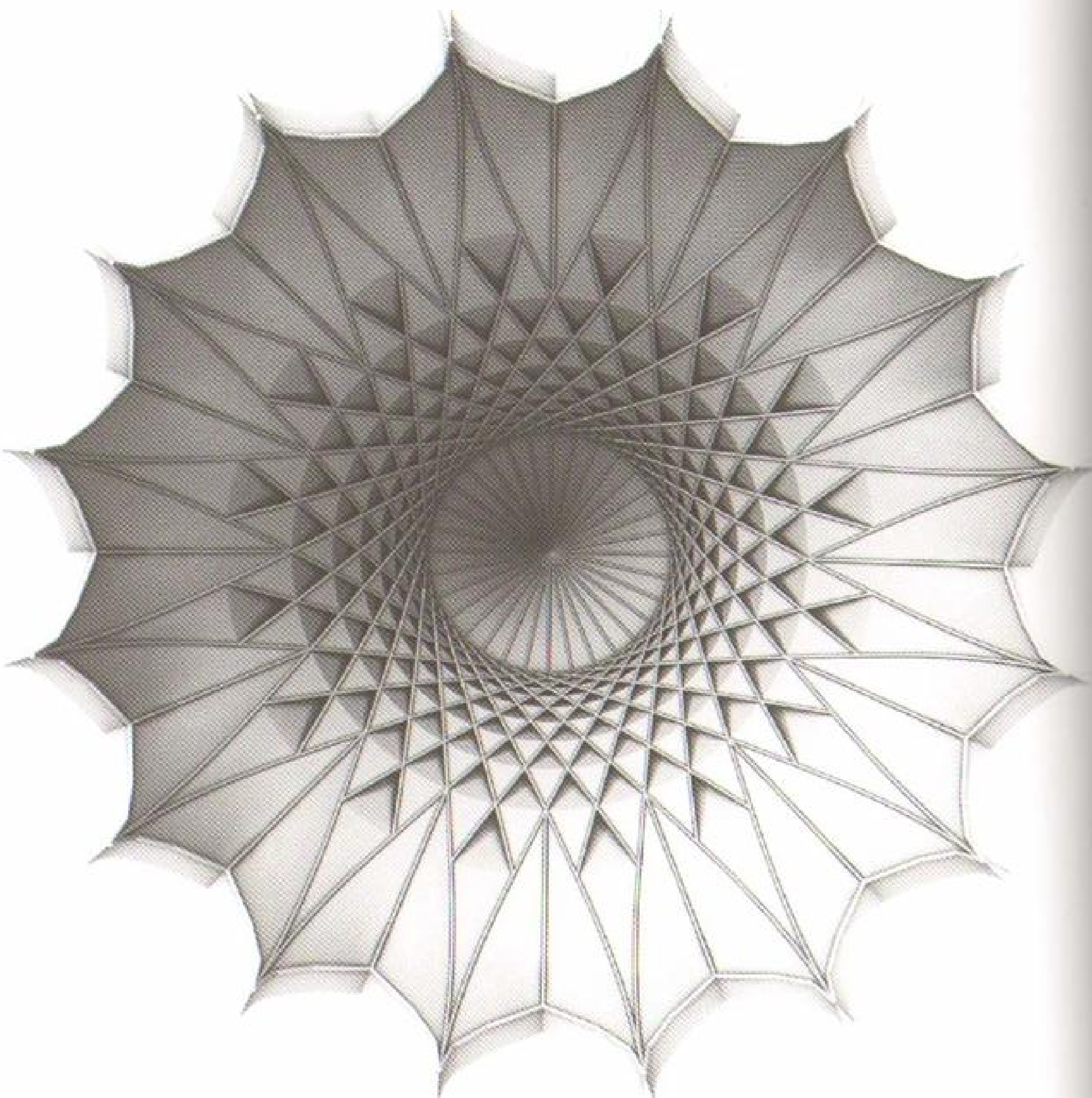




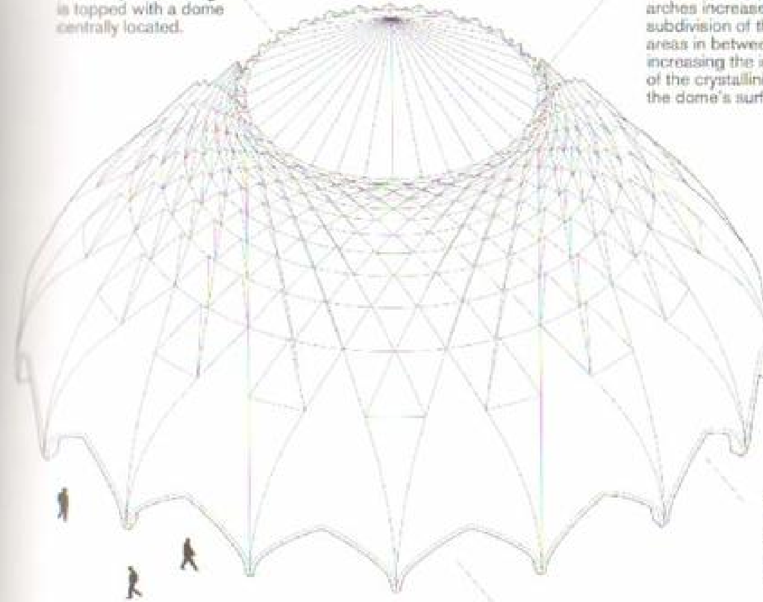


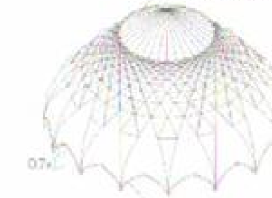
This dome is formed by a base unit composed of two pointed arches and four pendentives, which is repeated four times. The dome form is a transition from the circular compression ring at the top to an octagonal plan with four pointed arches at its base. The degree of subdivision of the kar-bandi's surface is determined by the number of arches and infill surfaces that are introduced, with the pendentive surfaces further subdivided into a diamond grid that produces triangulated facets. This kar-bandi dome assemblage transmits an optical affect of crystallinity, asymmetry and rotundity, and acoustical affects of focusing and diffusion.

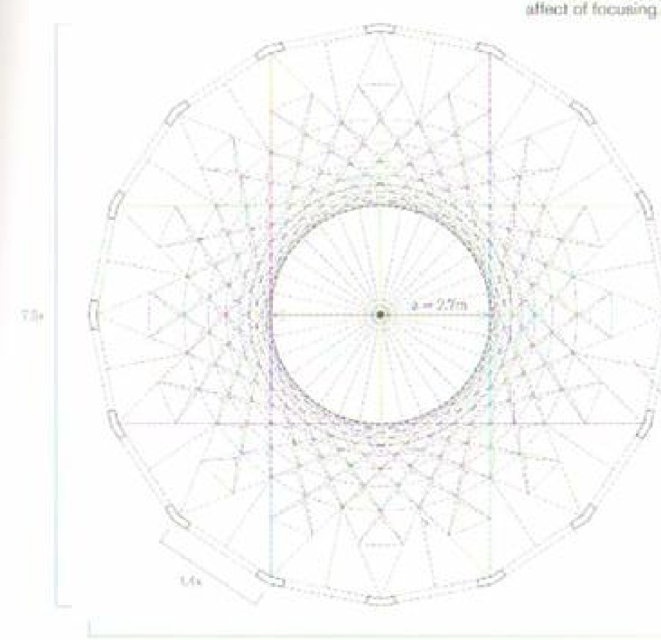
Crystallinity, Enclosure, Rotundity, Focusing, Diffusion



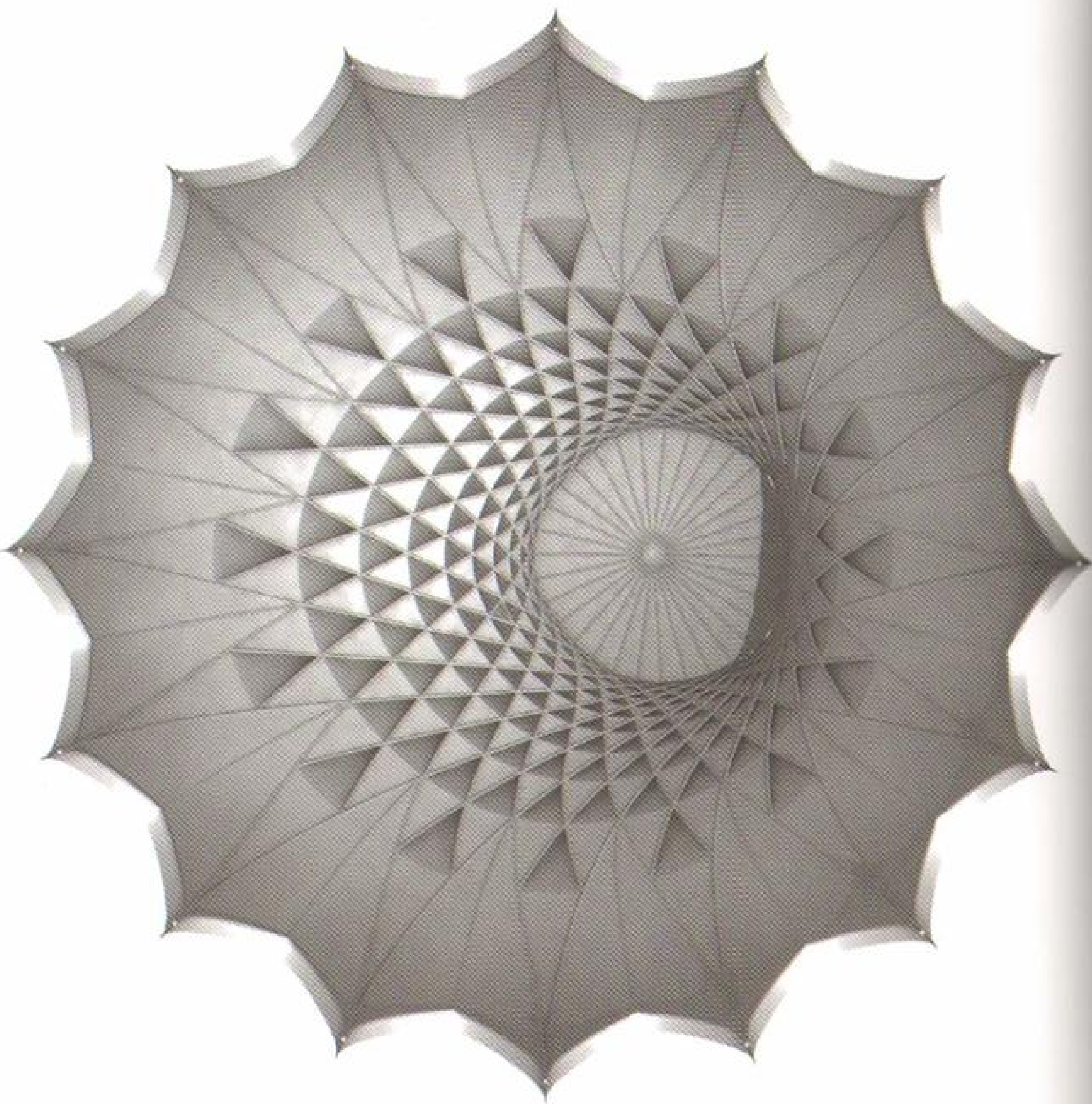
Horizontal / Kar-Bandi Dome



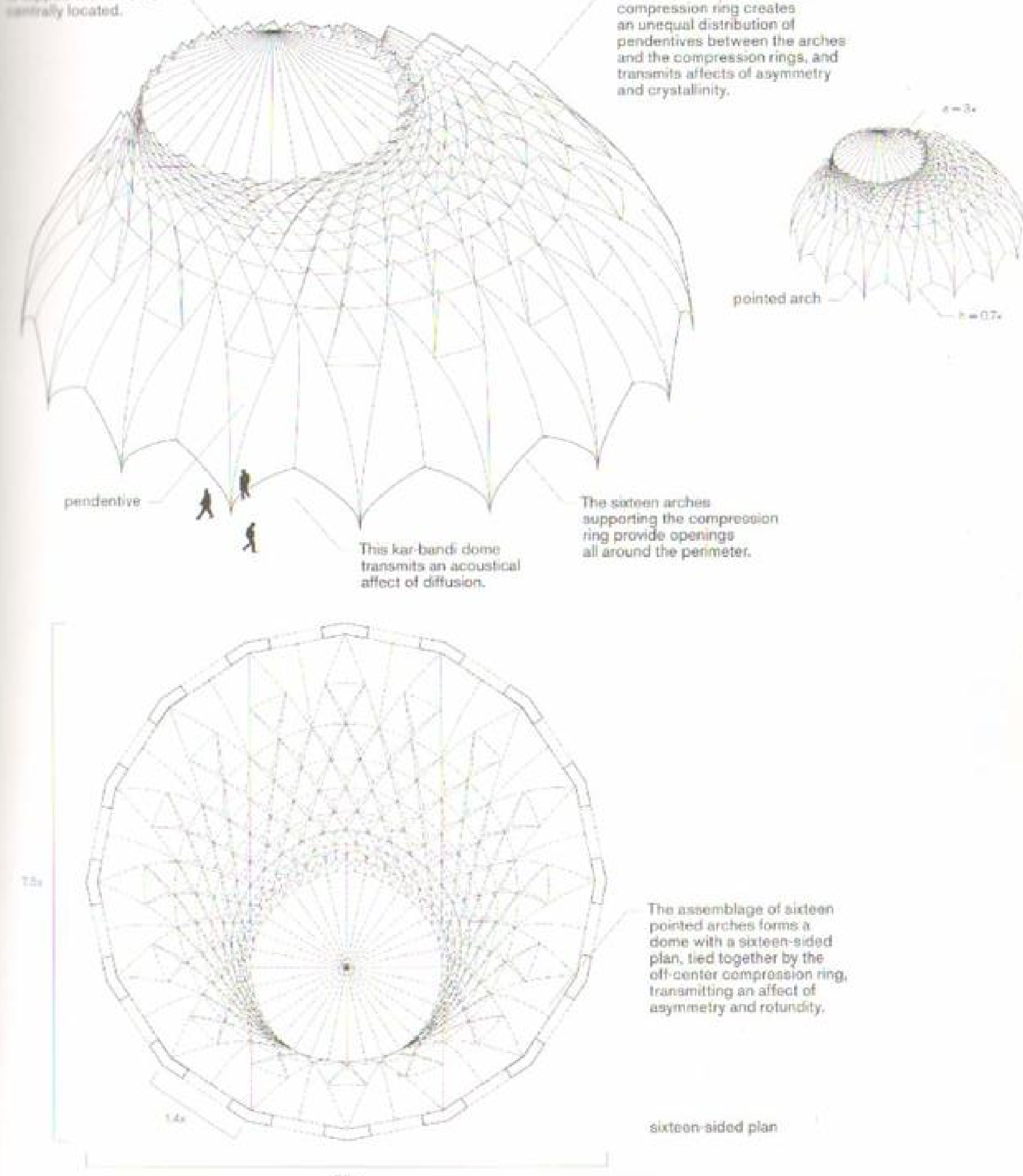




This dome is formed by a base unit made of two pointed arches and four pendentives, which is repeated eight times. The dome form is a transition from a circular compression ring at the top to an octagonal plan with four pointed arches at its base. The degree of subdivision of the kar-bandi's surface is determined by the number of arches and infill surfaces that are introduced, with the pendentives further subdivided into a diamond grid that produces triangulated facets. This kar-bandi dome assemblage transmits an optical affect of crystallinity, enclosure and rotundity, and acoustical affects of diffusion and focusing.

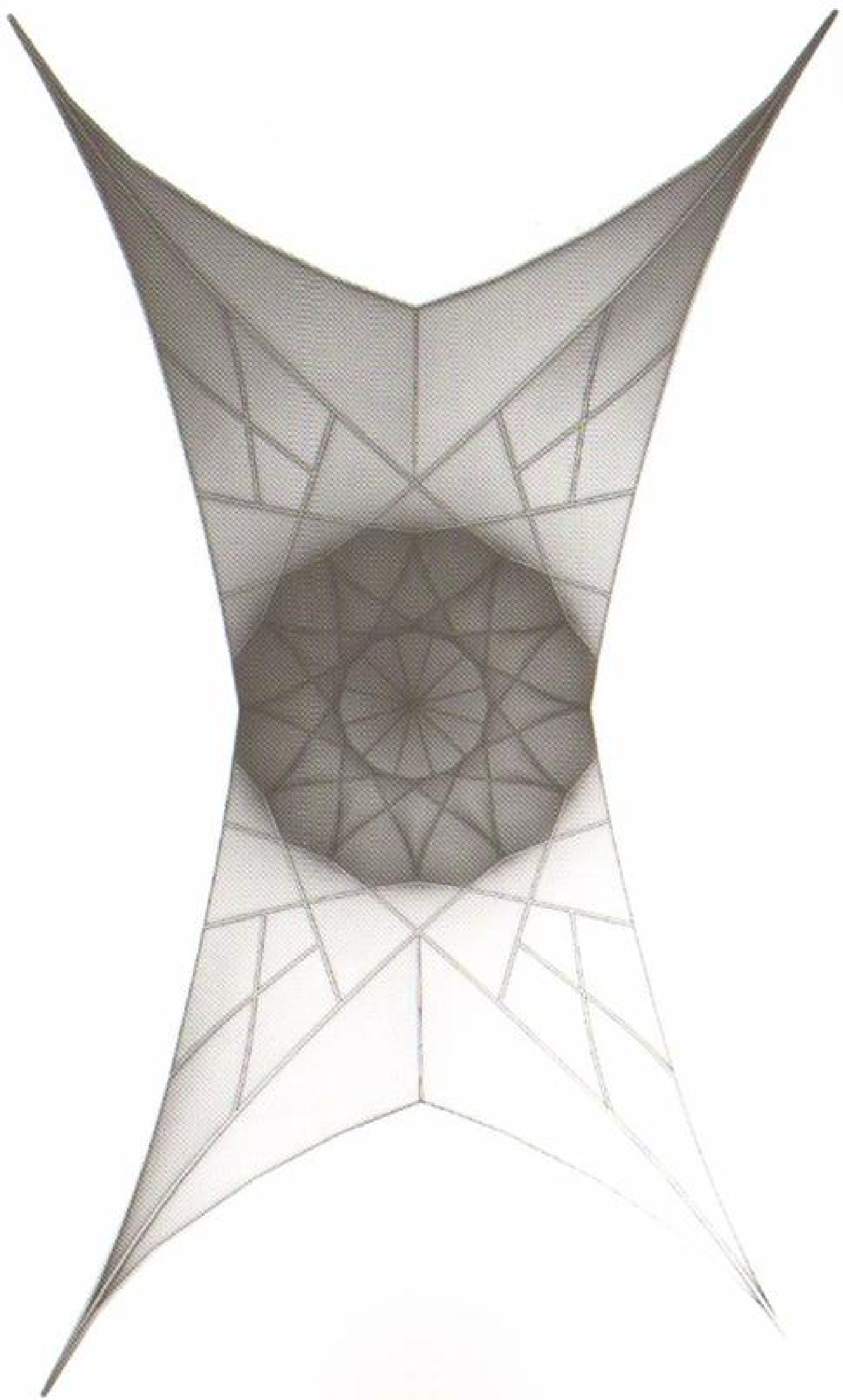


Horizontal / Kar-Bandi Dome

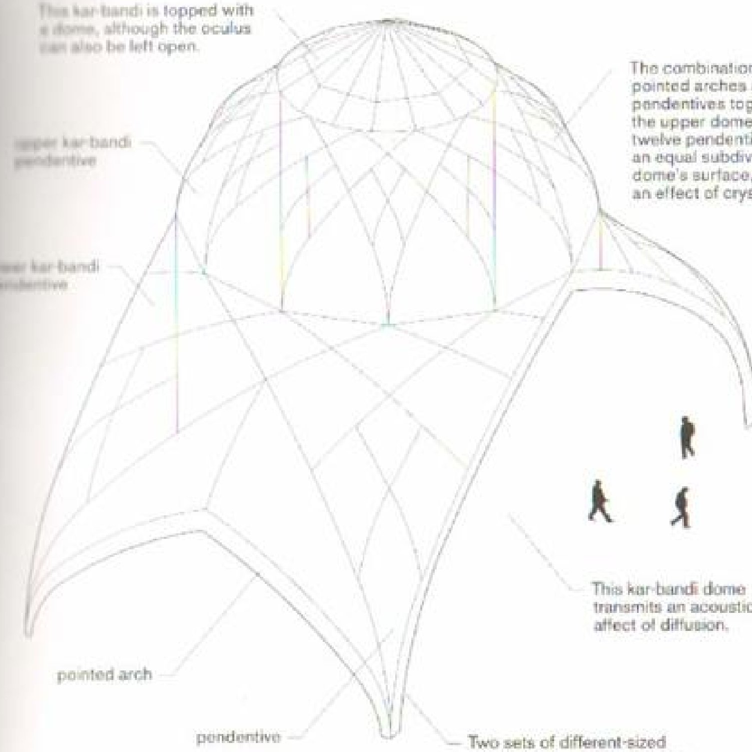


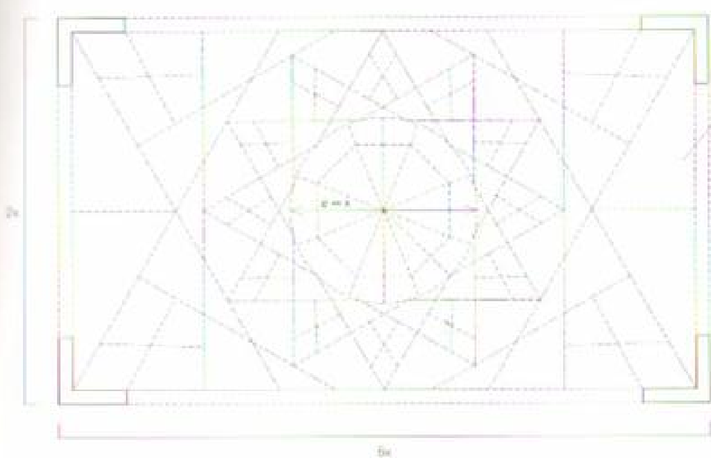
This dome is formed by a base unit made of two pointed arches and four pendontives which is repeated eight times. The dome form is a transition from a circular compression ring located asymmetrically at the top to an octagonal plan with four pointed arches at its base. The degree of subdivision of the kar-bandi's surface is determined by the number of arches and infill surfaces that are introduced, with the pendontives further subdivided into a diamond grid that produces triangulated facets. This kar-bandi dome assemblage transmits an optical affect of crystallinity, asymmetry and rotundity, and an acoustical affect of diffusion.

Crystallinity, Orientedness, Rotundity, Diffusion



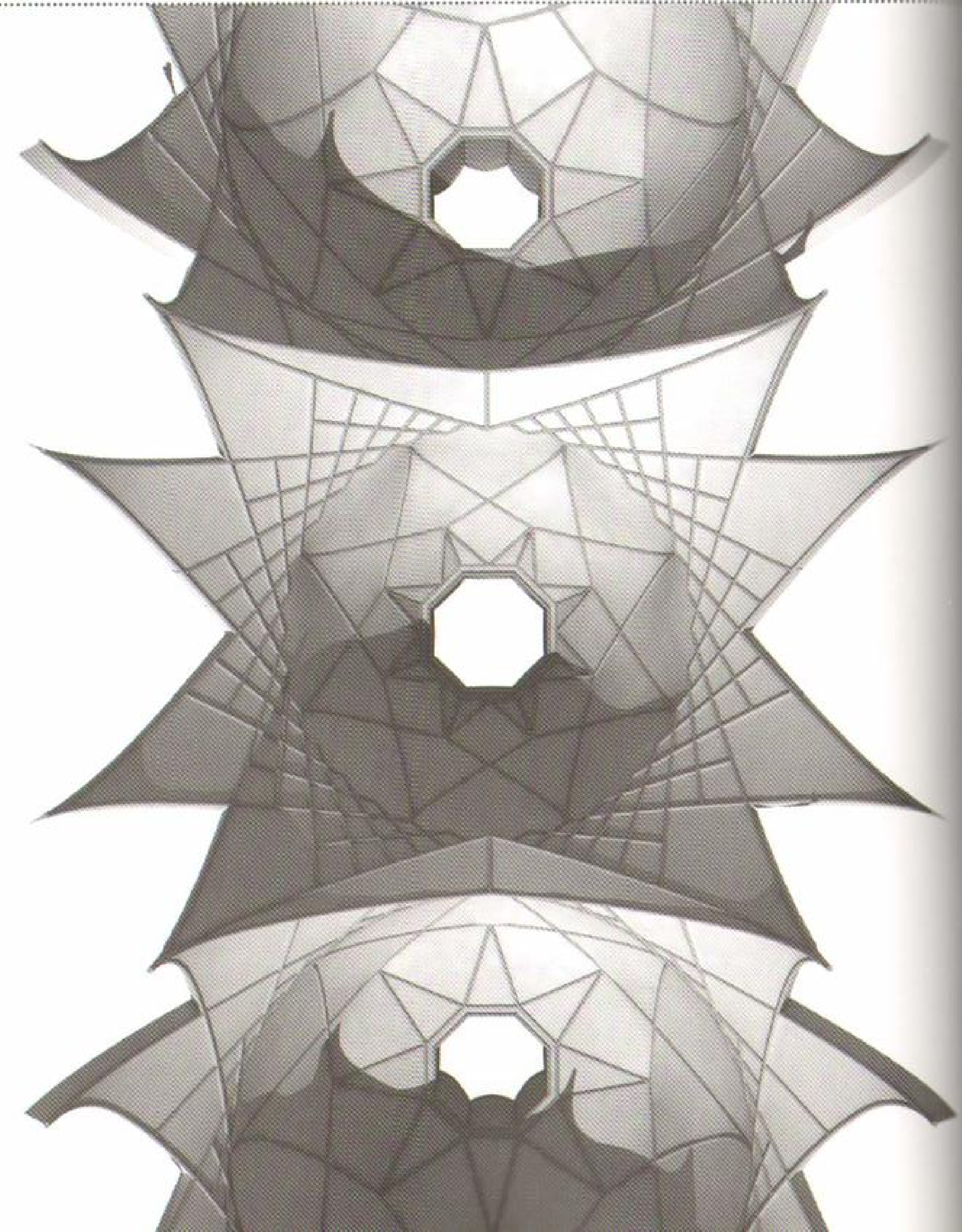
Horizontal / Kar-Bandi Dome



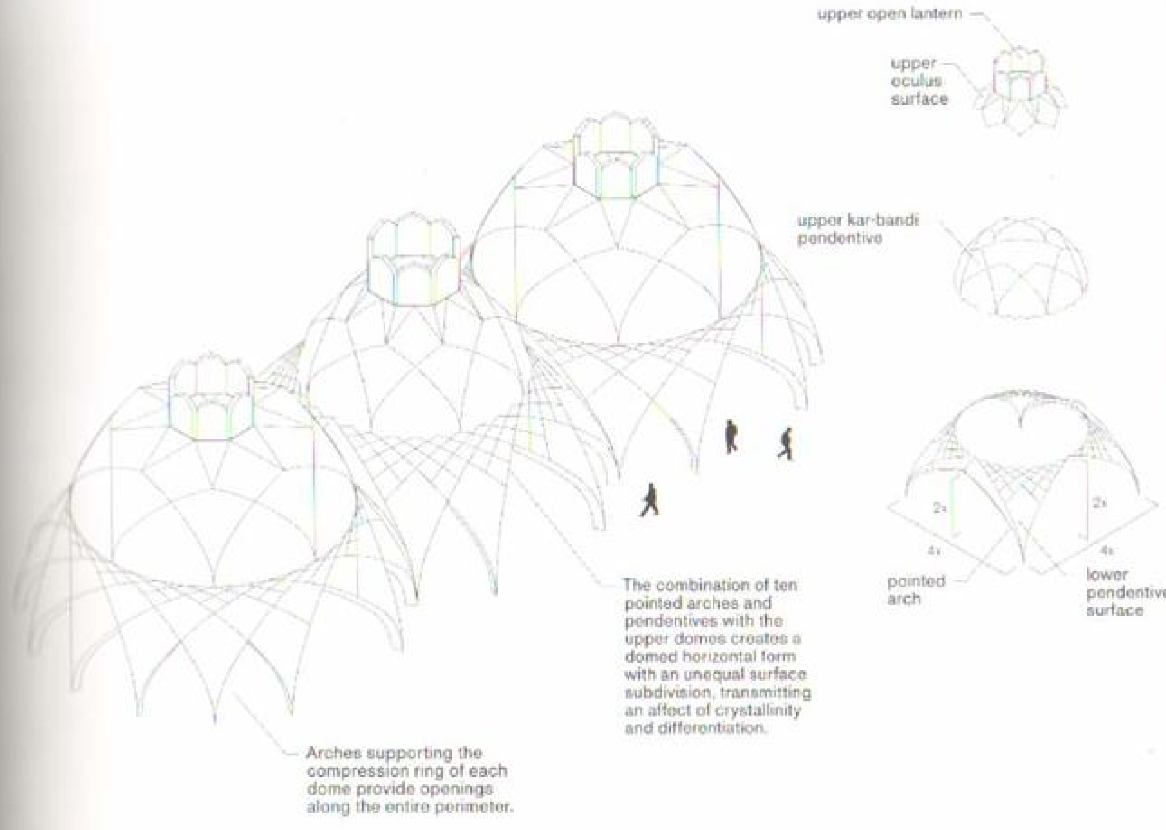


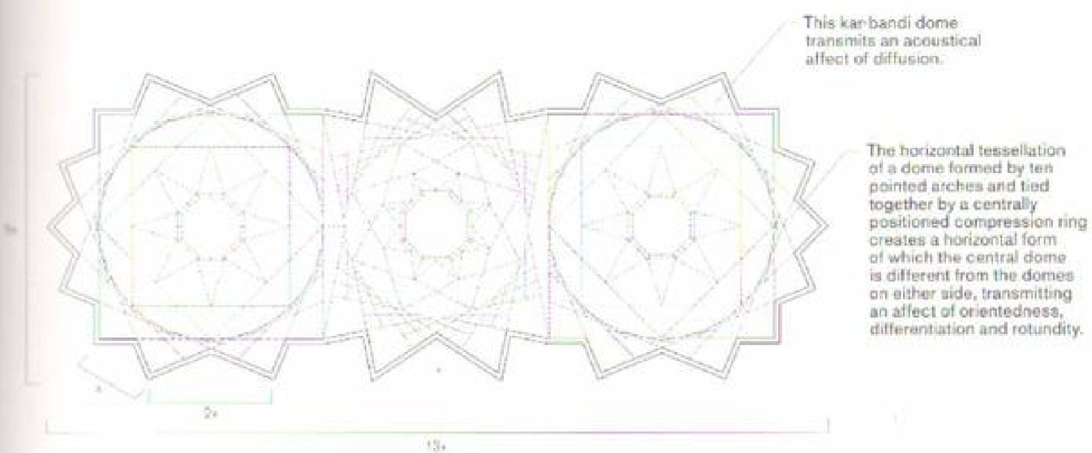
This dome is formed by stacking an upper and a lower kar-bandi base unit. Each base unit is composed of pointed arches and pendentives. The open ring or oculus formed at the top is covered by a shallow dome. The degree of subdivision of the kar-bandi's surface is determined by the number of arches and infill surfaces that are introduced, with the pendentives further subdivided into a diamond grid that produces triangulated facets. This hybrid kar-bandi dome assemblage transmits an optical affect of crystallinity, orientedness and rotundity, and an acoustical affect of diffusion.

Crystallinity, Differentiation, Rotundity, Orientedness, Diffusion



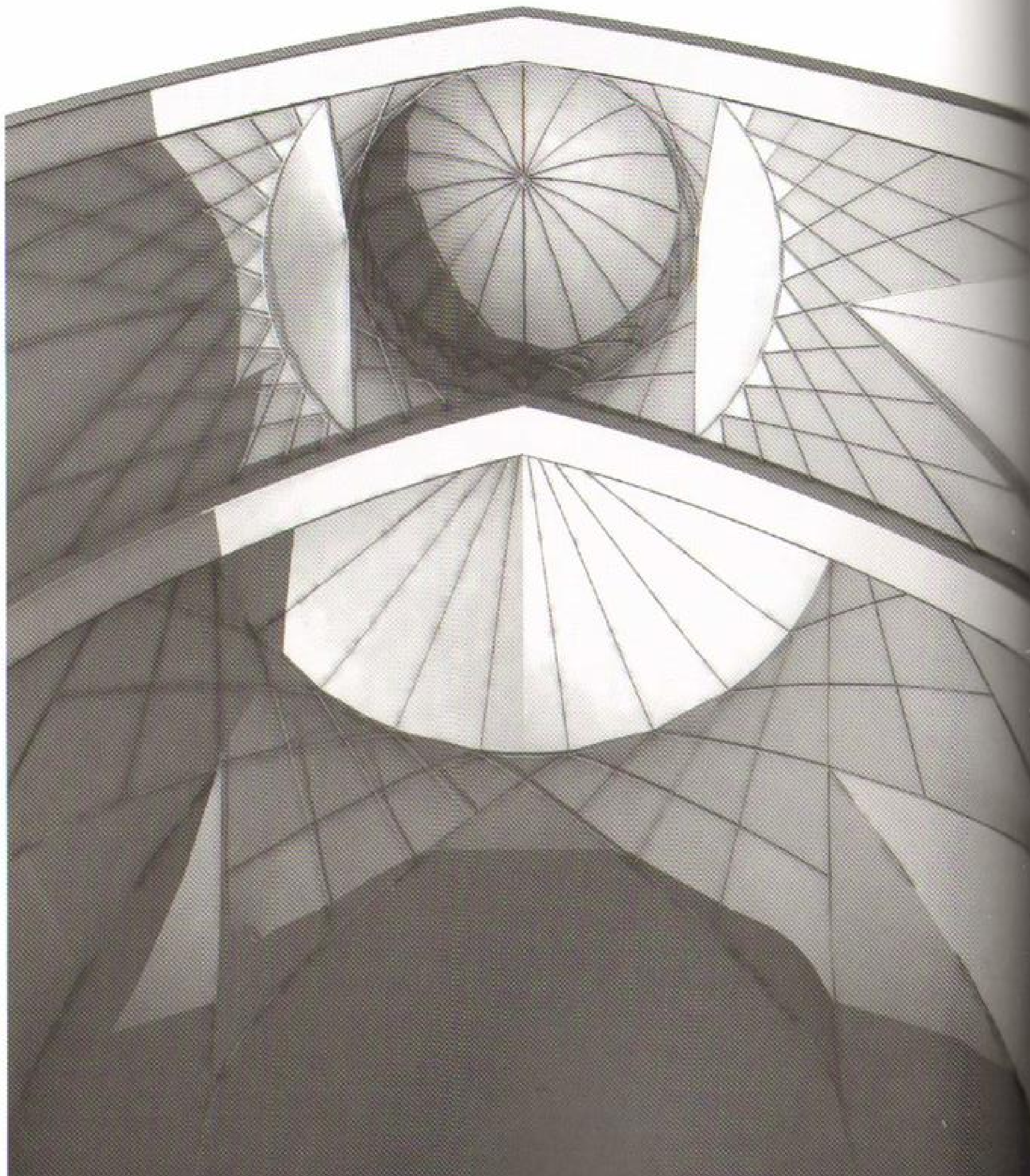
Horizontal / Kar-Bandi Dome





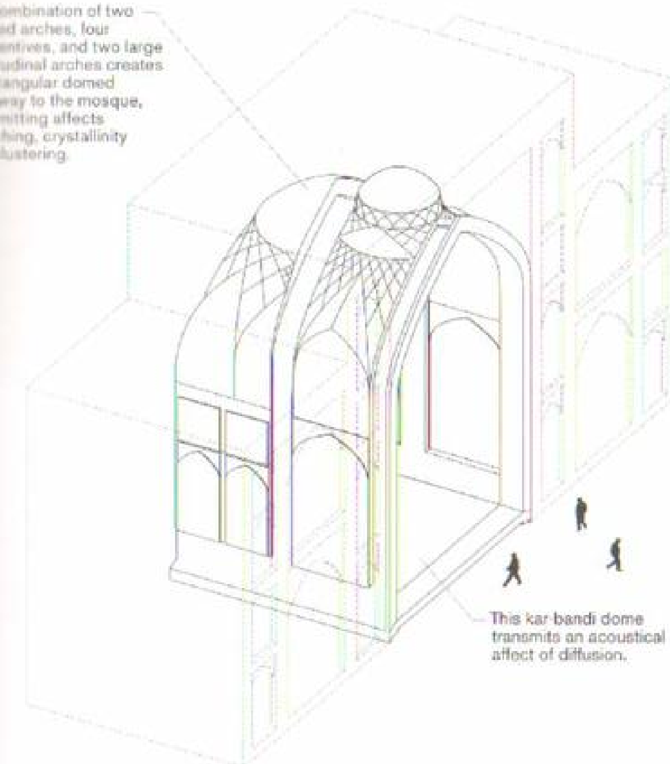
This kar-bandi dome assemblage is formed by the horizontal tessellation of a kar-bandi dome base unit. Each dome is formed by the stacking of an upper and a lower kar-bandi base unit. Each base unit is composed of ten pointed arches of varying scales and infill pendentive surfaces. An upper oculus surface and open lantern rest on the open ring formed at the top of each dome. The degree of subdivision of the kar-bandi's surface is determined by the number of arches and infill surfaces that are introduced, with the pendentive surfaces further subdivided into a diamond grid that produces triangulated facets. This hybrid kar-bandi dome assemblage transmits an optical affect of crystallinity, orientedness and rotundity, and an acoustical affect of diffusion.

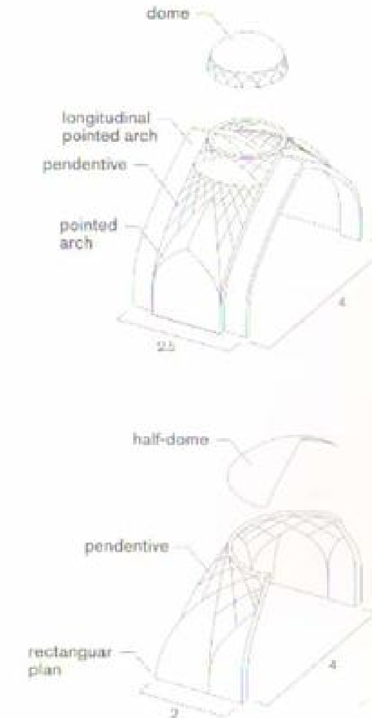
Rectangularity, Crystallinity, Arching, Clustering, Diffusion

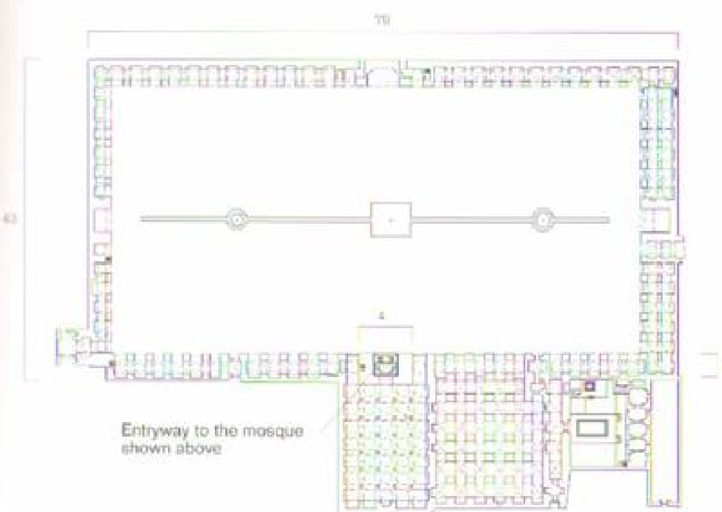


Horizontal / Kar-Bandi Dome

MASJED NOE MOSQUE | SHIRAZ, IRAN | 1750





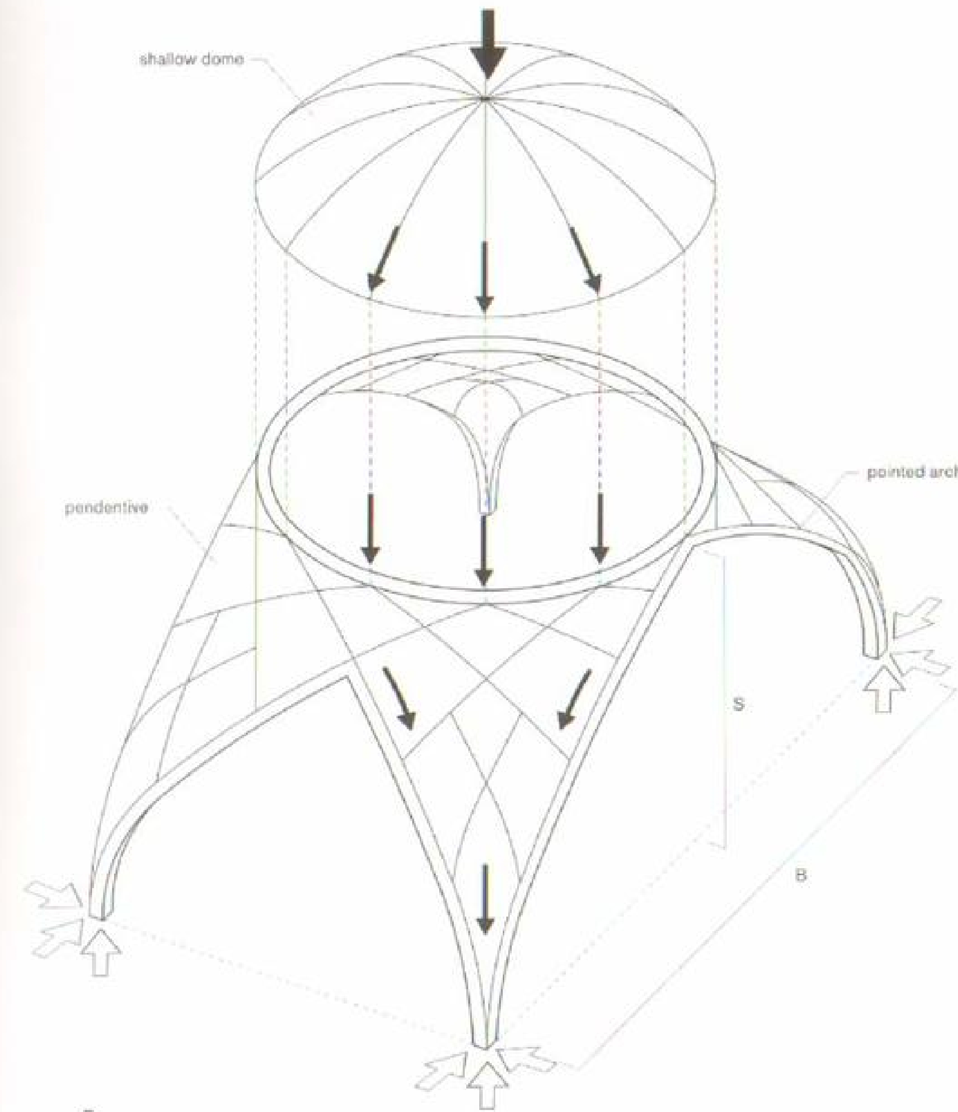


The entryway of Masjed Noe mosque is a hybrid combining a kar-bandi base unit with two larger side-arches. The base unit is formed by two pointed arches, four pendentive surfaces, and two larger arches which are longitudinal. The degree of subdivision of the kar-bandi's surface is determined by the number of arches and infill surfaces that are introduced, with the pendentives further subdivided into a diamond grid that produces triangulated facets. The entryway of Masjed Noe mosque transmits an optical affect of rectangularity, pleatedness, arching and clustering, and an acoustical affect of diffusion.

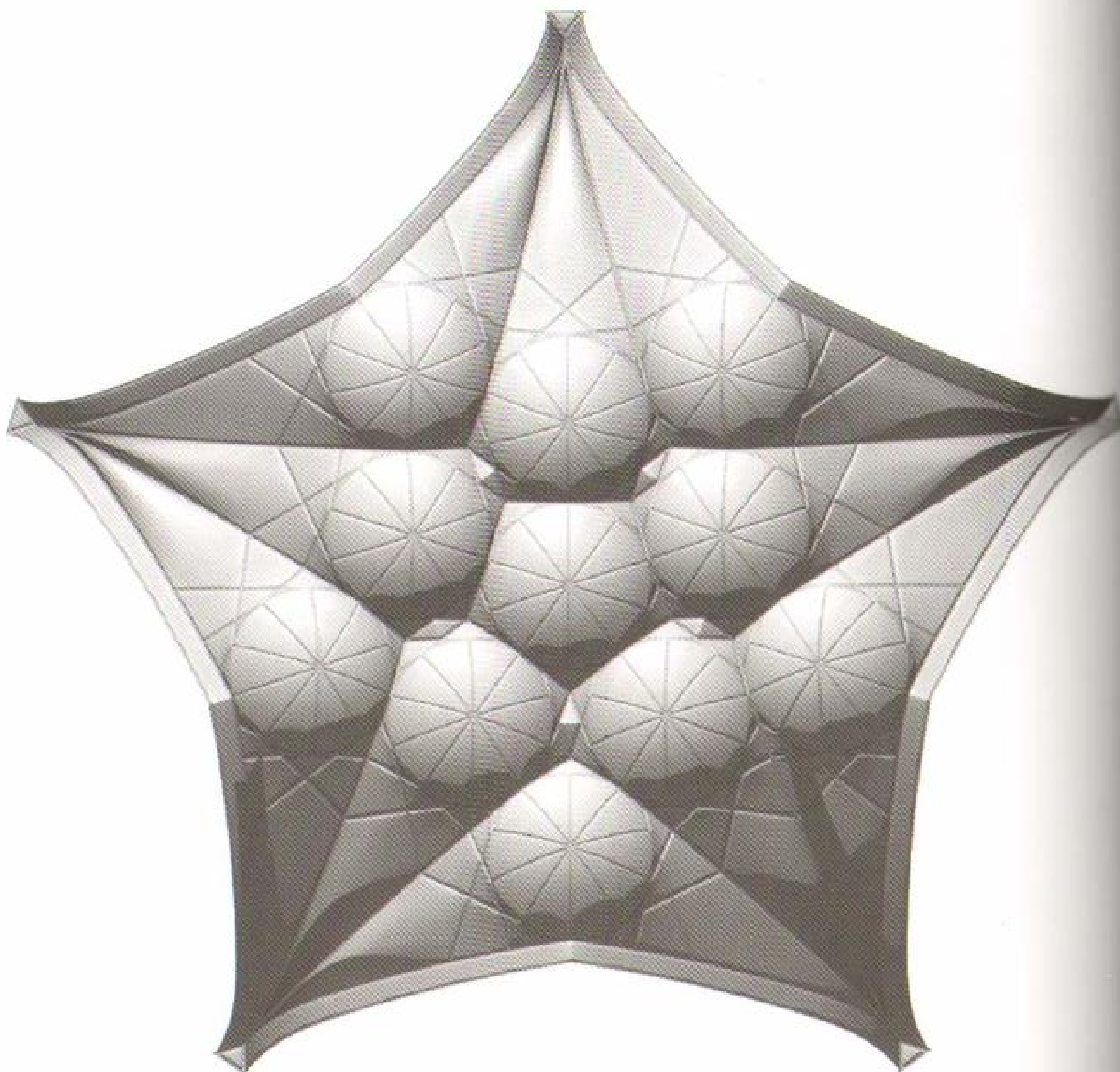
Kaseh-Sazi Dome

The base unit of the kaseh-sazi dome is composed of small shallow domes and a kar-bandi dome each made up of pendentive surfaces which span from a polygonal plan to a top circular ring. The shallow domes resting above the kar-bandi can take any shape or height as they do not have to provide structural strength to the entire assemblage. Structure is provided by the kar-bandi base whilst the shallow domes cover the opening formed by the kar-bandi. The kaseh-sazi dome system is therefore a hybrid assemblage which can be tessellated horizontally to create forms with a shallow domed ceiling. Kaseh-sazi domes direct the loads along both the upper and the lower surfaces, towards the pointed arches that form the perimeter. Kaseh-sazi domes are made primarily of masonry, where the pattern of the bricks can eliminate the need for form-work, but other surface-based construction techniques, such as steel-reinforced concrete, could also be used. This distribution of loads along masonry surfaces embeds kaseh-sazi domes with an optical affective property of rectilinearity and crystallinity that remains consistent within any space they define. The multiplicity of focal points, variations of curvature and faceting all create diffusion as the dominant affect.

Kaseh-sazi domes are flexible in several ways:
Scale: The protogeometry of a kaseh-sazi dome can be flexible in the degree to which the scale of the overall surface can be subdivided to accommodate polygonal plan forms with an increasing number of faces.
Depth: The depth of the dome that forms the upper section of a kaseh-sazi dome can be shallow or deep and this alters the depth of the overall section.
Profile: Kaseh-sazi domes can tessellate horizontally along straight or curved lines of growth to produce horizontal forms.
Affect: The affective property of a kaseh-sazi dome 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 rectilinearity and crystallinity, a kaseh-sazi dome can transmit other optical affects, including ribbing, stalactiformity, stellatedness, diagonality, pleating, rotundity, symmetry, faceting, rotundity, asymmetry. The acoustical affect is diffusion.

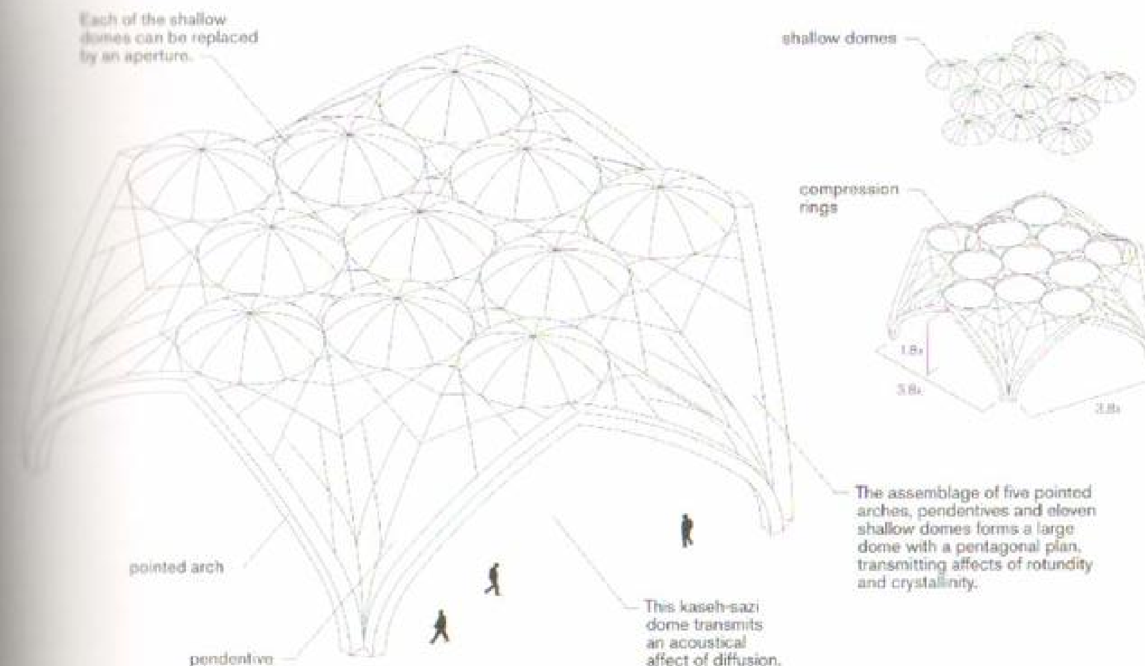


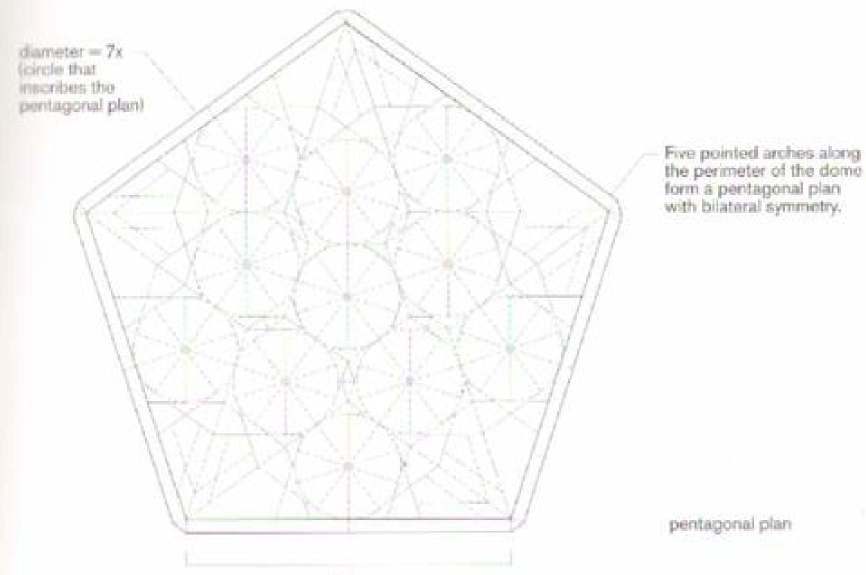
$$S = \frac{B}{2\text{-}12}$$



Horizontal / Kaseh-Sazi Dome

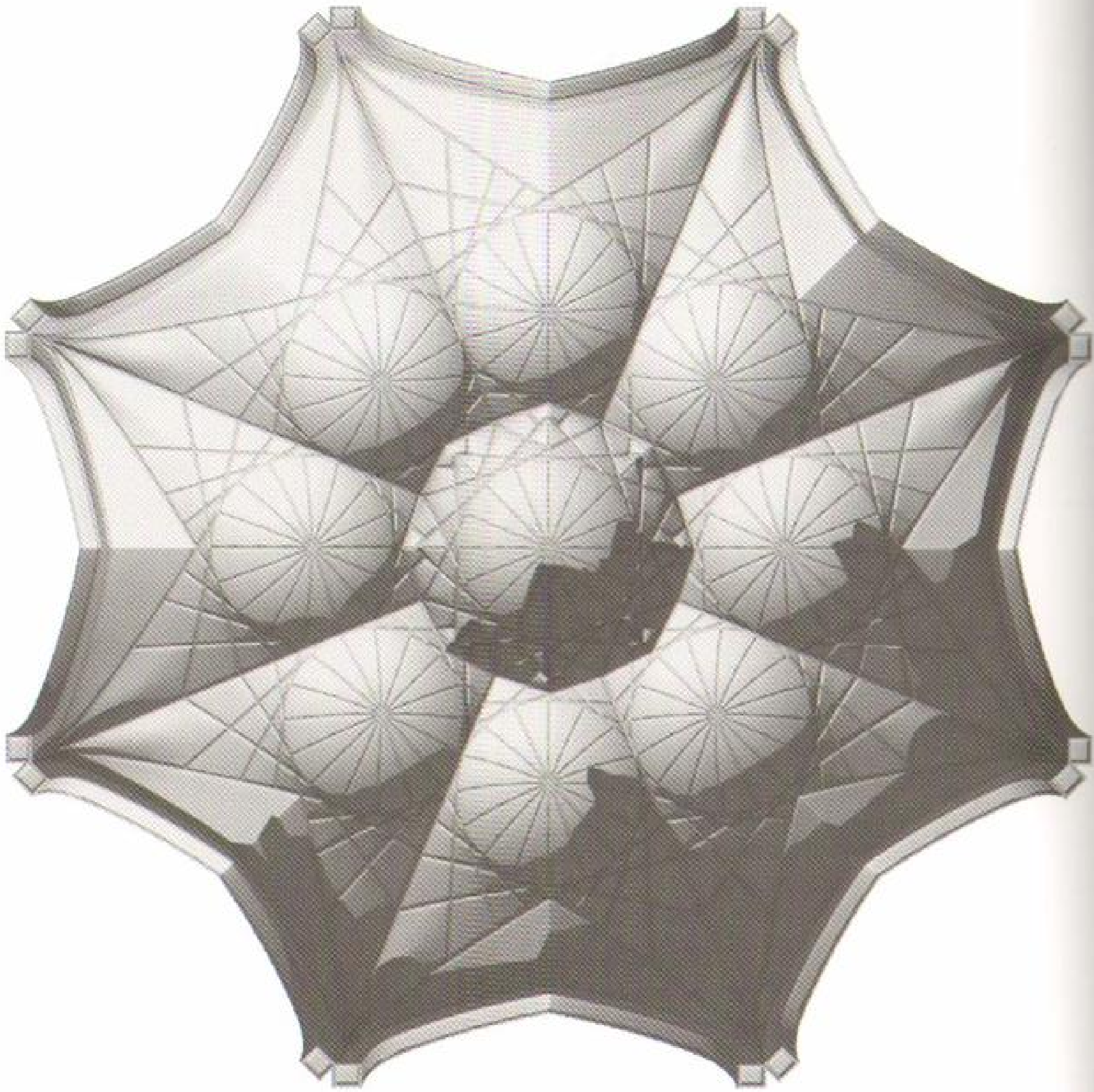
KASEH-SAZI DOME | O. ASGHAR SHAER-BAF | UNBUILT | 1960





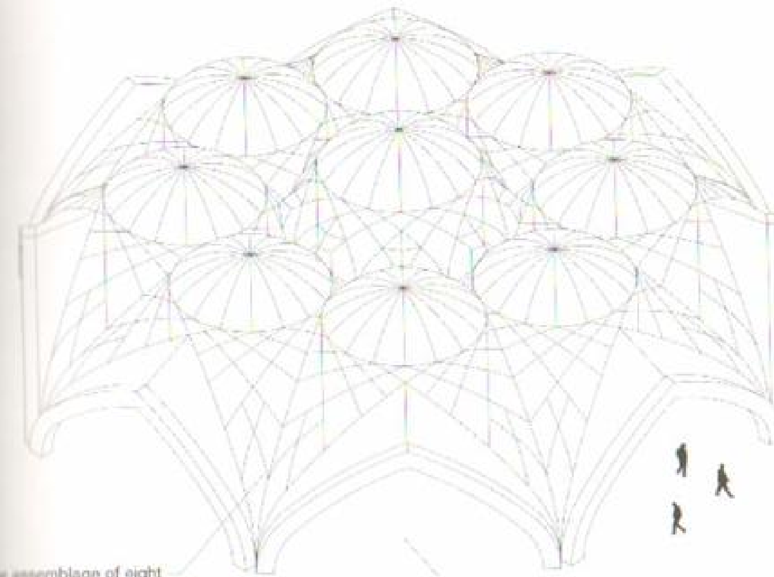
This dome is formed by five pointed arches and infill pendentive surfaces around a central pentagonal plan area covered by smaller domes. The degree of subdivision of the dome surface is determined by the number of arches and infill surfaces that are introduced, together with the upper surface which in this case is composed of eleven shallow domes. This kaseh-sazi dome assemblage transmits an optical affect of rotundity and crystallinity, and an acoustical affect of diffusion.

Rotundity, Crystallinity, Diffusion



Horizontal / Kaseh-Sazi Dome

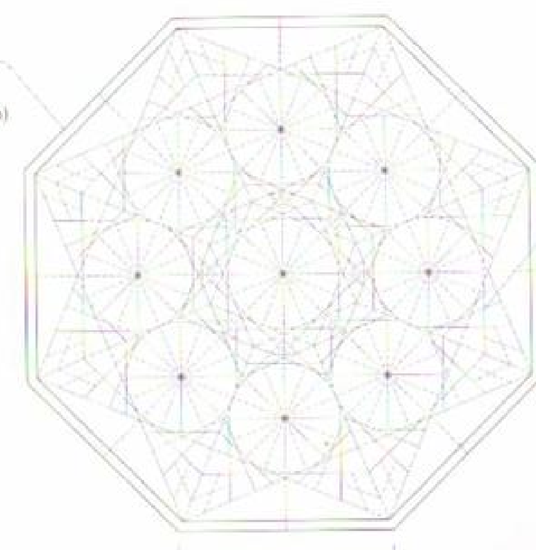
KASEH-SAZI DOME | O. ASGHAR SHAER-BAF | UNBUILT | 1969



The assemblage of eight pointed arches, pendentives and nine shallow domes forms a large dome with an octagonal plan, transmitting affects of rotundity and crystallinity.

This kaseh-sazi dome transmits an acoustical affect of diffusion.

diameter = 7x (circle that inscribes the pentagonal plan)

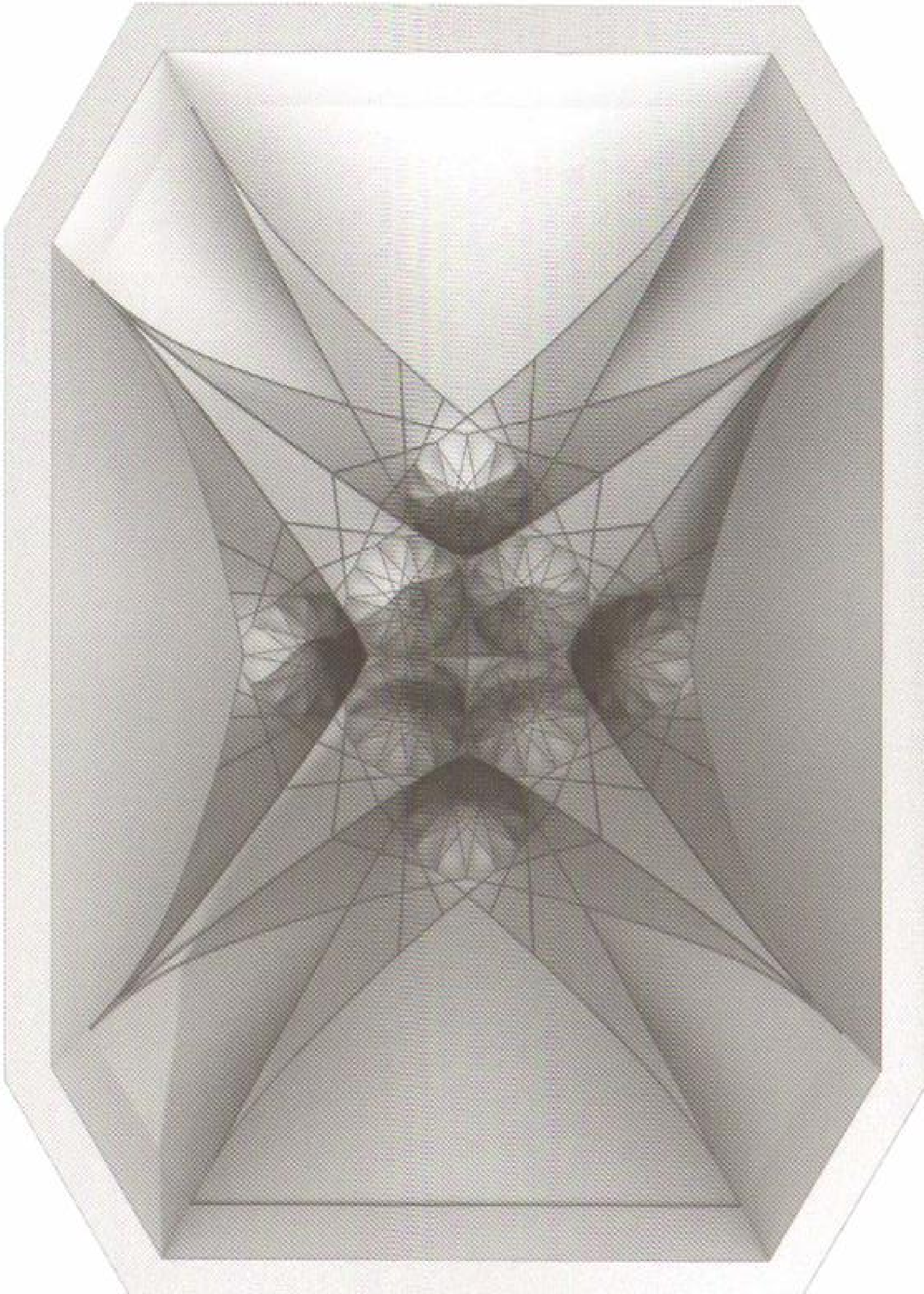


Eight pointed arches along the perimeter of the dome form an octagonal plan with bilateral symmetry.

octagonal plan

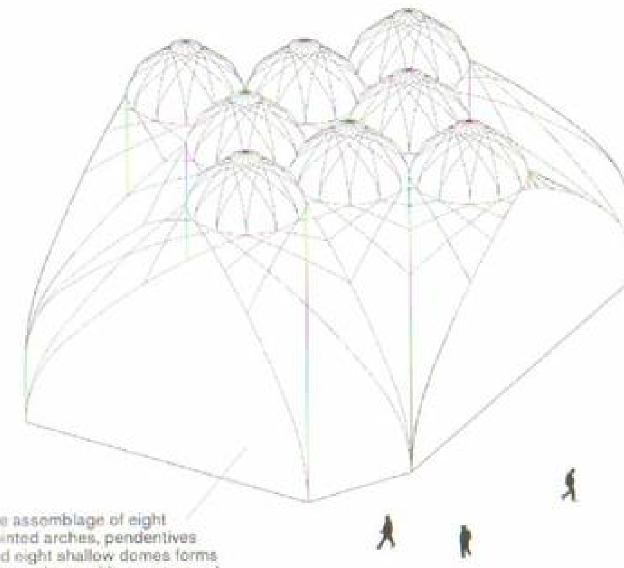
This dome is formed by a series of eight pointed arches that form an octagonal plan which are interconnected by a series of pendentives and covered by a large dome set within a ring of eight smaller ones. The degree of subdivision of the dome surface is determined by the number of arches and infill surfaces that are introduced, together with the upper surface which is composed of nine shallow domes. This kaseh-sazi dome assemblage transmits an optical affect of rotundity and crystallinity, and an acoustical affect of diffusion.

Rotundity, Crystallinity, Diffusion

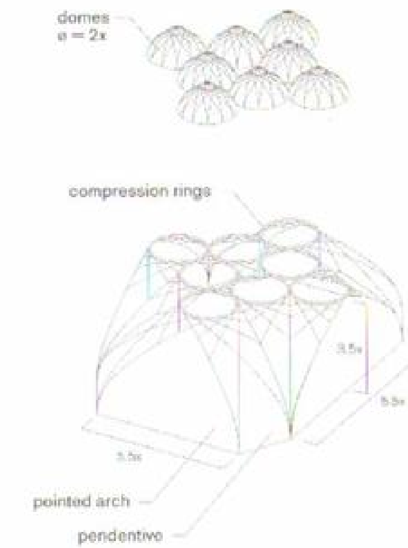


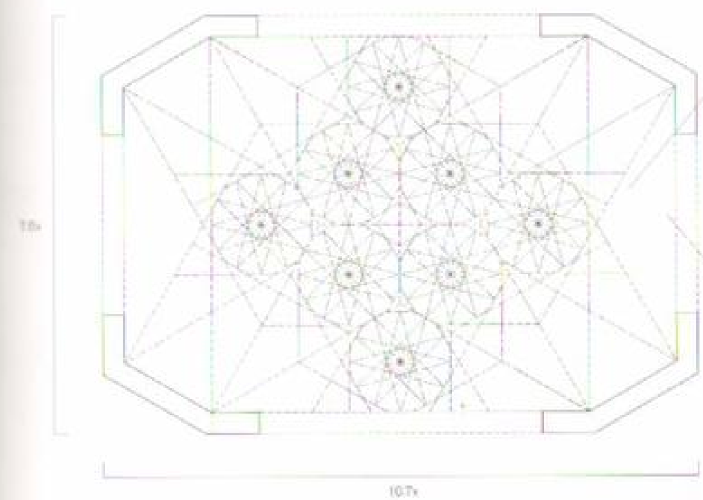
Horizontal / Kaseh-Sazi Dome

KASEH-SAZI DOME | O. HOSSEIN LOR ZADEH | UNBUILT | 1950



The assemblage of eight pointed arches, pendentives and eight shallow domes forms a large dome with an octagonal plan, transmitting affects of rotundity and crystallinity.





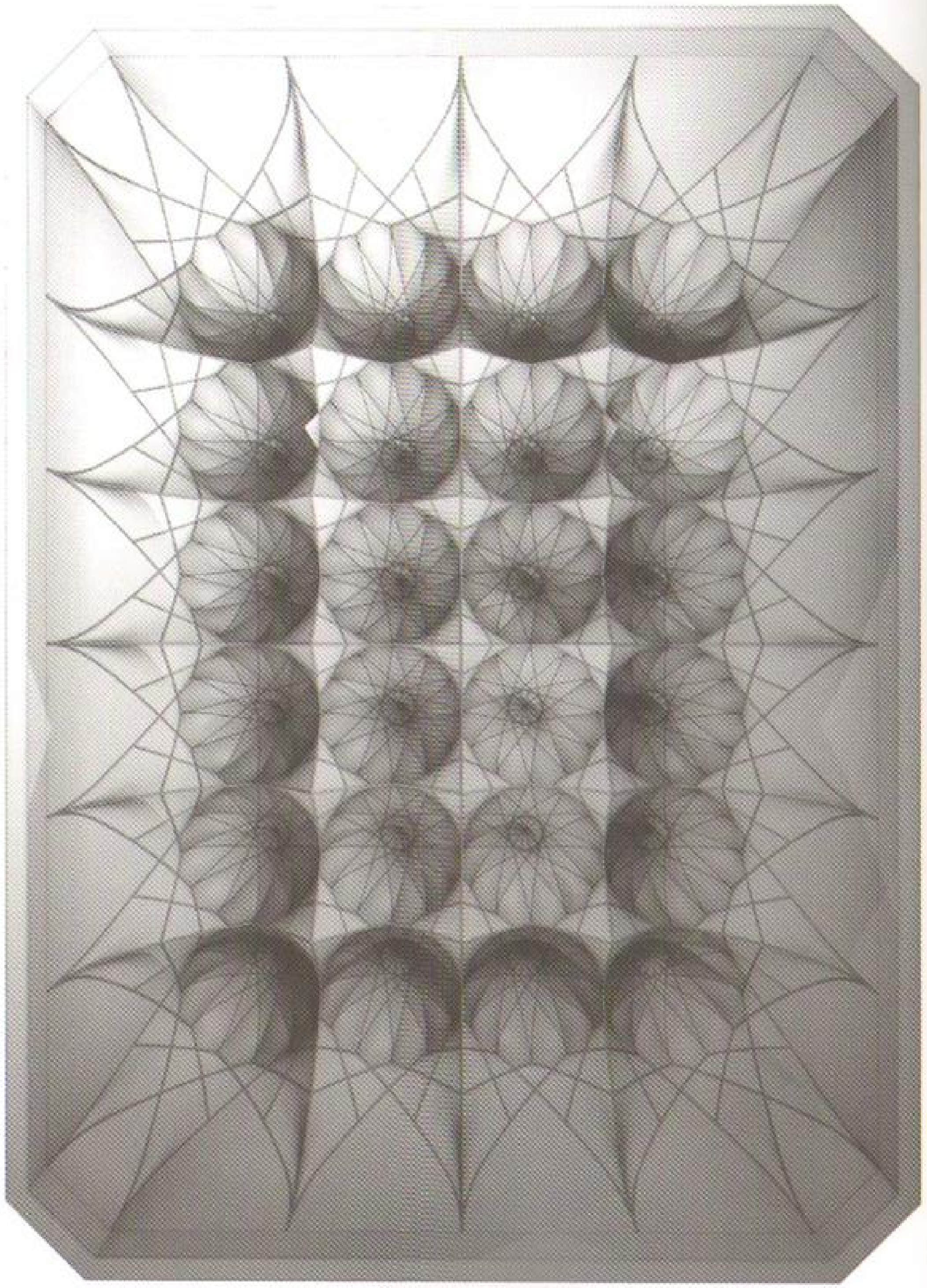
Eight differently scaled arches along the perimeter of the dome form an octagonal plan with bilateral symmetry.

This kaseh-sazi dome transmits an acoustical affect of diffusion.

octagonal plan

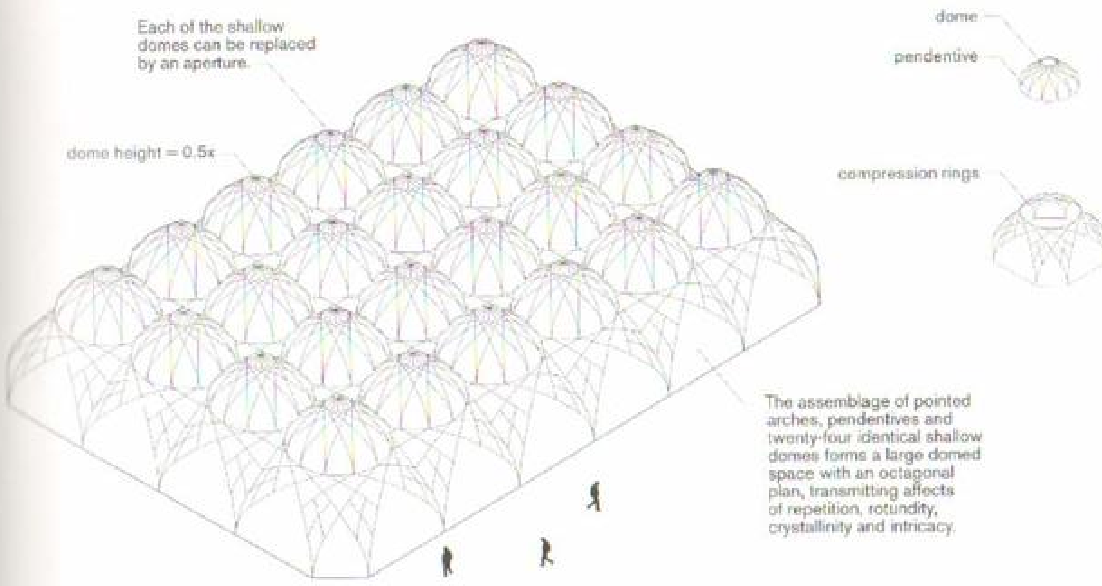
This dome is formed by the horizontal tessellation of pointed arched ribs and infill surfaces around a central area covered with smaller domes. The base unit is a series of pointed arches, octagonal in plan, which are interconnected by a series of pendentives to enclose the central area which is covered by eight identical domes. The degree of subdivision of the dome surface is determined by the number of arches and infill surfaces that are introduced, together with the upper surface which is composed of eight shallow domes. This kaseh-sazi dome assemblage transmits an optical affect of rotundity and crystallinity, and an acoustical affect of diffusion.

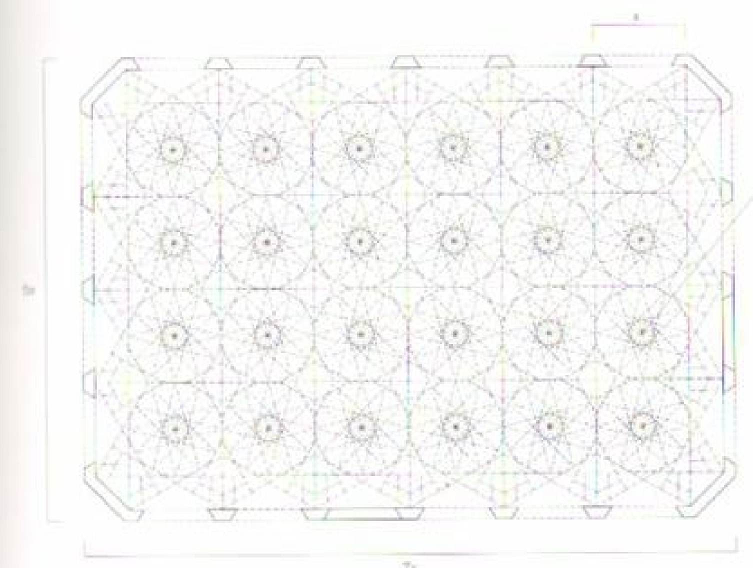
Repetition, Rotundity, Crystallinity, Intricacy, Diffusion



Horizontal / Kaseh-Sazi Dome

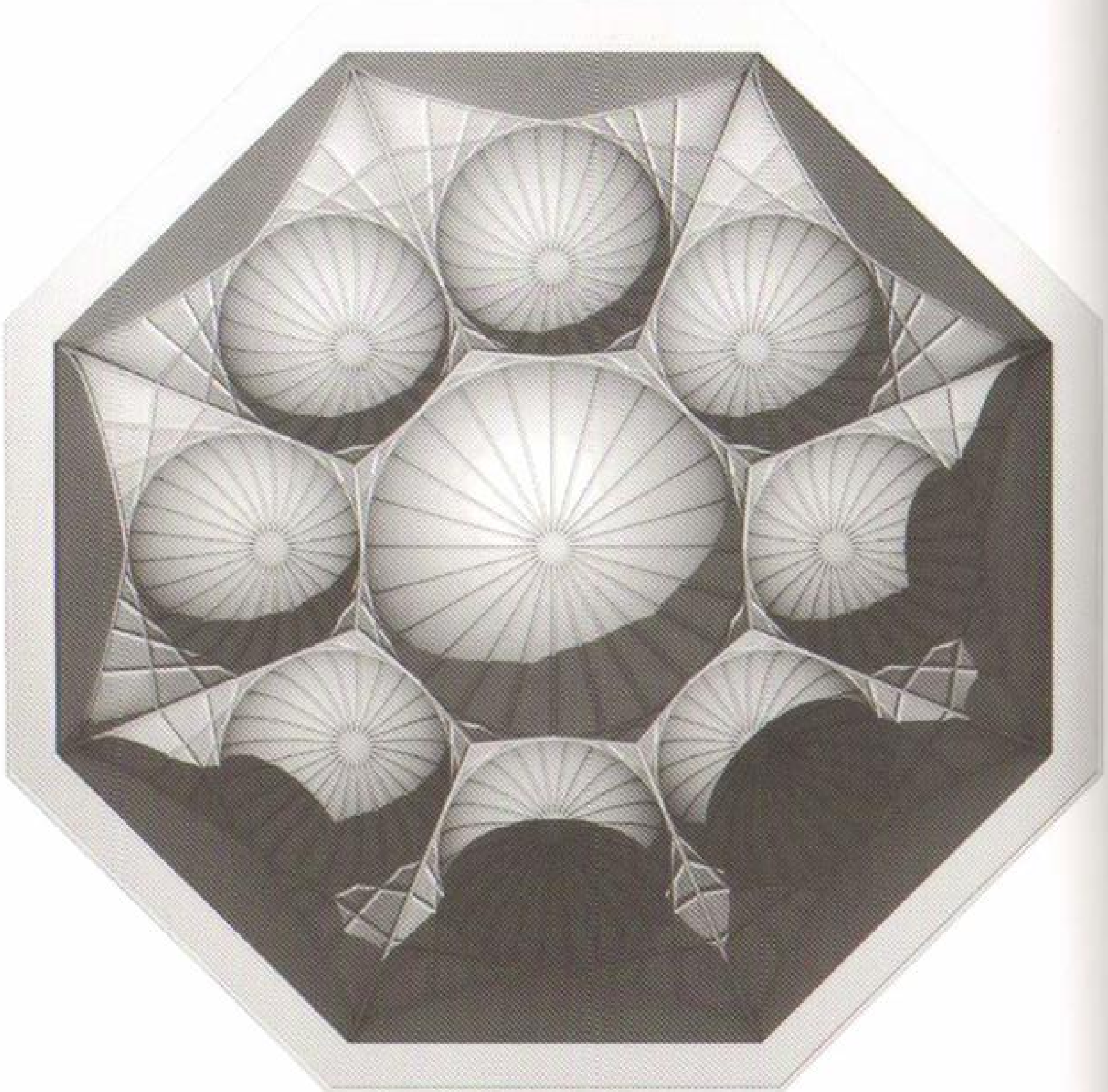
KASEH-SAZI DOME | O. HOSSEIN LOR ZADEH | UNBUILT | 1950





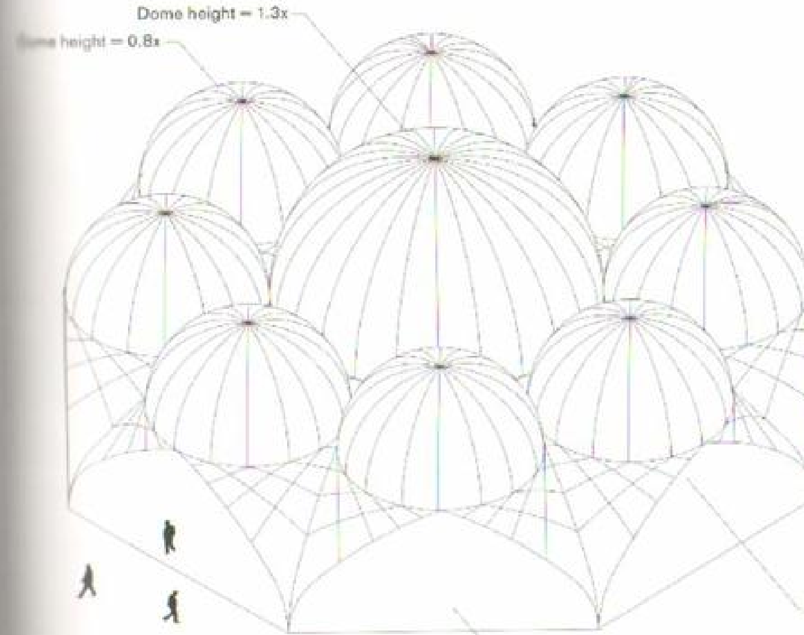
This dome is formed by the horizontal tessellation of pointed arched ribs and infill surfaces around a central area covered by smaller domes. The base unit is a series of four pointed arches which are octagonal in plan but approximate to a rectangle, and these arches are interconnected by a series of pendentives. The central area is covered by twenty four identical domes and small infill surfaces between them. The degree of subdivision of the dome surface is determined by the number of arches and infill surfaces that are introduced, together with the upper surface which is composed of shallow domes. This kaseh-sazi dome assemblage transmits an optical affect of rotundity and crystallinity, and an acoustical affect of diffusion.

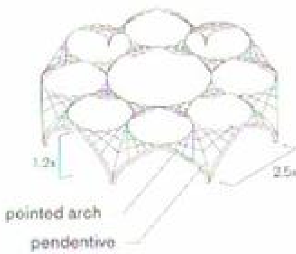
Rotundity, Crystallinity, Diffusion



Horizontal / Kaseh-Sazi Dome

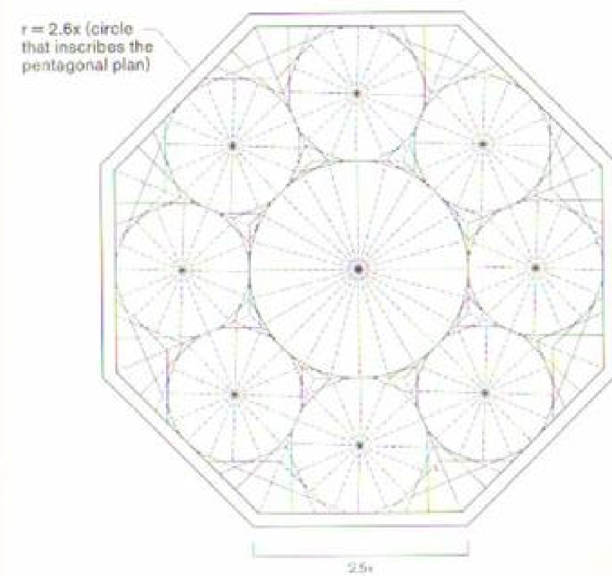
KASEH-SAZI DOME | O. ASGHAR SHAER-BAF | UNBUILT | 1950





This kaseh-sazi dome transmits an acoustical affect of diffusion.

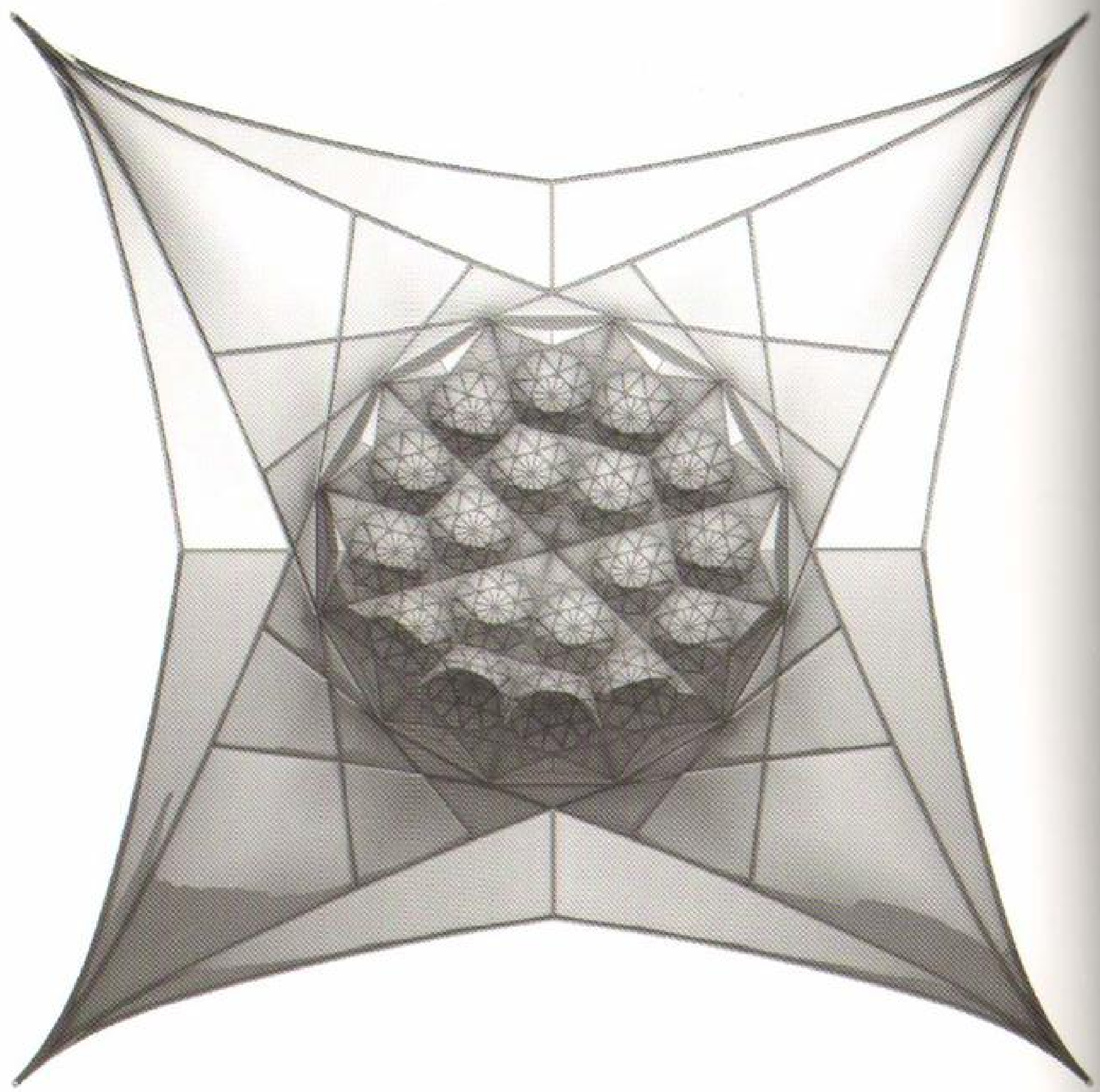
The assemblage of pointed arches, pendentives and differently scaled small domes forms a large domed space with an octagonal plan, transmitting affects of rotundity and crystallinity.



Eight pointed arches along the perimeter of the dome form an octagonal plan with bilateral symmetry.

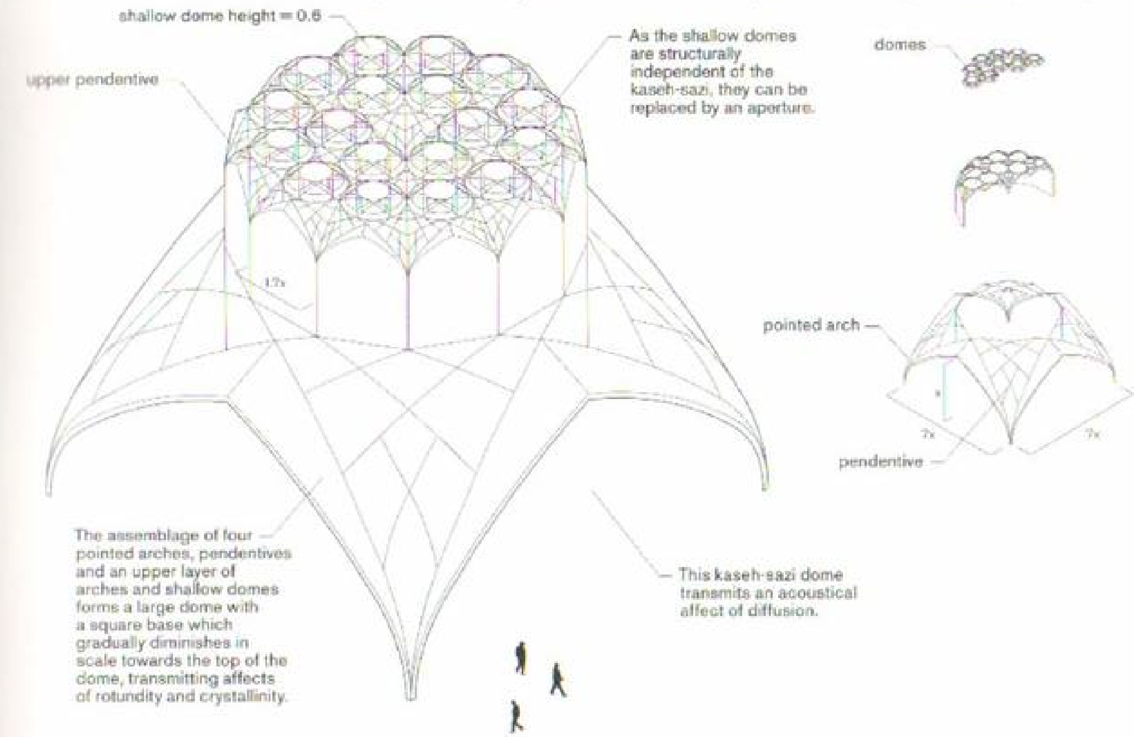
octagonal plan

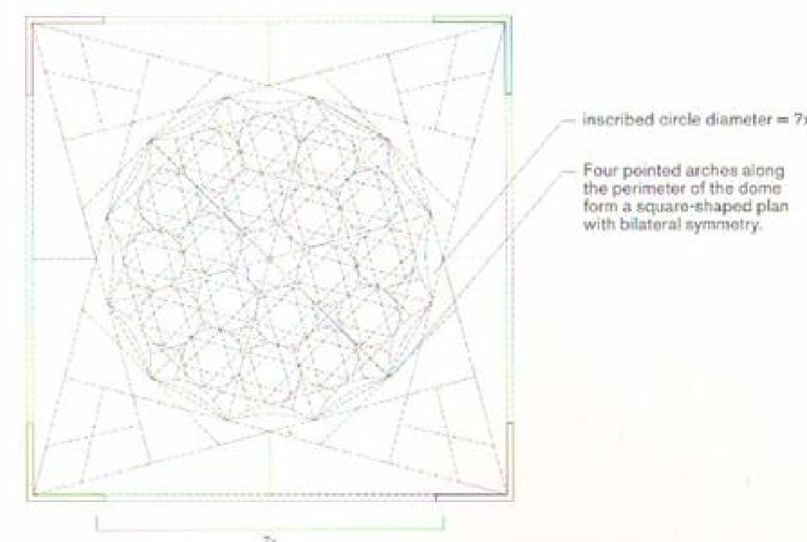
This dome is formed by the horizontal tessellation of arched pointed ribs and infill surfaces around a central area covered by a large dome surrounded with smaller domes. The base unit is a series of pointed arches, octagonal in plan, which are interconnected by a series of pendentives. The central area is covered by a dome with a ring of eight identical domes on its perimeter. The degree of subdivision of the dome surface is determined by the number of arches and infill surfaces that are introduced, together with the upper surface which is composed of shallow domes. This kaseh-sazi dome assemblage transmits an optical affect of rotundity and crystallinity, and an acoustical affect of diffusion.



Horizontal / Kaseh-Sazi Dome

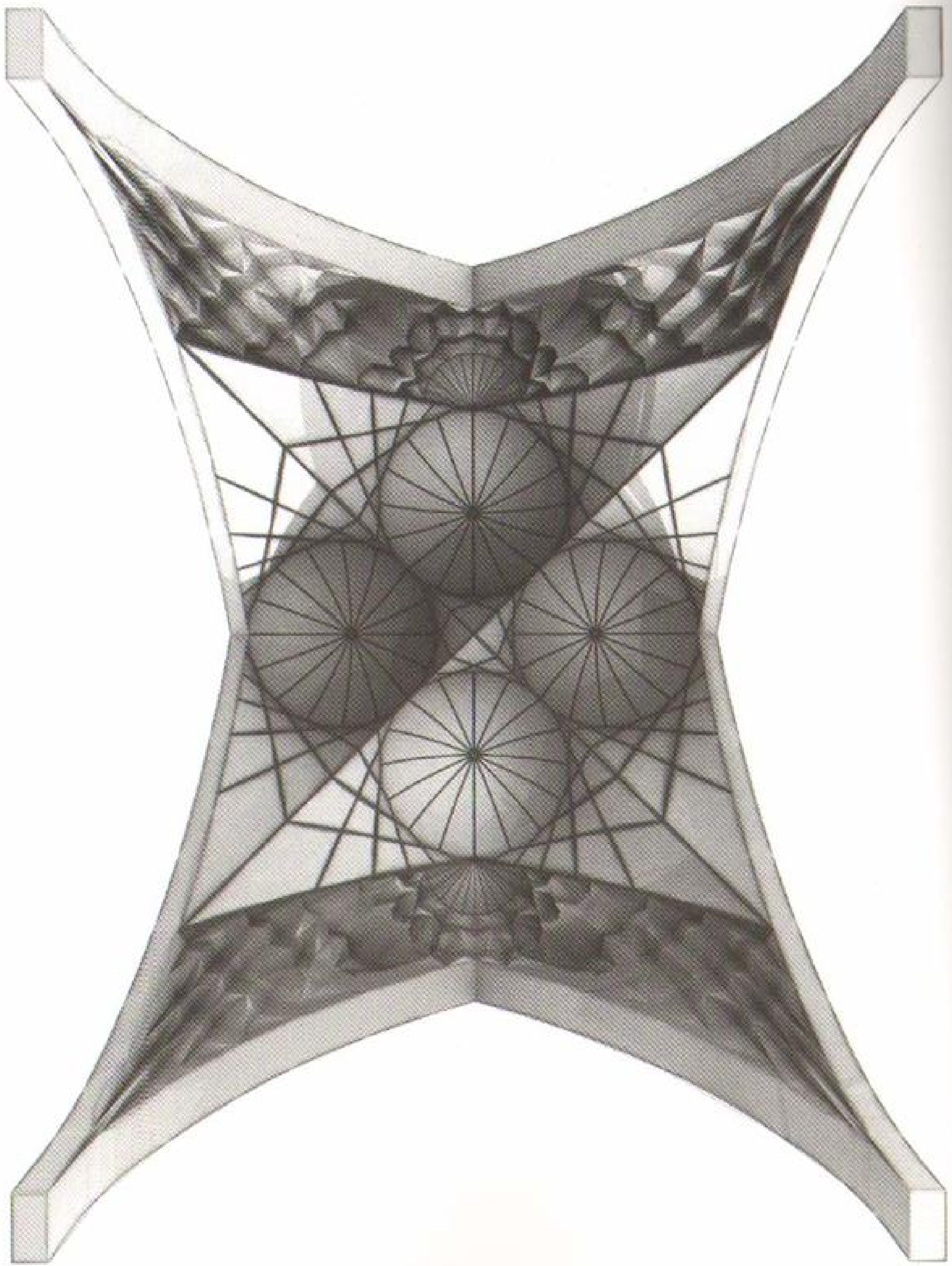
KASEH-SAZI | O. HOSSEIN LOR ZADEH | TEHRAN, IRAN | UNBUILT | 1950





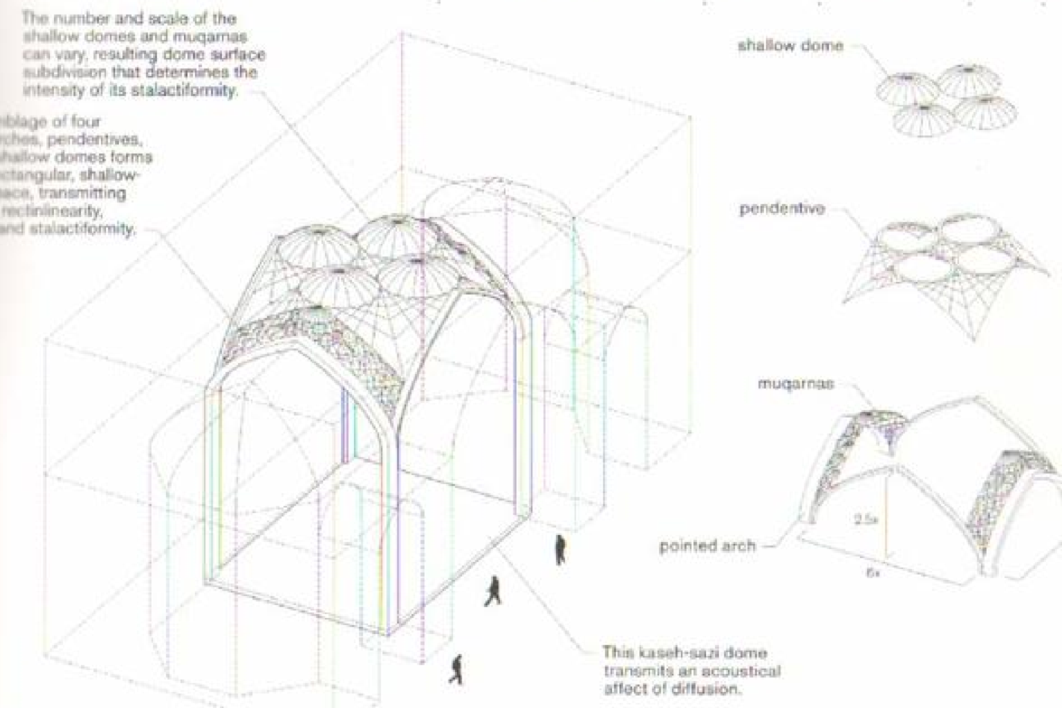
The kaseh-sazi assemblage is formed by the horizontal tessellation of pointed arched ribs and infill surfaces around a central area covered by a series of small domes. The base unit forms a square plan, with four pointed arches and four pendentives supporting an upper surface in the form of eighteen shallow domes and infill surfaces between them. The degree of subdivision of the dome surface is determined by the number of arches and infill surfaces that are introduced, together with the upper surface which is composed of shallow domes. This kaseh-sazi nave transmits an optical affect of rotundity and crystallinity, and an acoustical affect of diffusion.

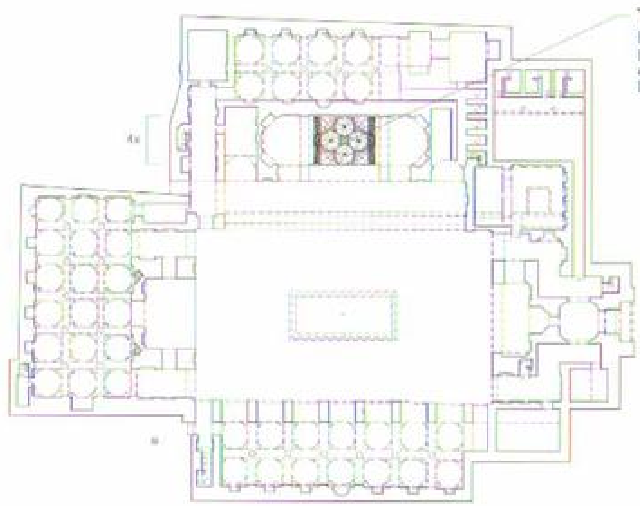
Rectilinearity, Rotundity, Stalactiformity, Diffusion



Horizontal / Kar-Bandi, Kaseh-Sazi and and Muqarnas Dome

MOSHIROLMOLK MOSQUE | UNKOWN | SHIRAZ, IRAN | 1770





The Moshirolmolk mosque is a hybrid formed by the horizontal tessellation of a kar-bandi, a kaseh-sazi and a muqarnas base unit. Together they form an assemblage of arched ribs and infill surfaces around a central area covered by smaller domes, combined with four larger pointed arches and two side areas with muqarnas. The base unit, which forms a square plan, is composed of four pointed arches and four pendentives supporting an upper surface in the form of four shallow domes. The degree of subdivision of the dome surface is determined by the number of arches and infill surfaces that are introduced. The Moshirolmolk mosque transmits an optical affect of rectilinearity, rotundity and stalactiformity, and an acoustical affect of diffusion.

Muqarnas Dome

The base unit of the muqarnas dome is composed of variable but repeating plan forms, or "tracks", which are stacked, corrugating the surface of the dome. Each track is composed of four major elements: pendentives (*shaparak*), flat surfaces (*takht*), squinches (*tas*), and extruded vertical planes. The pendentive is the most important of these elements, as it determines the position of all the others. The squinches are positioned between the pendentives, and the pendentives and squinches provide a transition between the ground plan and the plans of the subsequent trays. The flat surfaces, which act as a transition zone for very complex tracks, are the only flat element. The number of flat surfaces depends on the desired complexity of the dome. Toward the top of the dome they disappear, and the track radius is closed by pendentives and squinches. A muqarnas must include at least two trays; it can, however, have as many as desired. The trays must always be of the same height. Muqarnas domes direct the loads along the surface of each element of the assembly. Muqarnas domes can be made of stone or brick masonry, with a stucco or wood surface-finish. The distribution of loads along the surfaces of a muqarnas dome embeds it with an optical affective property of granularity and stepping that remains consistent within any space it defines. The multiplicity of focal points and curvature variations create an acoustical affect of diffusion which often overwhelms the focusing of the overall dome shape.

Muqarnas domes are flexible in several ways:

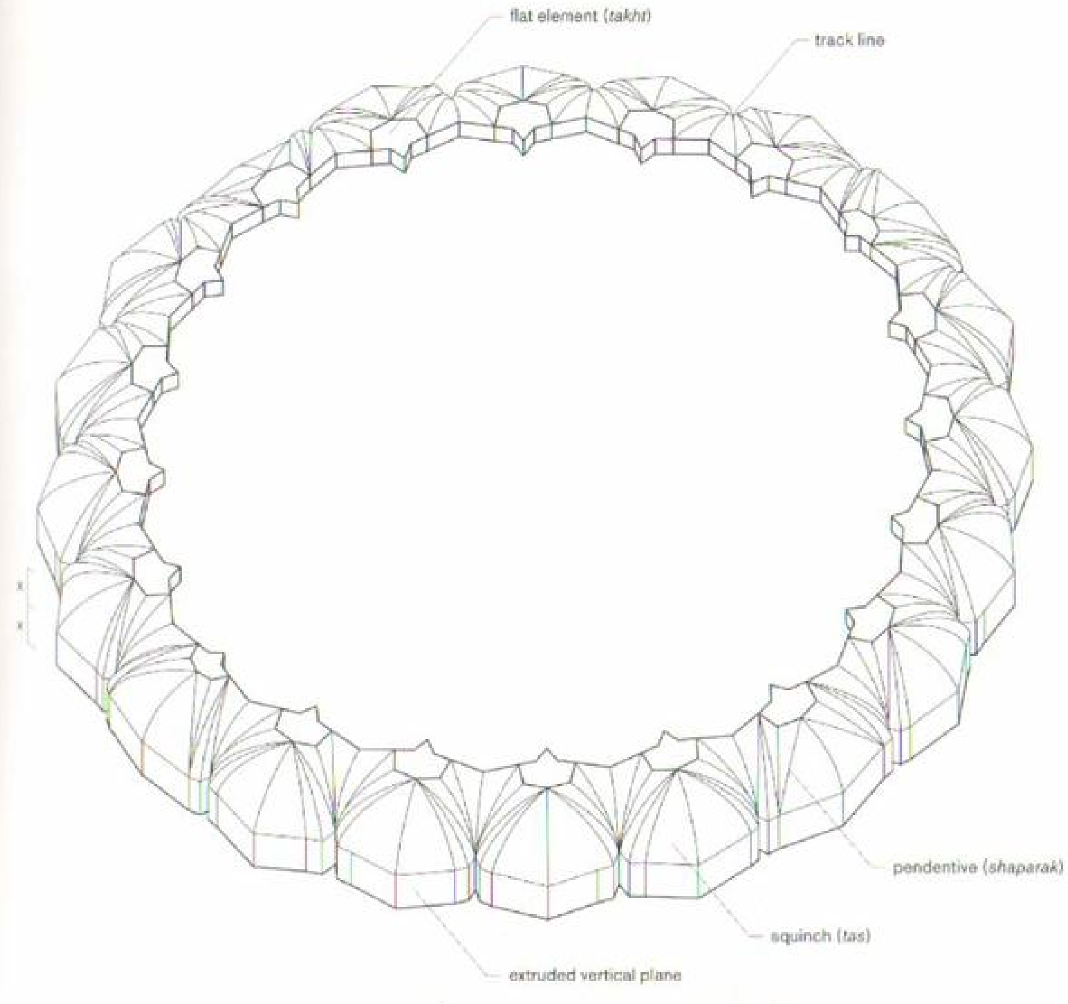
Plan: The protogeometry of a muqarnas dome can be flexible in its capacity to accommodate to variable plan forms, adjusting to a vast range of polygonal plans and offering a similarly vast range of arched openings at their base.

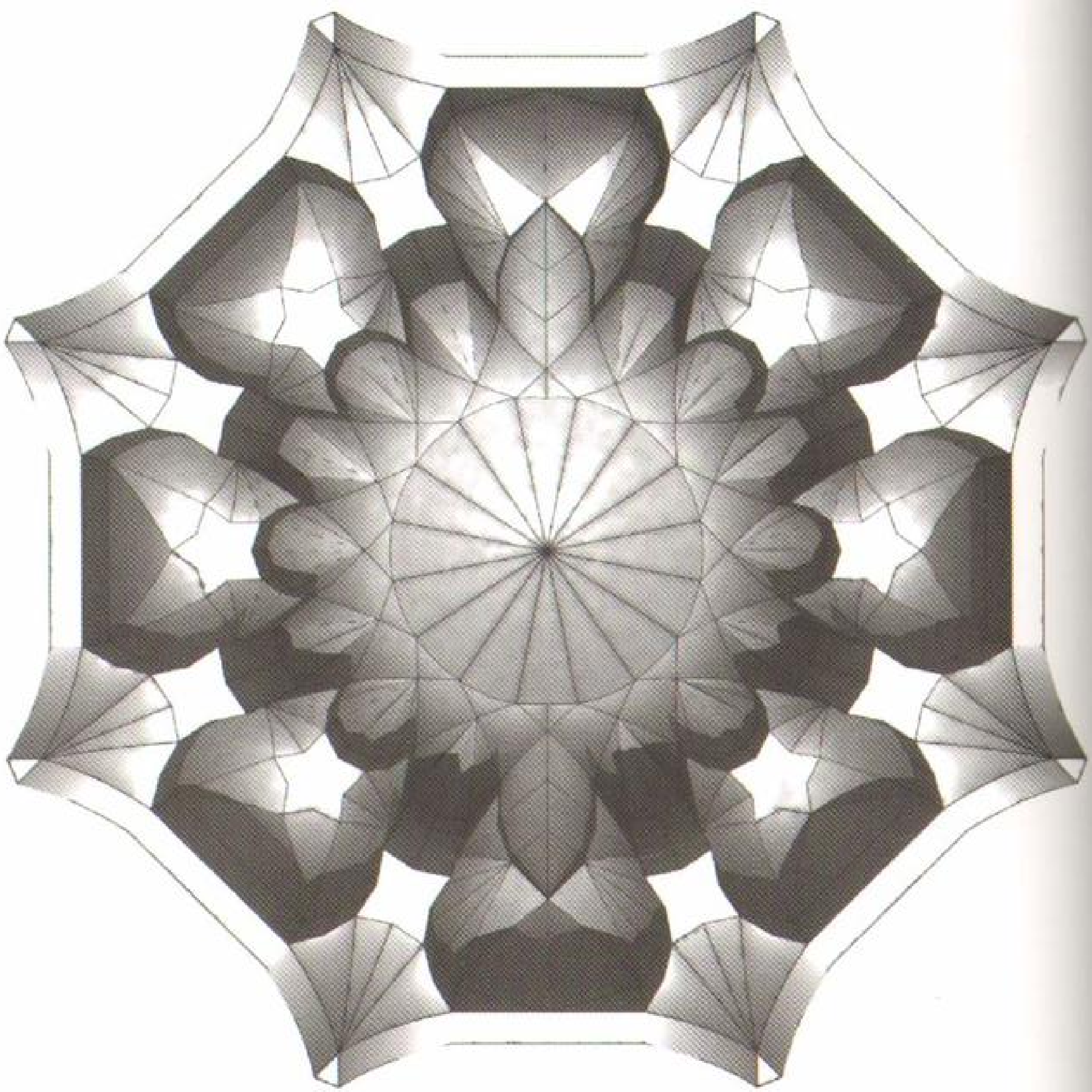
Profile: Changes in the degree of subdivision of the plan affect the degree of corrugation in the section. The height and depth of each of the elements of a muqarnas dome, and their aggregation, can affect the overall profile, making it steeper or shallower.

Scale: The scale of subdivision of the dome's surface also offers a range of granularity. Muqarnas domes can tessellate concentrically and horizontally along straight or curved lines of growth to produce horizontal or vertical structures.

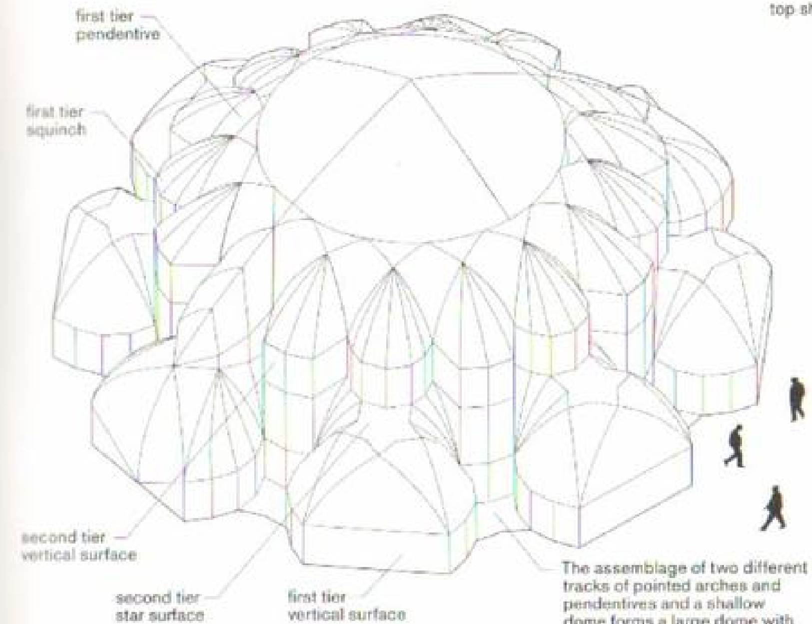
Depth: The curvature and depth of each element of a muqarnas dome assembly can affect the overall depth of the section.

Affect: The affective property of a muqarnas dome can be multiplied when the base unit imbricates or intertwines with external factors, such as asymmetries which respond to the physical constraints of the site, environmental considerations, programmatic requirements, etc. As a result, in addition to granularity and stepping, a muqarnas dome can transmit other optical affects, including faceting, rotundity, symmetry, enclosure. The acoustical affect is diffusion.

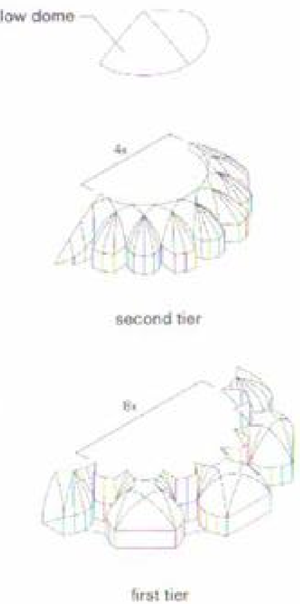




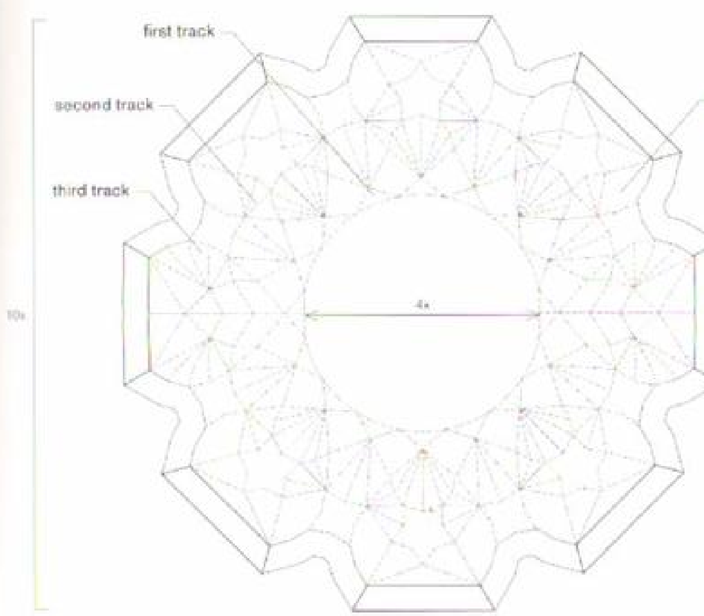
Vertical / Muqarnas Dome



The assemblage of two different tracks of pointed arches and pendentives and a shallow dome forms a large dome with a subdivided surface which transmits affects of faceting, layering and granularity.



The horizontal tiers in the muqarnas domes each need to be a full ring if they are to be independently structural. They are represented as half-rings here to make the elements forming each legible.

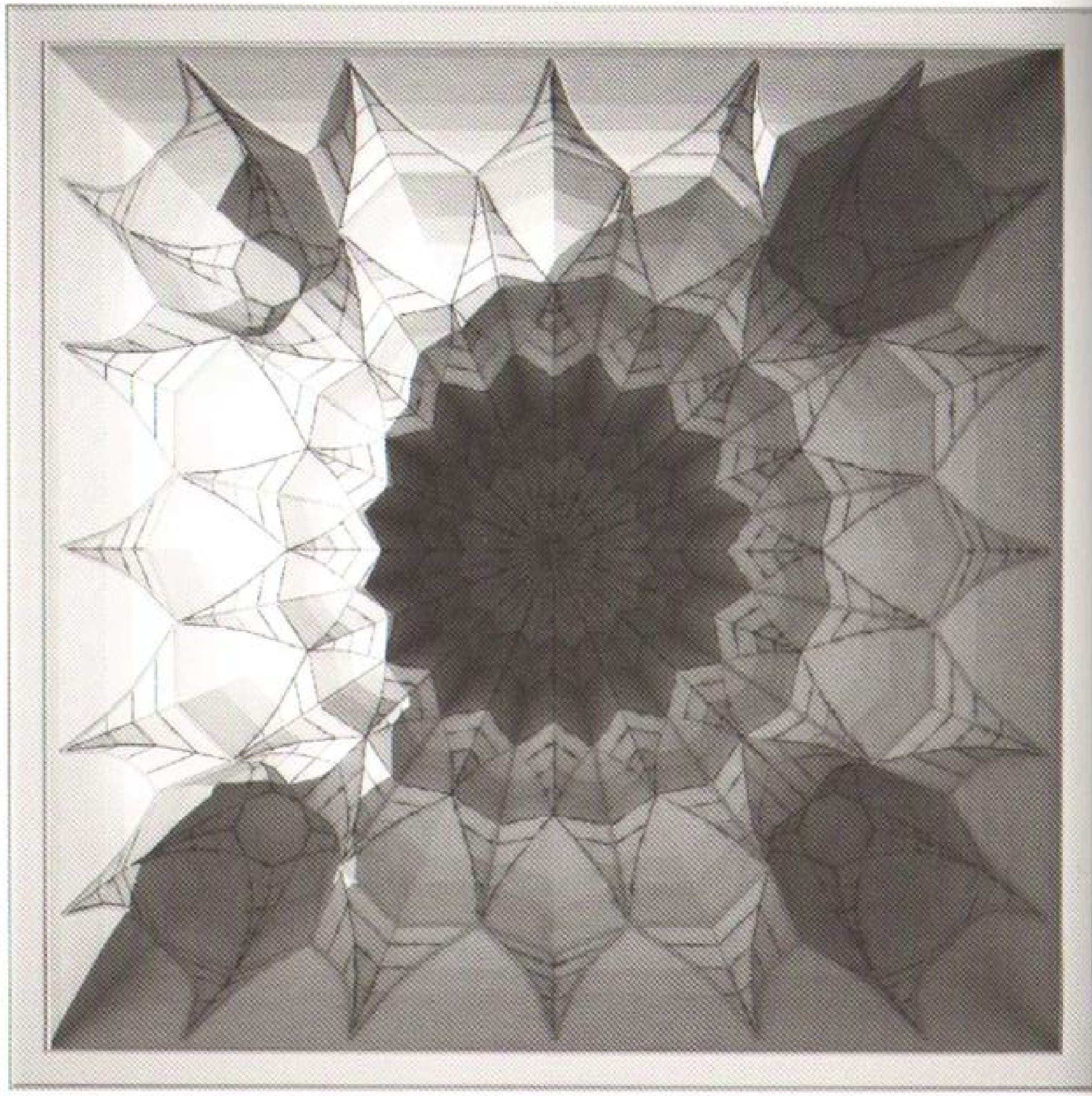


The top, shallow dome transmits an acoustical affect of focus, and the lower tier transmits diffusion.

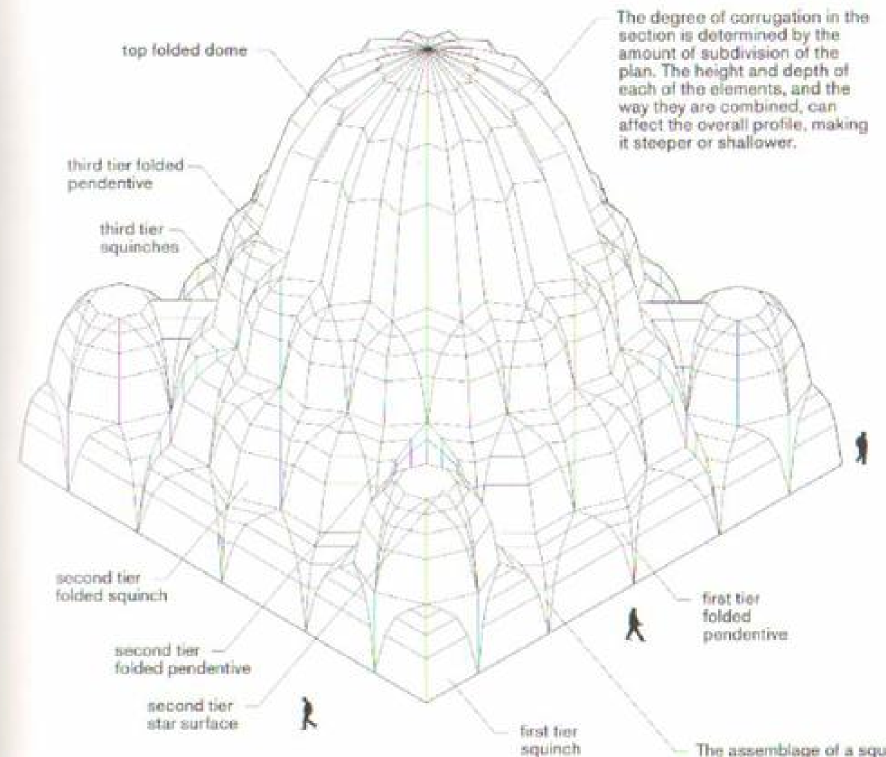
The radial, symmetrical arrangement of vertical surfaces, arches and pendentives creates a dome with a regular, corrugated perimeter, transmitting an affect of rotundity. The scale of granularity increases towards the top of the dome as the number of pendentives and squinches in the second track increase.

This dome is formed by the vertical tessellation of a base unit, or "track", composed of a series of varied yet repeating units arranged along a horizontal contour. The base unit varies as it repeats vertically to produce two different tracks, with a combination of straight and narrowing pendentives following the corrugation of the plan and reducing in scale as the surface of the structure rises. The perimeter of the plan changes from a sixteen-sided polygon at the base, to a circle at the top. This assemblage transmits an optical affect of faceting, granularity, and rotundity, and an acoustical affect of focusing and diffusion.

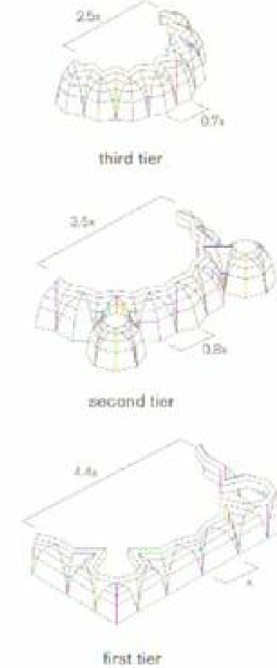
Orthogonality, Stellatedness, Granularity, Rotundity, Diffusion



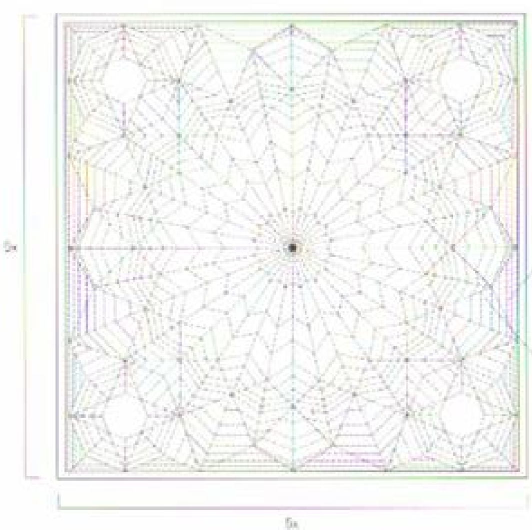
Vertical / Muqarnas Dome



The degree of corrugation in the section is determined by the amount of subdivision of the plan. The height and depth of each of the elements, and the way they are combined, can affect the overall profile, making it steeper or shallower.



The assemblage of a square-shaped track, followed by two circular tracks of corbelled units and pendentives, forms a large dome with a surface that is subdivided into many small facets, transmitting affects of orthogonality, stellatedness, layering and granularity.



This muqarnas dome transmits an acoustical affect of diffusion.

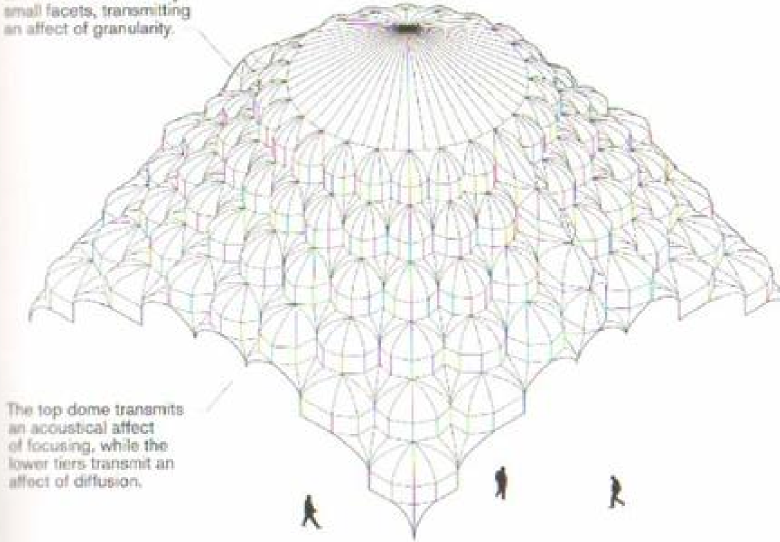
The combination of a square track, two round tracks and a topping dome creates a form that transmits, simultaneously, affects of orthogonality and rotundity.

This dome is produced by the vertical tessellation of a base unit, or a "track", composed of a series of varied yet repeating units arranged along a horizontal contour. The base unit repeats vertically to produce three different tracks, with a combination of straight and narrowing pendentives and squinches following the corrugation of the plan and reducing in scale as the surface of the structure rises. The overall corrugation of the dome surface is proportional to the number of units that form the tracks, and the degree to which they fold in plan. The perimeter of the plan changes from a square at the base, to a star-shaped figure at the top. This assemblage transmits an optical affect of orthogonality, stellatedness, granularity, and rotundity, and an acoustical affect of diffusion.

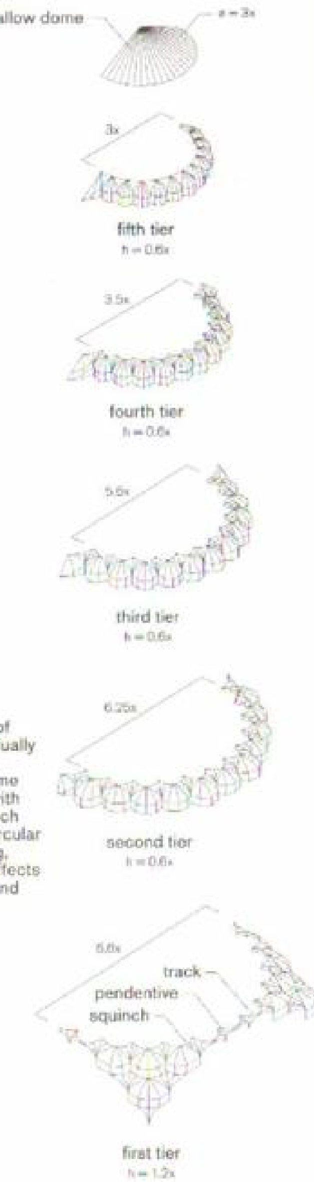
Orthogonality, Granularity, Rotundity, Focusing, Diffusion

Vertical / Muqarnas Dome

The assemblage of five tracks and a shallow dome forms a large dome with a surface that is subdivided into many small facets, transmitting an affect of granularity.

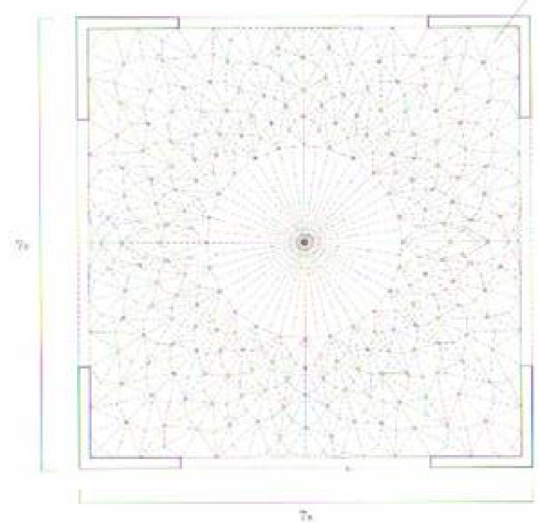


The top dome transmits an acoustical affect of focusing, while the lower tiers transmit an affect of diffusion.



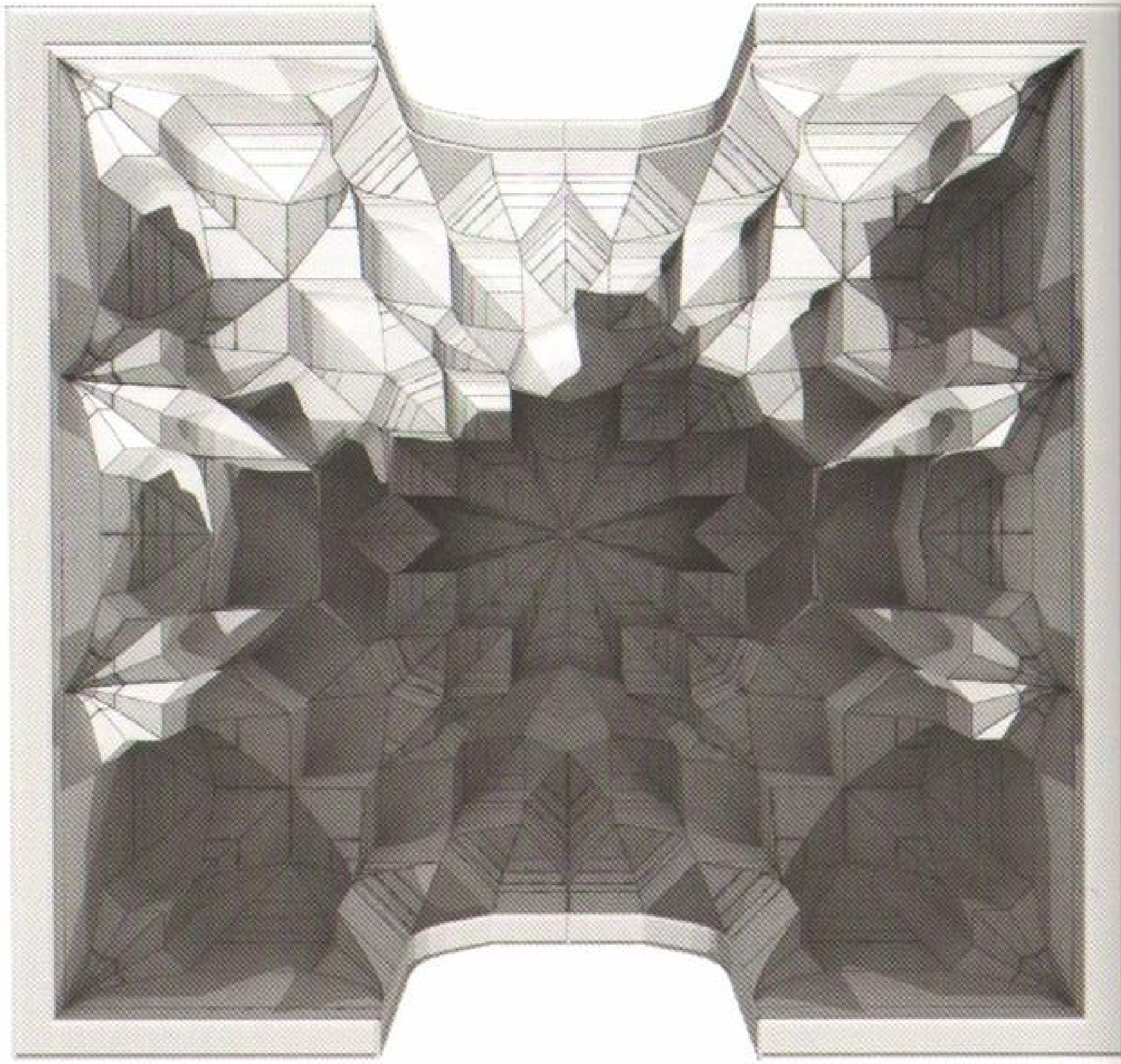
Height of squinches = 0.3x
Height of pendentives = 0.3x

The combination of five tracks of gradually diminishing size and a topping dome creates a dome with a square plan which culminates in a circular head, transmitting, simultaneously, affects of orthogonality and rotundity.

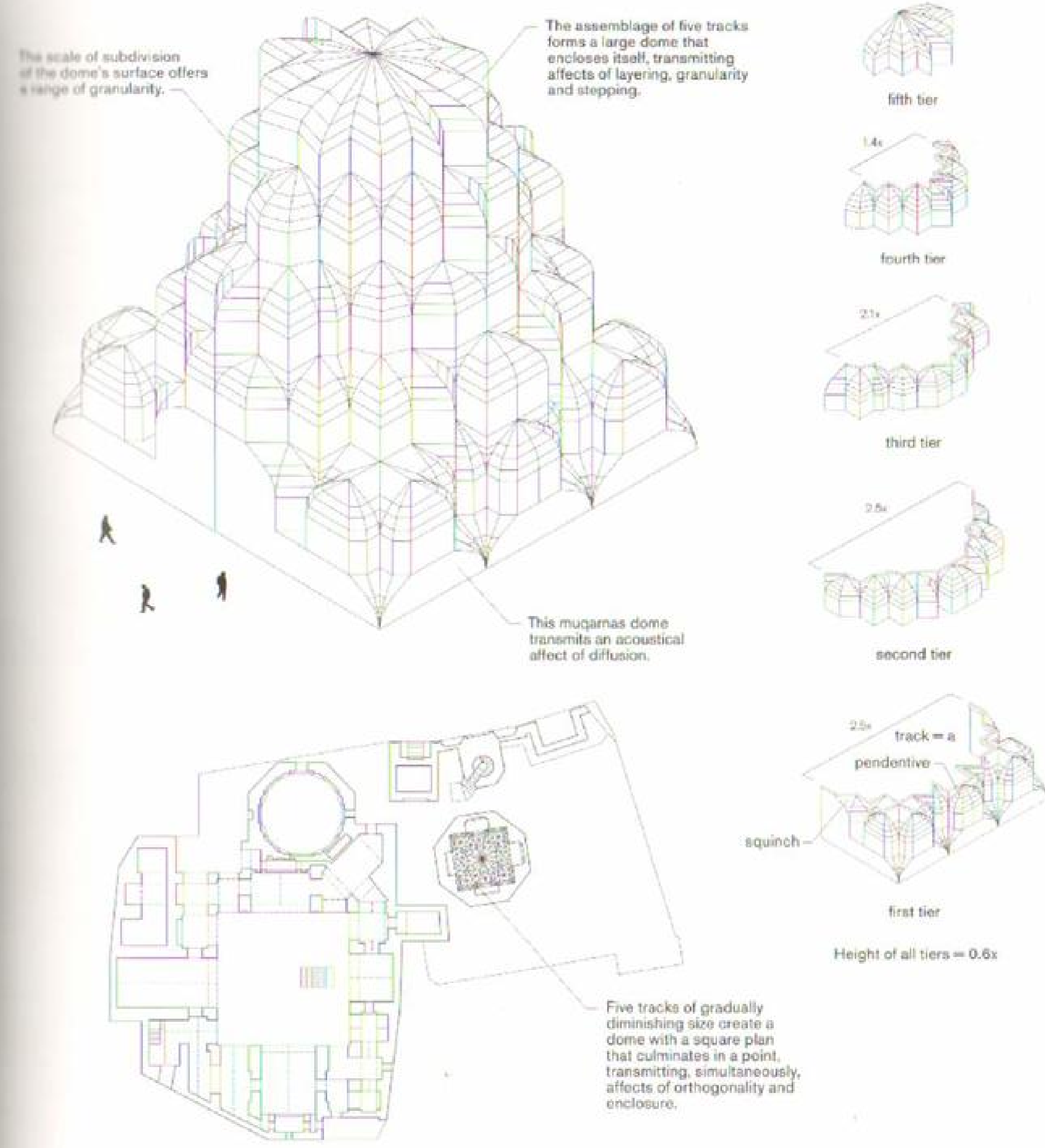


This dome is formed by the vertical tessellation of a base unit, or a "track", composed of a series of varied yet repeating units arranged along a horizontal contour. The base unit varies as it repeats vertically to produce five different tracks, with a combination of straight and narrowing pendentives and squinches following the corrugation of the plan and reducing in scale as the surface of the structure rises. The overall corrugation of the dome surface is proportional to the number of units that form the tracks, and the degree to which they fold in plan. The perimeter of the plan changes from a square at the base, to a star-shaped figure at the top. This assemblage transmits an optical affect of orthogonality, layering, granularity and rotundity, and an acoustical affect of focusing and diffusion.

Orthogonality, Stepping, Granularity, Enclosure, Diffusion

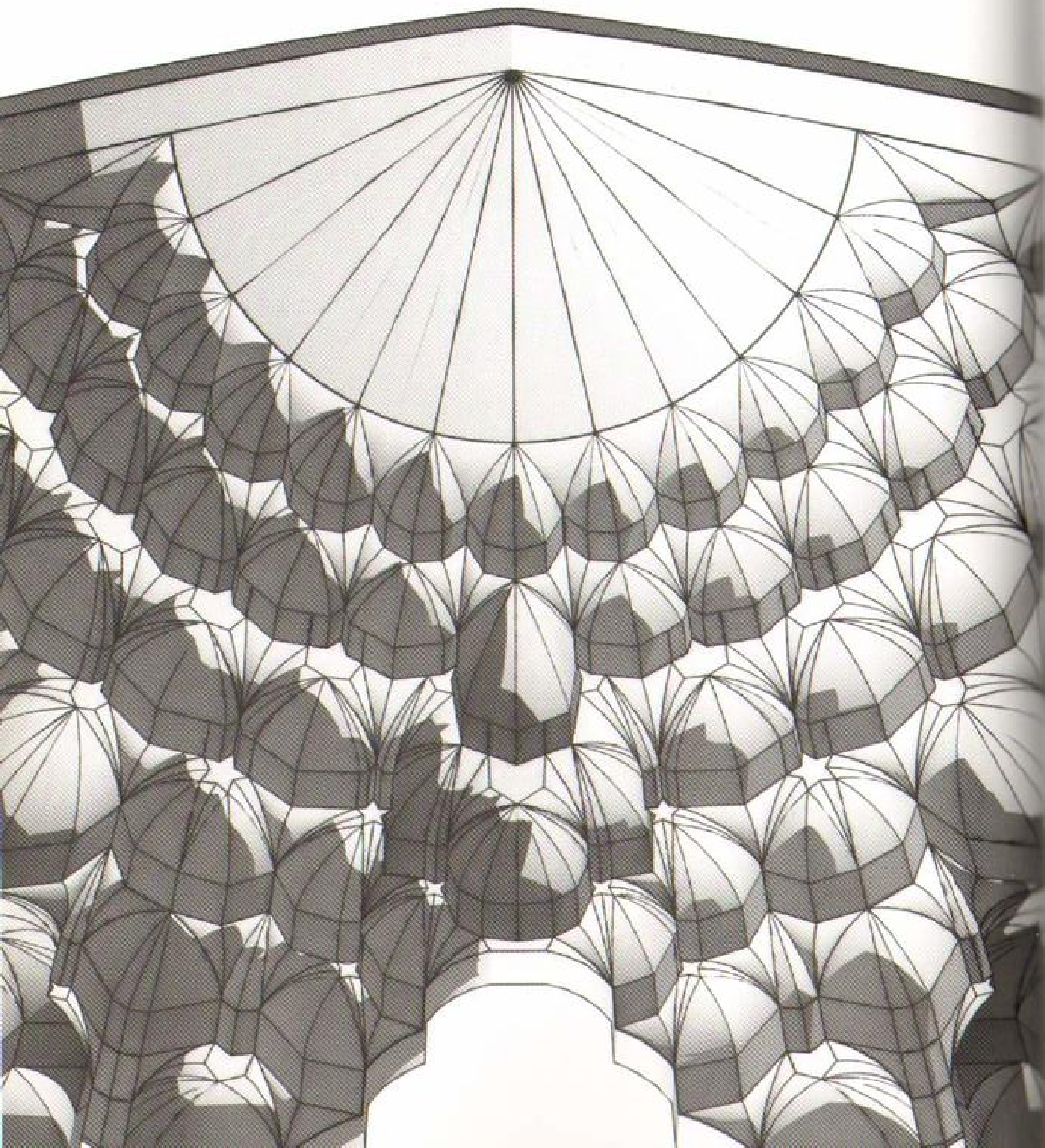


Vertical / Muqarnas Dome



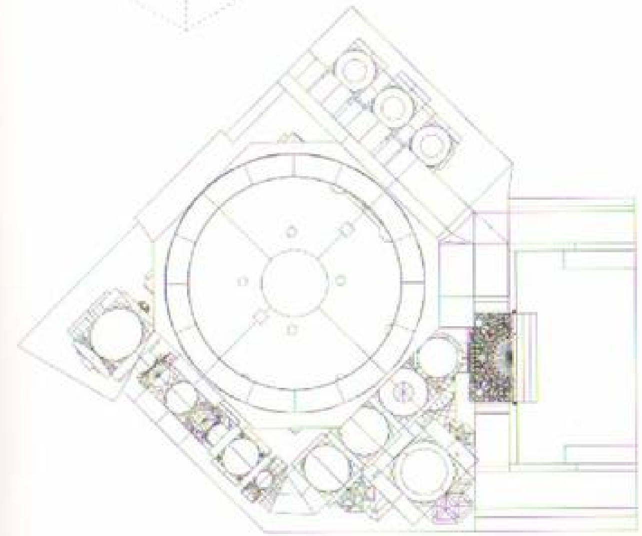
This dome is formed by the vertical tessellation of a base unit, or a "track", composed of a series of varied but repeating units arranged along a horizontal contour. The base unit varies as it repeats vertically to produce five different tracks, with a combination of straight and narrowing pendentives and squinches following the corrugation of the plan and reducing in scale as the surface of the structure rises. The perimeter of the plan changes from a square at the base, to a star-shaped figure at the top. This assemblage transmits an optical affect of orthogonality, stepping, granularity and enclosure, and an acoustical affect of diffusion.

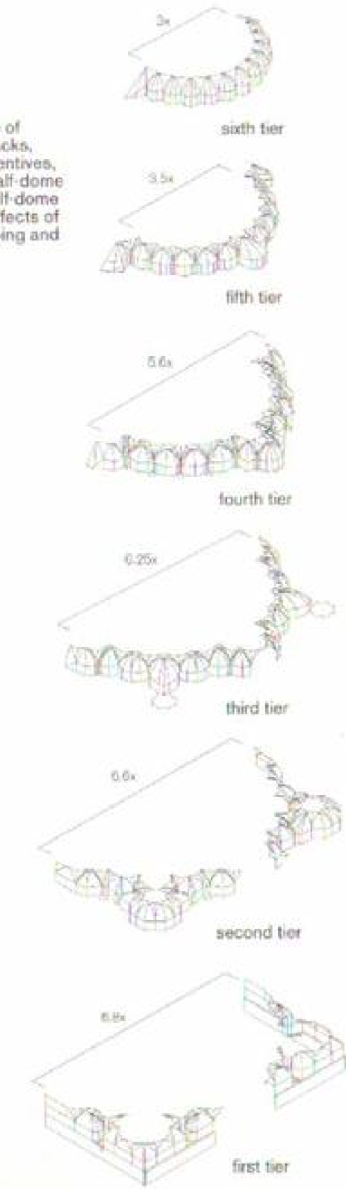
Orthogonality, Scalloping, Granularity, Rotundity, Diffusion



Vertical / Muqarnas Dome

SHEIKH LOTF ALLAH MOSQUE | O. HASSAN BANNA | ISFAHAN, IRAN | 1615



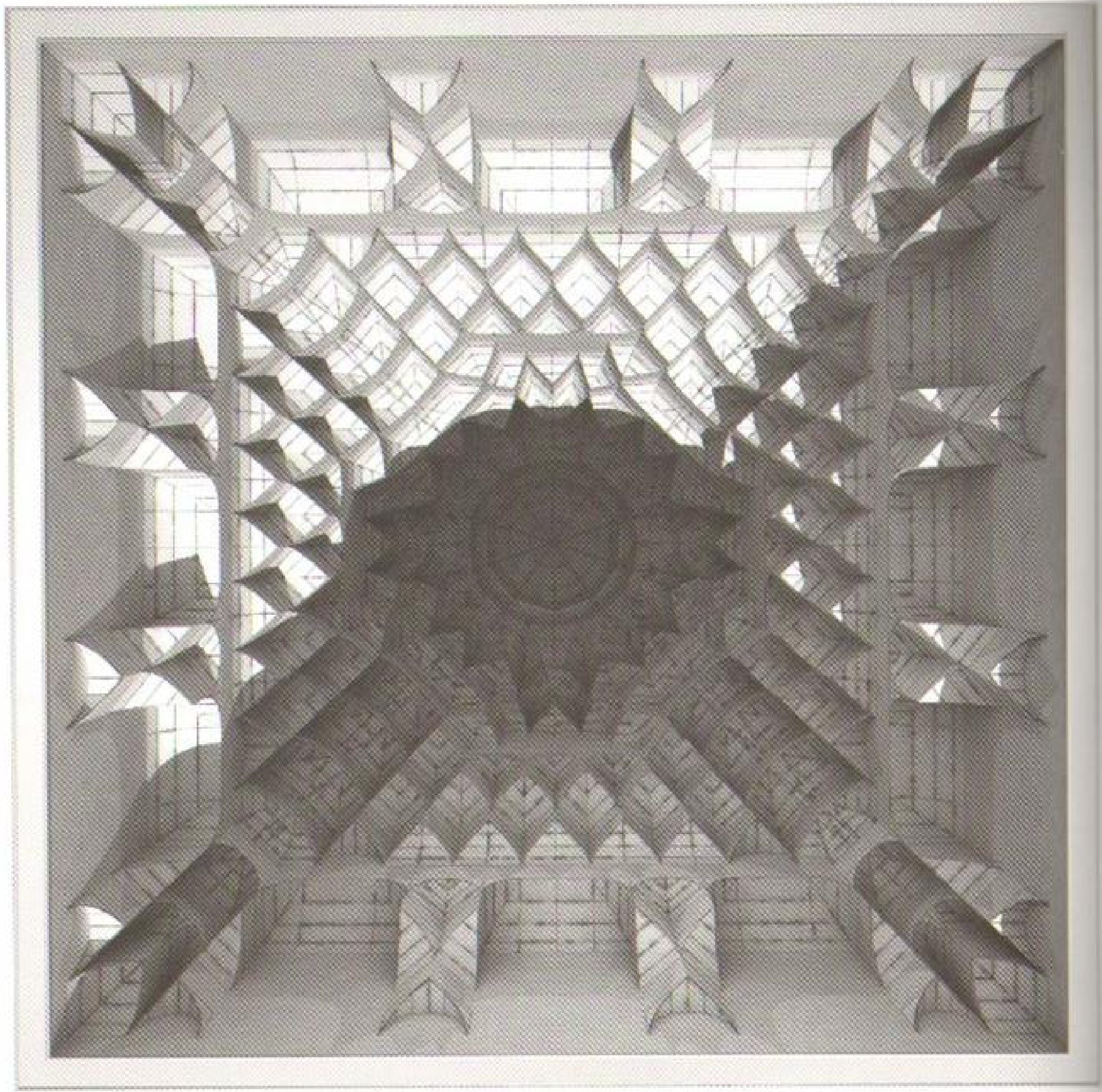


Height of all tiers = 0.6x

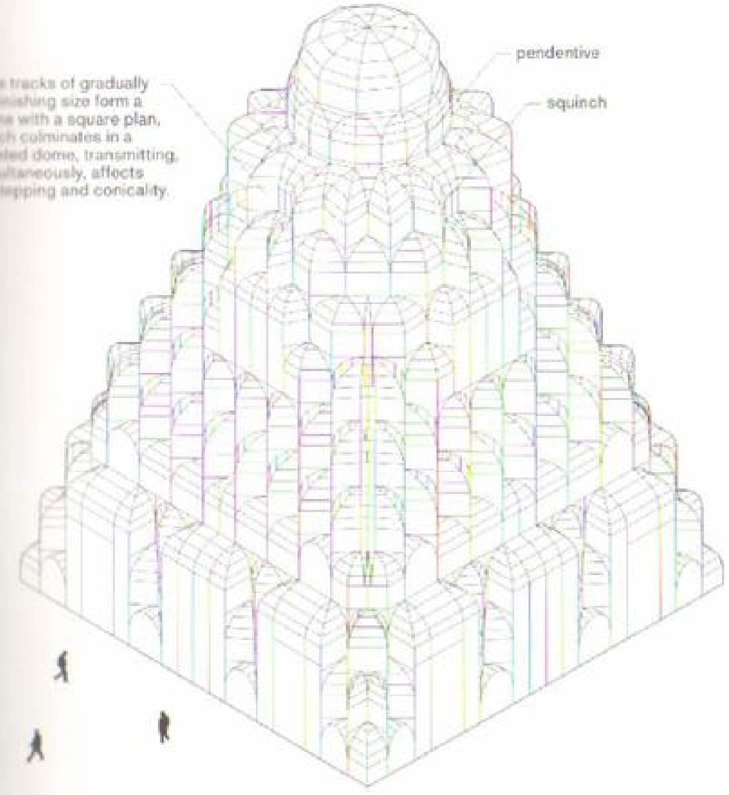
Sheikh Lotf Allah mosque gate is a hybrid formed by the vertical tessellation of a base unit, or a "track", composed of a series of varied but repeating units arranged along a horizontal contour working in conjunction with a pointed arch. The base unit varies as it repeats vertically to produce six different tracks, with a combination of straight and narrowing pendentives and squinches following the corrugation of the plan and reducing in scale as the surface of the structure rises. The overall corrugation of the dome surface is proportional to the number of units that form the tracks, and the degree to which they fold in plan. The perimeter of the plan changes from a rectangle at the base, to a half-circle at the top, buttressed by a pointed arch. This assemblage transmits an optical affect of orthogonality, scalloping, granularity, and rotundity, and an acoustical affect of diffusion.

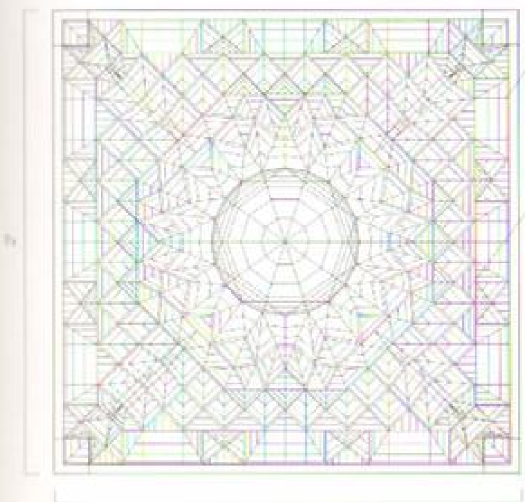
Enclosure, Stepping, Conicality, Diffusion

Vertical / Muqarnas Dome



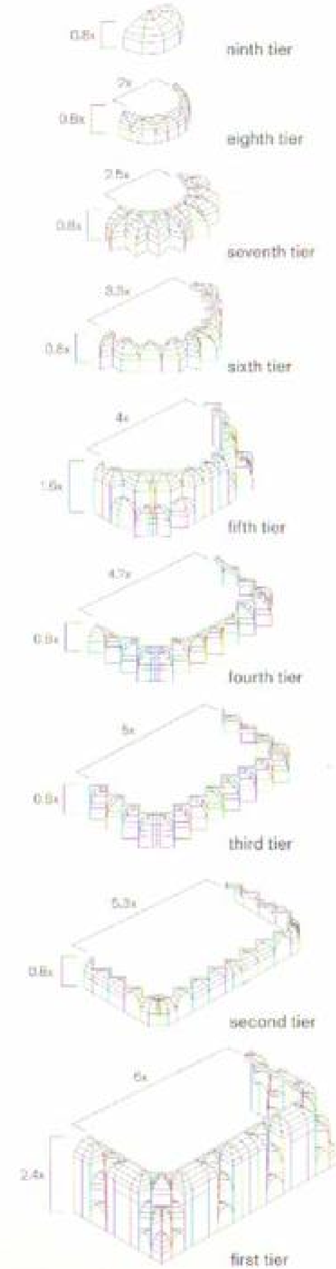
Nine tracks of gradually diminishing size form a dome with a square plan, which culminates in a faceted dome, transmitting, simultaneously, affects of stepping and conicality.





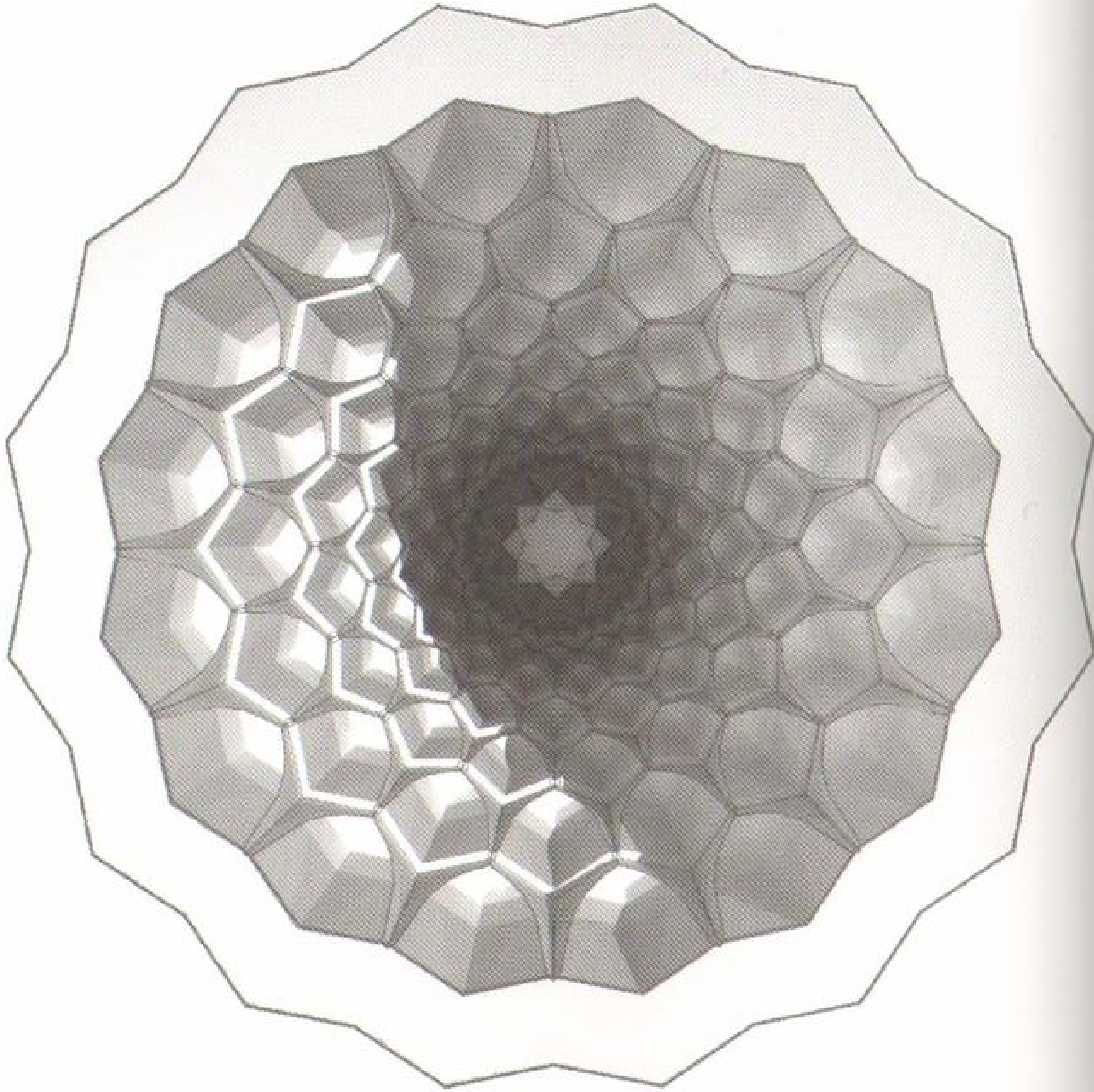
This muqarnas dome transmits an acoustical affect of diffusion.

The assemblage of nine square-shaped tracks of progressively smaller size forms a large dome without the need for a circular dome to enclose it, transmitting affects of enclosure, and conicality.



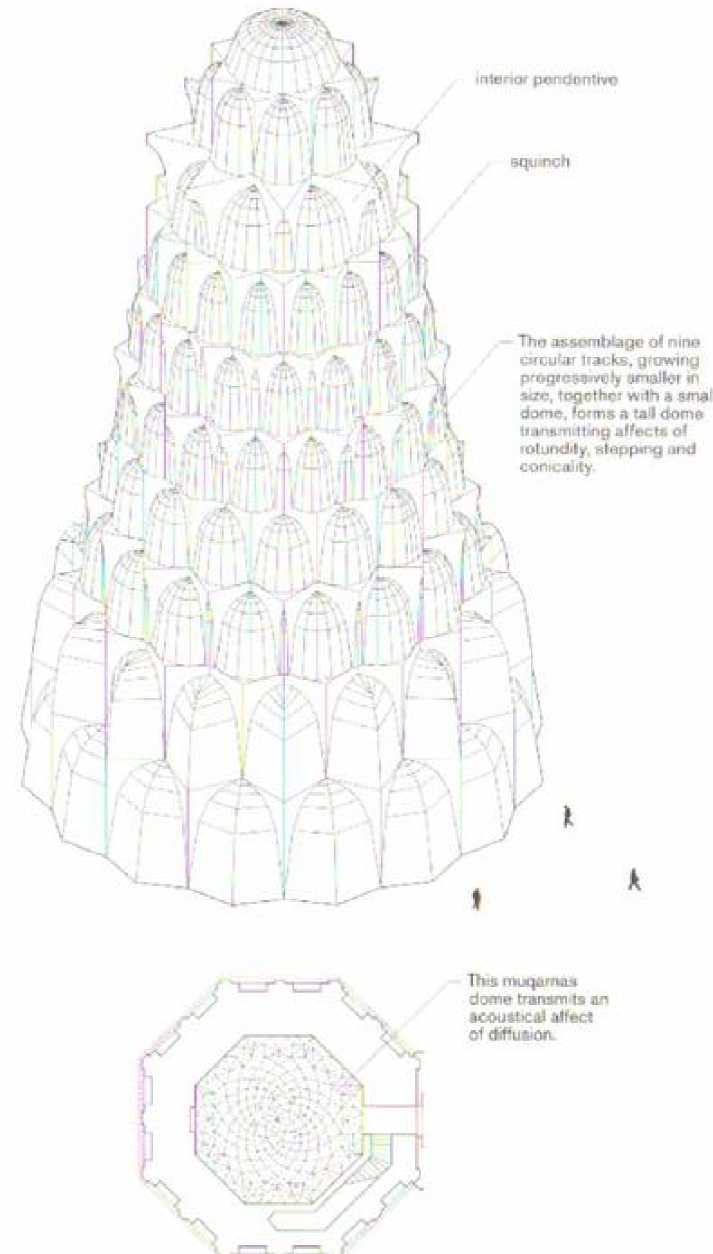
This dome is formed by the vertical tessellation of a base unit, or a "track", composed of a series of similar units arranged along a horizontal contour. The base unit varies as it repeats vertically to produce nine different tracks, with a combination of straight and narrowing squinches following the corrugation of the plan and reducing in scale as the surface of the structure rises. The overall corrugation of the dome surface is proportional to the number of units that form the tracks, and the degree to which they fold in plan. The perimeter of the plan changes from a square at the base, to a star-shaped polygon at the top. This assemblage transmits an optical affect of enclosure, stepping and conicality, and an acoustical affect of diffusion.

Roundity, Stepping, Conicality, Diffusion



Vertical / Muqarnas Dome

Sitt Zubaida Mausoleum, Shrine of Zumurrud Hkatun | Baghdad, Iraq | 1190



Height of all tiers = 0.3x

This Sitt Zubaida Mausoleum dome is formed by the vertical tessellation of a base unit, or a "track", composed of a series of similar units arranged along a horizontal contour. The base unit varies as it repeats vertically to produce nine different tracks, with a combination of straight and narrowing pendentives and squinches following the corrugation of the plan and reducing in scale as the surface of the structure rises. The overall corrugation of the dome surface is proportional to the number of units that form the tracks, and the degree to which they fold in plan. The perimeter of the plan changes from a thirty-two-sided polygon at the base, to a star-shaped polygon at the top. This Sitt Zubaida Mausoleum dome transmits an optical affect of stepping, conicality and rotundity, and an acoustical affect of diffusion.