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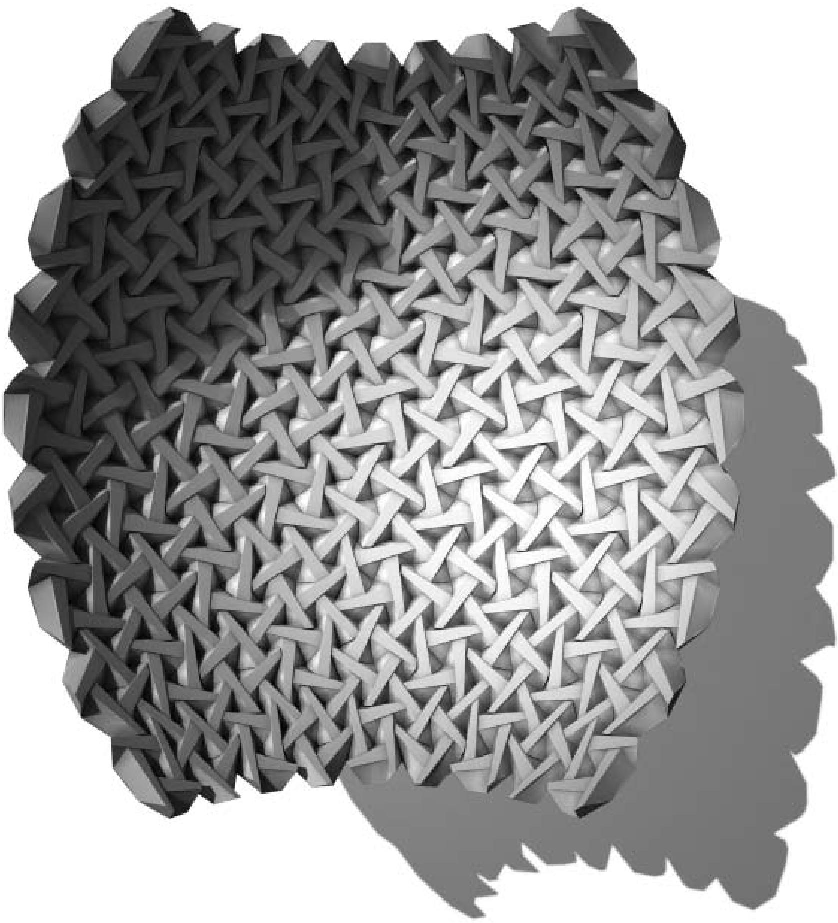
PLAITED STEREOTOMY
Stone Vaults for the Modern World



Richard Etlin
Giuseppe Fallacara
Luc Tamborero

STEREOTOMY
Acrobatic Stone Vaulting Past and Future

Edited by

Giuseppe Fallacara

Images

All 3d–models are realized by Giuseppe Fallacara during his research program at the ICAR Departement of Politecnico di Bari, directed by Prof. Claudio D'Amato Guerrieri.
The sketch on the right side is made by Giuseppe Fallacara.
The sketches on page 13 are made by Luc Tamborero.
The sketches on page 26 are made by Luc Tamborero and Luca Fraccalvieri (hand-made).
The image on page 27 (LMGC90) is made by Ali Rafiee.
The images on page 27 (lower) and page 34 are part of a study for stone and iron vaults that Maria Rita Campa has experimented during her doctoral thesis at the ICAR Department of Politecnico di Bari (*E.E. Viollet-le-Duc innovation and tradition: language of form and connection between form and structure in the conception of polyhedral vaults*).
The images on page 27 (lower) are realized in collaboration with Stella De Paola, Enrica Leonardis, Vincenzo Minenna, Francesco Peschechera, Rossella Refolo and Nicola Sacco during their final workshop in architecture degree thesis (2007–08) at the Politecnico di Bari (Professors: C. D'Amato Guerrieri, G. Fallacara).
All the images of the chapter *Projects* are rendered by Domenico Di Nardo.
The image on the cover is made by Giuseppe Fallacara and represents *Sphera*.

Photos

All the photos accompanying the text are made by the authors.

Projects

All the projects are made by Giuseppe Fallacara.

Constructions

Abeille vault is made by the company "Leopizzi 1750" of Parabita (Lecce – Italy) for the 2006 Venice Biennale directed by C. D'Amato Guerrieri.
Truchet vault is made by "3d Pierre" of Nanterre (France) for the *Summer School* of Madrid.
Flat vault is made by "3d Pierre" of Nanterre (France) for the *Stone Construction Stage* of Isle d'Abeau (Lyon).
Sphera is made by "SNBR" of Troyes (France) for the 2008 MarmoMacc of Verona.
All the costructions are made with the supervision of Mécastone.

Editing and graphic design

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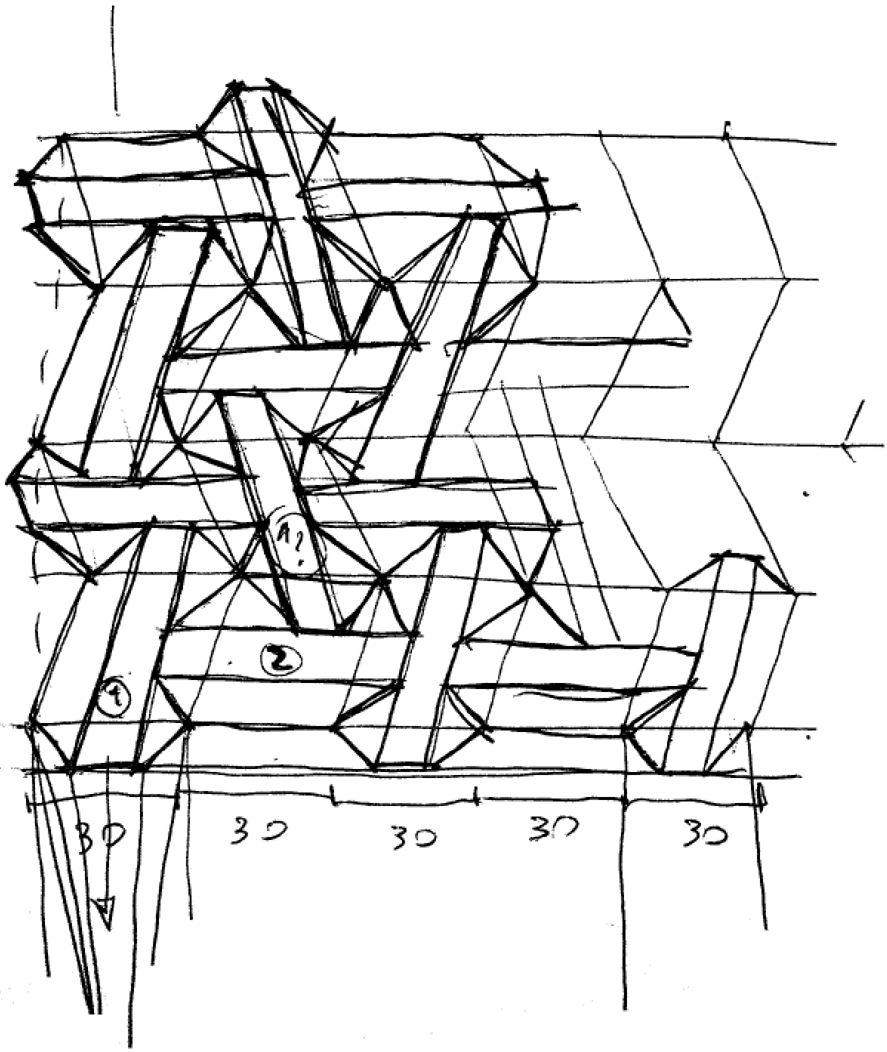
La main prodigieuse de l'artiste, égale et rivale de sa pensée.
L'une n'est rien sans l'autre.

Paul Valéry



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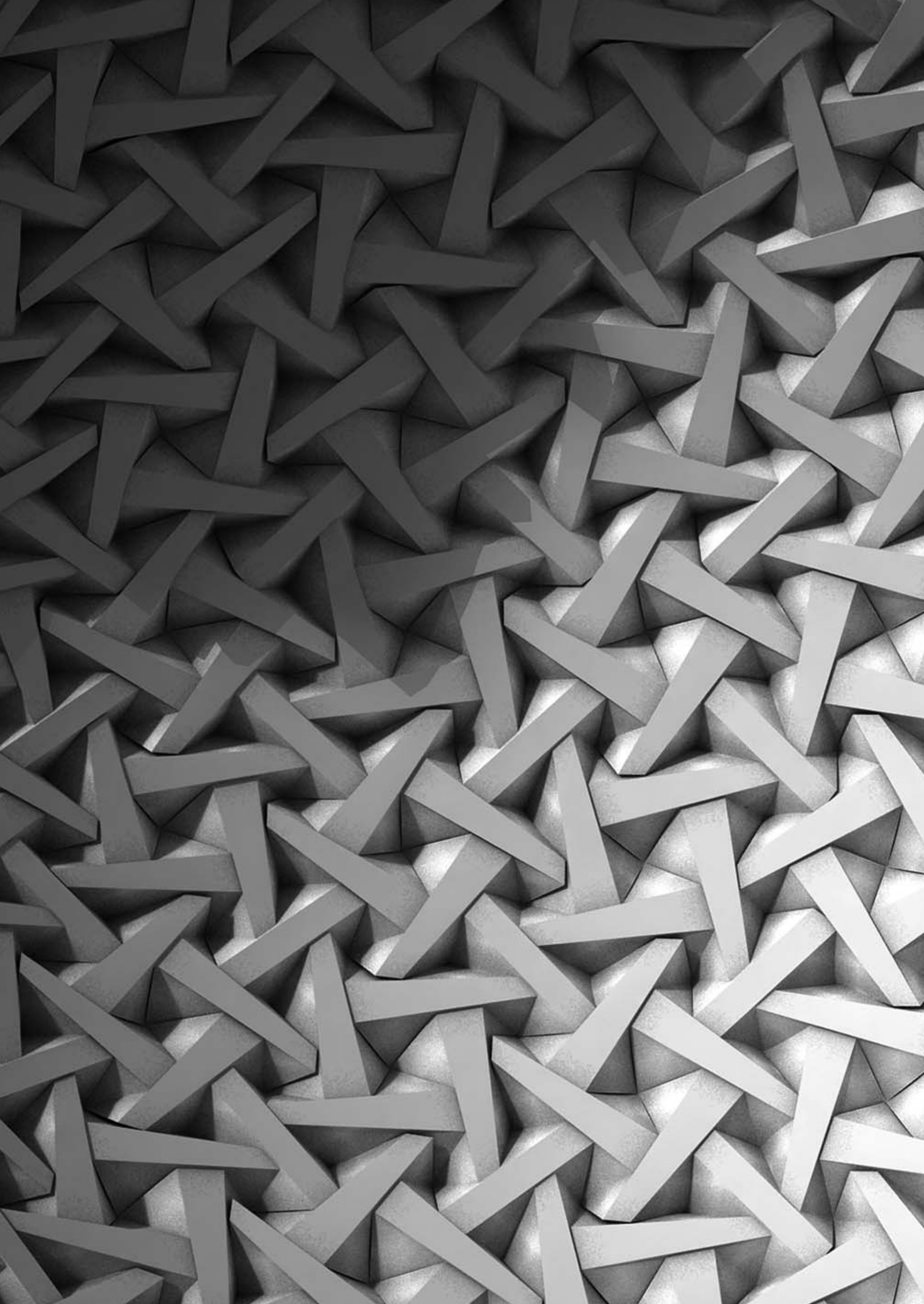
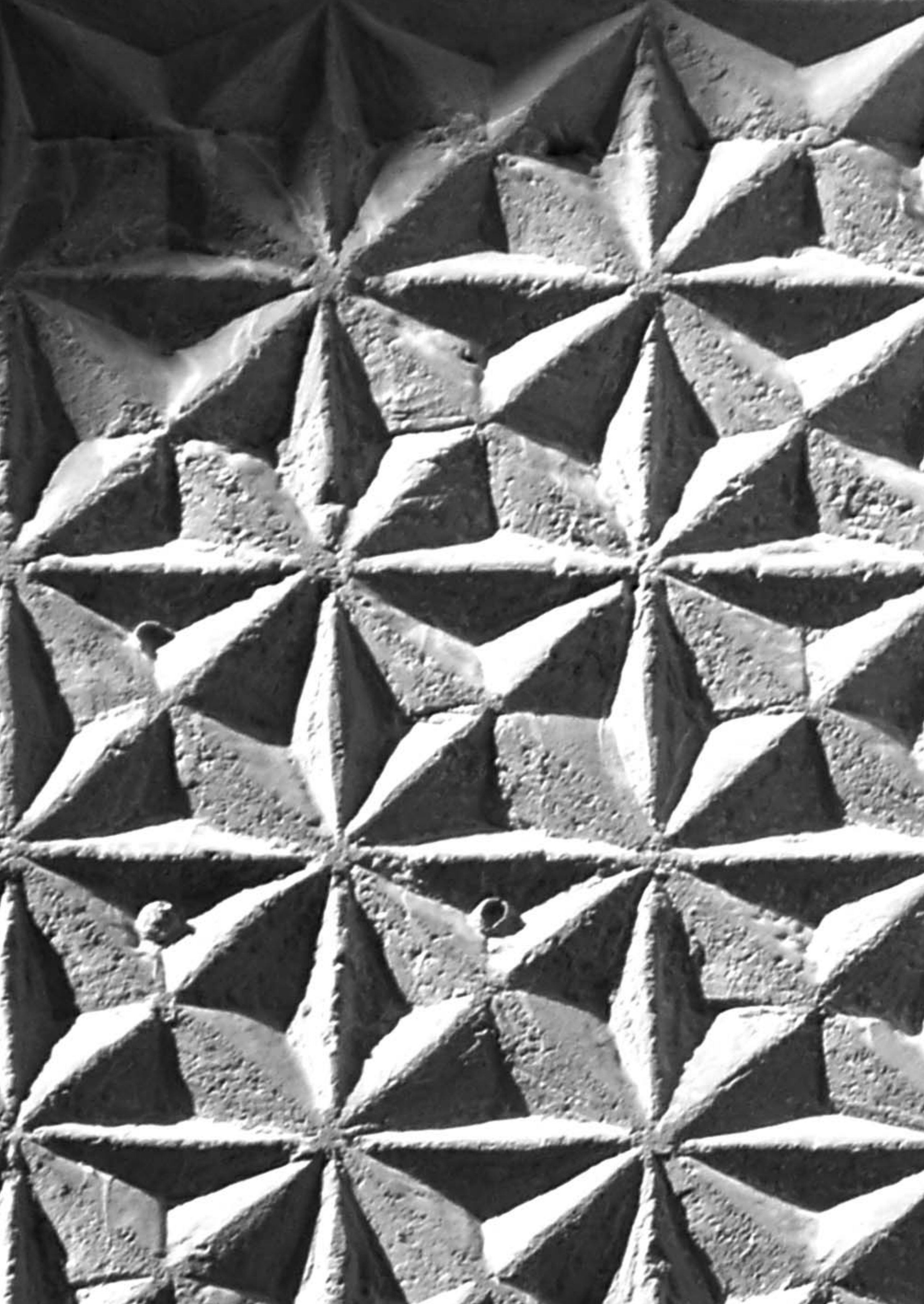


Stereotomy Revisited



The acritical acceptance of design paradigms developed in northern Europe and North America, has led to an increasing use of solutions that bear little or no connection with tectonic research and are often in blatant contrast with it, emphasizing their reliance on the pure domination of form. There has been a paucity of critical consideration of the relationship between design and construction, meaning the creative potential of technique, and this has led to the diffusion of certain characteristics in research and architectural production that have become evident today in the loss of a complex and unitary approach, founded on the values of the rationality of the architectural organism and on the acceptance by architects and engineers of the Vitruvian triad of *venustas*, *firmitas*, *utilitas*. This has occurred both in structural research that is not interested in the "form" of the building and, in a symmetrical and opposite manner, in experimentation with composition where the architect, like the fashion designer, simply stamps his signature on the product.

In order to reconstitute a unitary culture of design and construction that reaches beyond the particularities of modernism and post-modernism, the role of stereotomy, now based on computer modeling for post–processing with computerized numeric control (CNC) machines, may prove strategic because it can help restore theoretical and practical unity to the process of designing and building an architectural work. In the twenty–first century, the professional figures of the architect and the stonecutter may concretely become reunited once again in the same person.

Claudio D'Amato Guerrieri
Venice, July 2006

Some time ago, we were likely to think that stereotomy was a dead science, only surviving in some limited intellectual circles. Nowadays, only in a few European universities there are still some departments concerned with finding out about this science and recreating it, the mighty cultural phenomenon generated by stone masonry.

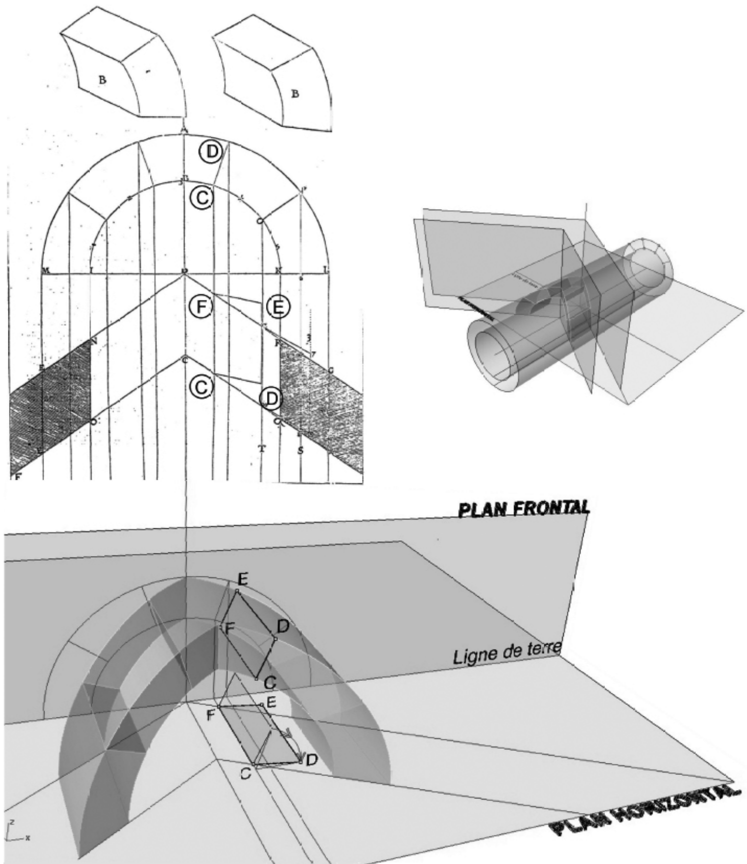
We are dealing with a scientific discipline that, for several centuries, led the art of building to the highest intellectual summits. Since the early Middle Ages, the vaults were designed as spatial networks so that they could be interpreted as separate arches, that is as curved lines whose geometrical shape could be monitored by the significant medieval geometrical tool: the plan/elevation projection. Later on, in Renaissance times, a higher level of geometrical knowledge will enable to define more accurately the complex volume of the *voussoires* with which the classical vaults were built, simple-shaped vaults but complex in their breakdown. In the following centuries, stone masonry, supported by a constantly evolving geometry, would reach its highest degree of development: utter freedom. From then on, any architectural shape can be imagined with the assurance of achieving the cutting of the voussoires' structure more appropriate and spectacular.

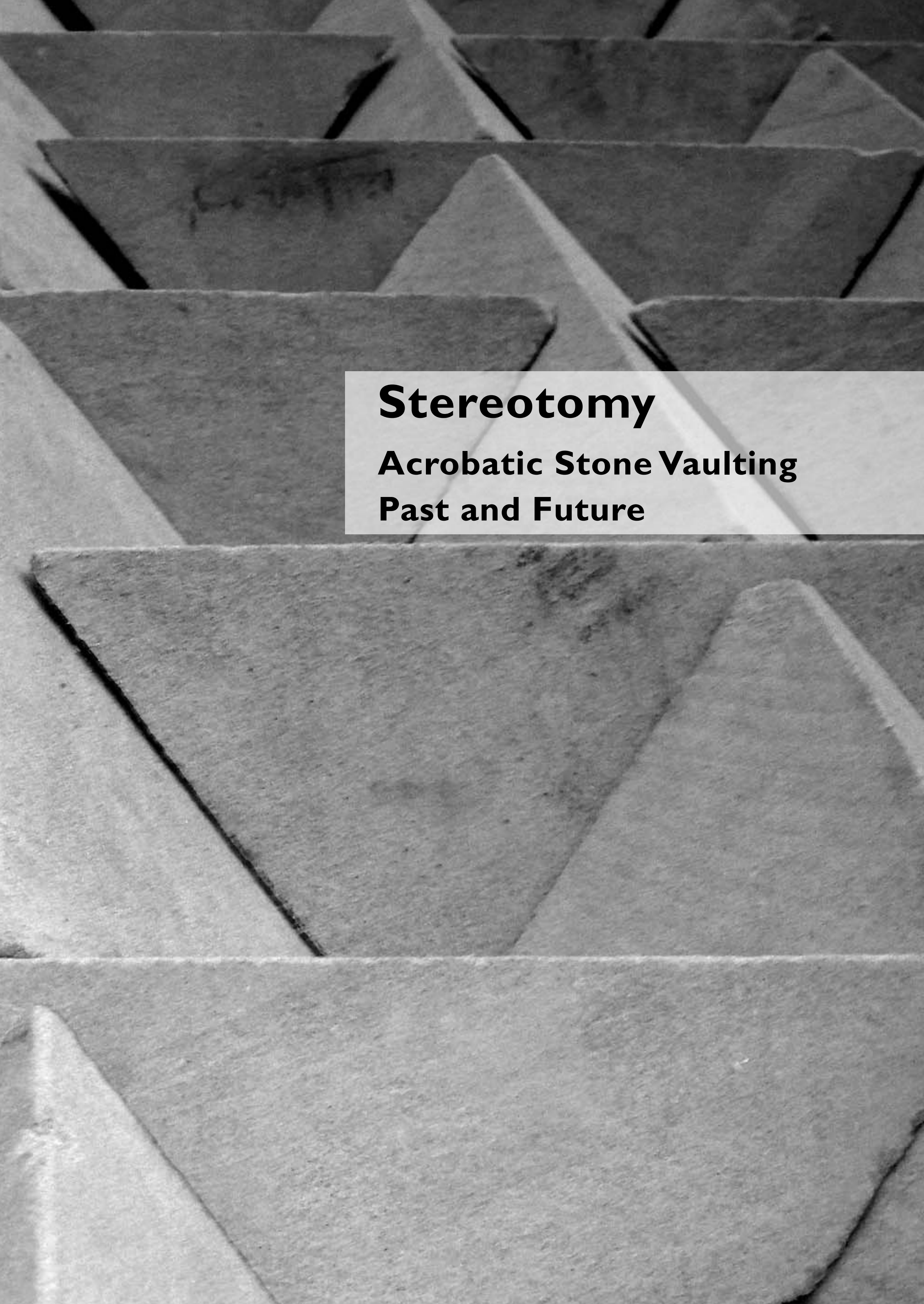
In the XIXth century, when this development had reached its very summit, stereotomy collapses and falls into oblivion; the massive masonries of traditional architecture succumbs to give way to a new architecture based on a structural set up never imagined before.

Nevertheless, there is still some hope. New geometrical skills gave way to new developments in stereotomy. Digital monitoring allows expansion of the limits of geometry.

These new tools, as in the past, enable us to explore new fields which were unattainable in stereotomy. When we believed that stone masonry belonged to the past, it has a great revival: the beauty of its proposals allows us to foresee a future, maybe elitist and sophisticated, but real and possible, for this discipline of architecture which we dreaded obsolete.

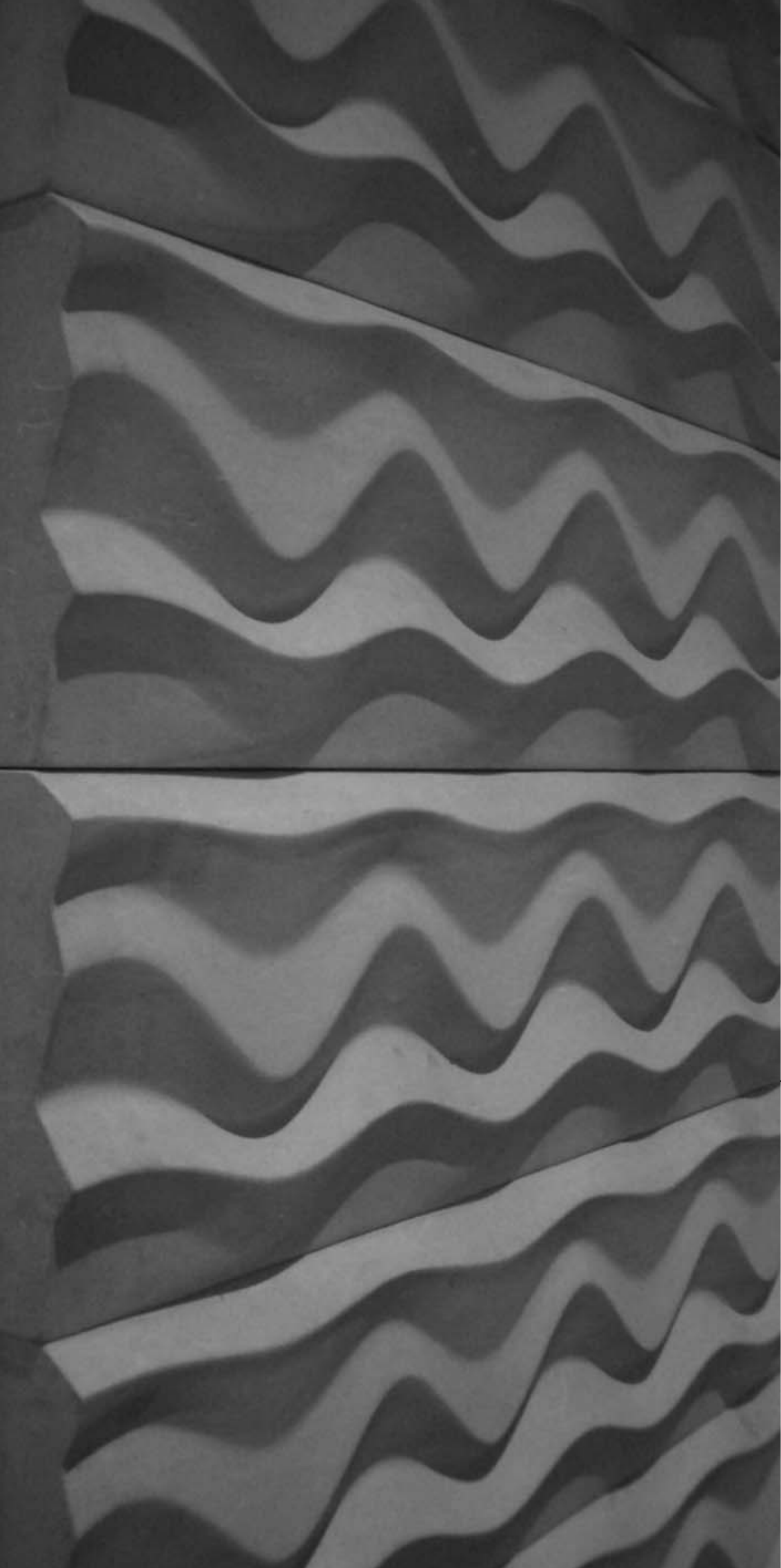
José Carlos Palacios
Madrid, September 2008





Stereotomy

Acrobatic Stone Vaulting Past and Future



Stone and vaults. Stone has always fascinated humans, who have used it as the noblest building material, because enduring, costly, and requiring ingenuity for its quarrying and construction. Vaults combine the psychological resonances of a sheltering space, evocative of the womb, with the grandeur of the sky and the heavens, which they readily suggest, as well as symbolize, especially when erected over vast interior spaces. Shelter and drama, womb and cosmos, at once intimate and exalting, the vault is the regal leader of architectural forms.

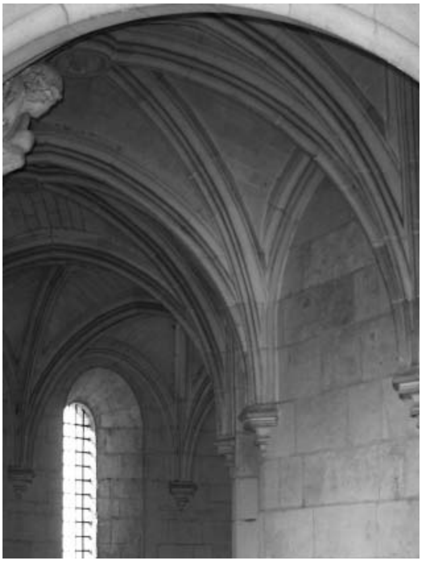
After nearly two hundred years of iron and then steel and concrete architecture, to talk of stone building might seem like calling back to life Don Quixote. Yet, the ecological qualities of stone are compelling: unparalleled durability, natural cooling, lack of pollution by toxic waste. The use of stone can reinforce the genius of the place by providing new buildings, however modern in form, that blend with the color, texture, and materiality of the past. Once a slow and painstaking process of cutting each stone by hand, now stone masonry can proceed rapidly with computer–guided cutters that can fashion more complex shapes than a person working manually with hand–held tools. And computer graphics enable architects to explore sophisticated forms, while subjecting them to static analysis for safety.

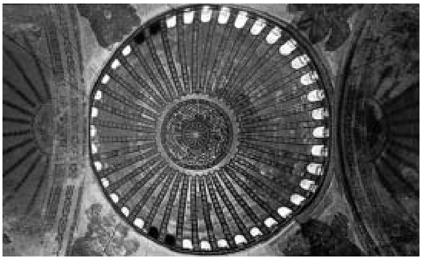
The Acrobatic Tradition

The Pantheon, Hagia Sophia, Chartres, Amiens, Saint–Denis and Cologne: the mere name of these edifices calls forth the image of a grand dome or noble vaults raised high above the viewer's head. Yet each of these buildings has still another startling quality: the dome or vault seems miraculously suspended overhead.

The large coffered dome of the Pantheon rested initially on a thin decorative band of diminutive pilasters, thereby giving the impression that the dome was suspended in space. The layered recesses of the coffers themselves are angled such that they seem to recede away from the viewer, carrying the dome upward, away from the ground. At Hagia Sophia, the miracle of the floating dome is repeated with a ring of round windows at the base of the dome, dubbed the *golden necklace*, that makes this cupola seem to be suspended magically high in the air. The dome itself, no longer sitting on the drum as in the Pantheon, rests upon a series of other partial domes to the east and west, whose supporting walls are largely opened with columns, arches, or windows, and on highly perforated screen walls to the north and south, thereby enhancing its suspended quality. In the great Gothic cathedrals, the soaring vaults seem to hover in the air, supported by thin, clustered stone shafts isolated within a sea of stained glass, the solidity of the walls transmuted into diaphanous, colored light. The tall piers, like trees, appear to spring upwards with a vertical thrust rather than to carry weight downward. Outside, thin arches of stones fly through space to buttress the thrust of these vaults creating web–like filigrees of towering piers and arching flyers. This Gothic architecture, as the German philosopher Arthur Schopenhauer once observed, creates the illusion of gravity having been abolished.

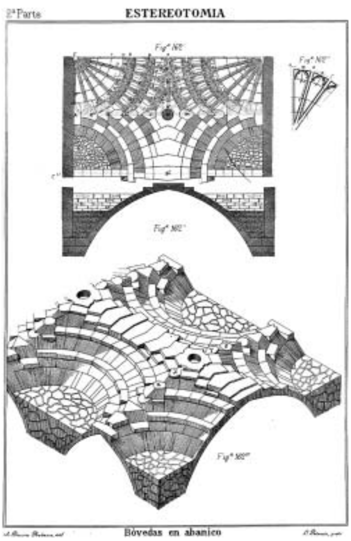
In all of these cases, it is an acrobatic architecture. Hence, the Roman Pantheon, the Byzantine Hagia Sophia, and the Gothic cathedrals of the High and Rayonnant styles all established a tradition of vaulting as an acrobatic architecture.





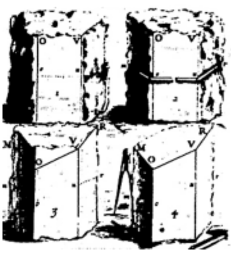
Stereotomy:

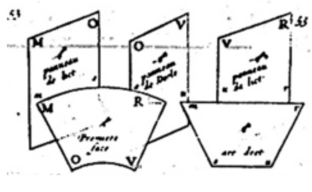
The Art of Cutting Stone

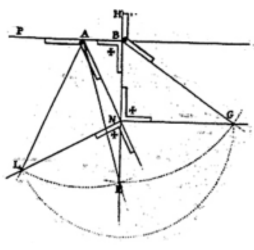


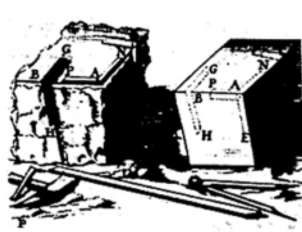
With the development of the Renaissance in Sixteenth century France and Spain, as well as Spanish possessions abroad, the ecclesiastical tradition of vaulted architecture passed into the realm of domestic and civic building and was accompanied by a new type of vaulting called *stereotomy*. In these lands, stereotomy dominated the vaulting of church and domestic architecture of the Sixteenth through Eighteenth centuries, until the advent of the Industrial Revolution and the shift to iron, steel, and concrete construction. Stereotomy, literally the cutting of solids or volumes as applied to stone vaults, is a word first used, it appears, in 1644 by Jacques Curabelle, an *appareilleur*, in other words, a master stonemason who directed the execution of these stone vaults in accordance with geometrical drawings. Throughout the Sixteenth through Eighteenth centuries, architects who favored stereotomic vaults often closely associated themselves with their favorite *appareilleur*, because a profound knowledge of the mason's craft was needed to execute such demanding works.

Current scholarship on the drawing practices of architects and masons suggests that in the late Middle Ages, drawings, whether on parchment, a plaster of Paris floor, or wooden planks erected on scaffolding, were used to set out the curvature of the vault ribs and the profile of their stones. In the Sixteenth century with the rise of stereotomy, it appears that a new type of drawing was produced that enabled the masons to establish not only the shape of the vault but also the often complex three–dimensional shape of each stone. The architect Philibert de l'Orme was the first to publish this new type of drawing in the 1560s, thereby spurring an entire tradition not only of books on the subject over the succeeding centuries but also efforts on the part of architects, engineers, masons, and mathematicians to develop new methods of drawing to create stereotomic vaults with different approaches to the stone work.





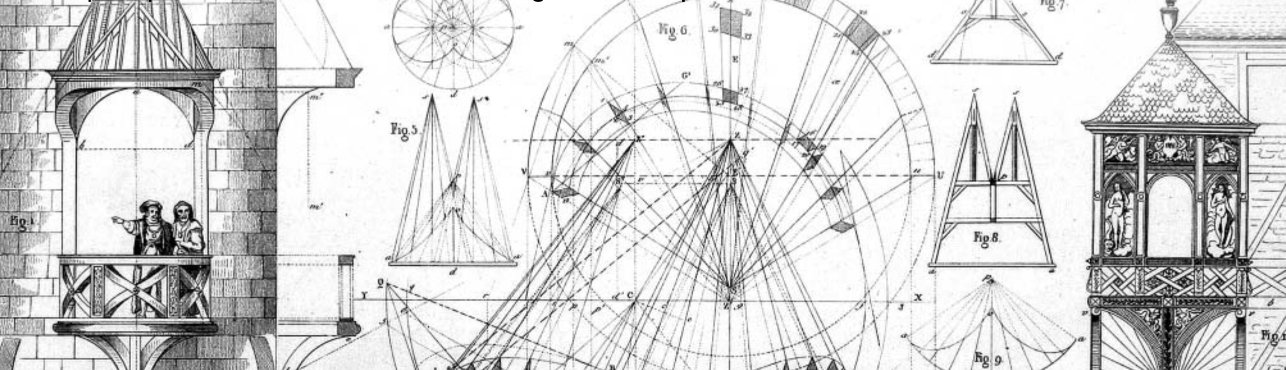








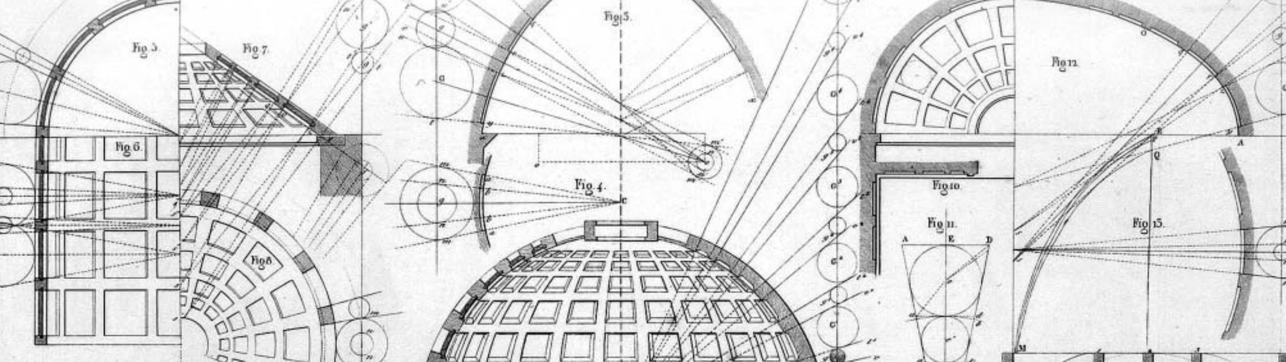
To what extent the drawings by De l'Orme and his Spanish contemporaries were a continuation of a late Gothic tradition still remains to be elucidated. An impetus for the development of more complete drawings in the Sixteenth century, giving indications for the shape of each individual stone, came from the nature of stereotomic vaults themselves with their combination of relatively large and regular cut stones, called *ashlar*. The Gothic emphasis on the curvature and profile of the ribs, often with elaborate decorative molding profiles, reflected the medieval tendency to build the ribs first, which also enabled them to serve as a scaffolding for the construction of the rest of the vault, whose infill, called the web, was made with small stones.
The Pantheon's dome consisted of brick and concrete and Hagia Sophia's was of brick. All three materials — concrete, brick, and small stones — are generous to the builder who can make slight adjustments as needed when erecting a vault or dome. Stereotomy, though, generally involves large, heavy pieces of cut stone (*ashlar*), often of different shapes and with tightly fitted joints such that each piece must be precisely cut on the ground before it is raised into place. It requires a sophisticated understanding of geometry.
True to the acrobatic tradition of historical Western vaulting, the architects of the new stereotomic vaults pursued their own version of an acrobatic architecture. These stones fit together such that, in the words of a Seventeenth–century admirer, the vault "uses the weight of the stone against itself to make it hang in air through the same weight that would otherwise make it fall". Whereas French stereotomy inherited the Gothic taste for breathtaking bravura vaulting, it culled from the Romanesque the sensuousness of smooth, flowing surfaces, a perceptual feature that rendered the magic of the suspended



forms even more captivating. The result was a flourishing of architectural forms all calculated to astound: the *trompe*, named for its trumpet shape, a vertical splay of stones seated in a shallow ledge that reaches out into space over the head of the viewer and carries a heavy stone tower, as well as its own weight. The *flat vault* or *nearly flat vault* whose horizontal stones hover miraculously overhead. The *suspended stair* that arches out from the wall, stone by stone, and rests effortlessly in space with no visible support.

When toward the end of the Seventeenth century Charles Perrault joined the debate about the achievements of contemporary culture in comparison with those of classical antiquity — the so–called *quarrel* between the ancients and the moderns — he knew that reference to the modern stone vaulting tradition called *stereotomy* would demonstrate the superiority of the contemporary age. At no other time, he observed, has the world seen "these astonishing trompes where one sees a building support itself by the strength of its shape and by the cut of the stones; these low–slung vaults, most of them totally flat; these flights of stairs that, without any pillar to support them, turn in the air along the walls that enclose them, and attach to landings that are equally suspending in air, without any other support than the walls and the ingenious cut of their stones".

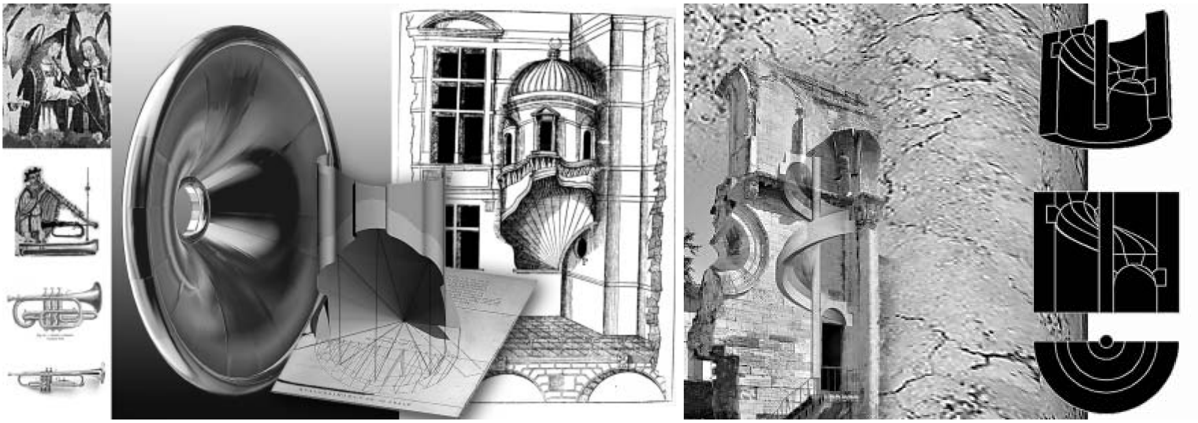
How is this done? The skilled masons and architects understood that they had to use the center of gravity to keep the vault from toppling down. But how to explain this stone by stone? The three–dimensional shaping of the stones reflected a knowledge that justified the title of one Seventeenth–century book that announced "the secret of architecture", a telling designation that was never explained.



Stereotomy:

Masterpieces

Like the earlier ages, the period of stereotomy had its widely admired masterpieces: the undulating trompe by Philibert de l'Orme that reached out into space ten to twelve feet to carry the heavy, domed stone cabinet, or private chamber, of King Henry II at the Château d'Anet (c. 1551) in Normandy; the triple vault and dome of the royal Château at Blois (1635) by François Mansart, its nearly flat dome opened in the center with a gaping hole, revealing the floating oval dome with raised central oculus; the undulating vault of the vestibule in the City



Hall of Arles (1673) by Jules Hardouin–Mansart, assisted by the local architect Peytret, 16.5 m (54 feet) to each side with only a shallow rise of 2.4 m (7.9 feet). And the stairs, among so many suspended stairs, the broad and gentle staircase with risers so gentle that one seemed to float up the marble steps, constructed by Philibert de l'Orme at the Tuileries Palace (c. 1563) around an ample void over the twisting barrel vault of vertically oriented stones known as the *Spiral of Saint–Gilles*, so thin and so graceful in profile that the Venetian Ambassador in France at the time described it as "miraculously suspended" in space. Even nearly two hundred years after its construction, a French chronicler wrote that it seemed built "by a sorcerer or fairy". The Spiral of Saint–Gilles itself, erected in the church and village of that name, had been an obligatory site of pilgrimage for the young apprentice masons, where they left their marks, carved into the wall to signal their passage, as they also did at the suspended stair in the convent of Saint–Trophimes of Arles.

By the end of the Eighteenth century, the acrobatic architecture of stereotomy was derisively dismissed as "bizarrely daring" and

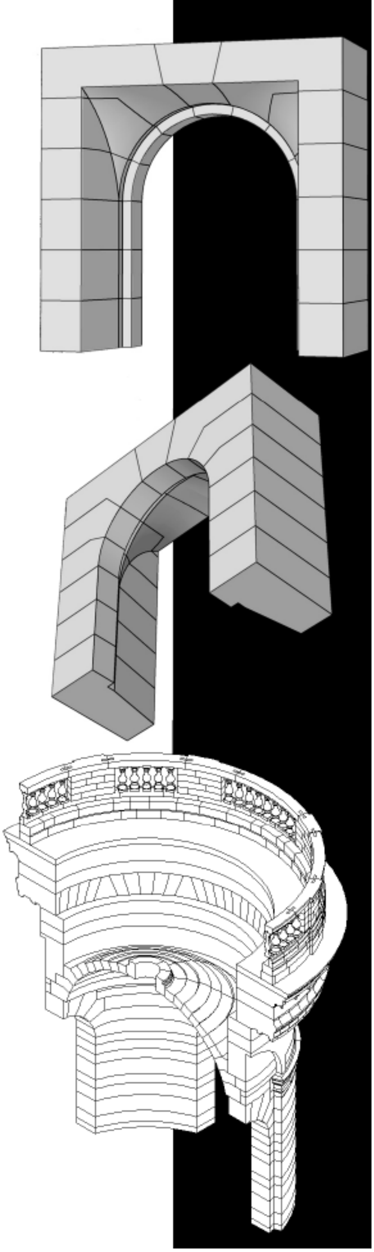
as "presumptuous temerity". Just as Gothic architecture had been criticized in the Seventeenth century by the Académie Royale d'Architecture for willfully denying an "appearance of solidity" by "seeming marvelous and astounding", so too would daring stereotomic vaults be criticized in the late Enlightenment for dramatically hovering in air, thereby seeming to deny the stability that a new, contemporary taste required of its architecture. The shift to iron, steel, and concrete construction with the advent of the Industrial Revolution helped to further undermine the primacy of stereotomic vaulting in French and Spanish architecture.

Stereotomy Today

Stereotomic stone vaulting has undergone a rebirth today largely through the efforts of the Politecnico of Bari in Puglia. Although scholars in various nations have been studying the history of stereotomy, spurred by several magisterial publications — *L'Architecture à la française: XVIe, XVIIe, XVIIIe siècles* (1982) by Jean–Marie Pérouse de Montclos, *Trazas y cortes de cantería en el renacimiento español* (1990) by José Carlos Palacios, *Epures d'architecture. De la coupe des pierres à la géométre descriptive XVIe-XIXe* (1996) by Joël Sakarovitch, *Forma Y Construccion En Piedra: De La Canteria Medieval a La Estereotomia Del Siglo XIXe* (2000) by Enrique Rabasa Díaz and *Arcos, bóvedas y cúpulas* (2004) by Santiago Huerta — the Dipartimento ICAR, directed by Professor Claudio D'Amato Guerrieri, of the Politecnico of Bari has combined historical studies with design projects, approaching stereotomy as a way to combine structure, form, and decoration into an indissoluble whole. Professor Giuseppe Fallacara completed a doctoral dissertation in this program, where he now teaches, and published a book — *Verso una progettazione stereotomica/Towards a Stereotomic Design* (2007) — that covers both the history and his own design work. This book also contains an essay by Luc Tamboréro, a Frenchman trained as a stonemason, called *compagnon du devoir*, who directs Mécastone, a stone construction and restoration enterprise.

Fallacara and Tamboréro collaborate on historical studies and modern designs and both led a summer seminar on stereotomy at the Universidad Politécnica de Madrid and San Pablo CEU in 2008. This September they join Professor Richard Etlin for a teaching project at the School of Architecture, Planning, and Preservation of the University of Maryland in College Park.

This new team of Etlin–Fallacara–Tamboréro combines three sets of complementary backgrounds and interests, all centered on a deep

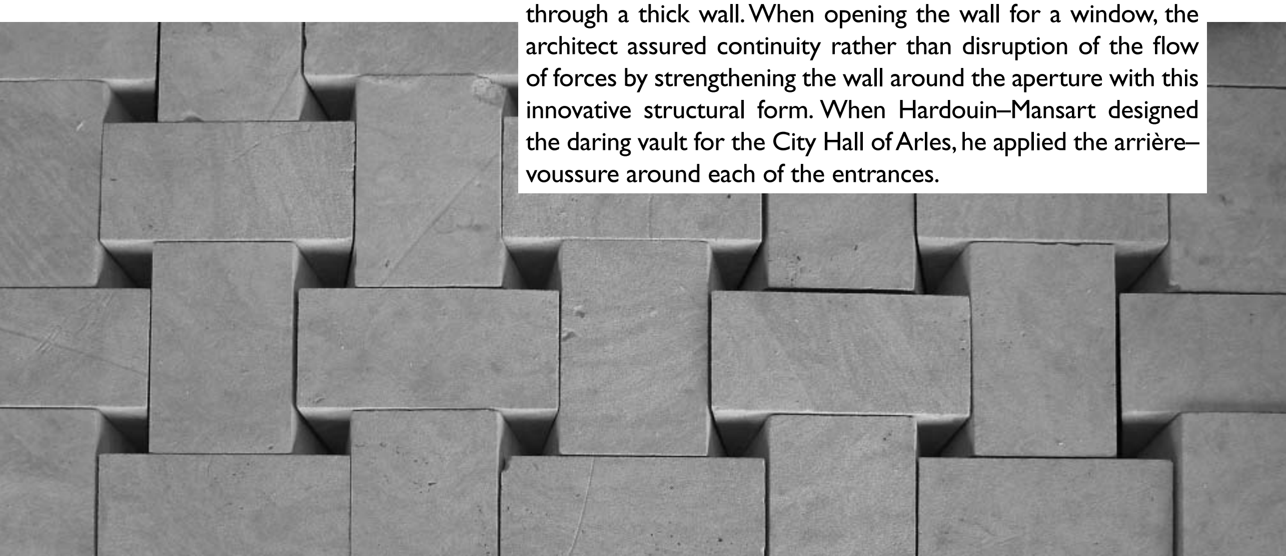


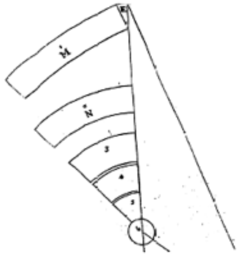
admiration for the acrobatic tradition of stereotomic vaulting.

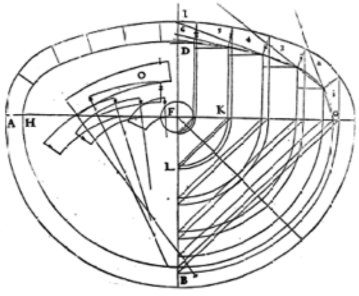
As an architectural historian, Etlin has long been interested in the relationship between form and structure. One of the principal themes of his book *Frank Lloyd Wright and Le Corbusier: The Romantic Legacy* (1994) was the importance for modern architecture of Quatremère de Quincy's idea of the three–part architectural system that coordinated a system of structure, a system of form, and a system of decoration. Quatremère de Quincy articulated this notion, which had guided the architecture of the past, in the early Nineteenth century just at the time of the major professional split between architects and engineers. Stereotomy, both historical and modern, integrates form with structure and decoration. Etlin is currently pursuing a study of stereotomy within a French cultural context.

As both a scholar and a teacher of architecture students, Etlin is particularly interested in the notion of "structural forms", a term taken from German engineer Curt Siegel's pioneering study of modern structures entitled *Strukturformen* (1961), because architects, engineers, and stonemasons, past and present, design creatively by employing a set of structural forms as the basis of their buildings.

One of the staples in the design vocabulary of stereotomic forms, for example, was the *arrière–voussure*, a type of shallow vault with vertically oriented voussoirs placed around a window or doorway. This vault combined grace and strength, since it braced the thrust of the main vault of a room and redirected the horizontal force downward. Perhaps it is not accidental that the earliest known use of the *arrière–voussure* is in a church in Saumur dating from 1180–1200, an example of Plantagenet Gothic architecture, a style that eschewed the use of flying buttresses in favor of buttressing through a thick wall. When opening the wall for a window, the architect assured continuity rather than disruption of the flow of forces by strengthening the wall around the aperture with this innovative structural form. When Hardouin–Mansart designed the daring vault for the City Hall of Arles, he applied the arrière–voussure around each of the entrances.



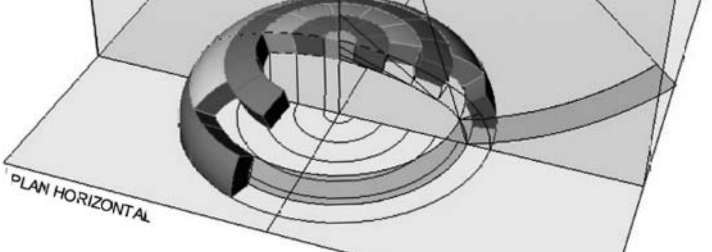


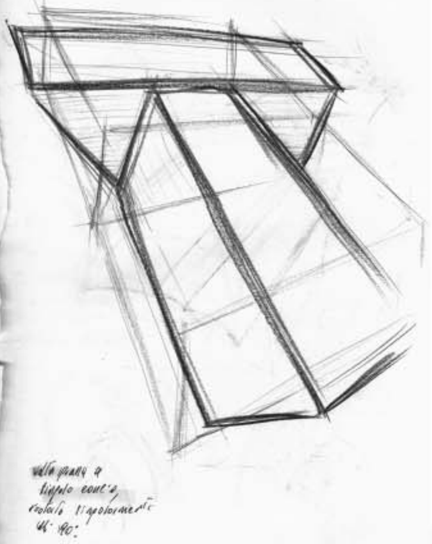


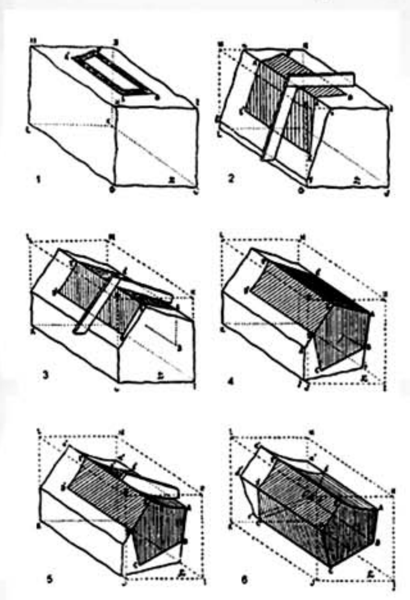
This is precisely the structural form that the stonemasons restoring the stone towers of the Eighteenth–century Parisian Church of Saint–Sulpice are using to brace the dome and to redirect thrust vertically toward the ground. This is a creative choice, because it replaces the iron ring and iron cramps of the original structure, which, over the centuries had damaged the tower and would do so again were they to be replaced. The structural forms, then, of the stereotomic tradition enable modern restorers of historical monuments to secure their future with appropriate forms.

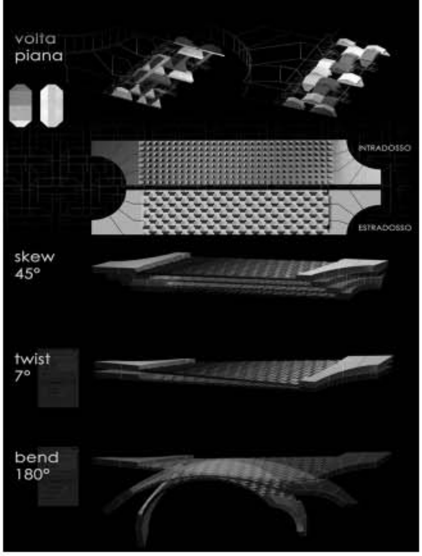
Tamboréro's ten–year apprenticeship to become a stonemason in a training program that dates back to the Middle Ages, along with his subsequent scholarly and professional work, has enabled him to study the stereotomic drawings, called *le trait* and *l'épure,* of the major figures of the French tradition for insights only available to a practitioner of the trade. In his Master's Thesis at the Ecole des Hautes Etudes en Sciences Sociales — *De Delorme à de La Hire, la recherche d'une méthode universelle dans les traités de stéréotomie. Opérations géométriques et emprunts* (2008) — Tamboréro focuses on innovative figures of the French stereotomic tradition who developed systems of drawing that could be applied to all cases of a particular type of stereotomic vault. This "universal method" constituted an important conceptual advance and practice tool for architects and stonemasons. Tamboréro has charted the increasing complexity in stereotomic design that each successive architect, stonemason, engineer, or mathematician developed and relates it to the traditional stonecutting techniques inherited from the Middle Ages.

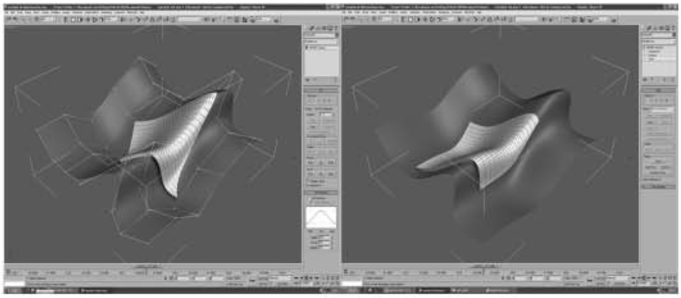
Tamboréro shows that each of the canonial stereotomic forms — De l'Orme's trompe at Anet, Desargues's angled descent into a cellar, and Hardouin–Mansart's vault in Arles — has not only an original form but also a particular manner of *trait unique* to its respective form and not capable of transfer to the others. Yet, at the same time, each of these three traits permits numerous other forms within the well–defined family of its type. In that sense, each is a "universal method", a goal sought by several of



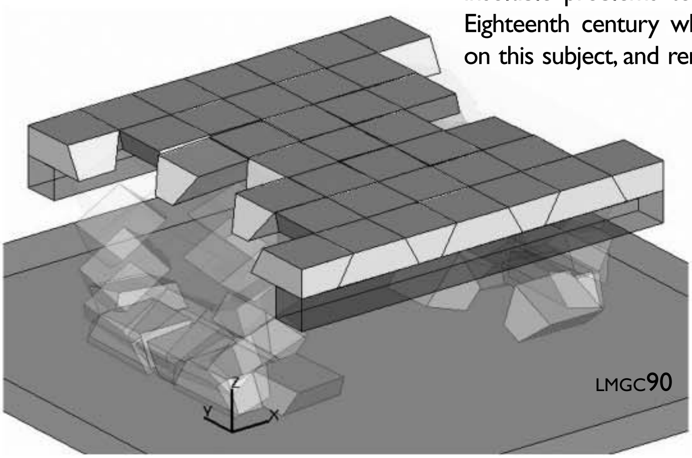




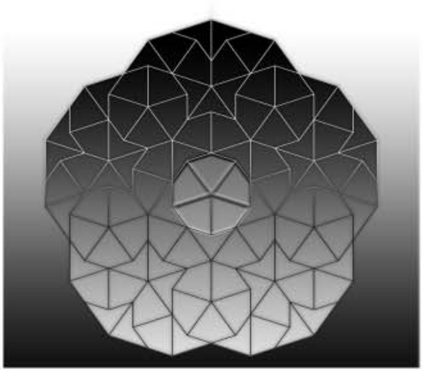


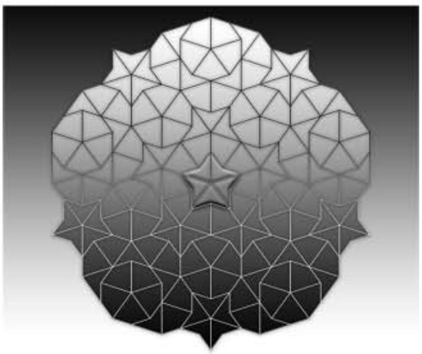


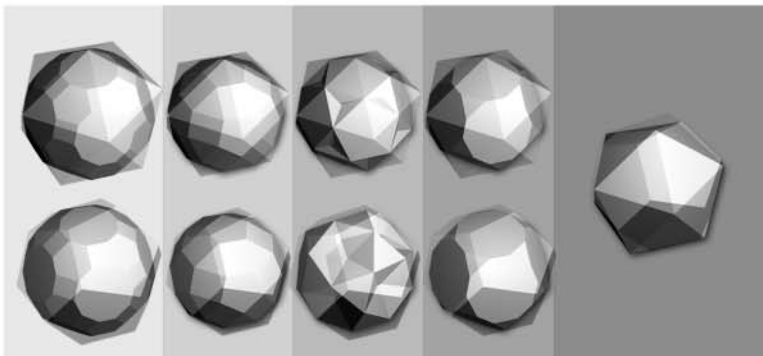
the historical figures who wrote about stereotomy.
Tamboŕero believes that the end of the great era of stereotomic vaulting came with the development of modern statics and the new outlook that required precise quantification of structural forces both to secure building permits and to satisfy insurance companies. The structural behavior of stone vaults, even of stone walls, presented insoluble problems to the engineers and mathematicians of the Eighteenth century who focused their new quantitative outlook on this subject, and remains a difficult engineering problem to this day. Yet, the computer, both through its graphic capabilities, and through the use of the *discrete element method,* in particular LMGC90, affords today's architects, engineers, and stonemasons a secure means for understanding the behavior of stereotomic vaults and for quantifying their forces. LMGC90 (*Laboratoire de Mécanique et Génie Civil*) is a multipurpose software developed at the University of Montpellier II, capable of modeling a collection of deformable or undeformable particles of various shapes and subsequently applied to buildings by the civil engineering team of the Ecole des Mines d'Alès (Nîmes, Pau).

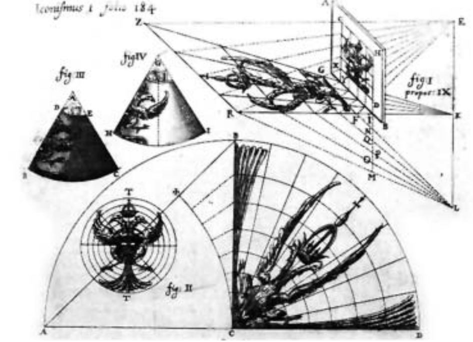

LMGC90

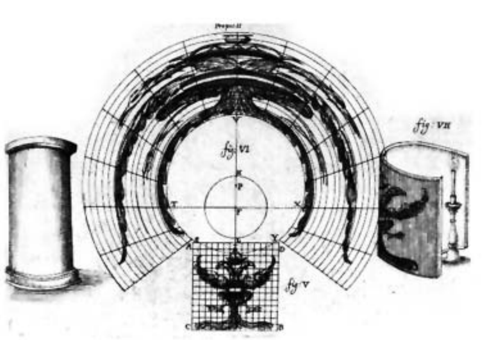
In his historical research, Tamboréro has argued that the development of new stereotomic forms coincided with new developments of techniques of representation and conception. Hardouin–Mansart's vault in Arles, for example, employs a stereotomic process traditionally used in carpentry but here applied to stone vaulting. Today, this creative evolution is being continued by Fallacara, who is applying topological geometry to stereotomy with the tool of the computer. Topological geometry can provide a new universal method for stereotomic design. Fallacara's method takes advantage of the possibility for transforming simple topological forms into various architectonic configurations. Whereas, from the perspective of topology, there is

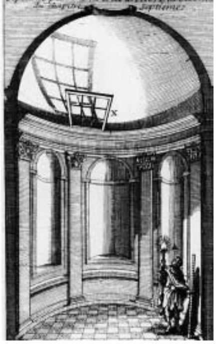








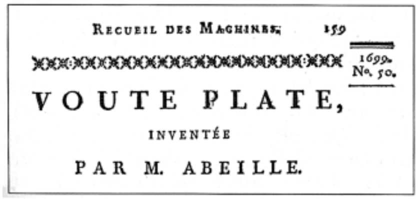




no difference between a plane or a cylinder, in stereotomy the stones will have different shapes in each of these and other forms. In classical stereotomy, the determination of the exact angles between the surfaces of various vaults and domes constituted a problem to be resolved. For *topological stereotomy* on the computer, the determination of the angles is resolved automatically as a consequence of the deformation of the initial shape. Through a virtual deformation, each *voussoir* of a vault is a numerical entity whose value is transferred automatically to the cutter. To optimize the assemblage of the vault, the designer should aim for the least possible number of different shapes for the individual stones. To address this issue, Fallacara has explored the domain of tessellation, whereby a limited number of shapes of interlocking forms is used to create a vault. In particular, he has sought a universal method through creative modifications to the tessellated flat vault designs of Abeille and Truchet.

In 1699, two Frenchmen, the engineer Joseph Abeille and Father Sébastien Truchet each proposed the design for a flat vault using only one shape of stone. These projects were then popularized by the military engineer Amédée–François Frézier, director of fortifications for Louis XV, who offered his own variants, in an extensive treatise on stereotomy (1737–39, 1754 second edition). Several flat vaults were constructed in Spain over the course of the next century after these models. The flat vaults envisaged by Abeille and Truchet presented the advantage of a thin stone ceiling and floor that could not warp, was free of rot, mold, and insects, and could be constructed of identical stone pieces with an inherent decorative pattern.

The Abeille vault came first, its interlocking stones leaving small, square voids on the underside that could be filled either with mortar or with a stone of different color so as to create a decorative pattern. Father Truchet developed his design as an improvement on the Abeille vault, since its interlocking shapes left no void at all on either surface. Yet, as the initial report published by the French Royal Academy of Sciences explained, the Truchet vault would be difficult to build: «This invention is truly ingenious, but it would perhaps be difficult to execute, because of the need to have the concave and



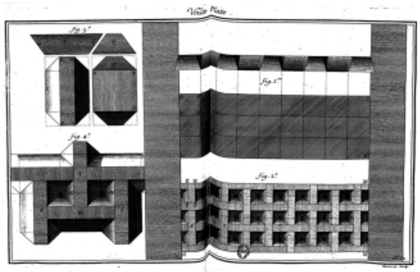
RECUEIL DES MACHINES. 159

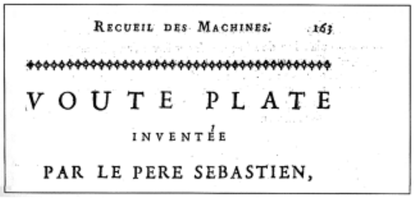
1699. No. 50.

VOUTE PLATE,

INVENTÉE

PAR M. ABEILLE.





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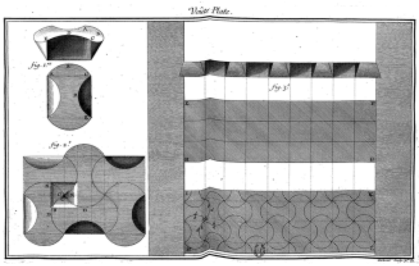
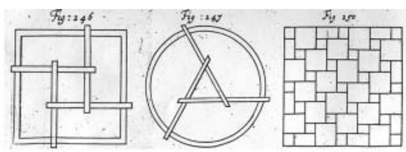
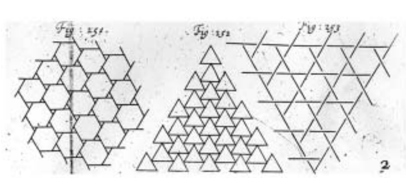
VOUTE PLATE

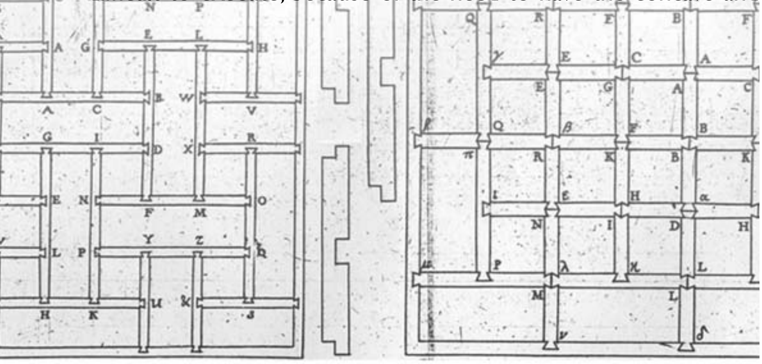
INVENTÉE

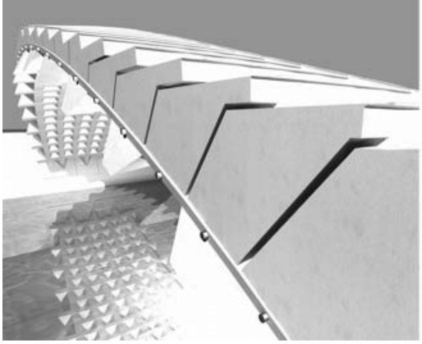
PAR LE PERE SEBASTIEN,

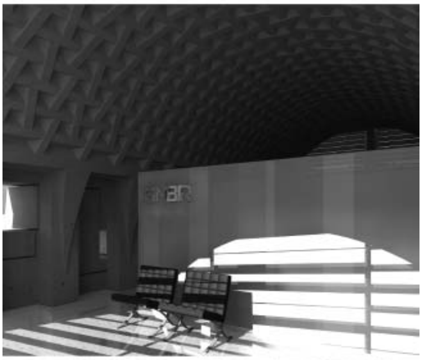




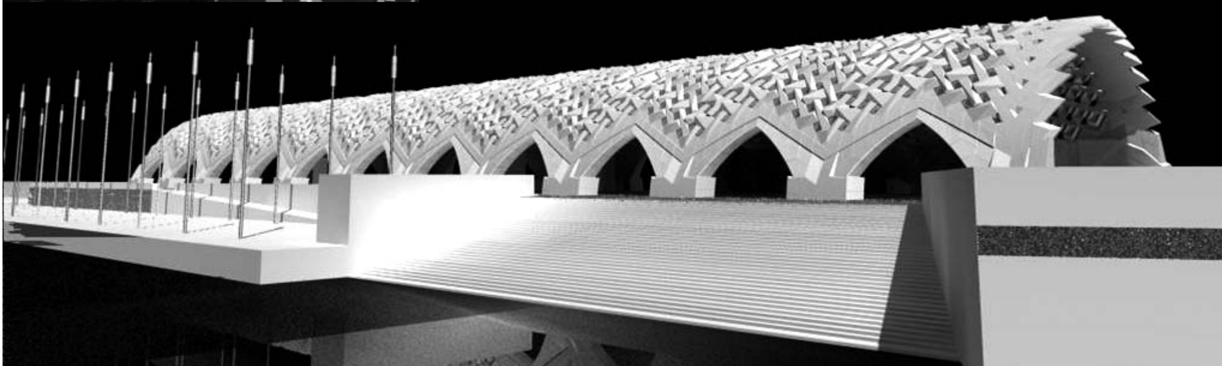


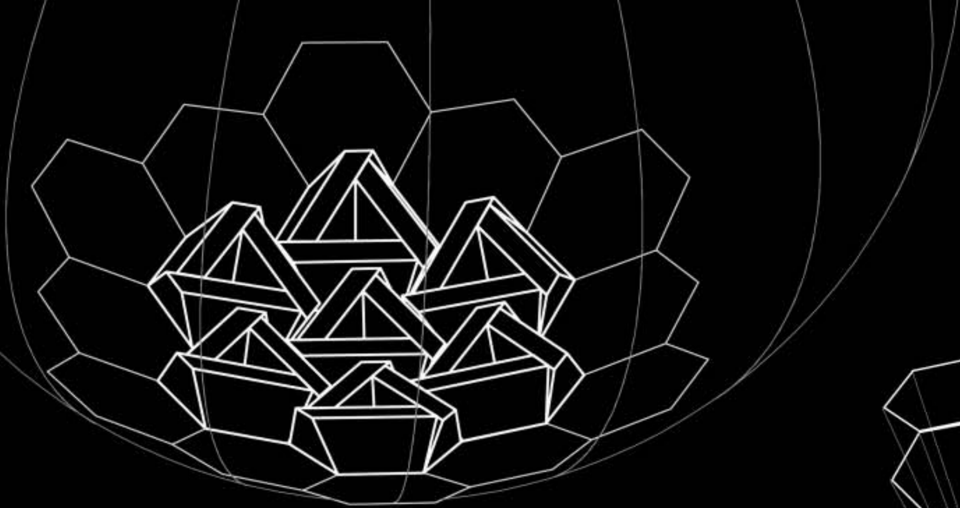


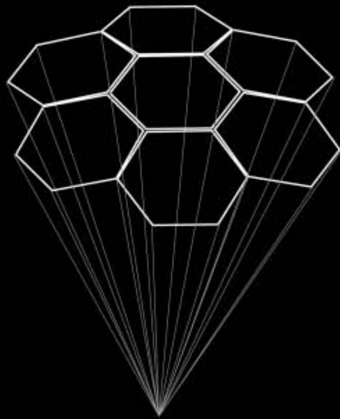


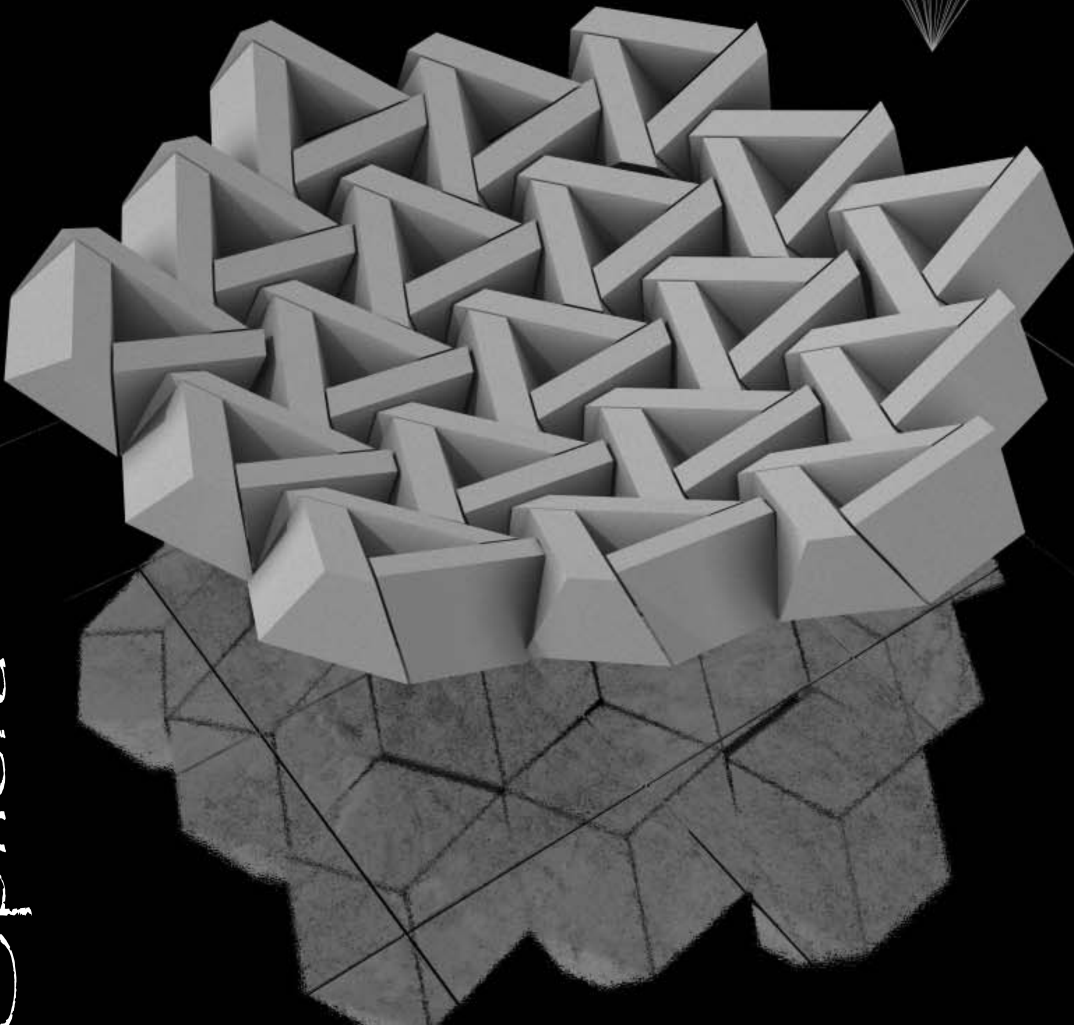


convex surfaces touch at all points, the curves being entirely different in profile along the entire joint». Today, with computer–guided cutters, this difficulty has been eliminated. In effect, such mechanized tools make the preparation of stone for either vault a relatively easy process, assuring the precision of fit required by these vaults.
Over the last decade, the Italian architect Giuseppe Fallacara has been experimenting with the Truchet and Abeille patterns, which he has transformed into freestanding, round arches. At the 2006 Venice Biennale, Fallacara adapted the Abeille pattern into a stone ceremonial entrance arch at the exhibition *Città di Pietra* (*City of Stone*) directed by Professor Claudio D'Amato Guerrieri. Then in 2007 Fallacara and Tambooréro led a summer workshop on stereotomy at the Universidad Politécnica de Madrid and San Pablo CEU, where they constructed another ceremonial arch, this time using a variant of the Truchet tiling pattern, which they skewed, thereby gaining a more dynamic visual effect, as well as a stronger structural form, individual pieces for this arch have been produced by the French company 3D Pierre, Paris, which for years has worked in the field of restoring important Paris historical buildings. Fallacara has expanded these studies to include projects for vast, vaulted halls and has varied the patterns as well. In addition to the aesthetic variety and interest of these designs, they also offer the possibility of thin profiles, hence both elegant and efficient, and of better cohesion between the stones of the vault through the interlocking patterns.
The original Abeille vault was designed as a stone analog to interlocking wooden construction and was highly evocative of woven wickerwork. Translated into tessellated stones, this tightly woven aesthetic expresses visually the strong anchoring between the stone pieces of the vault. This theme of interweaving, from both the aesthetic and static point of view, has guided Fallacara in his designs. In his latest development, Fallacara has proceeded beyond relatively simple tiling patterns arranged into barrel vaults for the realm of three–dimensional tessellation with double curvature, presented at MarmoMacc Verona 2008 in the form of the *Sphera* (*Sphere*). Both the

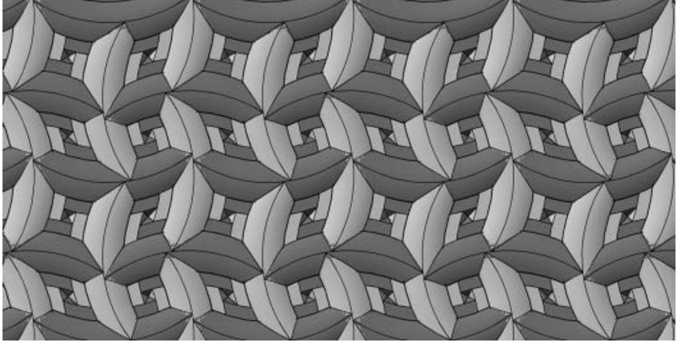


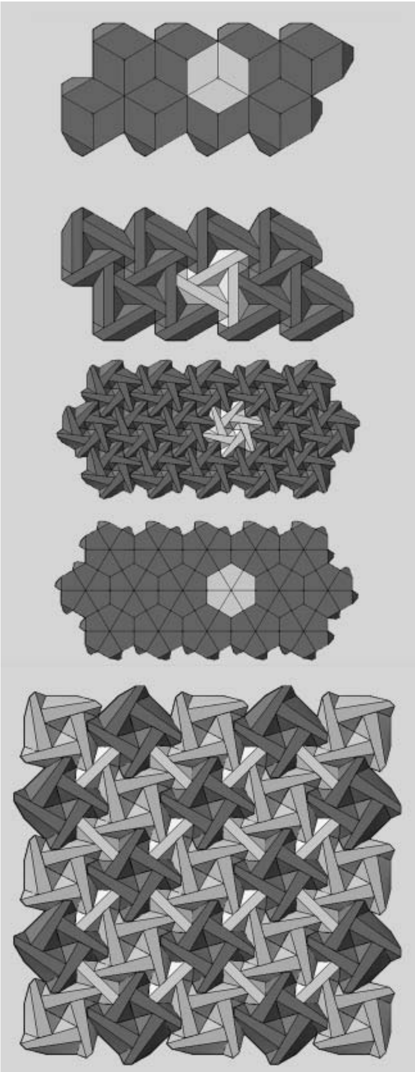




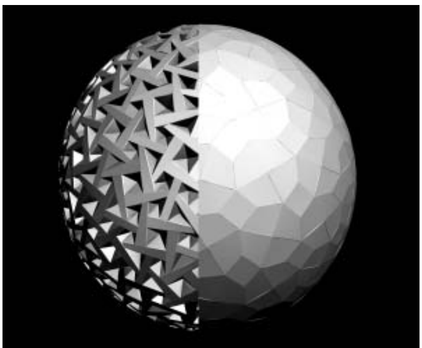


Sphera





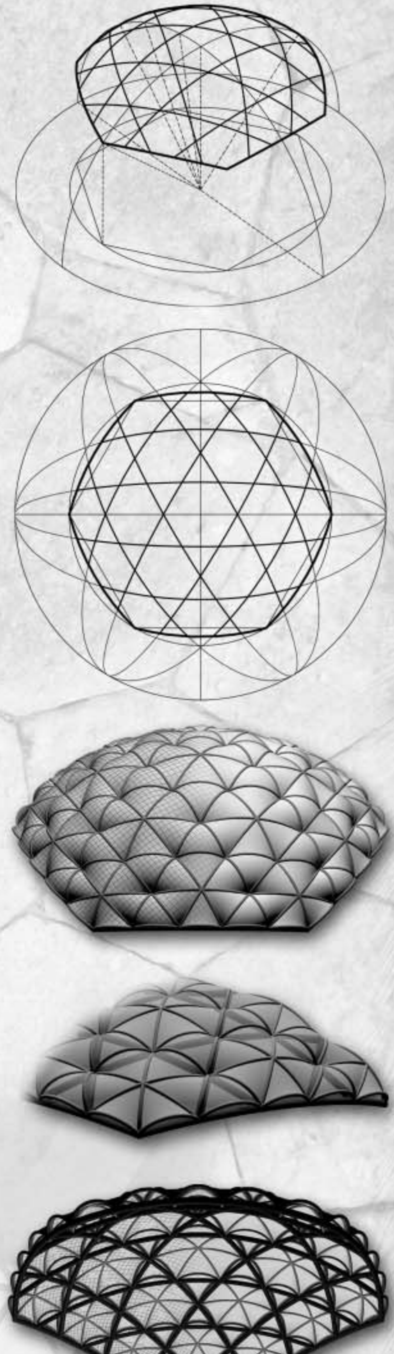
individual pieces and their assembly for *Sphera* have been produced by the French company SNBR–Troyes, which for years has worked in the field of restoring important French historical buildings.
In order to construct a sphere it is not possible to use a single shape of stone. The technique of construction passed down by the traditional manuals on stereotomy teach that to realize a surface with double curvature, such as a sphere, one must reduce the curvature by one degree. This means that the sphere becomes transformed into an assemblage of conical or cylindrical surfaces. The choice of form for the pieces is left to the designer or stonecutter who calculates the relationship between the size of the dome and that of the pieces of stone. Once either the conical or cylindrical shape has been selected, one then has a series of different shapes for the stone along the meridians and the parallels. Fallacara has designed *Sphera* by adapting the aesthetic of the Abeille flat vault with smooth outer surface and woven inner surface, using a hexagonal stone and accommodating for the lack of precise fit among the hexagons along the spherical contour with slight adjustments, invisible to the eye, at the joints.
At MarmoMacc Verona 2005, Fallacara and Tamboréro participated in a team endeavor that displayed a self-supporting stereotomic spiral stone stair, called the *Escalier Ridolfi*. This was a collaborative work undertaken by the Architecture Faculty of the Politecnico di Bari under the direction of Claudio D'Amato Guerrieri and Giuseppe Fallacara; Luc Tamboréro, who cut each of the stone steps by hand; Marc Vinches, Michel Suteau, Christian Buisson and Robert Perales of the Equipe du Génie Civile (Team of Civil Engineers) at the Ecole des Mines d'Alès, who performed a static analysis with the *finite element method*; and the company Fratelli Mele (Mele Brothers), who used CAD/CAM to direct a stone cutter that made two sample steps, one in Carrara marble and another in Lecce stone, so as to compare time and costs with the manual cutting of the stone by Tamboréro; and the company "Leopizzi 1750" of Parabita (Lecce), who donated the stone and their workplace, as well as directed the entire physical operation of the stone cutting and assemblage, which involved the

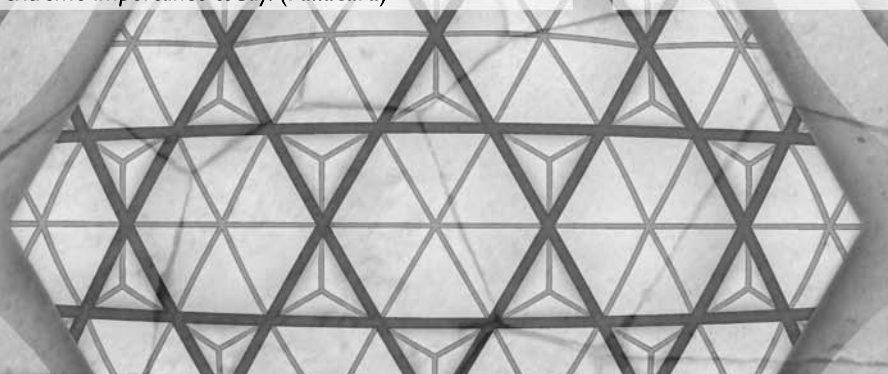


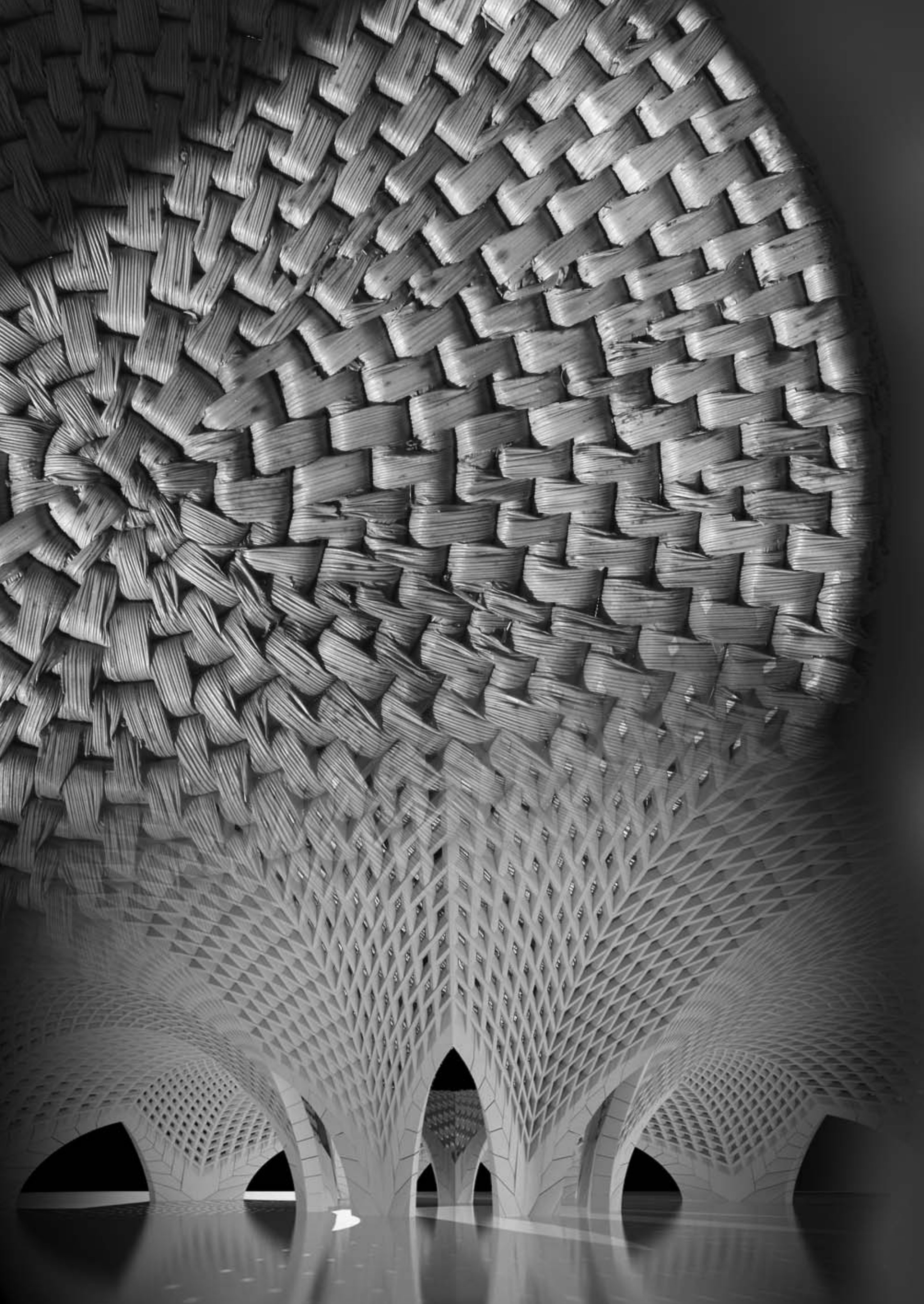
use of tension cables to substitute for the walls that would have contained the stair had it been constructed in a real building.
Etlin, Fallacara, and Tamboréro approach their historical research with the neutral eye of the scholar. Yet their choice of subject is not casual. They share with the great architects of the stereotomic tradition the conviction of the importance of an architecture, to borrow the words of Philibert De l'Orme, that "astonishes" through its "unaccustomed" forms and its obvious "difficulty". Such effects, which reveal human ingenuity as well as creative imagination, have arisen most effectively within the tradition of the acrobatic stereotomic vaults, to quote De l'Orme again, «suspended in air». De l'Orme's vocabulary resounded through the literature on stereotomy of the next two centuries and finds its echoes in the words of Fallacara, and Tamboréro today:

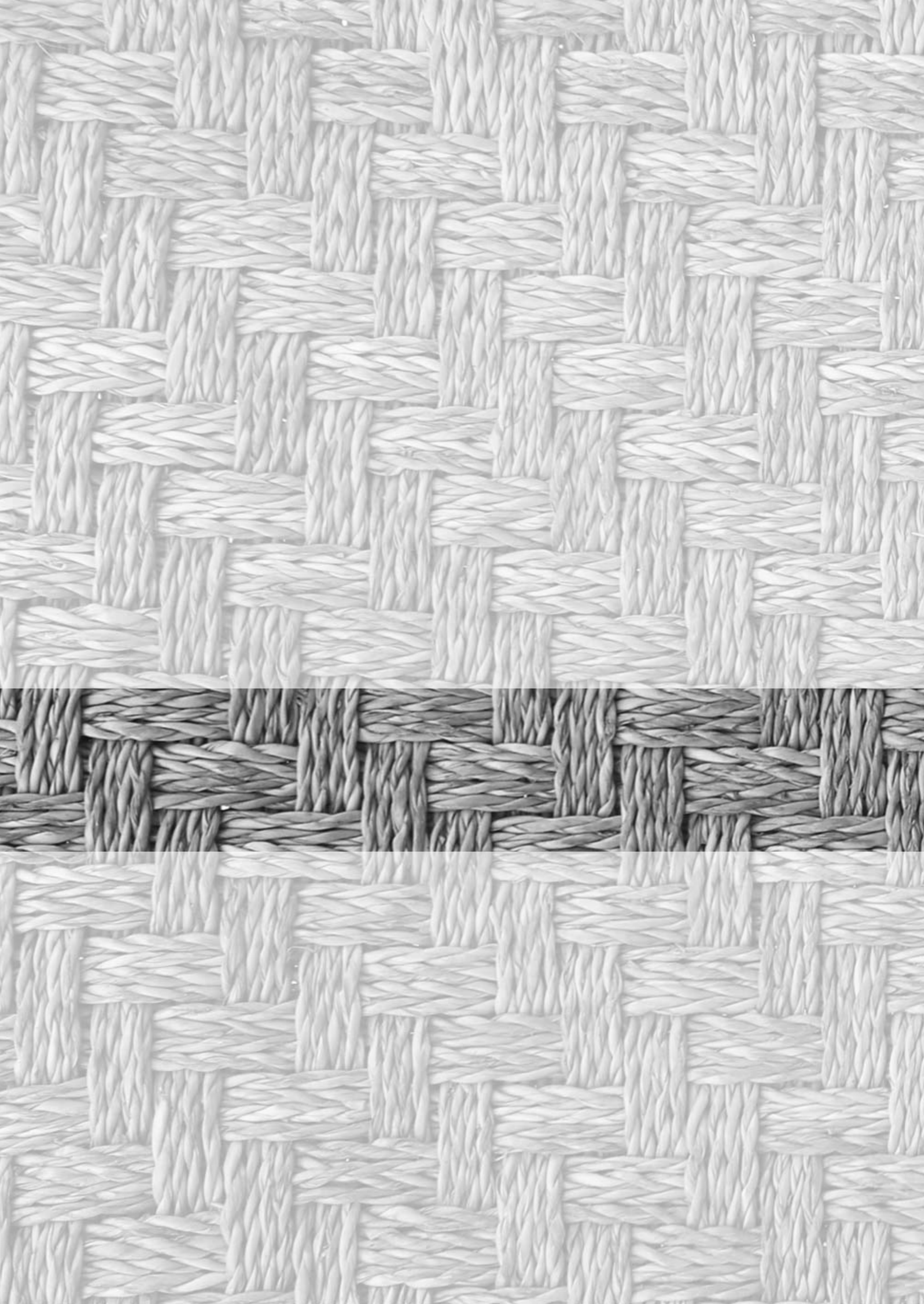
The typological language of vaults provides a tranquil world, ordered by mathematical certainties and by the names of the solids that give them form: cylinder, cone, and sphere. In that, there is nothing acrobatic. But since the architect prefers the stormy sea to the smooth mirror of a tranquil lake, the history of stereotomic vaults is marked by the appearance of acrobatic vaults. (Tamboréro)

Is it possible to think that the marvels of French and Spanish stereotomic construction between the Sixteenth and Nineteenth centuries are only tied to historical memory? Is it possible that the secrets hidden within the magical vault of the City Hall of Arles are no longer applicable to architecture today? Is it possible to believe that the technical knowledge of such vaulted spaces has been lost to us? Is it possible to believe that the language of stone architecture has been divorced from modern structural systems and methods of construction? We believe not! We believe, to the contrary, that the need to return to the construction of stereotomic vaults, renewed by a modern architectural vocabulary that celebrates the materiality of stone, is of extreme importance today. (Fallacara)

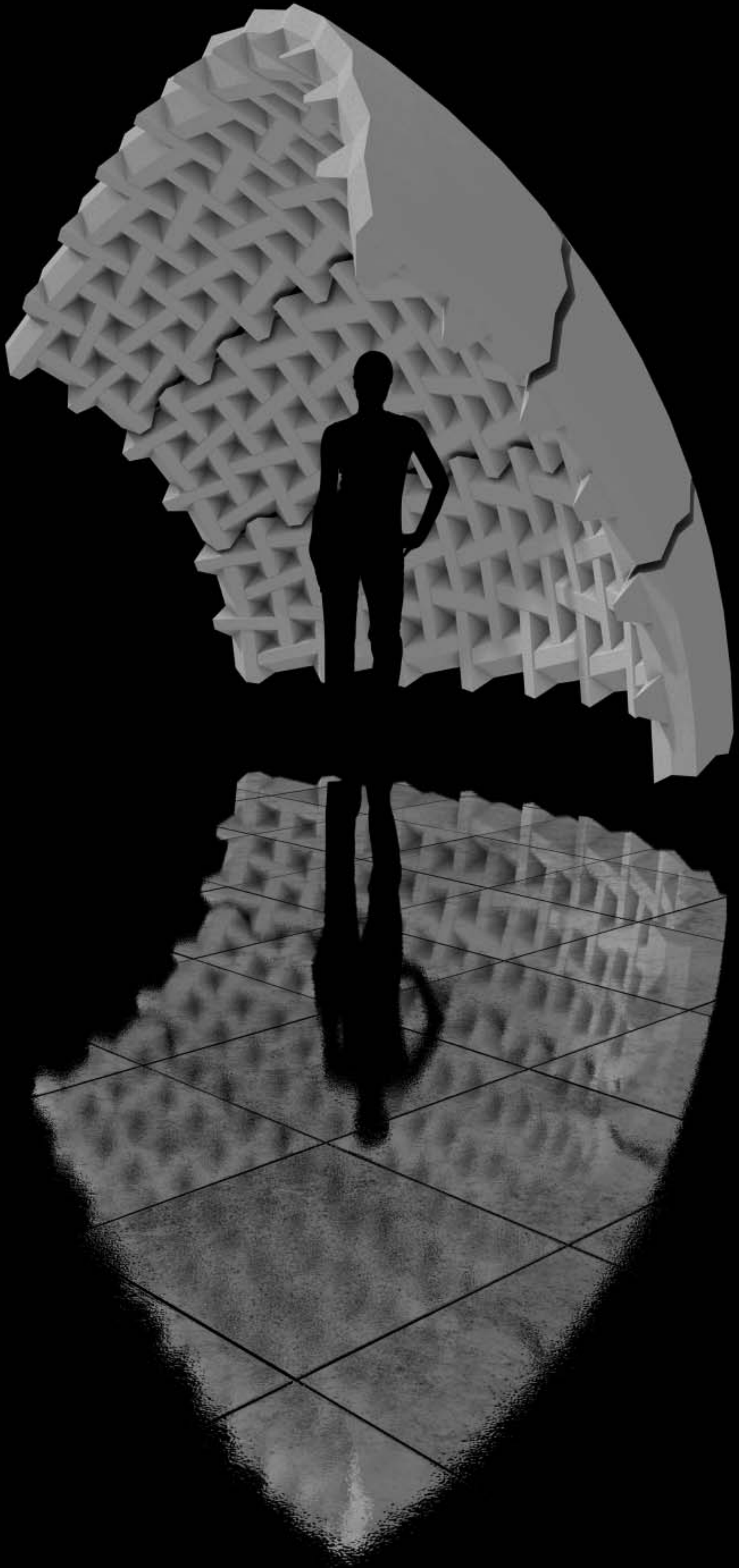


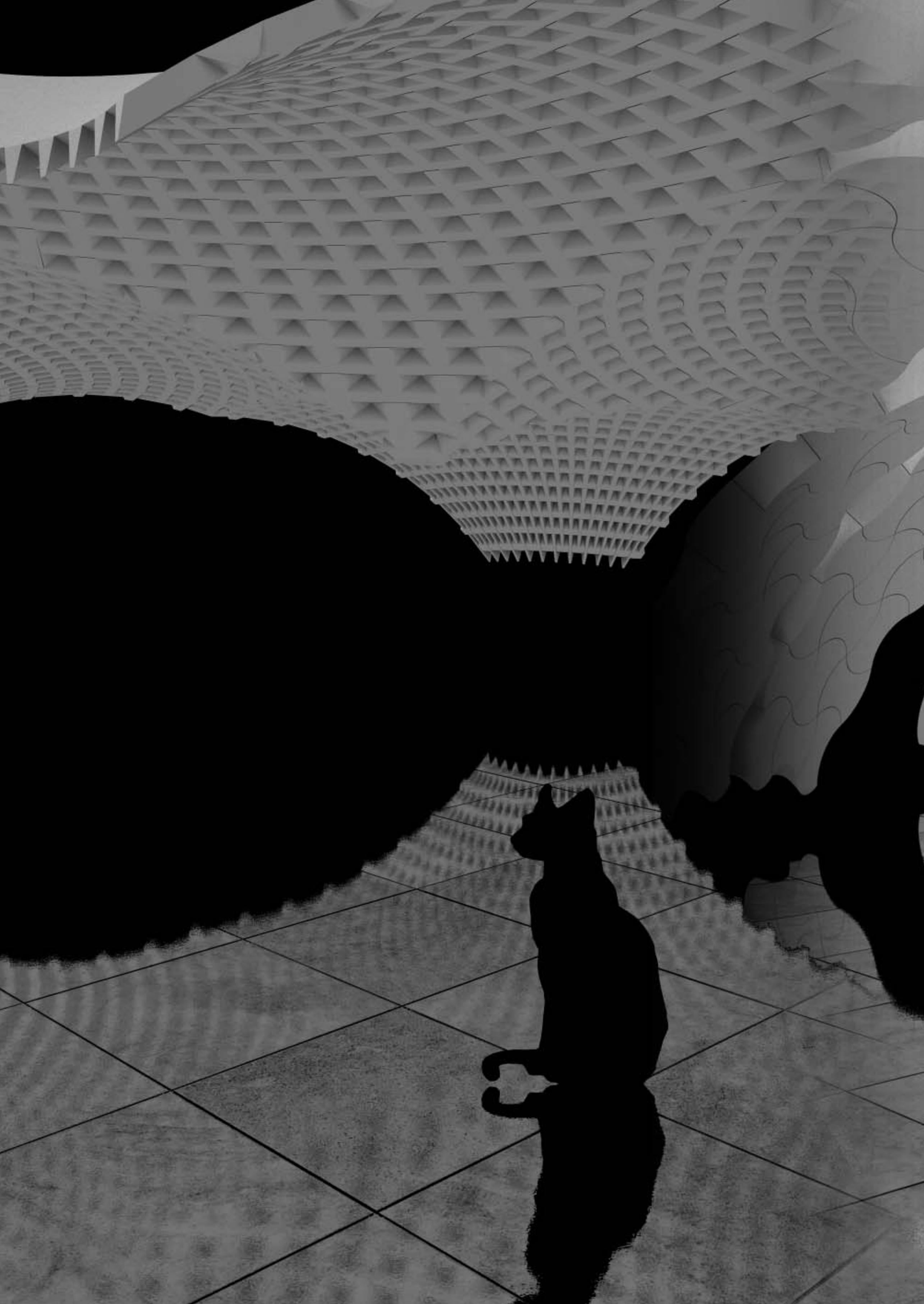


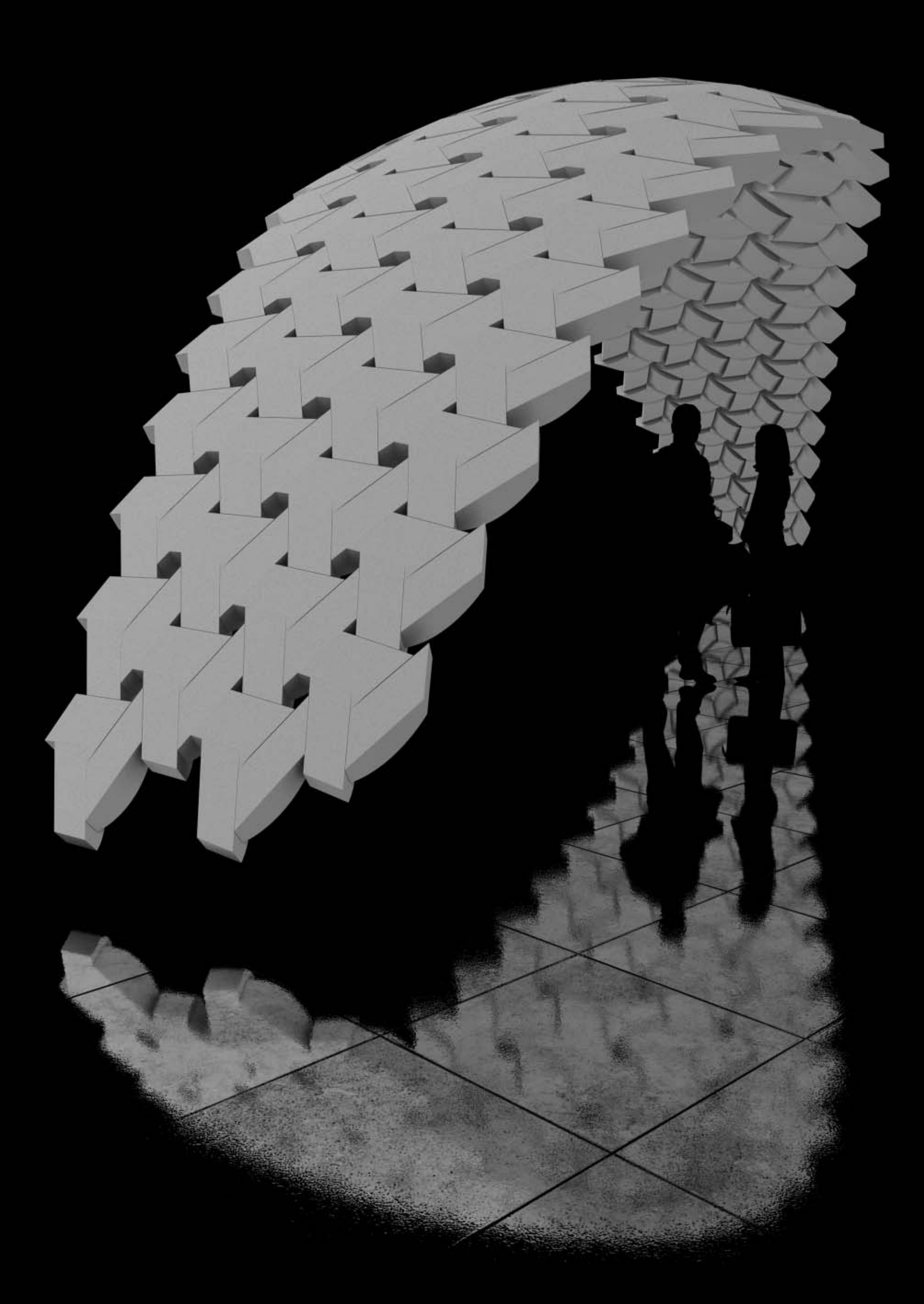


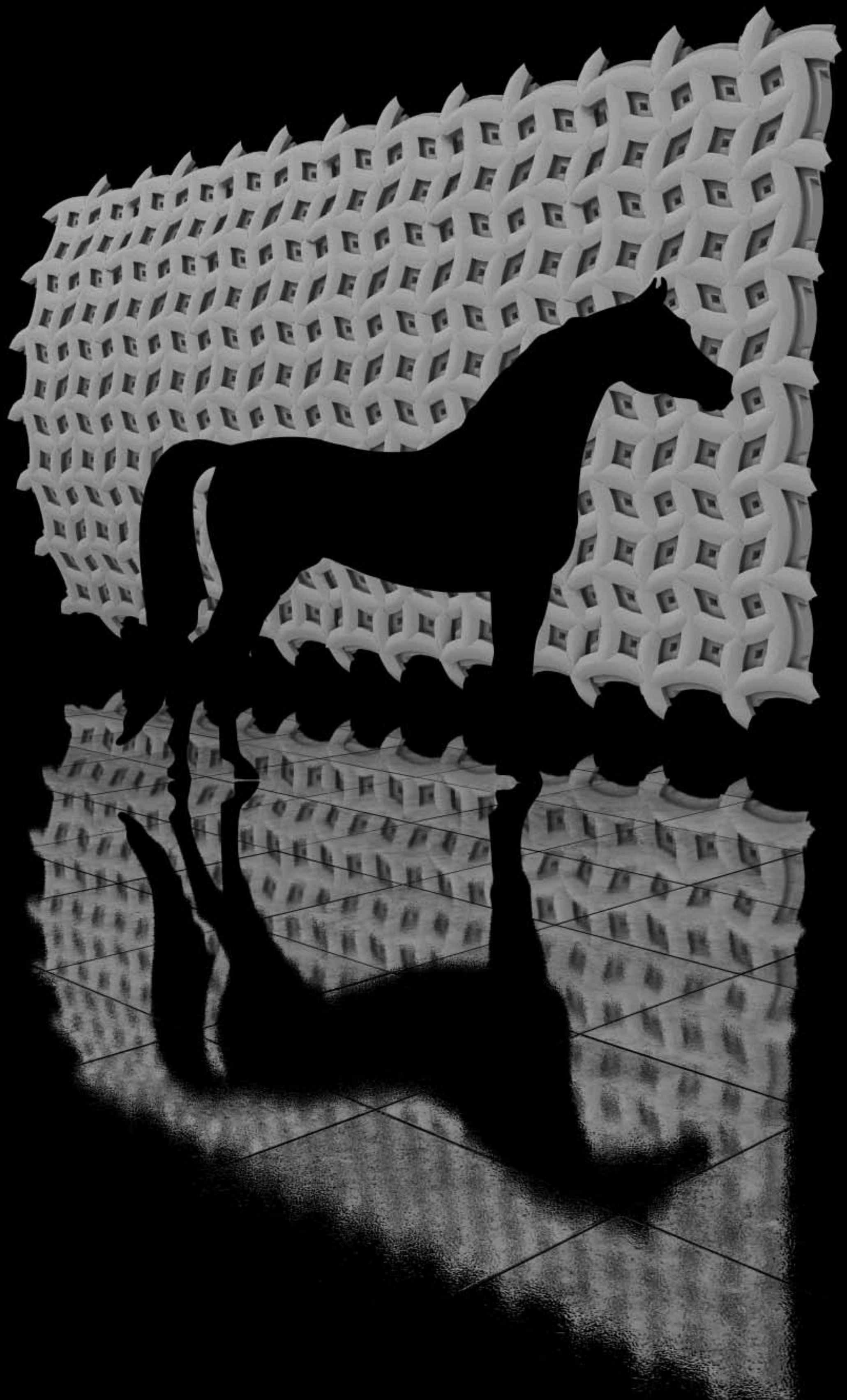


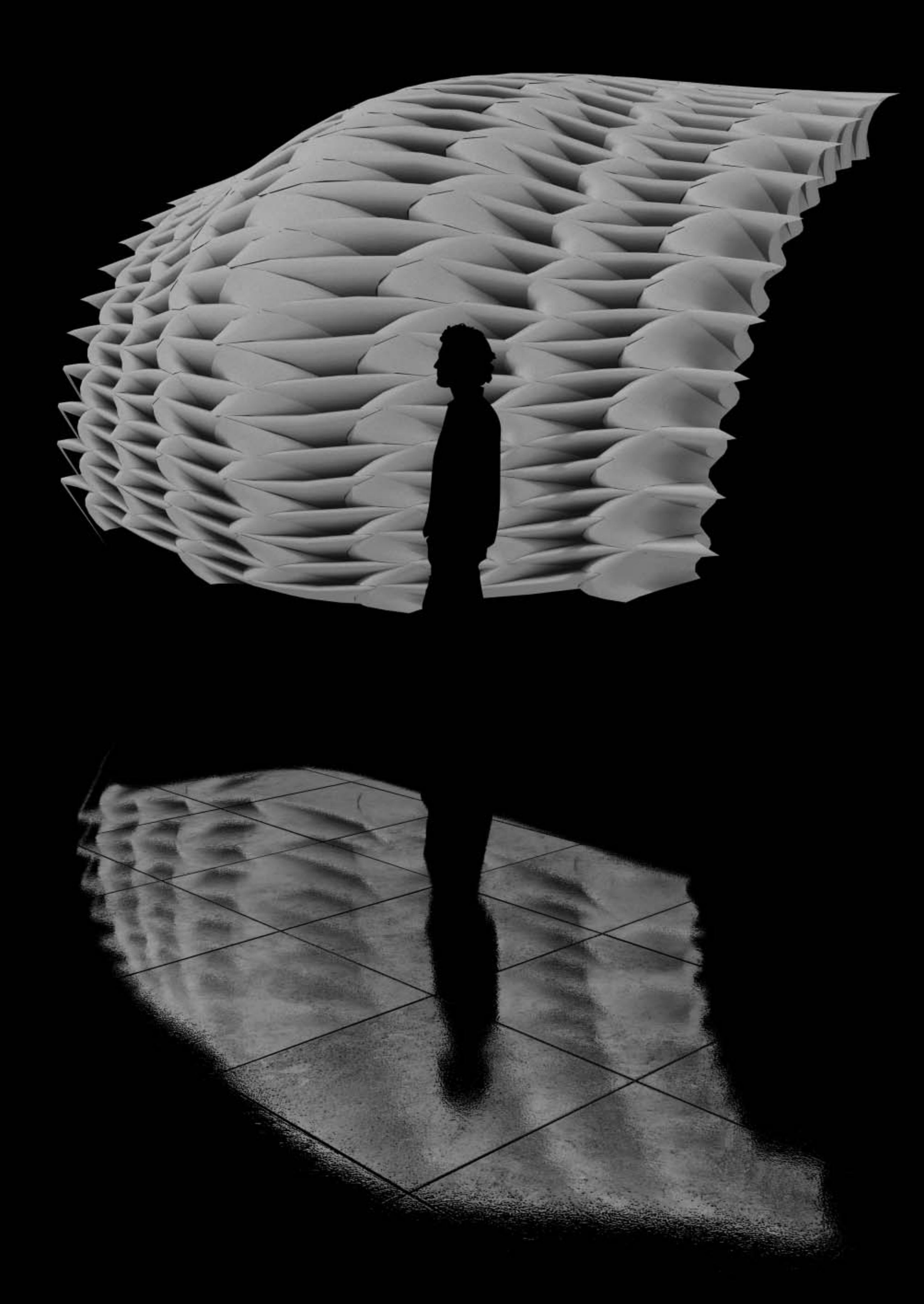
Projects
2008

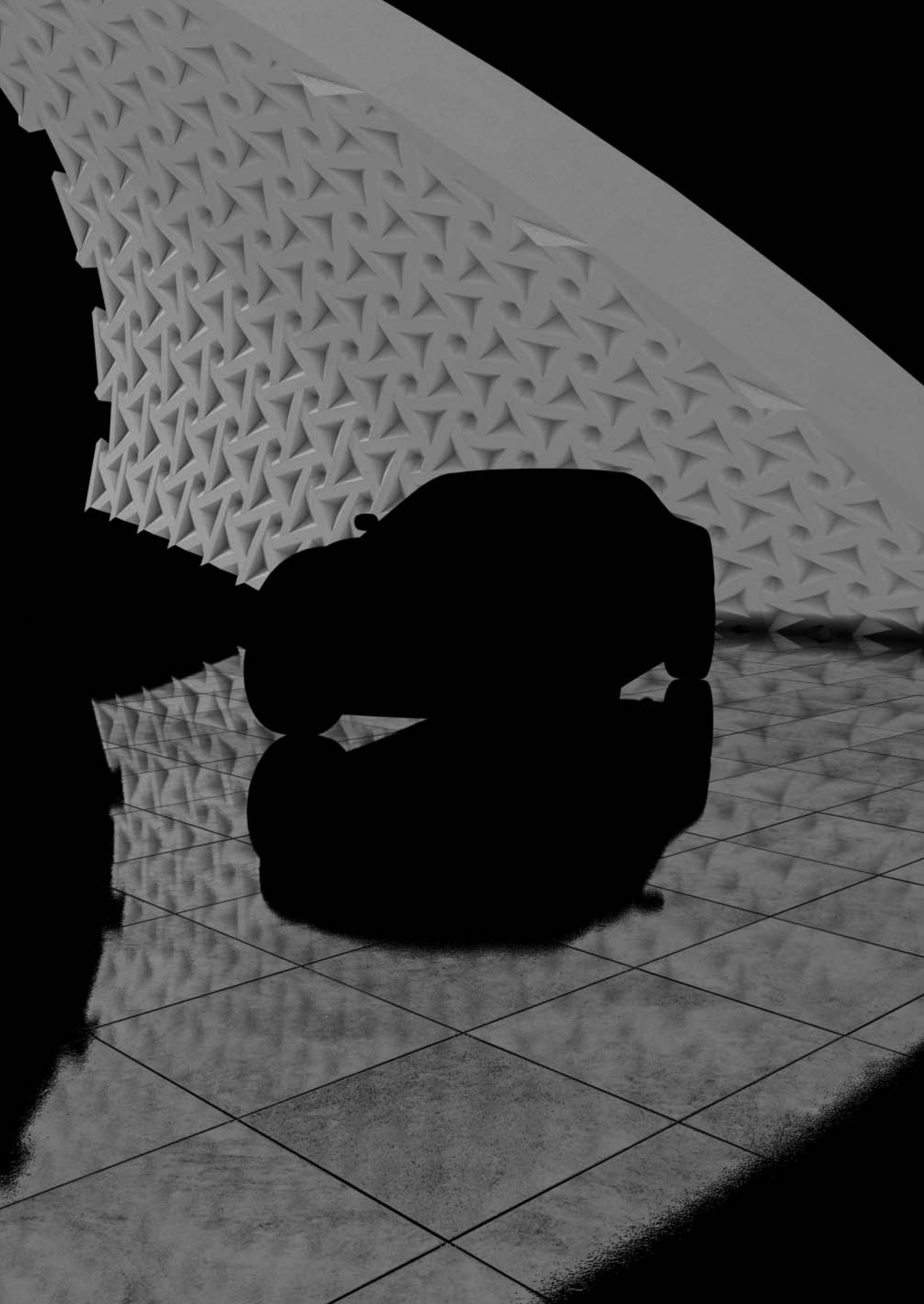


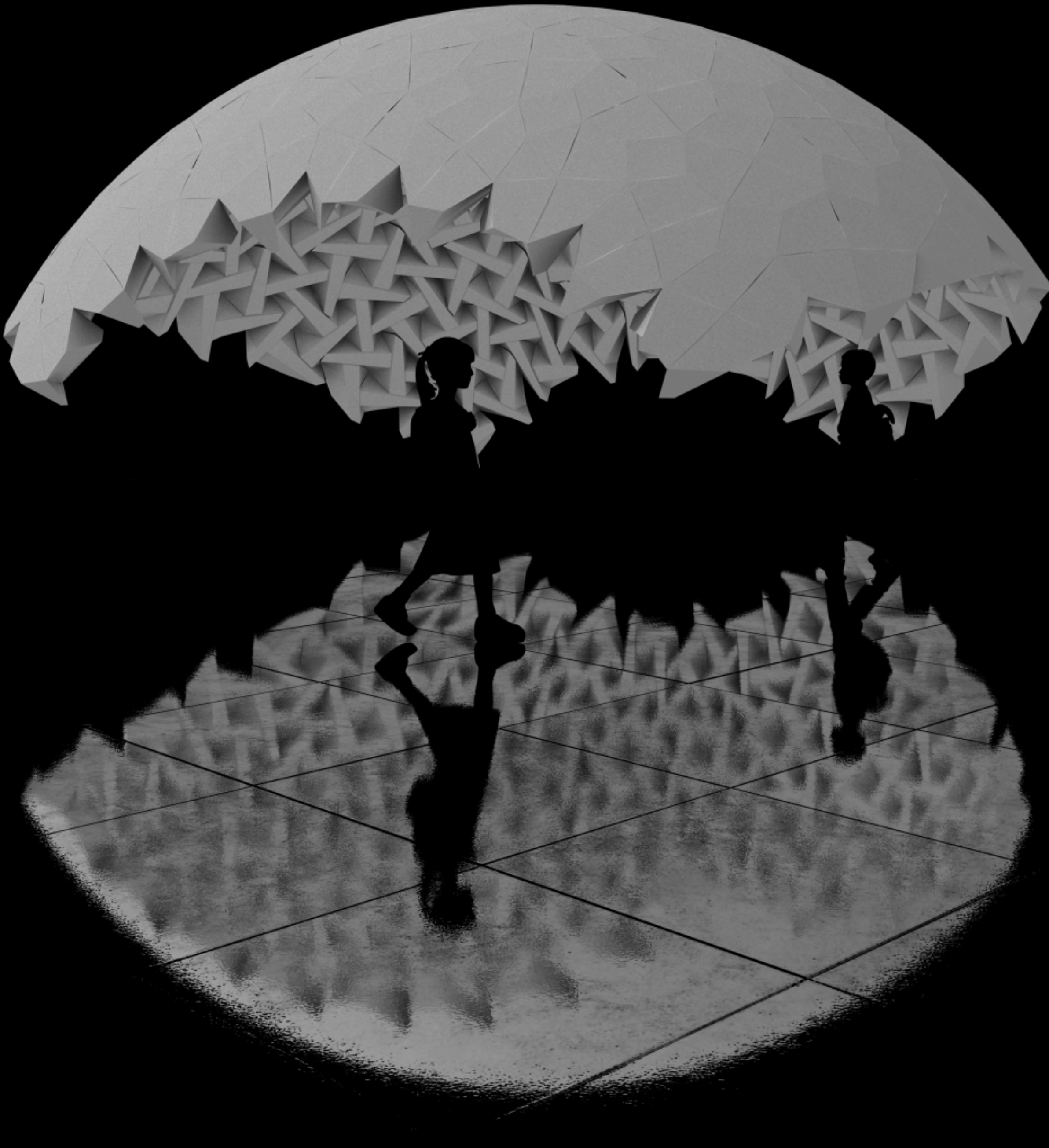


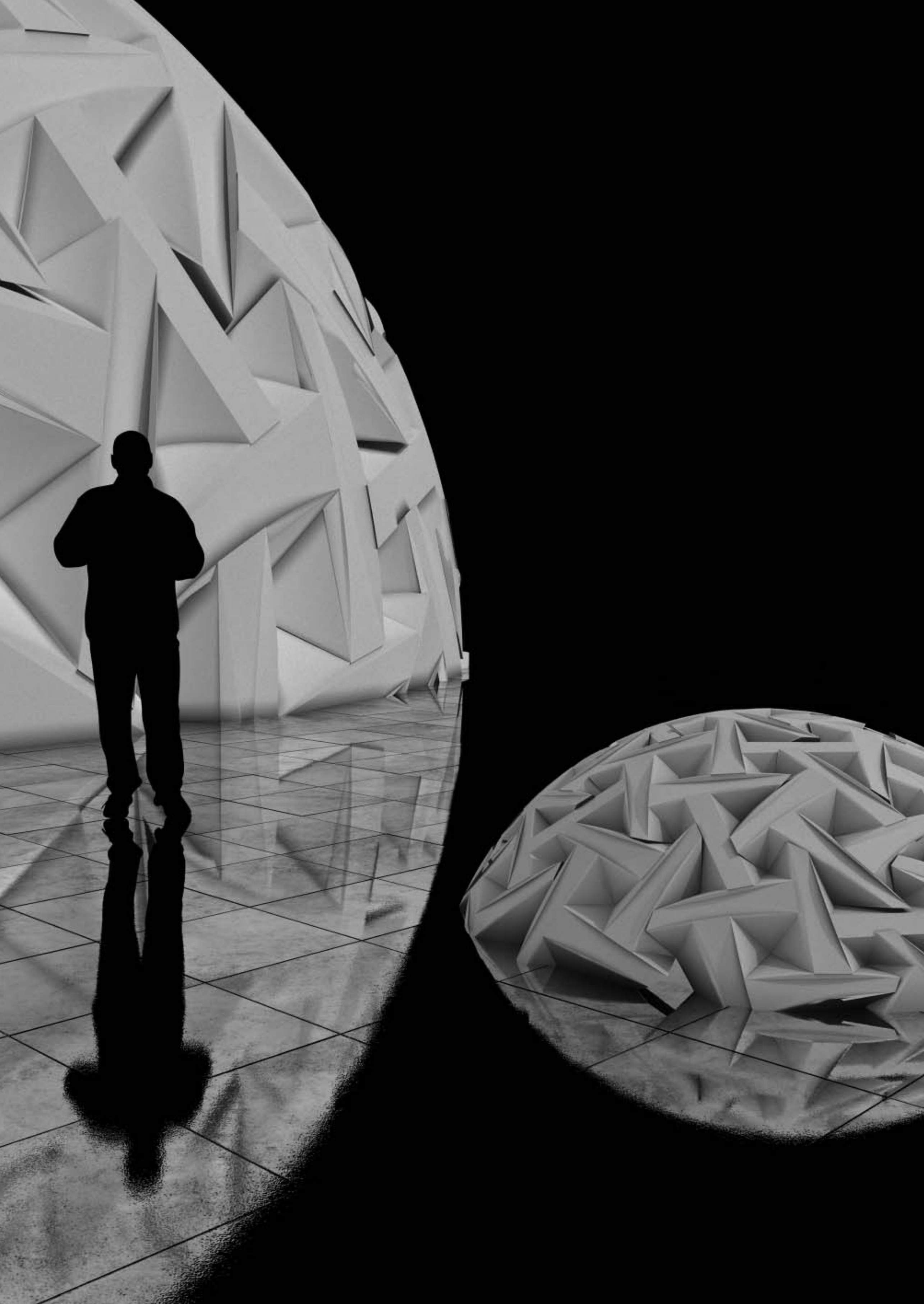


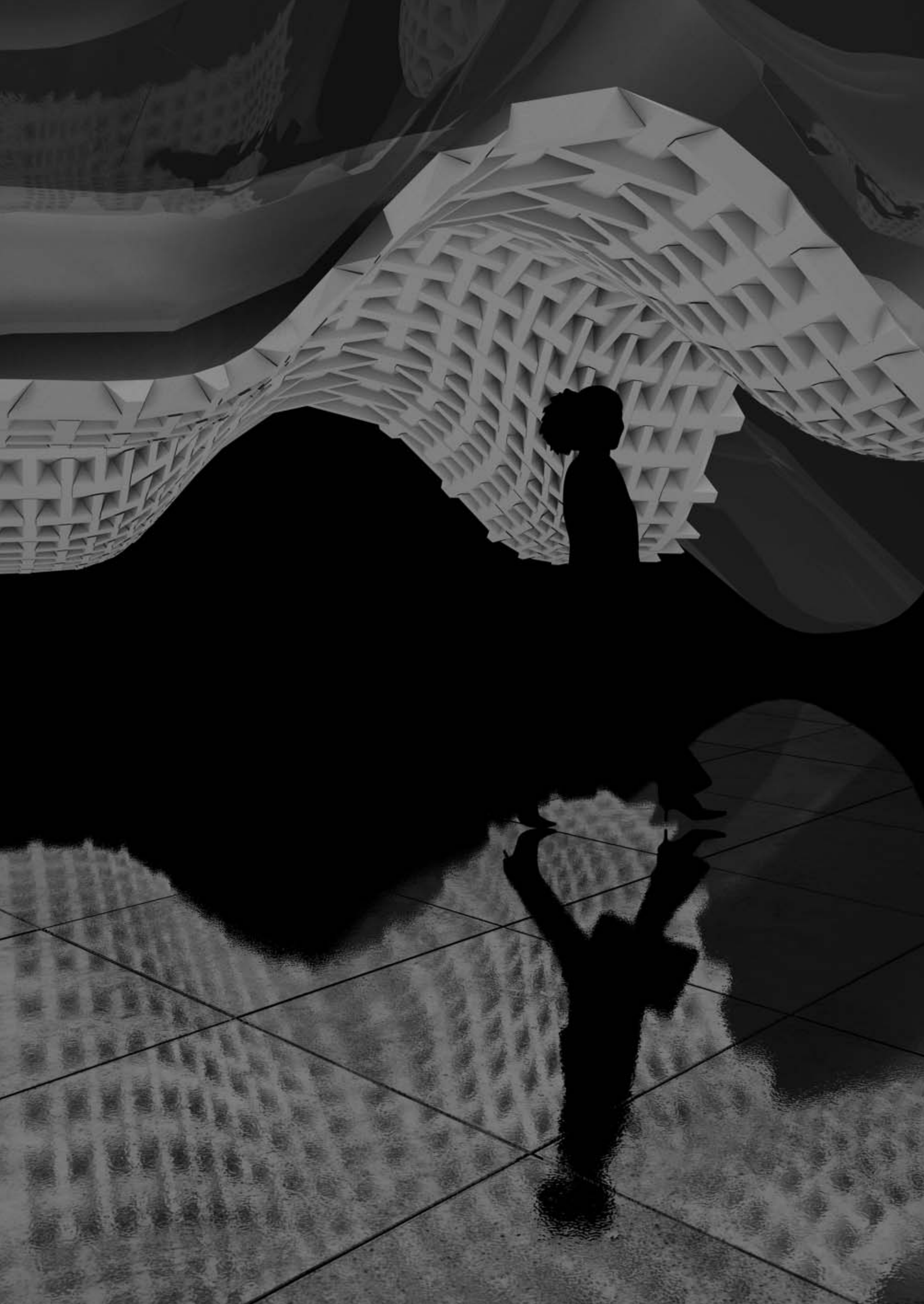


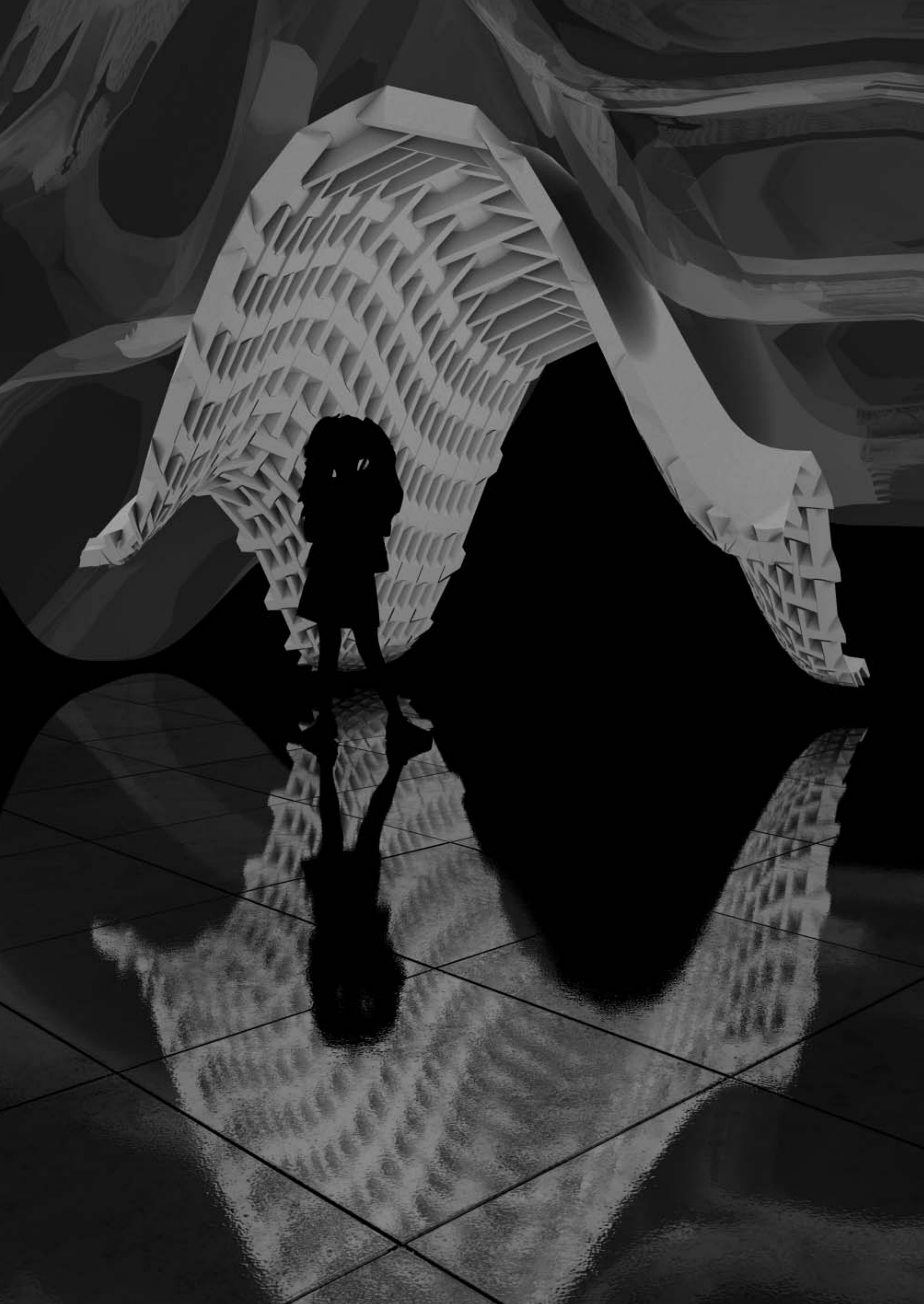


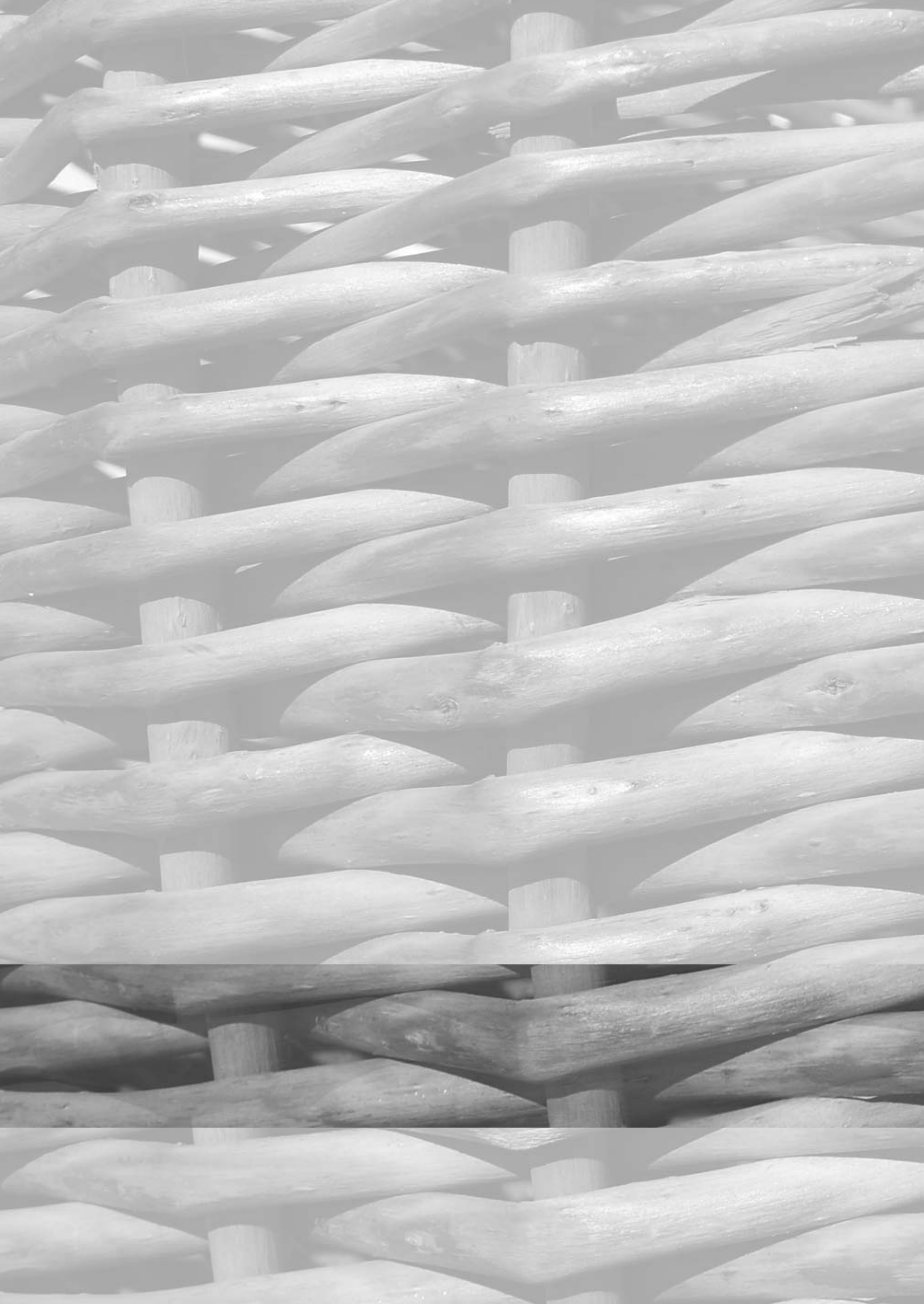






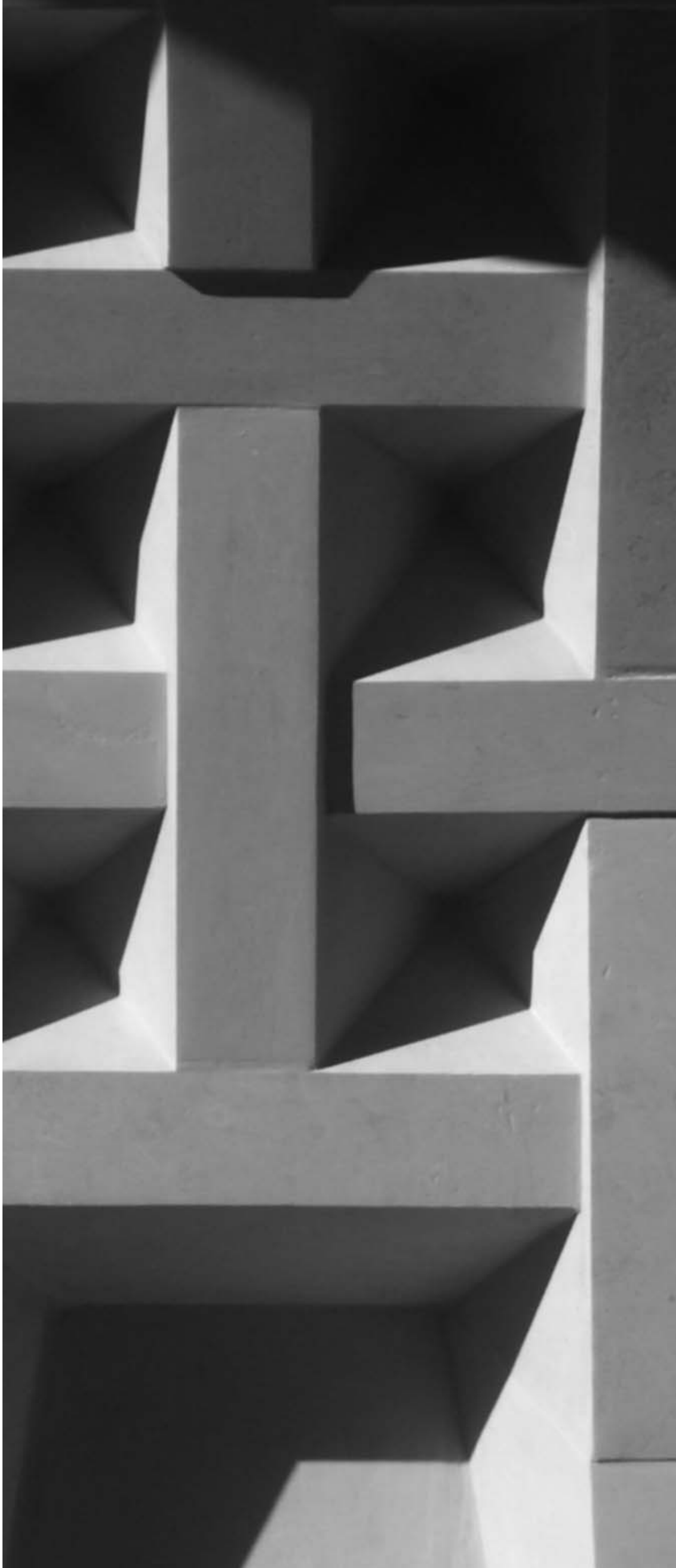






Constructions

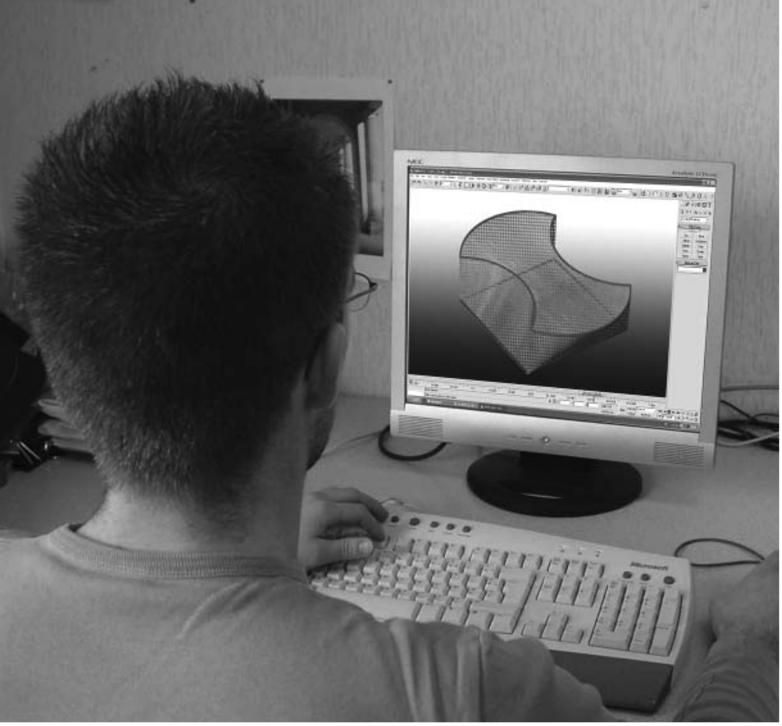
2006_Abeille vault *Venice*

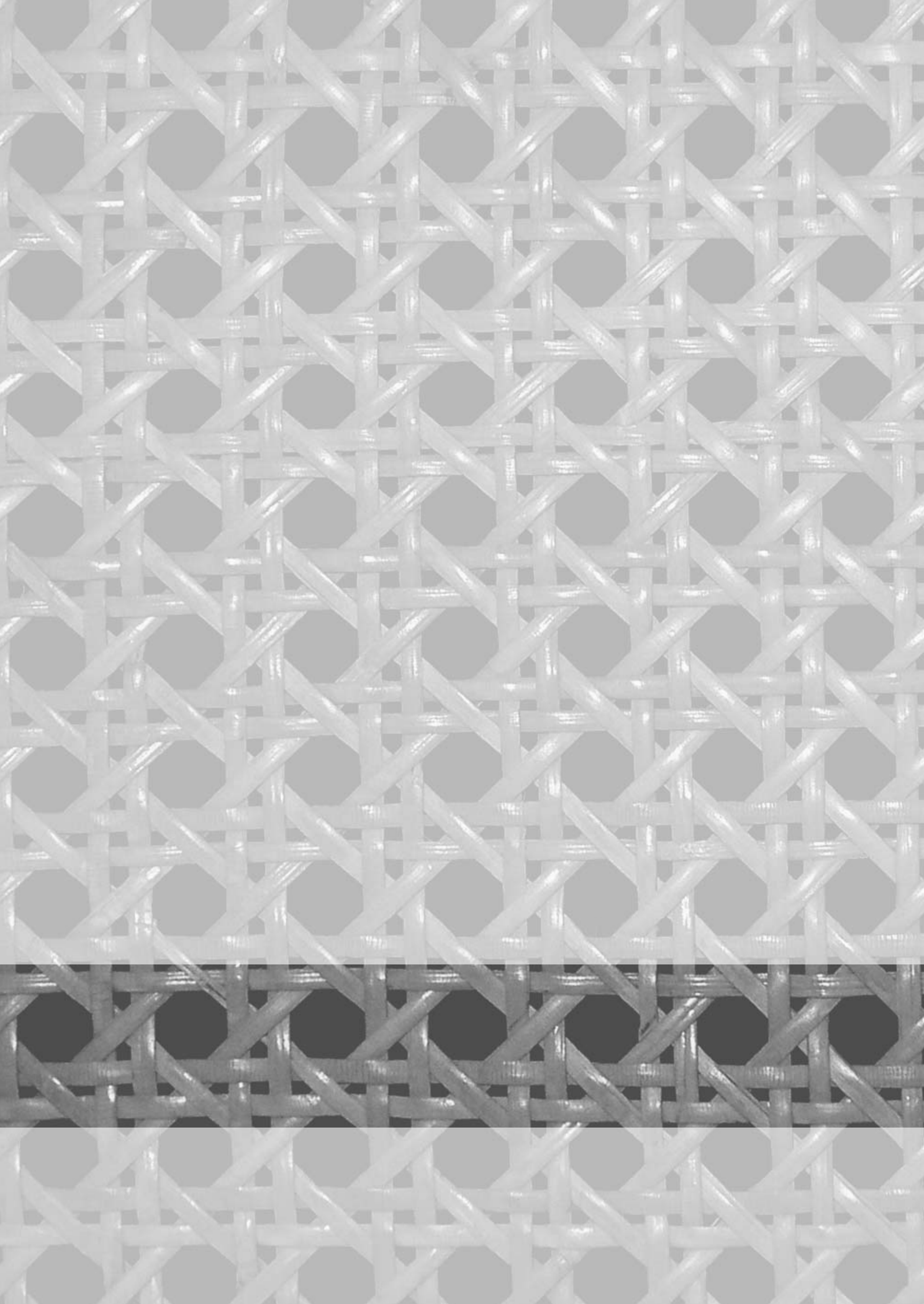


Constructions

2007_Truchet vault *Madrid*


16
14
4
20
12



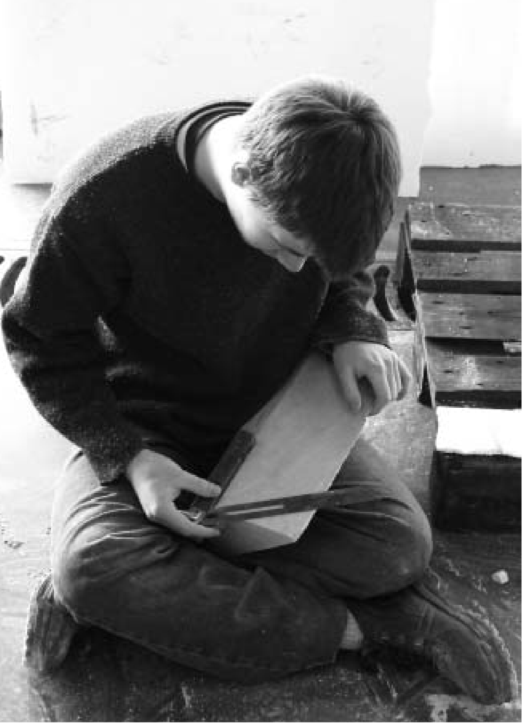



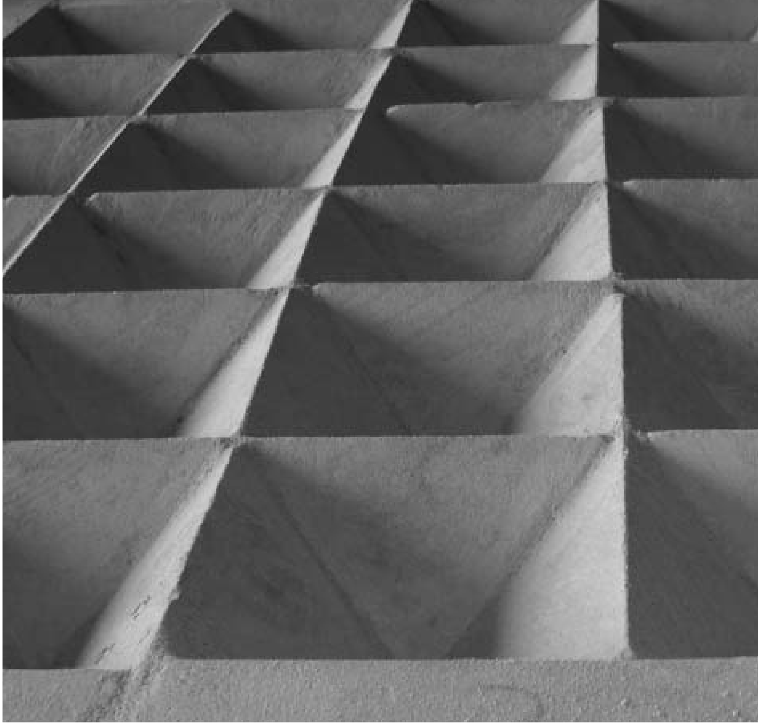
Constructions

2008_Flat vault *Lyon*

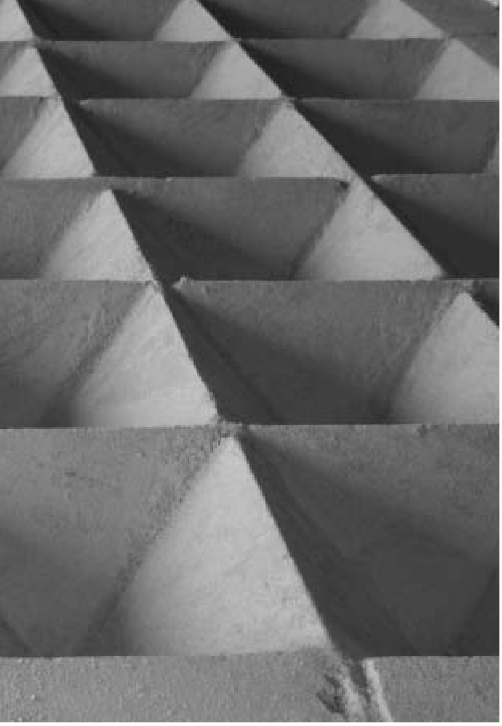

A2

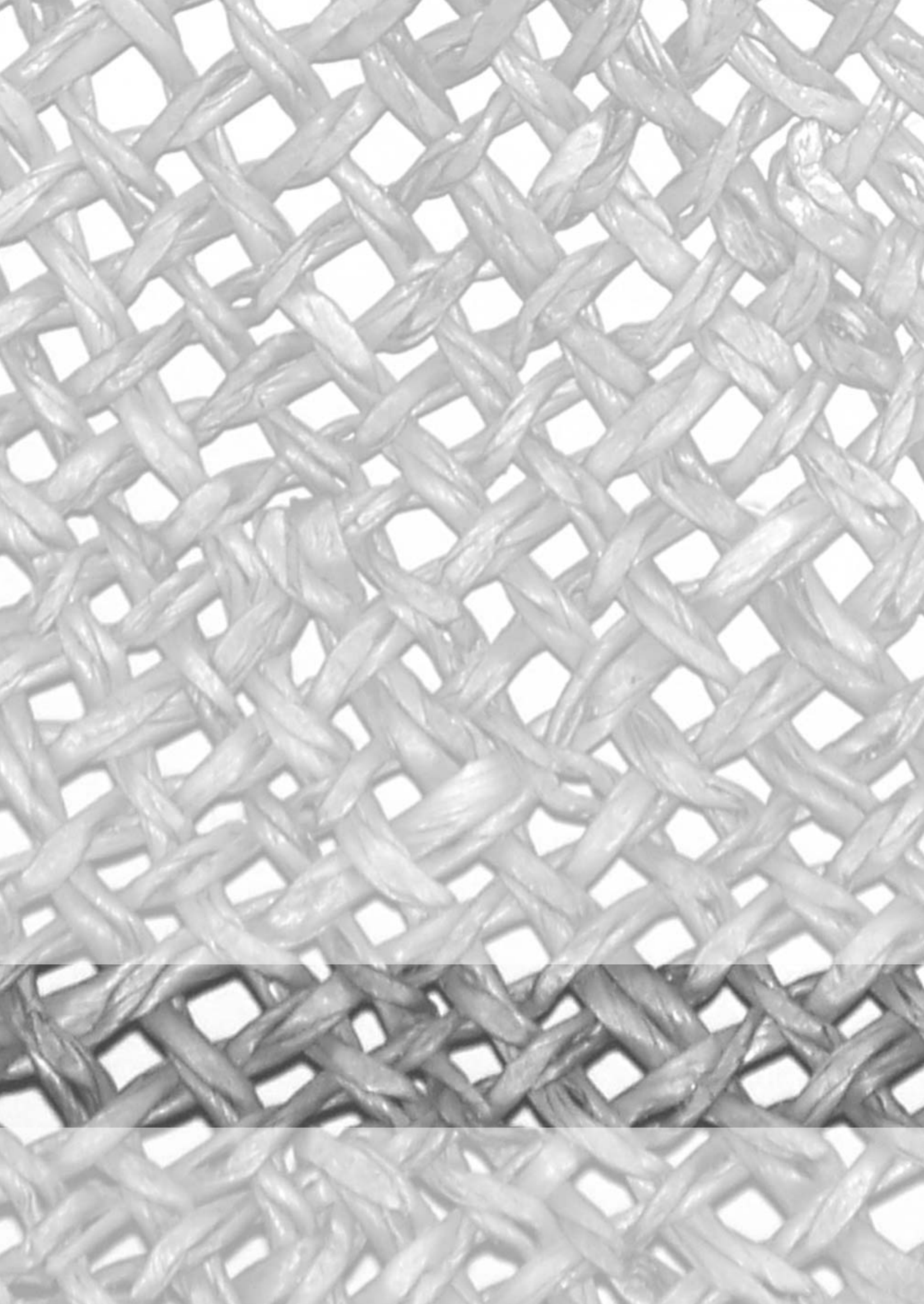

TÉTANOS

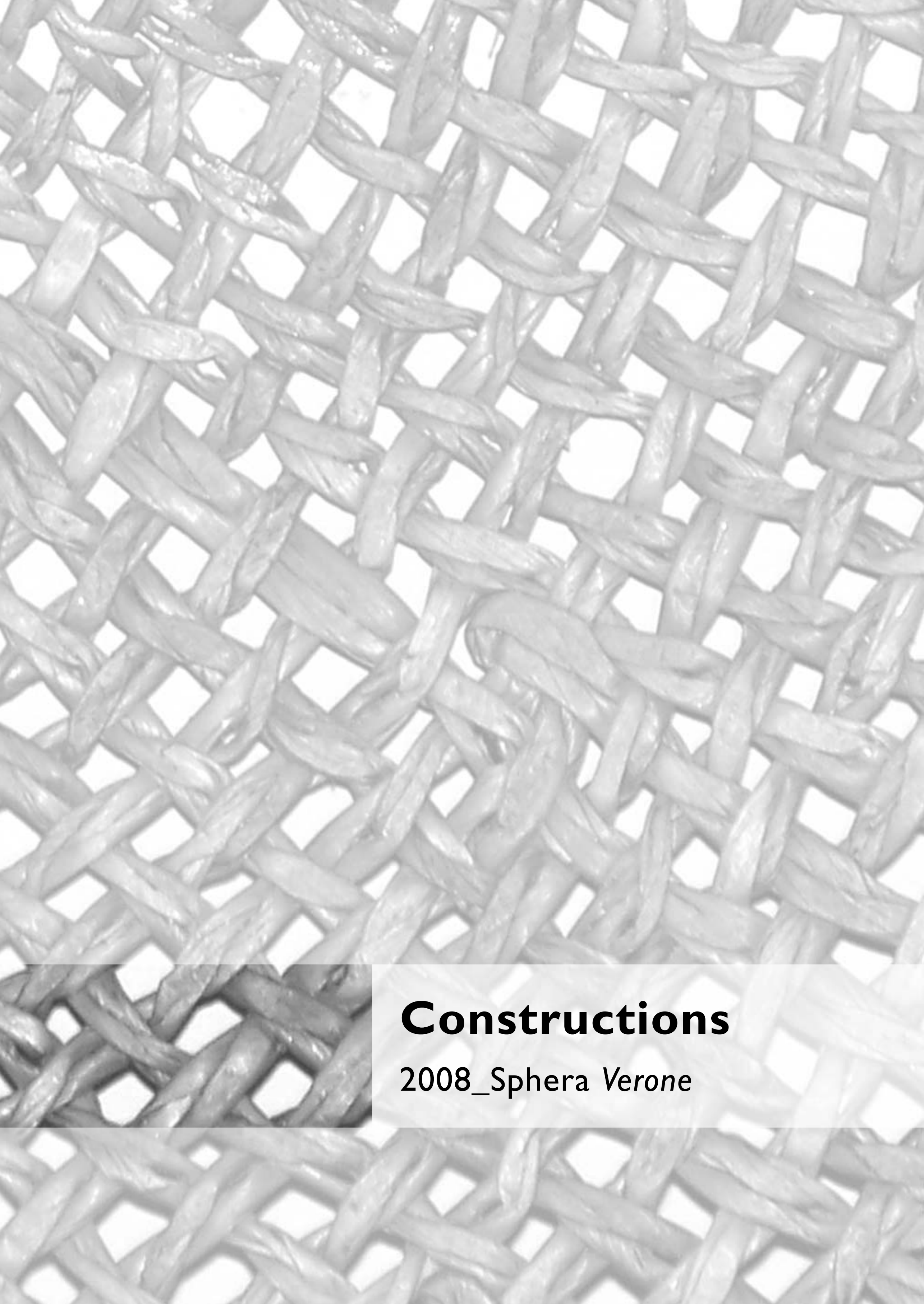





GAP ATHLETIC



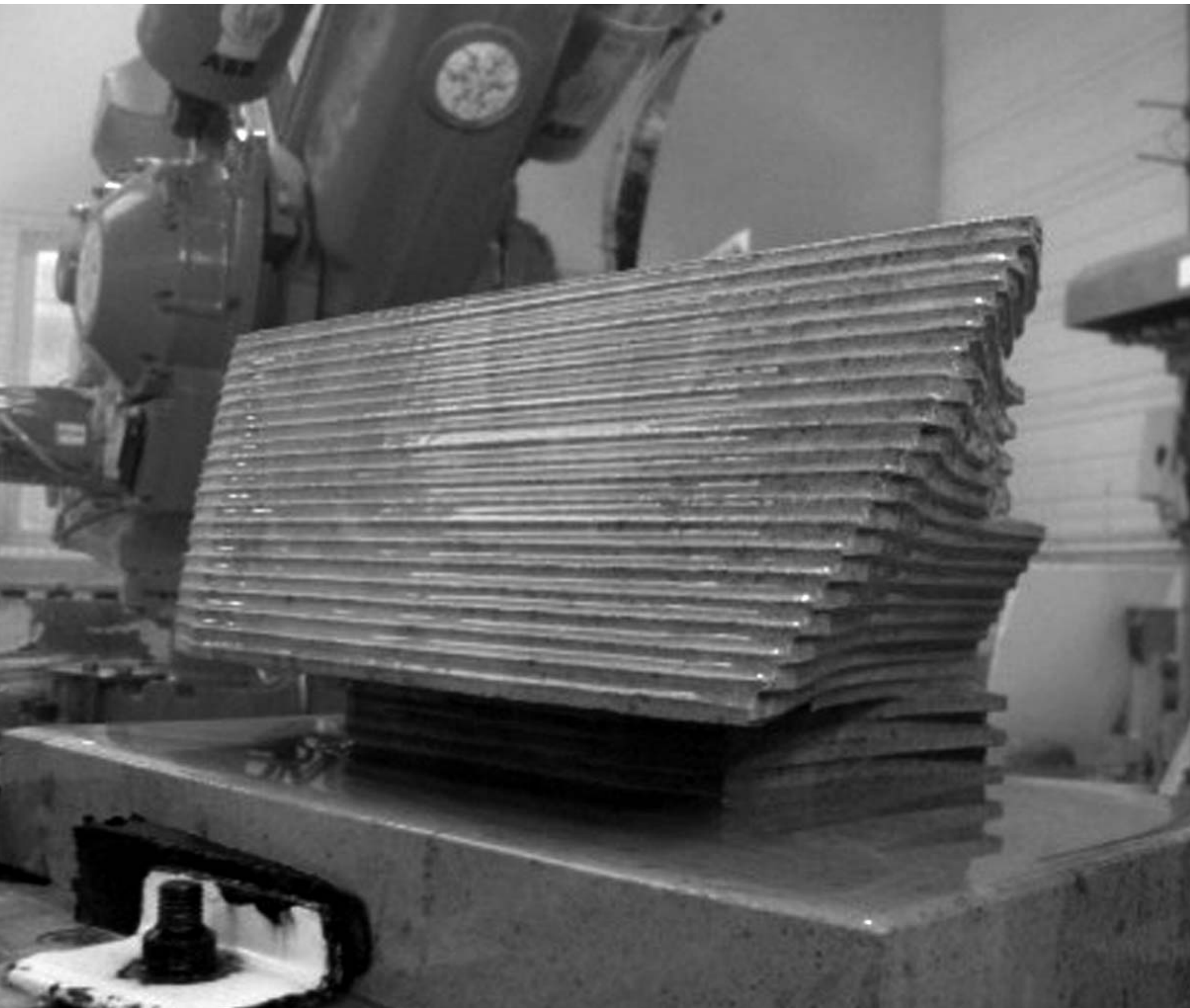




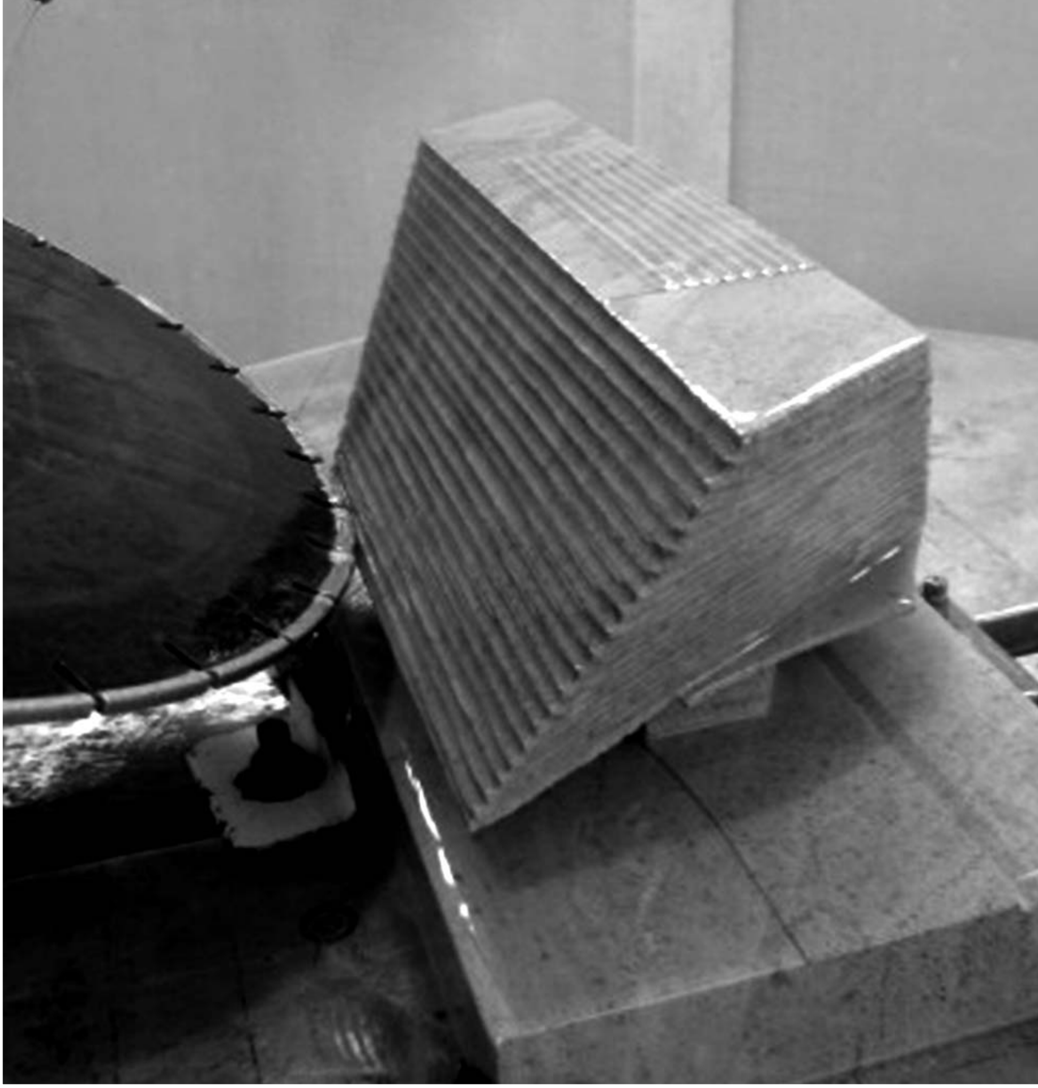
Constructions

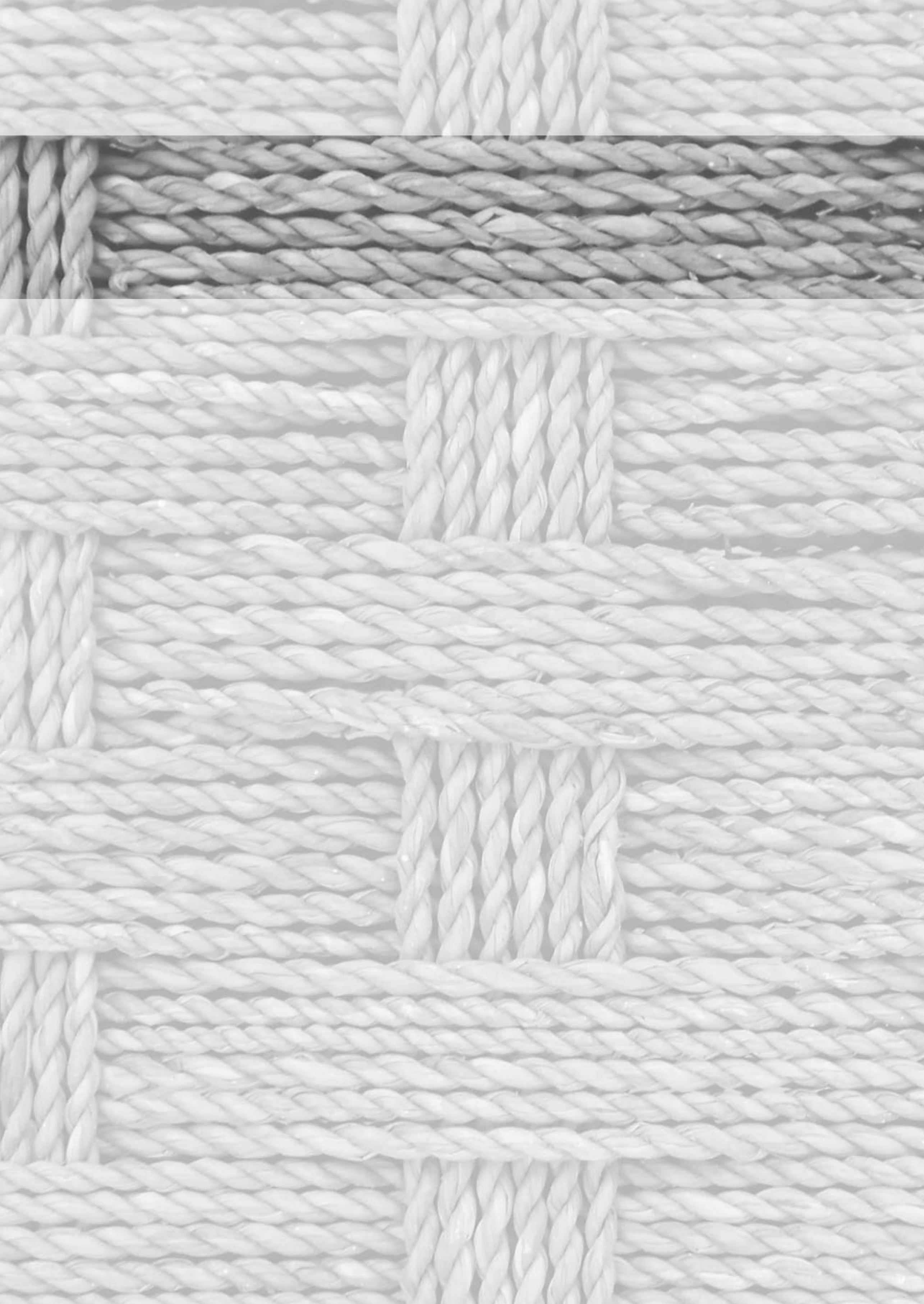
2008_Sphera *Verone*



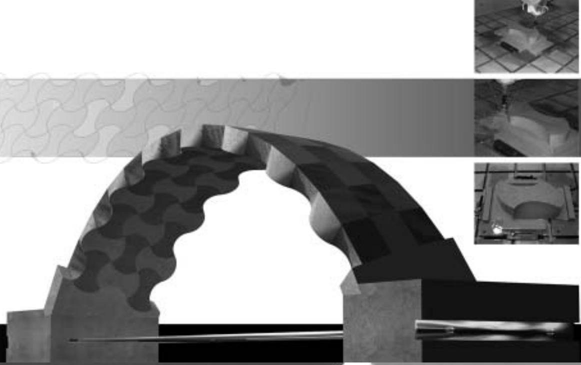




Credits

3D Pierre



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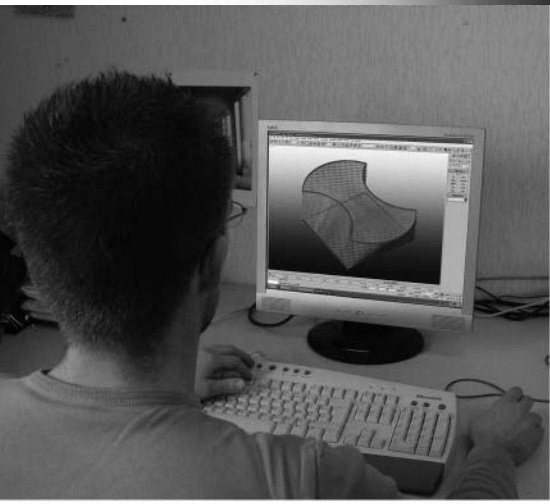

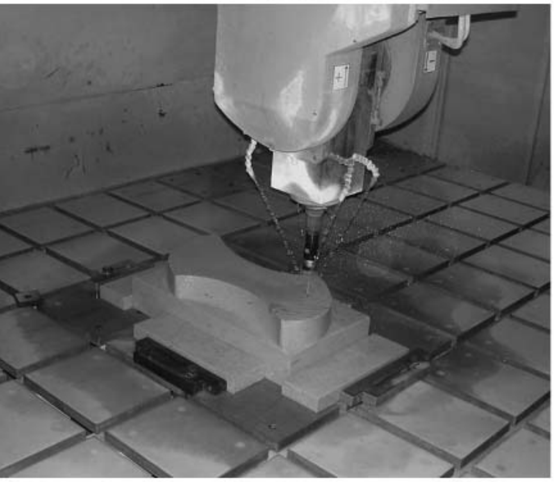

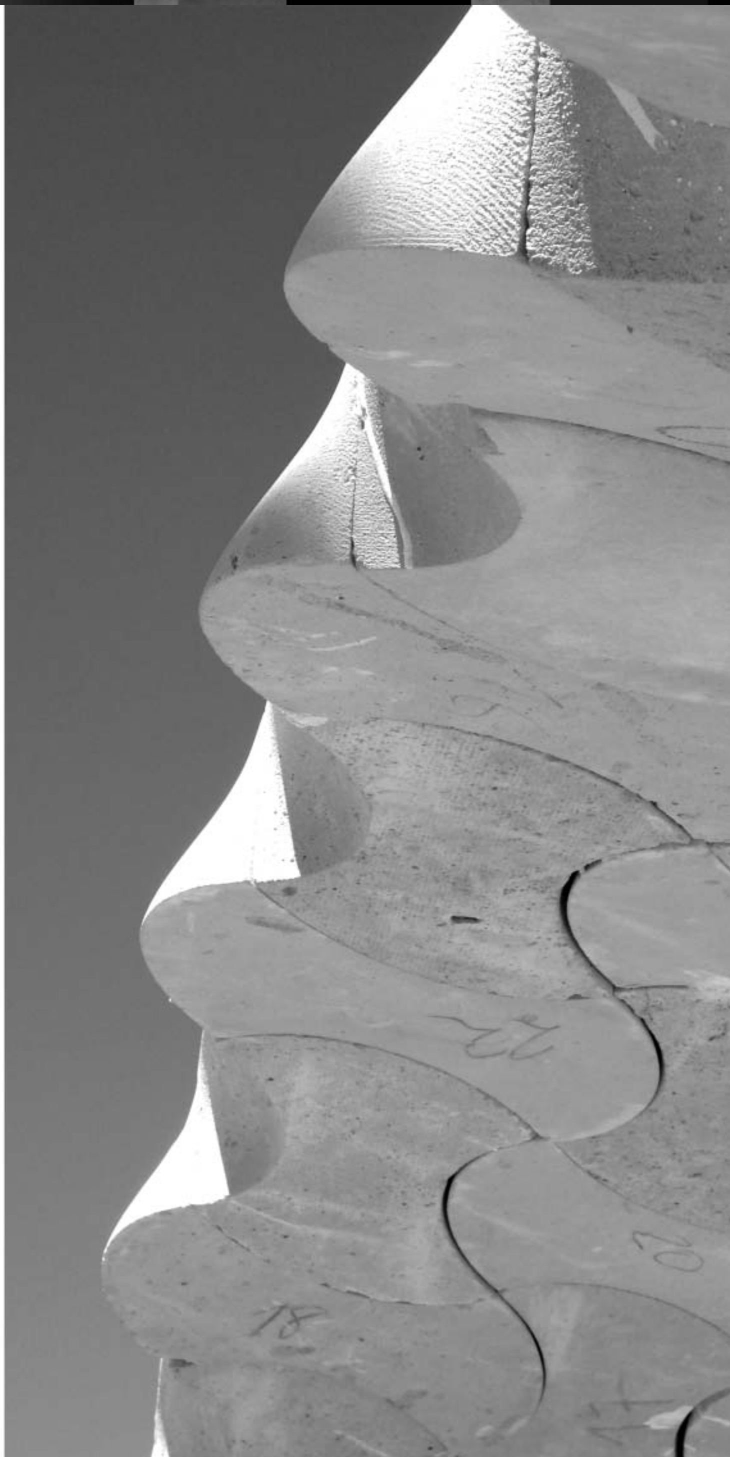

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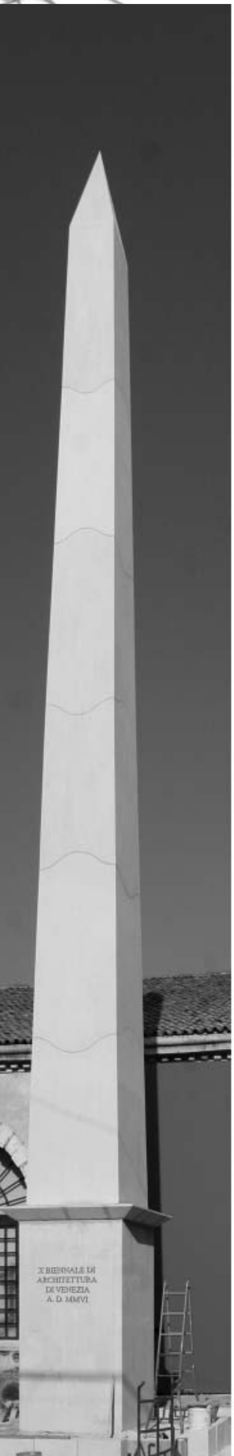

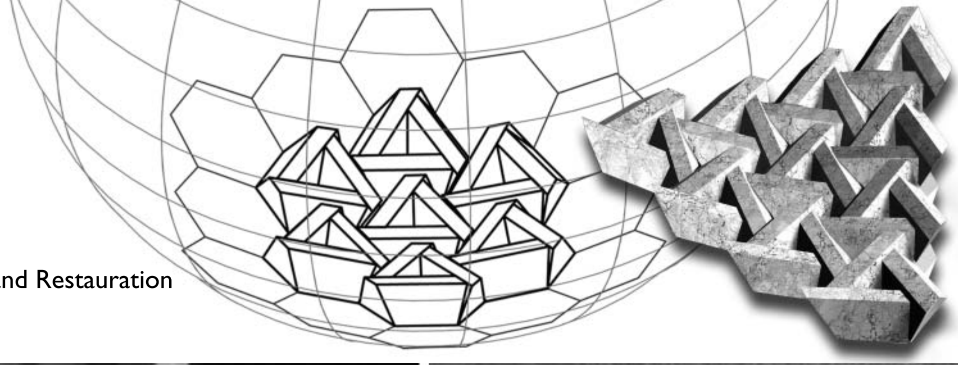

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