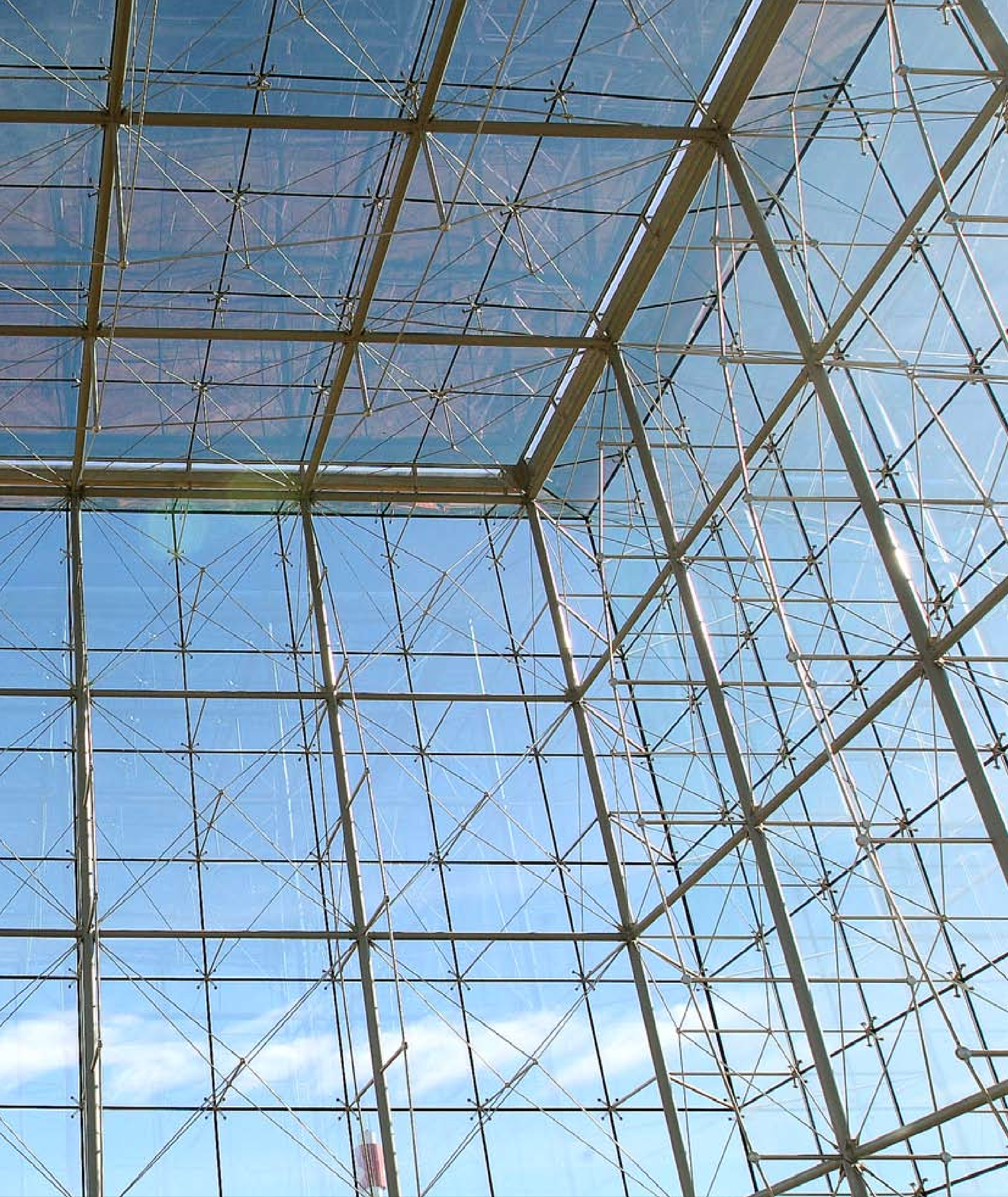

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25 years Design & Build Solutions

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Cover: Interior Glass Cube, Banco Santander, Madrid (architect Alfonso Millanes).

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1

Organisation

Octatube designs and realizes architectural, complex structures with a clear emphasis on frameless glass structures. With regard to the company set-up, Octatube is a combination of a design office and a production company. The company is in this composition unique in the Netherlands. Octatube has been a pioneer in technical developments at the time of the high-tech architecture (1980 - 1995) and of the free form or 'Blob' architecture since 1995. The Octatube objective is to continue a leading position in the field of technical innovations in the construction.

The origin of Octatube is found in the architectural office of Mick Eekhout in the Seventies. In the first decade, the emphasis was on space frame structures. In 1978, the engineering office Octatube Engineering BV was founded, after which the 'Design & Build' company Octatube Space Structures BV followed in 1983. Currently, the Octatube Group is composed of a holding company with various operational companies. Besides the above mentioned, Octatube International BV is the most important.

General director is Professor dr. Mick Eekhout, managing director is ir. Nils Eekhout. The main office in Delft, the Netherlands, houses 50 to 60 personnel, spread over various departments. Between these departments, close contact is maintained throughout the entire production process, which we regard as a necessity to come to good results. These departments are:

- Design & Engineering
- Production & Subcontracting
- Assembly & Supervision

1

1: Transport of trusses for the Glass Cube Banco Santander, Madrid

2: Mock-up in factory Octatube. Section of glass roof with glass fins of the Victoria & Albert Museum in London

3: Assembly in factory Octatube of entrances parking garage Westerlaan, Rotterdam

4: Assembly in factory Octatube of trusses Glass Cube Banco Santander

5: Office Octatube in Delft

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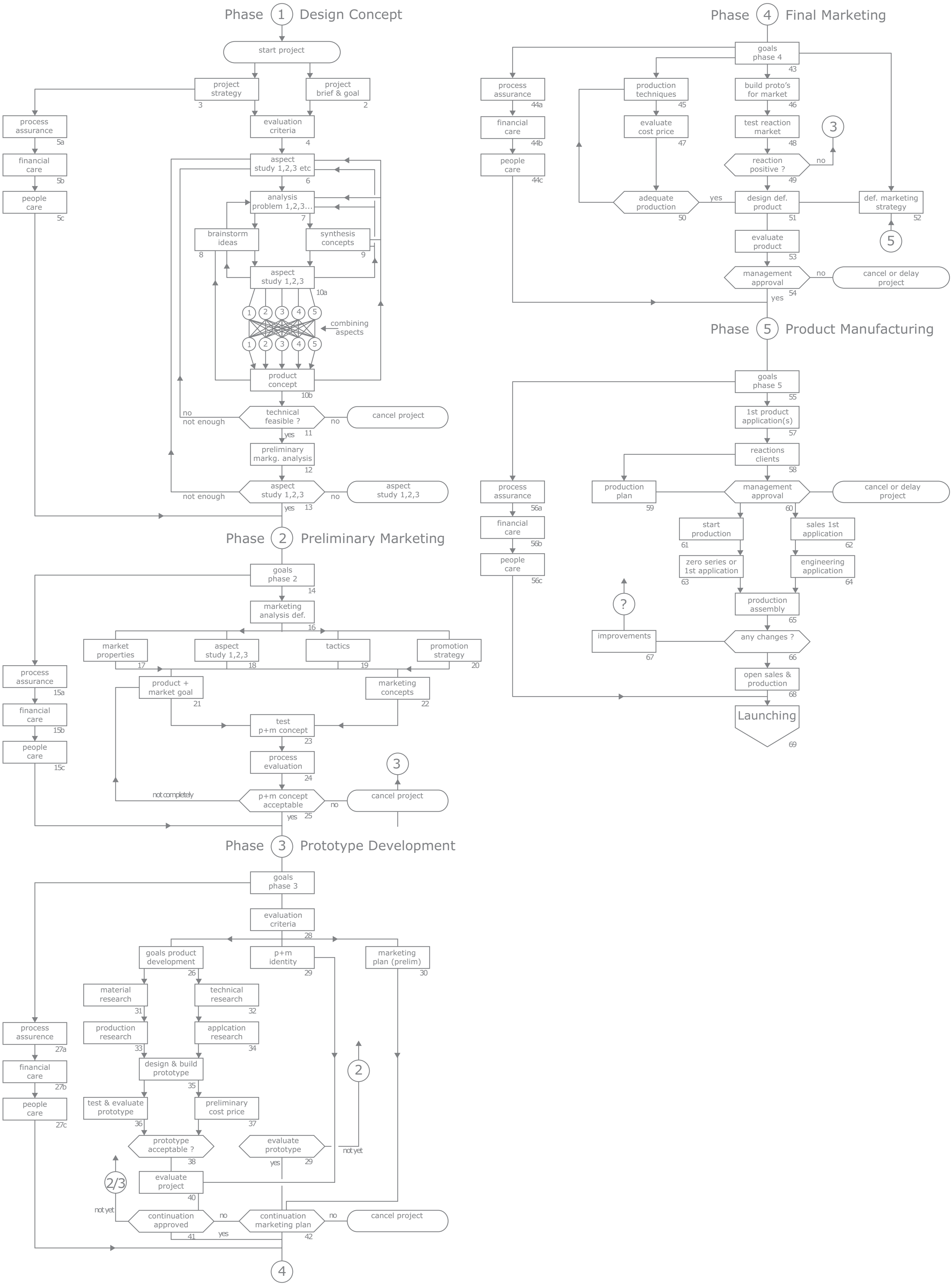

Phase 1 Design Concept
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project strategy
3
project brief & goal
2
process assurance
5a
financial care
5b
people care
5c
evaluation criteria
4
aspect study 1,2,3 etc
6
analysis problem 1,2,3...
7
brainstorm ideas
8
synthesis concepts
9
aspect study 1,2,3
10a
combining aspects
product concept
10b
no
not enough
technical feasible ?
11
no
cancel project
yes
preliminary markg. analysis
12
not enough
aspect study 1,2,3
13
no
aspect study 1,2,3
yes
Phase 2 Preliminary Marketing
goals phase 2
14
marketing analysis def.
16
market properties
17
aspect study 1,2,3
18
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19
promotion strategy
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15a
financial care
15b
people care
15c
product + market goal
21
marketing concepts
22
test p+m concept
23
process evaluation
24
not completely
p+m concept acceptable
25
no
cancel project
yes
Phase 3 Prototype Development
goals phase 3
evaluation criteria
28
goals product development
26
p+m identity
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marketing plan (prelim)
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process assurance
27a
financial care
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production research
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applcation research
34
design & build prototype
35
test & evaluate prototype
36
preliminary cost price
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prototype acceptable ?
38
evaluate prototype
29
yes
not yet
evaluate project
40
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not yet
continuation approved
41
no
continuation marketing plan
42
no
cancel project
yes
Phase 4 Final Marketing
goals phase 4
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44a
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44b
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evaluate cost price
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no
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Phase 5 Product Manufacturing
goals phase 5
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1st product application(s)
57
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56a
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56b
people care
56c
production plan
59
management approval
60
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62
zero series or 1st application
63
engineering application
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production assembly
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?
improvements
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any changes ?
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open sales & production
68
Launching
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Design & Engineering

This department fulfils three main functions: designing & consultancy, engineering and work preparation. In addition, this department takes care of estimates and tendering. These three functions closely co-operate, because of the great implications the one has for the other. Designers and engineers form the core of Octatube. A mix of architectural, structural and industrial designers and mechanically skilled engineers ensures technical innovations by continuously engineering on level of materials, elements and components, details, structural assemblies and erection methods and its application in architectural projects.

Production & Subcontracting

Production is the main task of the department Production & Subcontracting. This production consists of steel and aluminium elements and components, for which the major processings are sawing, drilling, twisting and welding. Besides, there is the supervision over element products that are being subcontracted and, afterwards, assembled at the plant of Octatube.

Carrying out tests, the making of small and big prototypes, as well as the mechanical testing of structural products, is done by the company's own staff, whether or not with the assistance of TNO Bouw (Netherlands Organization for Applied Scientific Research TNO, Department of Building Industry). Octatube's department of Design & Engineering is closely associated with these projects.

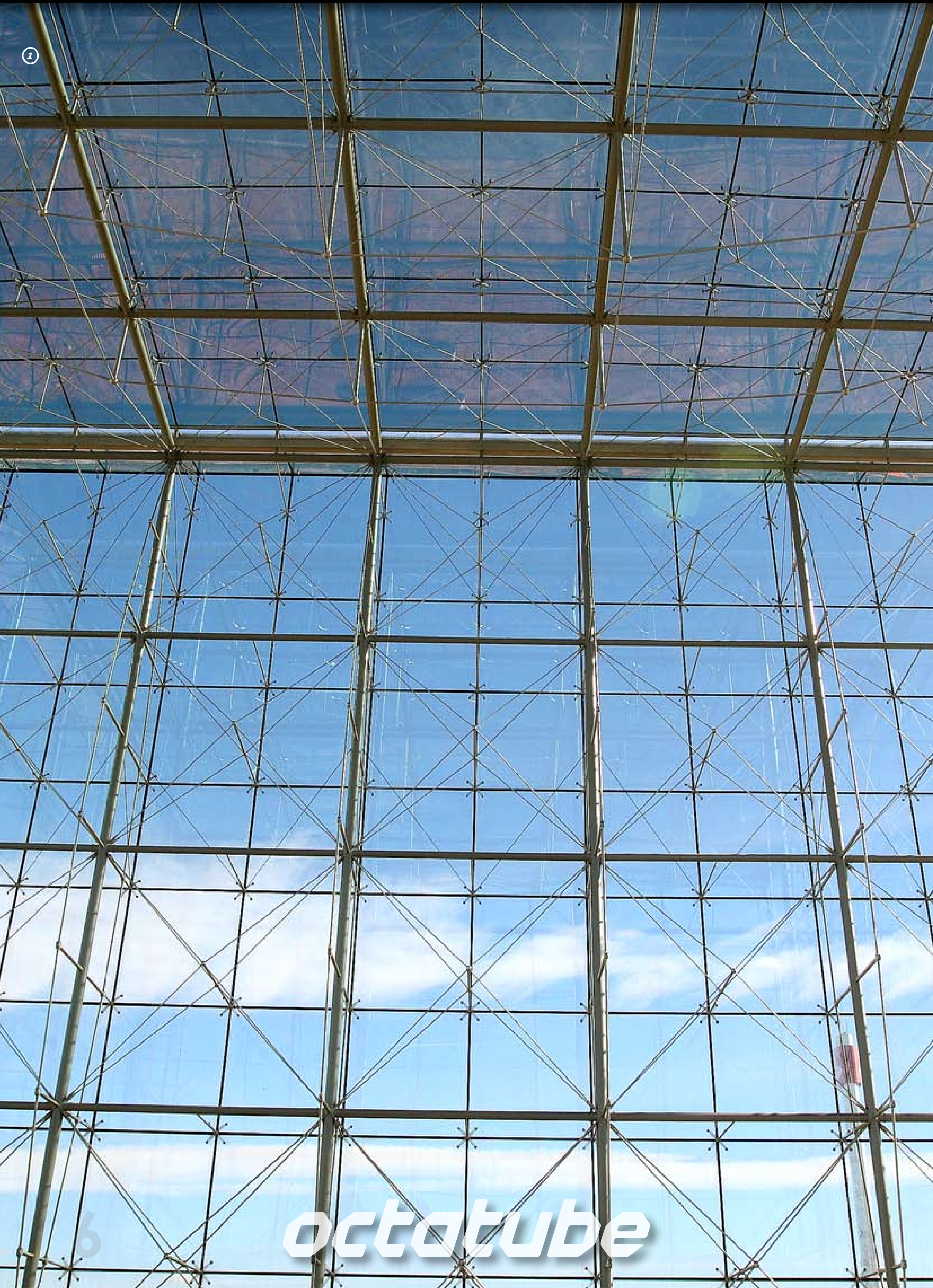
Assembly & Supervision

This department, among other things, takes care of the transportation and shipment of the products from the plant to the building site. After that, assembly and installation follows. In the Netherlands, this is done entirely by the company's own staff. Abroad, these operations are carried out by local staff of the subsidiary company or by the local agent, but all is carried out under the supervision of Octatube.

Organograms are drawn to provide a clear understanding of the engineering, production and installation process of each contracted project. Two types of projects are distinguished: the experimental and the routine project. The page left shows an organogram of the second type. This indicates that it is not just a question of subcontracting. Because of the complexity of the various functions (designing, calculating, producing, assembling and installation), strict logistics are behind the realization of an order. One of the consequences is that, with very complicated or large-scaled projects, the order for designing or engineering is given in an early stage; preferably well before the date of tendering for production and installation.

1: Organogram for standard building products from the teachings of Prof. Eekhout

2: The unloading of trusses Glass Cube, Banco Santander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The basic starting points

The essence of the company philosophy of Octatube consists of the following three starting points.

- The development of new products and systems
- The synergy of architectural, structural and industrial design
- The integration of design, production and building

Development of new products and systems

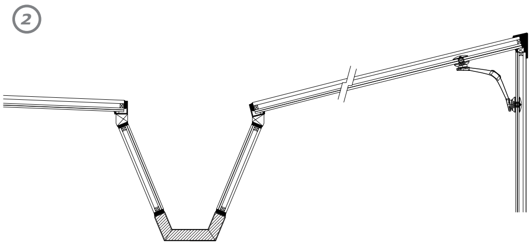
Innovation and development is typical at Octatube. From the very first beginning, innovative products have been designed and applied; an inventive mindset and economical considerations are the driving powers during 25 years.

During the entire process of development, all departments of Octatube are involved. The design follows a route from designers to engineers and productionstaff and back again; to production for the making of a prototype and back again. As often as it takes the product to meet the requirements. Chapter 4 elaborates further on this point.

The synergy of architectural, structural and industrial design

The very close co-operation and frequent discussion between these three disciplines results in quick multi-level decisions. This multidisciplinary designing process proved to be a condition for pushing back frontiers and creating innovative designs and products. In the following text, these three types of projects and their synergy are described.

2



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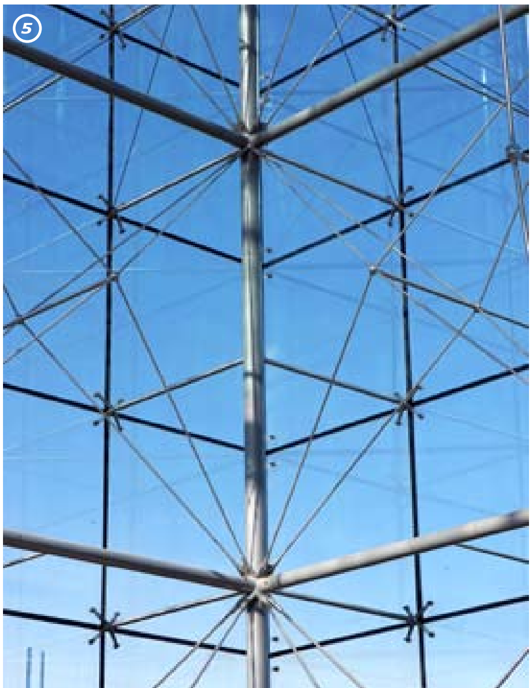

1: Interior Glass Cube Banco Santander, Madrid (architect: Alfonso Millanes)

2: Typical gutter with sandwich bottom and two flanges and the corner detail.

3: Exterior

4: Detail interior

5: Interior corner column

Architectural design
The product designer at Octatube is responsible for the fitting in of a spatial structure in the overall architectural design of the project architect. The entire building concept, the details, the connections to other building components, all are scrutinized. Therefore, the dialogue with the architect is rule rather than exception. It will be clear that the sooner contact between architect and product designer takes place, the better the results will be.
The architectural components are often a great incentive and affect the architectural concept of the project architect.

Structural design
The most important task of the structural designer is to convert the design into a structural scheme. This scheme shows how the external loadings are transferred via the structural form to the bearing points or the support points.

The choice for this structural scheme is greatly influenced by the architectural concept. The structural attention at Octatube has always been directed to the realization of elegant and slimlined designs of spatial structures.

Design of slender structures is more important than usual in the steel world.

Industrial design
Industrial design, in this context, is directed towards industrial manufacturing. Optimizing the production, assembly and fit for installation and sometimes fit for demounting and remounting, plays an essential part during the designing process.

Integration of design, production and assembly
These joined forces of designing, producing and assembling, the so-called 'Design & Build" concept, provides for the client only one party of reference. This bears fruit, particularly for products with components that are very specific, new or experimental.

In technical architecture, engineering is the essence of the game. All problems that occur during production and building, must be anticipated in this particular field. To the many designers in their different fields in the company, the presence of production facilities means a continuous physical confrontation with the basic materials, the processing techniques and the resulting products. Production provides inspiration.

Furthermore, experiences, gained from producing and assembling, are exchanged with the designers. These experiences are carried along to subsequent designs.


2

*1: Installation of shells
Yitzak Rabin Center, Tel Aviv
(architect: Moshe Safdi)*

*2: Interior Aeropuerto Manises, Valencia
(architect: Francisco Benitez)*

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The architectural objective of frameless glazing is to build glass planes with a maximum of transparency. The structural objective is to produce self-supporting structures with a maximum input of glass. Frameless glazing is applied, for the greater part, to roofs and facades. Interior applications also occur; they come in the shape of inner walls and floors, sometimes stairs. Characteristic of frameless glazing structures is that not one single window frame structure is to be found between the glass panels. Either the glass is self-supporting, or a slimlined steel structure is placed behind the glass to realize the span. Strength and rigidity of the whole glass panel are derived from a point-shaped connection of the glass panels to each other and to the supporting main façade / roof structure. Usually, for this glazing type fully tempered glass is used, which can absorb stresses up to five times higher than float glass.

All Quattro systems, engineered and realized by Octatube, consist of the following subsystems:

- glass panels
- glass panel connections
- Quattro joints
- stabilizing supporting structures

Glass panels

The glass panels, applied without frames, can be composed in different ways. There is the choice between single and insulating double glass, heat-strengthened and fully tempered, laminated or monolithic glass. Furthermore, the glass plates of which the glass panels are composed, differ in light transmissions and in heat transfer manipulative qualities to meet the specific project demands. In general, a choice will

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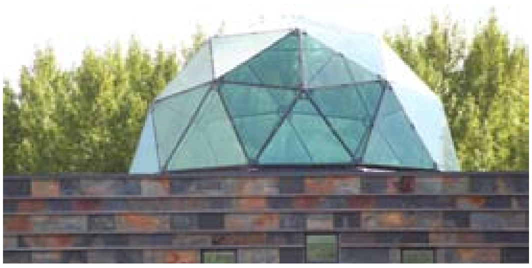

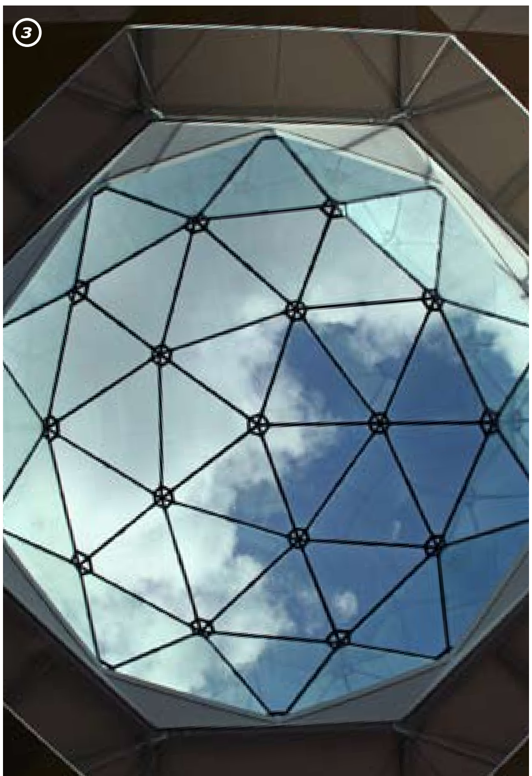

1: Detail of frameless glass façade at Aeropuerto Manises, Valencia

2: Koepel Selimiye Moskee, Haarlem, NL (architect: De Architectenkamer)

3: Interior

1

have to be made from clear glass, body tinted glass, (hard) reflective solar coatings at the outside, the cavity or the inside; soft solar coatings at the cavity side, (soft or hard) low emission coatings (low E) at the cavity inside and, finally, graphic screenings.

With regard to the size of the glass panels, two independent criteria are determining. Firstly, the production technical possibilities play a part. Sizes are restricted by the pre-stress ovens, the lamination autoclaves and the heatsoak tanks. To the majority of the applications, this means maximum sizes of 2,14 x 3,60m. Only a small number of companies in Europe can supply Octatube with panels that have larger sizes, for a higher price per square metre. Secondly, the structural rigidity (size of the plate versus gauge) is a criterion. In addition, the arrangement of the connection points plays a part. For a modest plate thickness of 10mm, and an economical price, a maximum free span of 1,8m between the joints is generally recommended.

Deformed glass

Traditionally, there is the possibility of hot deforming of cylindrical and conical glass plates, then to pre-stress them and possibly reprocess them into double glass panels. The hot deforming of glass panels with a double curved shape is very expensive, because each panel needs its own mould.

For some years now, experience with the cold transformation of glass panels has been acquired within our own plant. Cold bending of casing glass has been applied earlier to cylindrical roofs. However, cold bending of point-shaped glass, laminated and/or double glass, is also possible. This way of bending was used for the Floriade Pavilion 2002. Here, 50% of the bending stress was used for the bending itself; the other 50% was used to absorb the windloads (photo 4).

It is also possible to twist glass panels in laminated and/or double glass shapes into a window case. Consider the zigzagging window frames of the Kunstgalerie in Stuttgart, Germany, by the late architect James Stirling from 2 decades ago and the recent (2002) smoothly twisted spaghetti façade of the town hall in Alphen, the Netherlands, designed by Erick van Egeraat, where 25% of the tension was used for twisting (photo 3).

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1 & 2: Frameless glazing of the cityhall in Alphen aan den Rijn, NL (architect: Erick van Egeraat Associates)

3: Twisted glazing in the 'spaghetti-strips' at the back of the cityhall in Alphen aan den Rijn

4: Floriade Pavilion Haarlemmermeer, NL (architect: Asymptote Architects, New York)


1

Structurally loaded glass

Extreme structural applications of prestressed glass structures do not only result in external loads perpendicular to the glass panels, but also in normal forces, i.e. tension or compression in the surface of the plate. This way, glass is truly structurally strained and hence is called structural glass. The glass plates have then become an essential part of the main supporting structure, which is perceived as being immaterial, transparent and abstract. For the structural analysis and dimensioning of such a scheme, modified safety coefficients are complied and details are applied that do not lead to 'progressive collapse' of the entire structure, because of the possible collapse of one single glass panel.

Glass panel connections

The glass panels are connected to the main façade / roof structure by means of Quattro joints. This can be done in a number of ways. The main differences occur in the mechanical and chemical connection methods.

For mechanical methods, a bolted connection is applied through holes in the glass. These holes can be made straight, as well as countersunk. The chemical method makes use of flexible sealants, based on silicones, or of rigid glues, based on thermosetting glue. Point-shaped fixings always are applied on a basis of a thermosetting structural glue.

The glued connection is developed at Octatube. Research has been done in its own laboratory and at the Glueing Institute of the Faculty of Aeronautics, University of Technology, Delft. The results are glass roofs with a completely smooth surface without thermal bridges. For a considerable time now, next to the roofs, also glued facades are build, but only after shortened long duration tests with regard to creep, temperature behaviour and the UV-resistance of the glue. The glued connection is patented in the Netherlands, as well as in a number of European countries.

1: Façade van Lange Voorhout 37 te Den Haag (architecten: Fred Bos en Karel Rosdorff, final engineering: Octatube)

2 - 5: Various connector fastenings:
2: glued, interior view
3: bolted connection
4: half glued connection
5: glued, exterior view

1

Quattro connections

The Quattro joints are the intermediary between the glass panel on the one hand and the stabilizing main façade / roof structure on the other. In general, they have a shape that is derived from the shortest distance between the holes in the glass plate and the central bearing of the stabilizing rear structure, which usually runs in the axis of two glass plates. For four holes in the corners of four glass plates, this results in a typical diagonal cross shape: the so-called Quattro connection. Although the Quattro systems derive their name from this most frequently occurring connector form, the four-pointer, also 'Trio's', 'Duo's and 'Mono's are possible. The names are self-evident. This way, two holes next to one another, result in a straight connection over the central support: the Duo joint.

As is the case with the systems and products, connectors can also be distinguished in special, system and standard connections. The wax-cast stainless steel Quattro connector is a typical example of a standard joint.

The connectors are made of metal: aluminium (cast), iron (nodular cast iron), steel (welded or pressed) or stainless steel (cast, welded or pressed). Obviously, these connectors can be treated and finished in very different ways.

The stainless steel cast connections for the glass cube in Madrid (30x30m2) have a specially developed design and size: 350x350mm (photo 4).

Filigraine structures

In modern architecture, ultra slender structures depict a high grade of development, an expression of decades of design, development & research refinement. Especially in restoration and renovation projects, these visually extremely light structures of glass and steel play a major role. The contrast between existing (brick) mass and a visually almost weightless canopy or glass façade has by its maximum contrast an intense effect that is used by many architects. There are many examples of this contrast in this catalog.

Stabilizing support structures

Stabilizing support structures may consist of already available building components, i.e. a steel structure by a third party, or of metal components, supplied by Octatube. This rear structure must meet the structural demands of sufficient strength, rigidity and stability.

For aesthetical reasons, the Quattro glazings of Octatube are combined with slender support structures. A distinction can be made between super slim-lined structures (i.e. pre-stressed tensile trusses), slimlined (i.e. circulair and ellipse-shaped tubes), robustly lined (rectangular tubes and trusses) and common structures (i.e. open steel profiles).

The tensile trusses and elliptical tubes, structures often applied by Octatube, are closer examined hereafter.

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1: Façade 'Helicon' building, Finsbury Pavement, London (architect: Sheppard Robson, engineering: Octatube)

2 & 3: Details of glass connection through the joints

4: Quatro node 350 x 350 mm for glass panels 2500 x 2500 mm. Glass Cube Banco Santander, Madrid (see cover & page 6,7)

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Tensile trusses

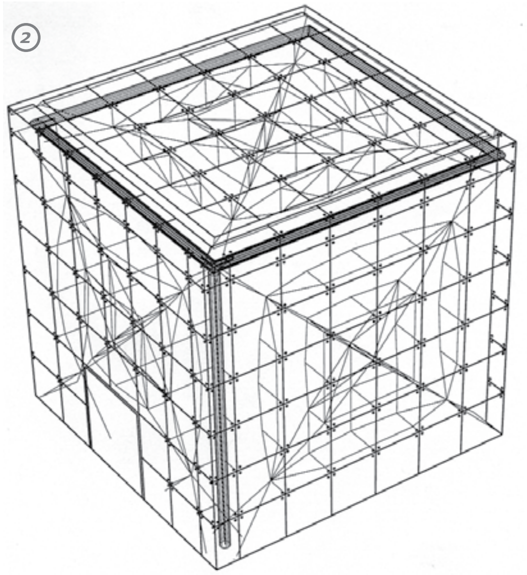
These ultra slender structures can be divided into open and closed trusses. An open tensile truss is tensioned between two opposing reinforced concrete building structures and obtains its high reaction (tensile) forces from there. With a closed tensile truss, a linear compression tube is introduced to achieve the structural independent unity of tensile and compression forces. This scheme can be realized in a linear truss shape, as well as in a spatial shape.

Tensile trusses can be made either of steel tensile cables or massive steel rods, or from a combination of these with compression bars. The shape is determined by the bending moment line, which results in the characteristic belly-shape, lens-shape or fishbone-shape.

Arch-shaped tensile trusses, for both positive and negative load (wind pressure, snow load and deadweight versus wind suction), will result in two antipodally buckled arches. The three basic positions of these two (concave and counter formed) arches, with regard to the glass plane, may be:

- on both sides of the glass
- on the inside of the glass
- on the outside of the glass.

The two tensile arches can be put together in two ways: lens-shaped (placed against each other) or fishbelly-shaped (placed through one another). In both cases, the single underspanning arch is the basis, for which one-dimensional subtended structures are designed. The belly-shape, which follows the moment line, has underspanning tensile trusses with the exact same diameter all over. However, a-symmetrical loading results in the additional triangulation of the plane of subtension. Obviously, between lens-shape and fishbelly-shape intermediate forms are also possible.



Lens-shaped tensile trusses

The footings of the two polygonals coincide and the depth of the lens-shape is twice the structural distance 'a' from the formula M = F x a, practically meaning: a = 1/10 of the free span.

Tensile trusses with compression tubes (compression-tensile trusses) always have a lens-shape, because at the ends of the tube, also the tension members coincide, so that a structural entity is formed.

Fishbelly-shaped tensile trusses

The two arches intersect in such a way that the total depth equals one time 'a'. This always results in two times two support points at a distance 'a' from each other. The advantage of this shape is that it spares structural depth. Usually, this particular composition is applied to one side of the glass. However, a double sided arrangement with a bit complicated nodes perforating through the glass line, is also possible. In this case the detailing will be developed in a demountable fashion.

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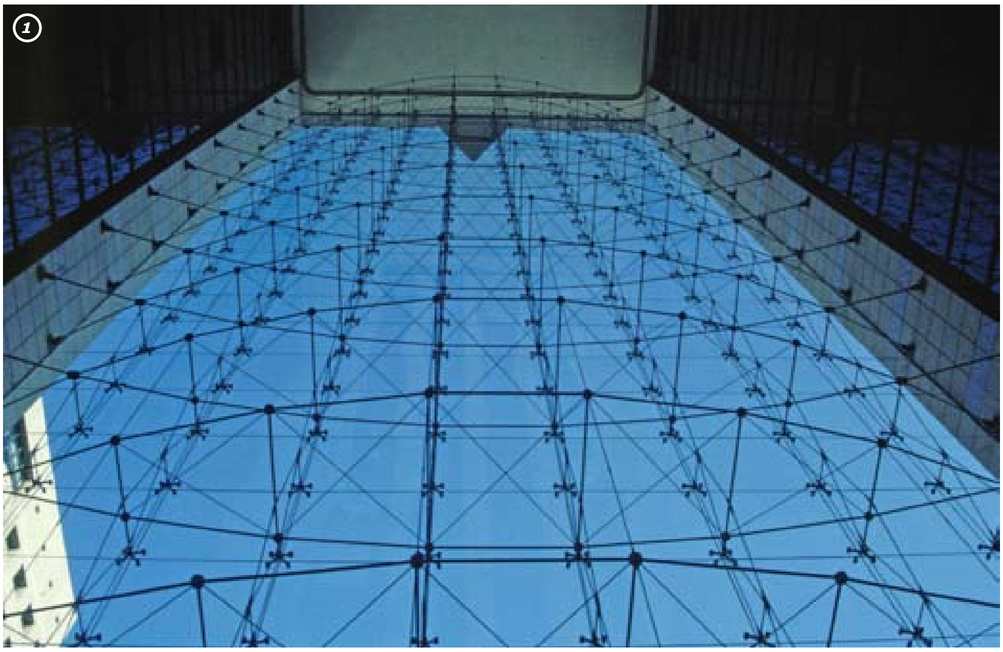
1: Entrance hall of the 'Museon' in Tel Aviv. Size: 12 x 12 x 12m (architect: Dan Eytan).

2: Isometry



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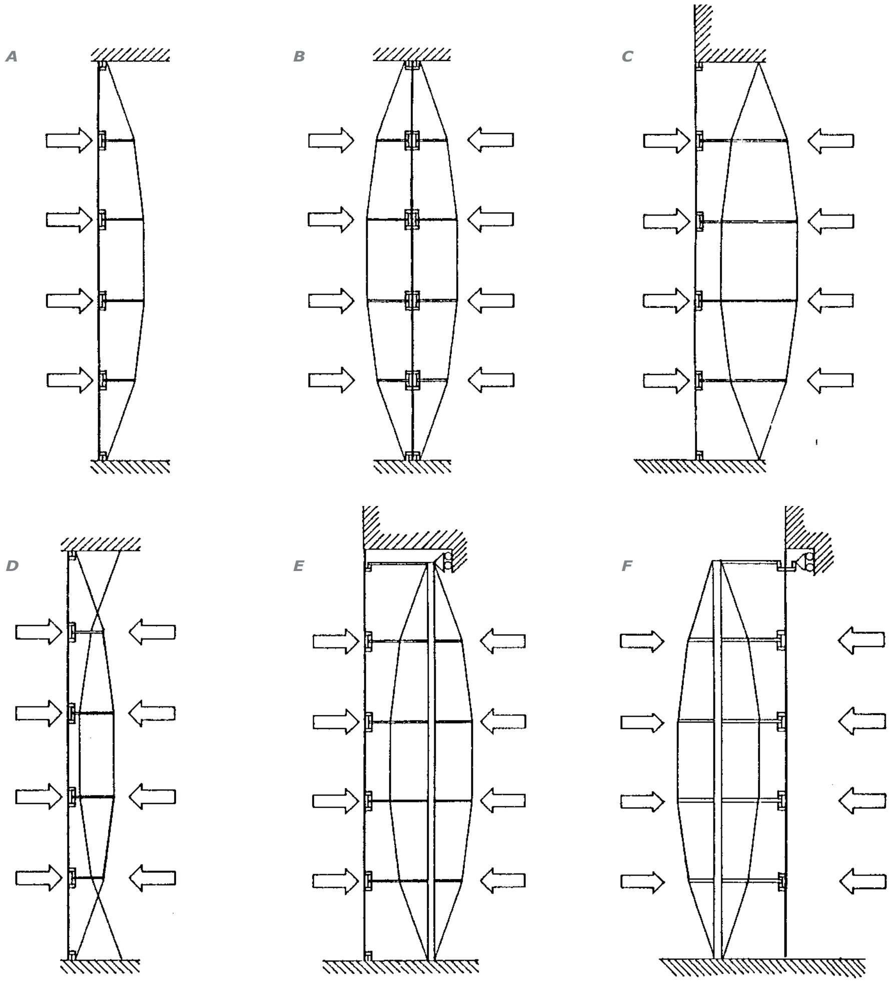

Six modes of stabilisation of frameless glass façades by stiff tensile trusses

A:
Stabilisation against wind pressure

B:
Stabilisation against wind pressure from both sides with glass plane central

C:
Stabilisation against wind pressure and wind suction in two catenary lines

D:
Stabilisation against wind pressure and wind suction with glass plane excentrically positioned in two intersecting lines

E & F:
Autonomous systems with internal compression forces concentrated in central pole so as these systems do not influence the surrounding structure with their tensile reaction forces

3D tensile trusses

In 1990, a system was developed which consists of diagonally intersecting tensile trusses that are capable of supporting a square roof surface. The roof surface is composed of 3 x 3, 4 x 4 or 5 x 5 glass panels.

This arrangement is often combined with a macro tubular system of compression tubes. By introduction of the tensile forces only in the 4 corners of the tubular frame, the glass panel stabilisation only acts in tension while the tubes are mainly stressed in compression. Large roof surfaces can be made when the macro tubular system is stabilised with bow string trusses as well. Flat roofs of around 30x30m2 free span are possible with in the system with a tubular grid of 7,5 to 8m square.

This diagonal layout can also be applied to round roofs: the so-called 'bicycle wheel principle'. An example of this if the design of the glass roof for the new accommodation of the Bancopolis bank in Madrid (see Chapter 'Domes' page 34).

3

1: OZ building, Tel Aviv, (architect: Avram Yaski)

2: 6 Modes of stabilisation of frameless glass façades by stiff tensile trusses

3: 'Shoppingcenter Overvecht' Utrecht, NL (architect: ONB architecten)

4: Interior

5: 'Orangerie' in Artis (ZOO), Amsterdam, with elliptical purlins suspended freely from the columns and the roof structure (architect: Onno Vlaanderen)


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Ellipse tubes

The introduction of elliptical tubes at Octatube occurred in 1996, as a direct result of Mick Eekhout's book 'Tubular structures in Architecture'. Elliptical tubes were designed out of the simple thought: "if there are square hollow sections and rectangular hollow sections, why are circular hollow sections not complemented with elliptical hollow sections?" This was the dawning of a new period of maturity for frameless glazing. Not only did frameless glazing meet the architectural needs, but also the economical needs were fulfilled.

The idea of elliptical profiles was taken up by the European tube manufacturer Tubeurop. Circular tubes are deformed by several deformation stations. In each deformation station the tubes are deformed by hot rolled circular tubes to elliptical forms.

Elliptical tubes are popular in yachts where they serve as aluminium masts. In the deeper direction they are strong, in the cross direction they are strong, slender and aerodynamic. In the assortment of steel profiles, the application of ellipse shaped tubes is based upon their double attractiveness: they have bending strength in the deep (cross section) direction and in the cross direction they have a radiant elegance. The elliptical tubes range in their commercial sizes from 120x60, 150x75, 180x90, 200x100, 250x125, 300x150 up to 480x240mm in various wall thicknesses mostly in high yield steel (S355).

Especially for frameless glazing a type of façade construction is developed with great strength, slenderness and elegance which is relative economical to produce and build. The sailors among the readers recognize the mast shape.

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1: Interior atrium DMG, Waalwijk, NL (architect: Van Aken Architecten)

2: Peace Center, Tel Aviv (architect: Avram Yashi)

3: Detail corner

4: Detail ellipse tube with Quattro node


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Frameless glazing

Experiments with frameless glass structures are carried out for over 20 years now. The first 'frameless' graduation project at the TU Delft was in 1988 by Rik Grasshoff. The Glass Music Hall in the Exchange of Berlage in Amsterdam (1990) was the first application of tensile loaded glass panels in the Netherlands. Since then, many different designs and prototypes of structural and frameless glazing have been made all over the world. In addition, Octatube has consistently run ahead in development of inventions and innovations, national and played internationally its role also.

In many applications, however, the architect does not want a completely frameless construction. It is possible to design lightweight trusses, with a (slightly curved) compression element in the middle and cables on the top and bottom and perpendicularly placed purlins, so that the whole structure still has visually a 'floating' character. Such a system is designed for the cover of the restaurant street of the 'Westelijk Handelsterrein' (photo 1) in the Vollenhovenstraat in Rotterdam. Its visual floating character dominates and surprises. The detail of the linear support profiles has been chosen with care. Here also the flowing of light around the elliptical profile plays a role: an elliptical cross section shape with a narrow U profile on the head to fix the glass panels upon is usual. Crossing profiles (imaginary cutting in two different areas) is here a cause of amazement.

A material consideration for linear profiles is the safety of the constructive behavior, and sometimes the economy. Thus, vertically positioned parabolic shaped aluminum profiles were used for the glass dome of the Friesland Bank (page 30). The bent laminated panels of the 'Broerekerk in Bolsward' have been imposed on the bent side and have been positioned, which gives an almost perfect safe support in the case of breakage (photo 4). The linear profiles (T form) in the circular current ceiling area in the church emphasize the evident glass area, apart of the sharp V-frames on top.

It is a matter of design and of generates visual tension in the design, that also make linear profiles subject of architectural interest.

2

3

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1: Atrium Westelijk Handelsterrein, Rotterdam (architect: Jan van der Weerd)

2: Glass Music Hall in the exchange of Berlage, Amsterdam

3: Givataim Shopping Mall, Tel Aviv (architect: Asif Malis Architects)

4: Broerekerk, Bolsward, NL (architect: Jelle de Jong)

3

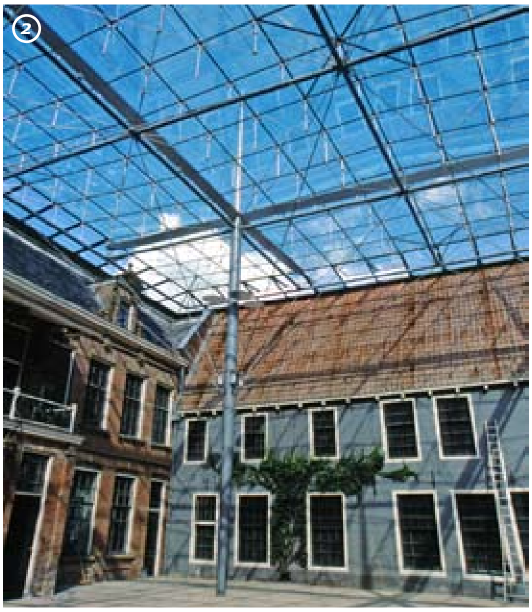

1

Monuments

Architectonic applications in monuments offer an extreme contrast between visual transparency of glass constructions, with the minimum commitment of steel components and presence of massive brick buildings of architectural history, a great visual tension in the design.

Many architects take up that aspect to put strength (architectonically) in their restoration and modernization. Frameless glazing express contemporary designs and avantgardistic structures, while the historical buildings are architecturally and technically untouched.

Best should be if the glass façade and roof structures were qualified as reversible (removable without leaving traces). This sometimes has impact on the chosen scheme. The Glass Music Hall in the Exchange of Berlage and the Glass Hall in the Prinsenhof in Delft have been designed this way. The elaboration of the glass constructions can carry clearly the signature of the architect, mainly in the design of the steel framework. Finesse and flexibility, or robustness and sharpness each lead to other profiles of the supporting lightweight frames.



1: Provincial House of Groningen, NL (architect: MAD Moerhrleinvandelft architekten)

2: Fries Natuur Museum, Leeuwarden

3: Synagoge Liberaal Joodse Gemeente, Den Haag (architect: Mick eekhout)

4: Glass museum hall Prinsenhof Delft (architect: Mick Eekhout)

5: Droogbak, Amsterdam (architect: Joop van Stigt)

Space frames are three-dimensionally active trussed structures, ideallyindustrially manufactured. Space frames were first supplied in 1907 by Graham Bell and became popular in the 60's by the Mero space frame system invented by Max Meringeringhausen. Octatube's name is attached to the Octatube space frame system that was invented in 1973 by Mick Eekhout as his TU Delft graduation project and also patented.

Usually, these space frames are made of circular or square steel tubes, as an exception they are made of aluminium or even solid timber, bamboo or cardboard.

Because of the revolution in the building industry from producer orientation to consumer orientation, the interest in industrial space frames has changed into special spatial structures as treated in the previous paragraph. The consequence is that many designs of spatial structures no longer result in a standard system. A specially designed project version will then be applied. Not the producer governs the system, but the project architect representing the customer.

The Octatube System

The Octatube system is composed of an ensemble of octagonal steel welded joints and circular tubes. It is possible to apply a maximum of 18 member connections to a double joint. The connection of members to joints is done by means of high tensile bolts. The system has proven to be quite economical.

The Tuball System

The Tuball system also consists of steel joints and circular tubes. However, the nodes are spherical hollow cast nodes. The tubes have welded props with a threaded hole. These are fixed to the spheres by means of an internal hidden bolted connection. The components can be made either of aluminium, or of steel. The system is after 25 years still regularly used. The South and East Serre at the Faculty of Architecture, TU Delft were realized in 2009 in an extremely speedy construction rate, made possible by the large experience with this system.

4

1: Tuball Space Frames; Airport Terminal in construction, Dubai (architect: G.S. Ramaswamy)

2: Octatube system; Detail bordercrossing Holland/Belgium at Hazeldonk, NL (architect: Benthem & Crouwel)

3: Detail

3: RVW Domplein, Utrecht (architect: Naked Architecture) Photo: Cornbread Works

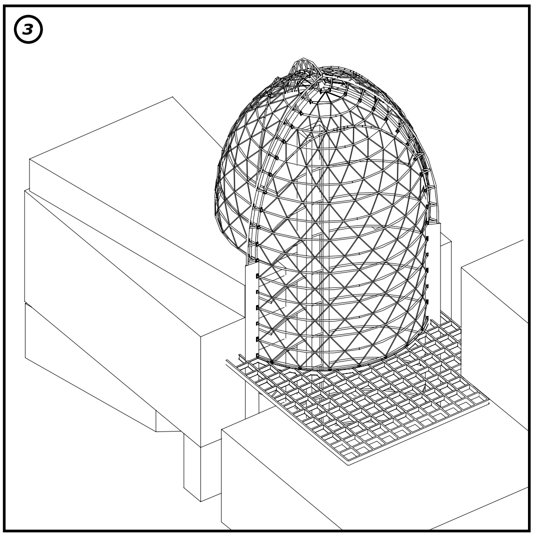
5: Zuid Serre Bouwkunde, TU Delft (architect: Mick Eekhout)


1

The Streamline System

The Streamline system was introduced in 'Architecture in Space Structures', written as a dissertation by Mick Eekhout in 1989 [010 Publishers, Rotterdam, ISBN 90-6450-080-0] and for the first time realized in the dome of the Friesland Bank in Leeuwarden the Netherlands by architect Aad van Tilburg. This system consists of fluently blend rings and diagonal tubes. With regard to the dome, a special project system has been developed, with round bent horizontal tubes and diagonal bars in-between. The high tensile bolted connection is completely concealed.

The dome of the Friesland Bank is composed of a single-layered space frame in network geometry, fixed between three triangular space frame trusses.



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1: Interior Friesland Bank Leeuwarden, NL (architecten: Aad van Tilburg en Harmen Grunstra)

2: Interior

3: Structural diagram

4: Exterior

5: Music dome, Haarlem (architect: Wiek Röling, structural design: Mick Eekhout)

1

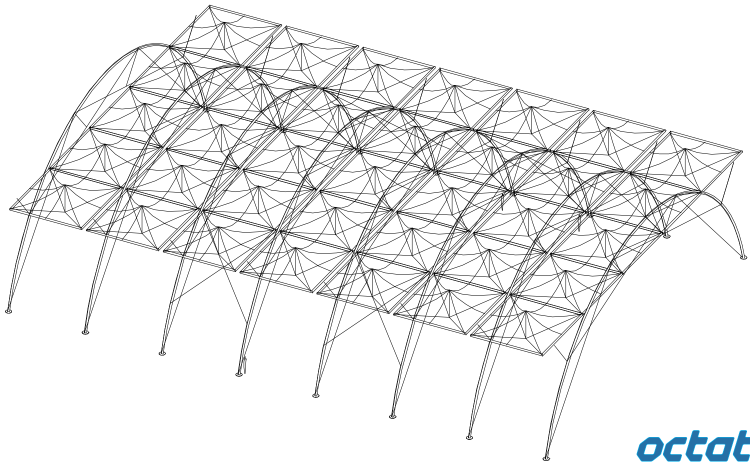
Stressed membrane structures, or 'tents', in their architectural and structural shape, have been known since the work of Professor Frei Otto in Stuttgart in the Sixties. Currently, in the Netherlands, canopies, umbrella roofs, covered walkways and free coverings for shopping centres, are most frequently applied.

The most occurring shape is a roof plane, which is spatially curved, both concave and convex, so that the fibres of the textile enforcement of the fabric stabilize each other at alternating wind loads. These so-called 'anticlastical' (= counter curved) shape of the membrane can be reached by compressed concave or convex reducing cables that have been introduced in the roof plane, by rigid pressure arches of steel tubes or laminated timber, or by steel poles that push up the membrane surface, sometimes enforced by means of field cables.

For optimal structural design, a co-design dialogue between the project architect and project structural engineer on the one hand, and the product designer and product structural engineer on the other, is an absolute necessity. Stretched membranes are always special products that can rarely be reproduced, due to the direct influence on the shape, caused by different dimensions and different supports.

In the Netherlands, smaller membranes are usually made of polyester reinforced PVC fabric with a life span of 15 to 20 years. The alternative is glass fibre reinforced Teflon (PTFE), which is incombustible and is of a better quality; its life span is over 40 years. However, because of the considerable higher costs, this fireproof and maintenance-free material is hardly ever applied in the Netherlands. The unreinforced ETFE results in almost transparent membrane structures.
One of the most recent designs is 'The Urban Roof' for the Binnenhof Festival in The Hague, designed by architects Maarten Grasveld (LIAG Architecten) and Mick Eekhout. The roof is designed as flexible, because of its required yearly re/demountability.

2



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1: Interior Papertube Dome (architect: Shigeru Ban, Paris)

2: Design temporary canopy for the Binnenhof Festival in Den Haag. Size 52 x 35m (architecten: Maarten Grasveld/ LIAG, Mick Eekhout)

3: Canopy shopping Mall 'De Ridderhof', Ridderkerk, NL (architect: Cees van der Goes, structural design: Mick Eekhout)

4: Mobile tent 'Veronica Muziekland' (architect: Mick Eekhout)

5: Canopy Royal Palace Noordeinde, Den Haag (architect: Mick Eekhout)

1

Domes and cylindrical roofs may be composed in various ways. One possibility is to apply a space frame system for the structure, i.e. the Tuball system (photo 2 & 3).

Cylindrical roofs have the curved shape of the roof only in one direction and lack the stabilizing effect in the other direction. Therefore, compensation is required. When applying a space frame, it must be realized minimally in the shape of triangular joists, which have a strong stability when placed perpendicular to the glass plane. Each of these delta trusses needs fixed anchor points under each of their 'feet'. If these are not available, a horizontal main delta truss must be introduced to make the large free span to a lesser number of support points.

Domes may be divided into:

- spherical domes
- conical domes
- special domes

Spherical domes

For these domes, the Octatube and the Tuball system may be applied. One of the possible realizations is a dome of a socalled 'Schwedler geometry'. This system is composed of vertical radials and ringshaped horizontals, the quadrangles of which are either triangulated for torsion, or the connectors are made rigid. Another possible realization can be found in the socalled 'network geometry'. This consists of horizontal, circular rings and equal-sided triangles inbetween. The dome of the Haagse Poort in The Hague, architect Rob Ligtvoet, may serve as an example. The mosque dome on page 11 also belongs to this category. The free-form Green House of Malmö is a contemporary geometry of a deformed and sketched dome (page 36, 37).

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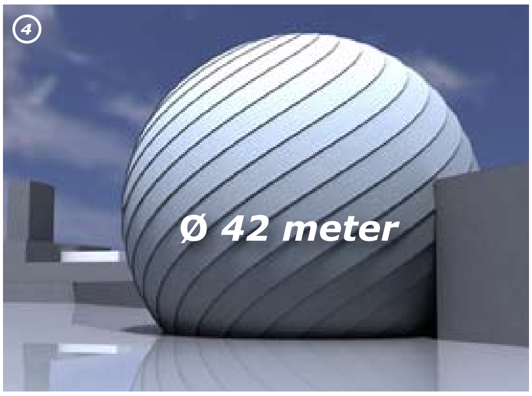

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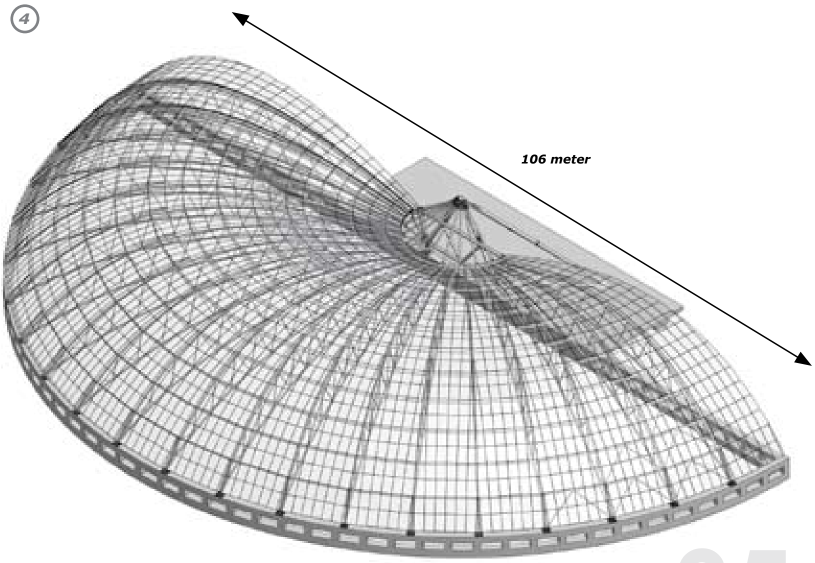

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1: Bancopolis glass roof, Madrid (architect: Kevin Roche, New York)

2: Dome Haagse Poort, Den Haag (architect: Rob Ligtvoet)

3: Interior Haagse Poort

4: IMAX theater Cotrocenipark project, Bucharest, (Romania) (archtect: Alon Yitzahki)

5: Atrium DOME Cotrocenipark project

6

1

Conical domes
Conical domes cannot be made in single layered space frames, due to the required rigidity of the verticals. For this reason, hot rolled ellipse-shaped tube profiles are often chosen for frameless glazing. Quattro connectors and frameless glass panels are applied to the tubes. An example of such an application is the Samson Centre in Tel Aviv, architect Moshe Safdi (photo 3).

Special domes
Another example of a special dome is the design of the quite remarkable dome for the theatre company Jeannette van Steen in IJburg. It consists of cardboard tubes and metal connectors, the architects of which are Shigeru Ban and Wouter Klinkenbijl. After the dome was stored for one year, it was rebuilt and furnished in the summer of 2004 in the newtown of LeidscheRijn in Utrecht as a temporary music room (until summer 2009).

Blob domes
Apart from the domes and cylindrical roofs, the increasingly emerging freeform domes or blob domes are well realizable in the described structures. A blob is a skin of a building in free shape, with mixed concave and convex parts, larger and smaller radiuses in the plane; the surfaces are double curved. Basically, these blobs are very well realizable in the described structures, although it is crucial that design and realization of the support structure is done in one hand with that of the cladding.

The origin of freeform designs is in the possibilities of computerized design manipulations by the architect; The project structural engineer usually is fully occupied to get this arbitrary form to follow structural laws. It usually is a struggle of sculptural design versus efficient structural design. Architectural tention often loses over the economy of structural realization.

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1: Greenhouse Malmö, S (architect: Monica Gora)

2: Entances parking garage Westerlaan, Rotterdam (Ector Hoogstad Architecten)

3: Samson Centre, Tel Aviv (architect: Moshe Safdie)

4: Assembly Papertube Dome. (architect: Shigeru Ban)

5: Greenhouse, Malmö


1

Apart from the already described designs and products, Octatube often gets the opportunity to think along from the start of the design phase towards a special design. By invitation of clients, project architects and artists, a number of designs resulted in projects with an entirely personal characteristic structure. In contrast with the basic production, these special designs came about according to the express wish of a designer. Sometimes, by repeated application, a multiple, sometimes a system product or sometimes even a standard product is made. To Octatube, these products often exist in the periphery of the building market and the product assortment available. Sometimes, these products are processed in small series by the engineering department of Octatube. This takes place in co-operation with either industrial designers (i.e. DOK), or structural designers (Atelier One), or architects (Jord den Hollander), or artists (Marijke de Goey). As impulses from outside, they often had a stimulating influence on the expertise, knowledge and insight of the design and production of Octatube. There are a number of mayor categories.

Bridges

Various bridges have been realized, from glazed skybridges, suspended between two building components, to footbridges and bicycle bridges. The aim is to assemble the bridges as often as possible at the own plant and then transport and fit them as a whole.

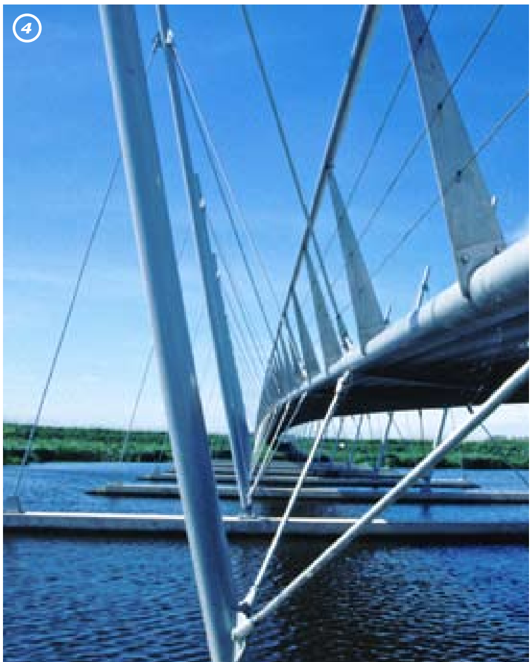
Stairs

A curved-rolled steel tube forms the structure of the glass stairs in Jeddah. The steps are realized as transparent/translucent connectable priva-lite laminated glass panels. These stairs provide an excellent example of 3D-engineering techniques. Simpler designed stairs are also realizable in glass (page 41, photo 2).

Canopies

Canopies are sets of building components in the shape of a roof, which all have the same function: to shield and guide incoming and outgoing pedestrains to and from a building or between buildings.

Shapes are usually derived from the fact that canopies are connected to the entrances of buildings and so offer the visitor a first impression of the building. For this reason, often a reasonable budget is set aside for the designing of a canopy.



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1: Pont du Gard (France) (architect Shigeru Ban)

2 & 3: TGP, Hoofddorp, NL (architect: Veenendaal Bocanet & partners)

4: Pedestrain bridge Purmerend, NL. Steel poles and aluminium flooring freely suspended with tensile rods (architect: Jord den Hollander)


1

The structural system, materials and finishings, elements and components, differ strongly because each architect designs a canopy with its own identity. This may vary from a design that follows the building, to a design that breaks free from the building to become a work of art on its own. Canopies may either assimilate or distinguish.

Works of art

A large series 'one off' works of art has been realized for various artists, being Loes van der Horst, Krijn Giezen and Marijke de Goey. Frequently, works of art were trendsetters for complex geometrical designs, which were later absorbed by architecture.

Shell structures

As a result of a growing demand for Blob structures and claddings Octatube has developed a shell technology of load bearing sandwich structures composed of polystyrene or polyurethane foam core and glass fibre reinforced polyester skins at the top and bottom of the foam core. In this mode the skins are smooth, self supporting according to the statical analysis per project. These sandwich constructions can be designed as secondary enveloping skins on top of a steel structure or as a self supporting main structure-and-cladding-in-one. The first of this series of proposals was done for the 5 shell wings of the Yitzhak Rabin Centre in Tel Aviv, designed by architect Moshe Safdie, in which the biggest wings measure 30 m length and 20 m width. Both the production technology and the logistics are specially developed for these purposes. The 3-D master model engineering results in a number of material prototypes machined on CAD/CAM basis to check the geometry of the shells in the total composition.

2

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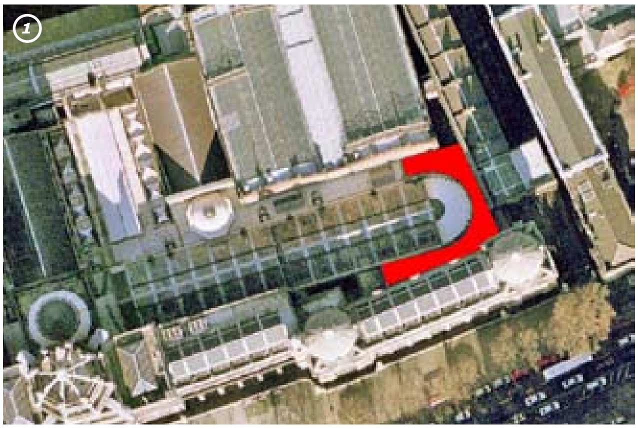
1: Detail photo 'Zuidpoort' canopy in Delft. A twisted canopy, covered with cold bent glass (architect: Mick Eekhout)

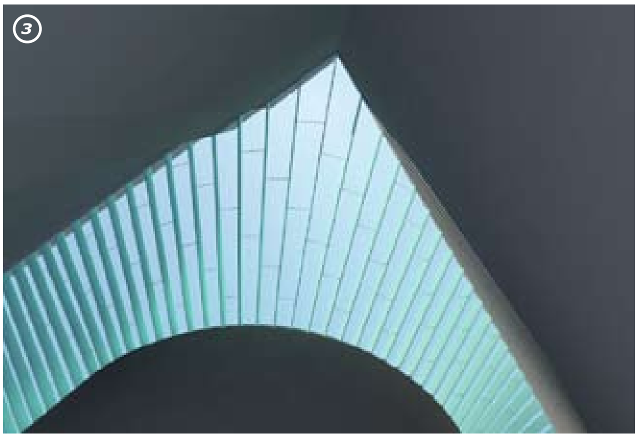
2: 'Zuidpoort' canopy

3: Staircase in Jeddah (architecten: Atelier One & Areen Design, Octatube)

4: Table (designers: Mick Eekhout & Marijke de Goey) Photo: Marijke de Goey

Victoria & Albert Museum





Yitzak Rabin Center

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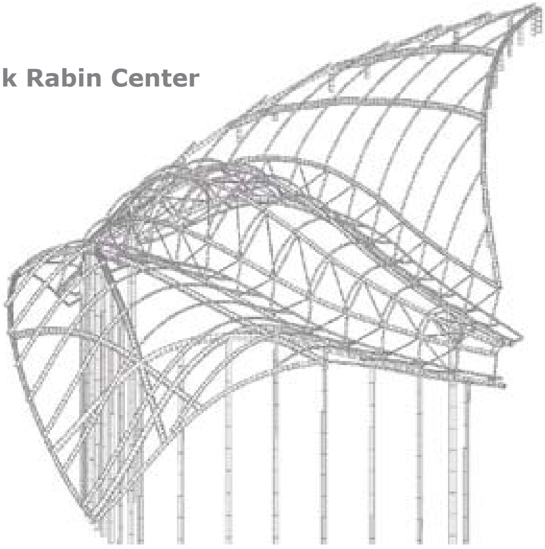

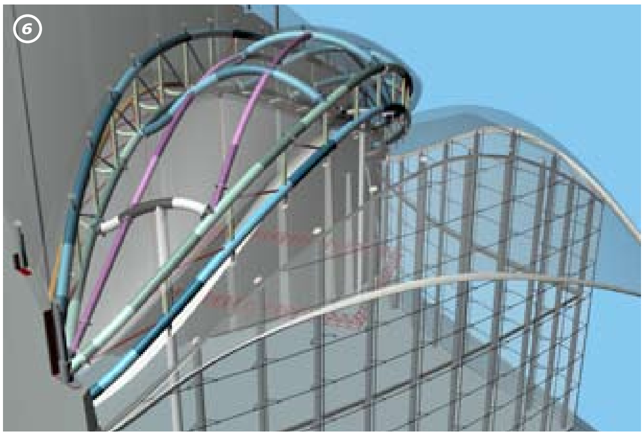

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With reference to Chapter 2 Philosophy of the Company, the development of new products is one of the essences of Octatube. The term 'products' is broadly based: ranging from products to components and systems even. The development of new products often requires fundamental technical research, which takes much time and energy. Generally, in the building industry, however, this is very unusual and financially almost impossible, but it is of vital importance for continuous product development.

Compared to similar companies, Octatube actively carries out many experiments. Yet, on an annual basis, Octatube processes a mixture of projects, allowing no more than 20% of experimental projects, as opposed to 80% of routine projects. Over 20% experimental project would jeopardize the economical business objectives.

Obviously, product development is regarded from the viewpoint of a relatively small business. In the building industry market, a broad assortment consists of various products that evolve in time and therefore change. The request for a new or deviating product can always be met, if the required engineering mindset and manufacturing techniques are housed in the company. Each demand may result in a special product.

When applying a system product, the project architect involved may want to incorporate some typical individual project data in the system design. If smaller components are frequently re-used, they may be realized as standard products.

In all of our product developments and component designs the design and engineering department of Octatube proved to be the core of innovation in the particular building process.

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Victoria and Albert Museum, London

The atrium roof is constructed of cold twisted insulated glass panels, which connect the secretariat with the surrounding buildings.

The glass roof panels are mounted on a structure system of long glass fins with a varying span to 11 meters in length in one piece and a varying girder height. The fins are triple laminated and have glued torque profiles on top of them and glued shoes at both connection ends.

Yitzak Rabin Center

The design for the Yitzak Rabin Center in Tel Aviv is characterized by two special building parts: 'The Great Hall' and the 'Library'. Both hall designs have remarkable and plastically designed roofs, ca 30x30m. The architect requested a seamless solution in the roof. To realize this Octatube has developed a shell technology of load bearing sandwich structures composed of polystyrene or polyurethane foam core. The roofs are constructed of this foam with stressed GRP (Glass Fiber Reinforced Polyester) skins at the top and bottom of the foam core. Co-producer of the polyester wings: Holland Composites of Lelystad.

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1: Victoria & Albert Museum, London, location (architect: Muma Architects)

2: Model

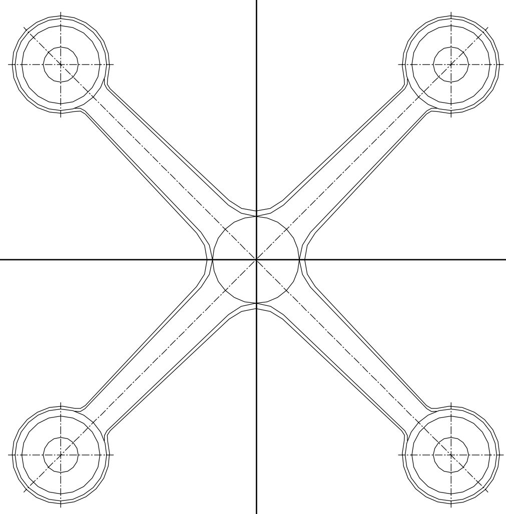
3: 3D rendering of part of the roof

4: Mock-up in factory of Octatube

5: Yitzak Rabin Center Tel Aviv, construction model (architect: Moshe Safdi)

6: engineering 3D model

7 & 8: exterior



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