

Single Storey Long Span Structure

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Classification of structural forms

- Form active systems
- Vector active systems
- Section active systems
- Surface active systems

Loads acting onto a structural systems

1. Dead load
2. Live load
3. Wind load
4. Stress created by temperature differences
5. Stress created by other form of disruption including ground movement, vibration, deformation or earthquake

Materials suitable for construction

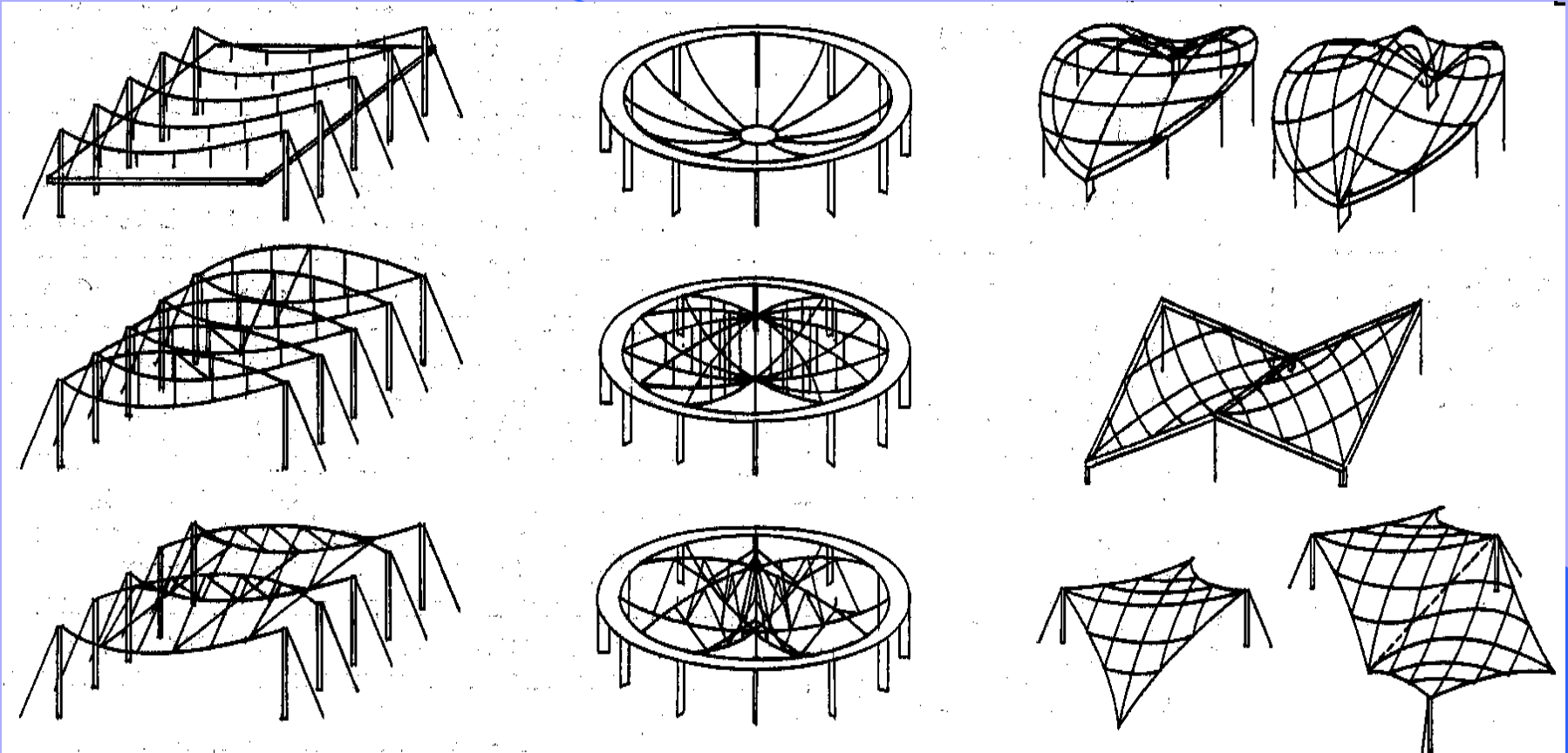
1. All reinforced concrete
2. All metal (e.g. mild-steel, stainless steel or alloyed aluminium,
3. All timber
4. Laminated timber
5. Metal/RC combined
6. Plastic-coated Textile material
7. Fiber reinforced plastic

Form active structural systems

. . . are systems of flexible, non-rigid matter, in which the redirection of forces is effected by particular form design and characteristic form stabilization

Example of structures:

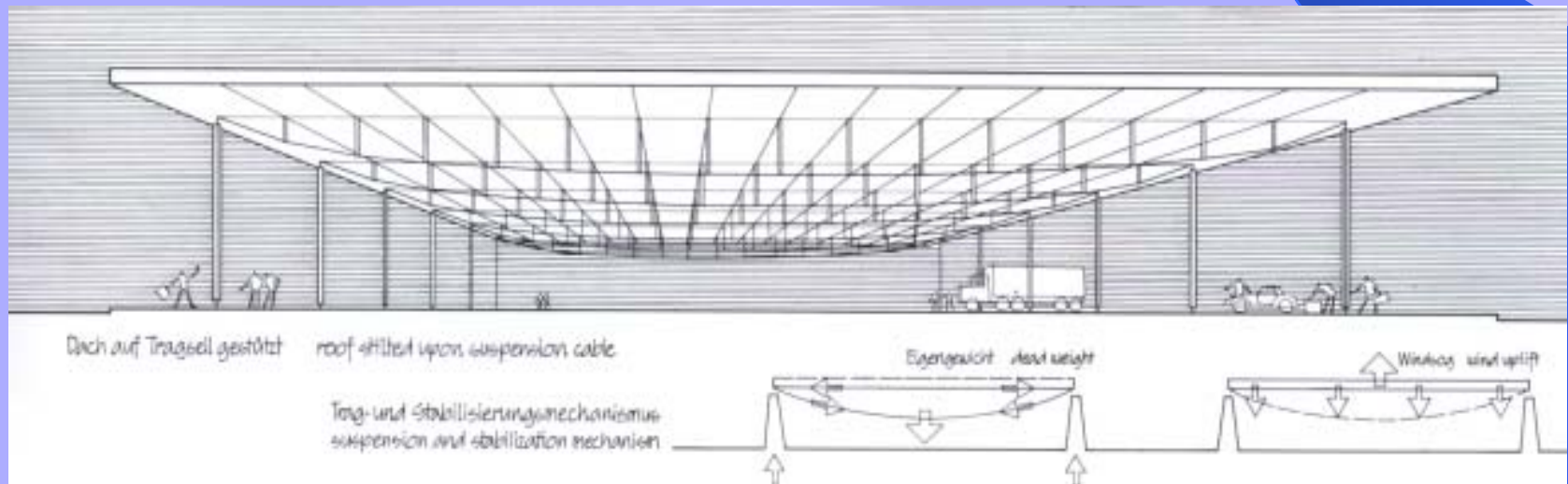
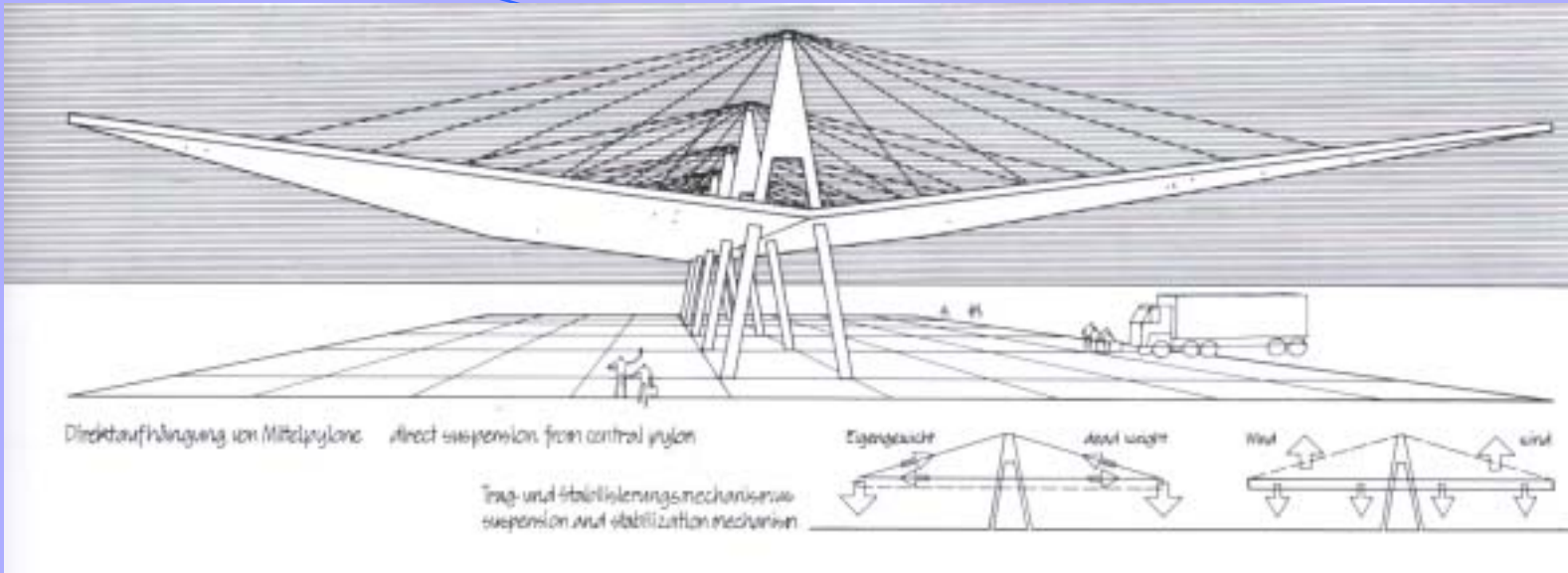
1. Cable structures
2. Tent structures
3. Pneumatic structures
4. Arch structures



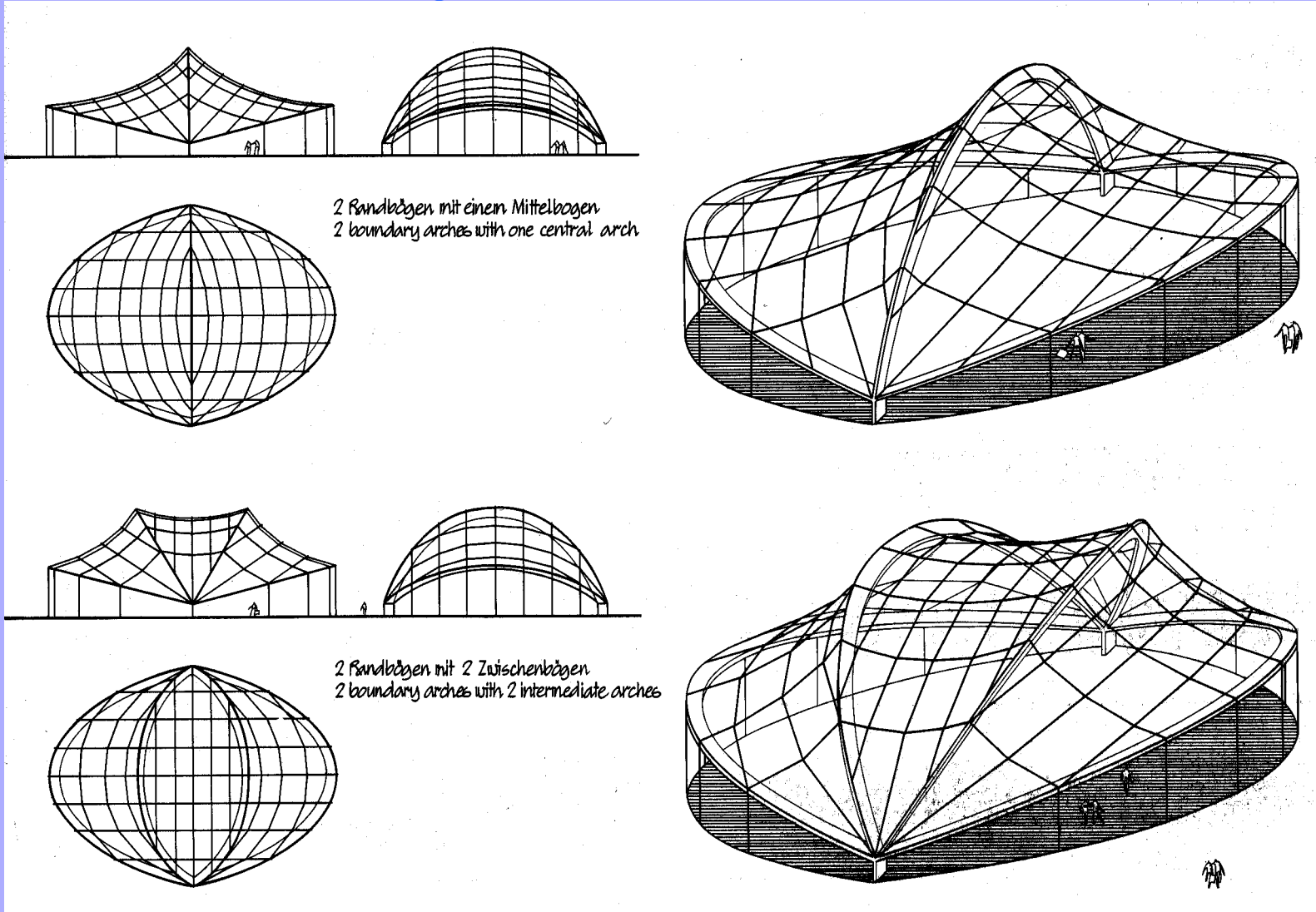
Parallel cable

Radial cable

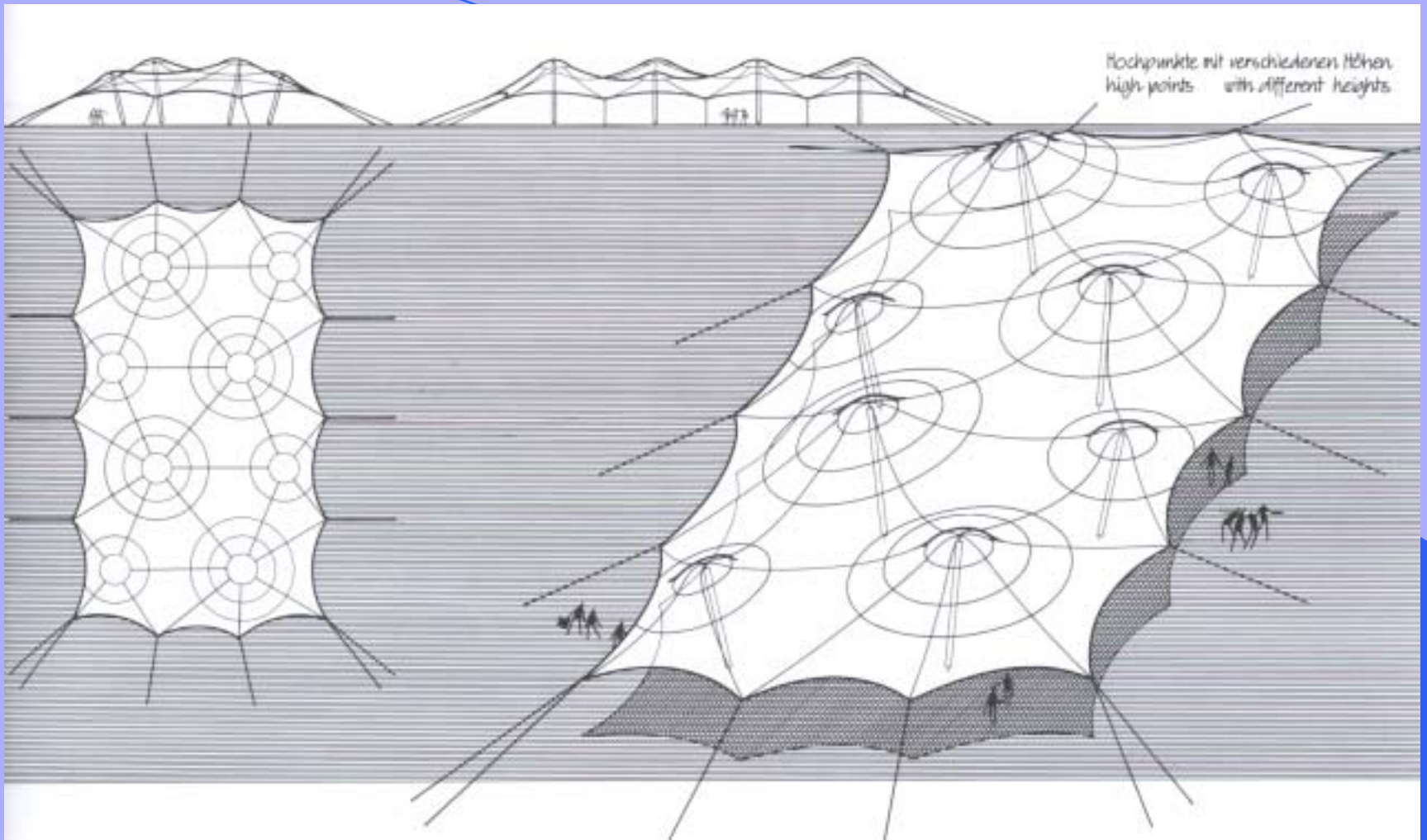
Biaxial cable



Illustrated examples of parallel cable structures

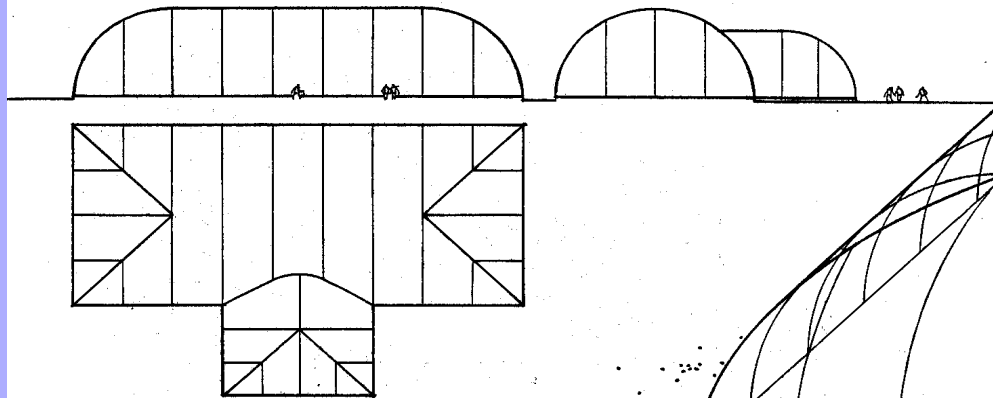


Examples of cable structures formed by arch

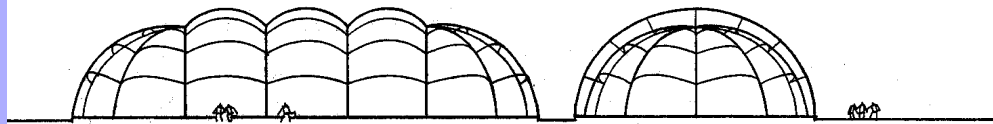
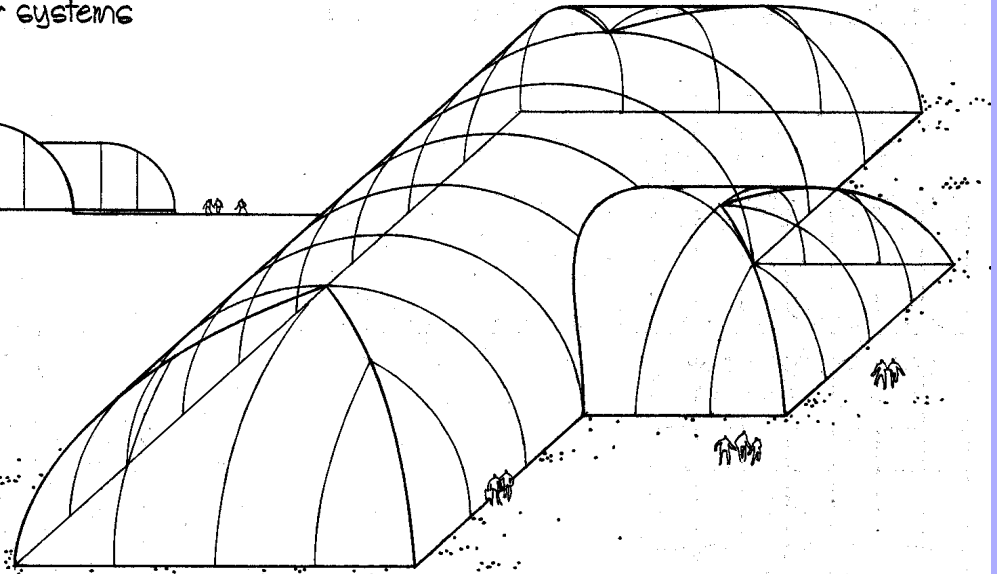


Examples of tent structures

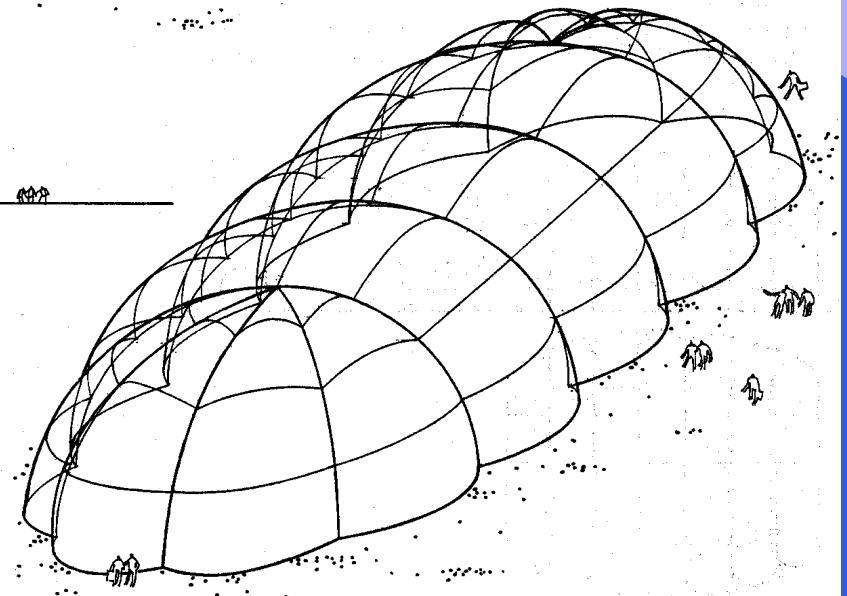
Lufthallen-Systeme / Air controlled indoor systems



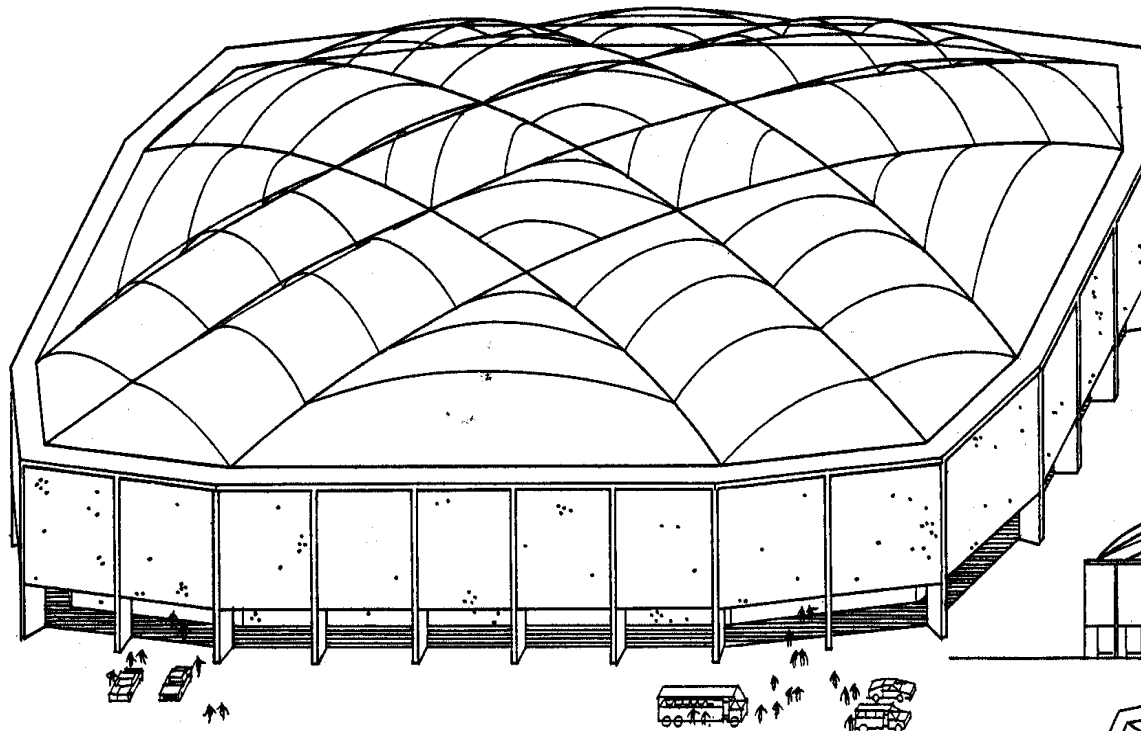
Zylindrische Membranen als primäre Tragelemente
Cylindrical membranes as primary structural elements



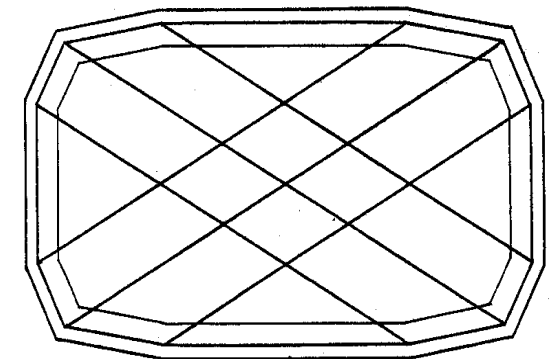
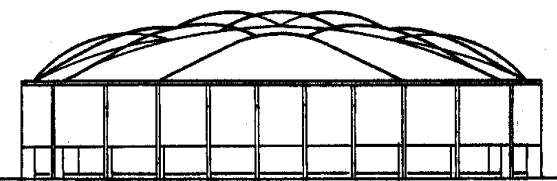
Torusmembranen zwischen gereihten Seilspannungen
Torus membranes between load cables in row formation



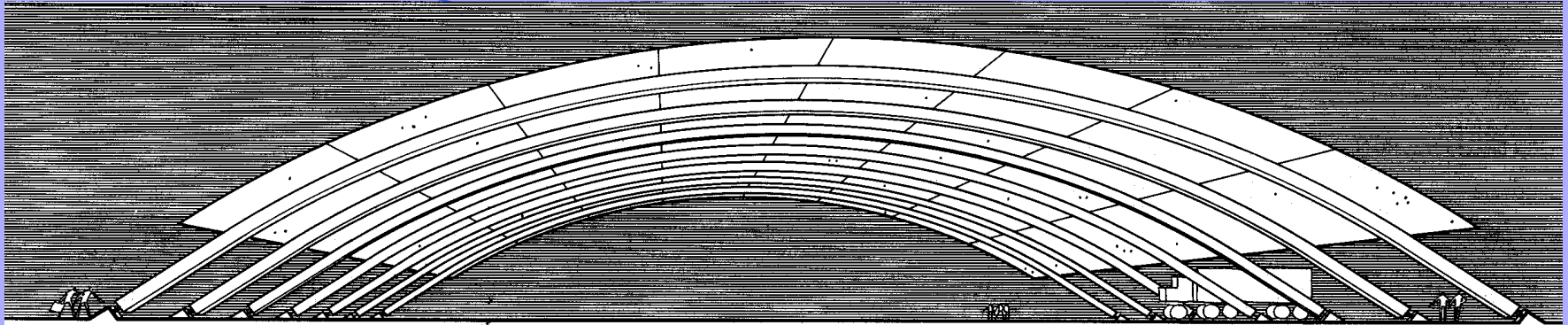
Examples of pneumatic structures



Membrane mit Einzelsell-Abspannung
Membrane with single-cable restraining



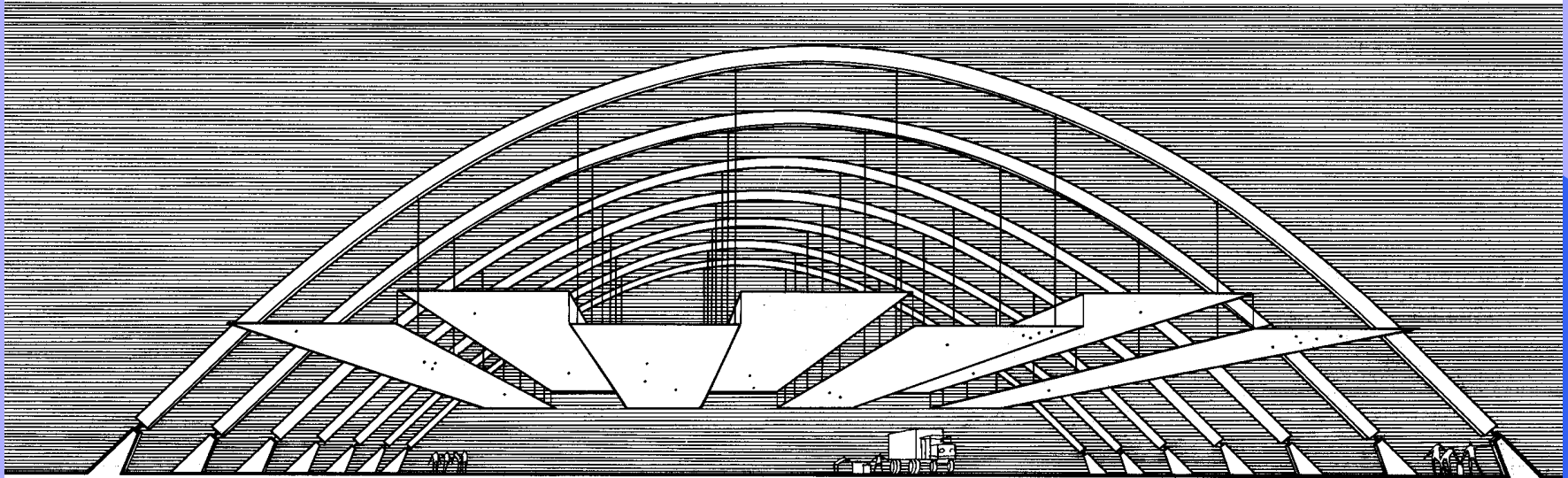
Examples of pneumatic structures



Erdverankerte Bögen mit aufliegender gewölbter Dachkonstruktion
 foundation arches with curved roof structure on top

Form der Stützlinie: Kettenlinie
 funicular curve: catenary

Scheitelhöhe = $\frac{1}{8}$ Spannweite
 arch rise = $\frac{1}{8}$ span



Abgestrebte Bögen mit abgehängter horizontaler Dachkonstruktion
 buttressed arches with suspended horizontal roof structure

Form der Stützlinie: parabolisches Polygon
 funicular curve: parabolic polygon

Scheitelhöhe = $\frac{1}{8}$ Spannweite
 arch rise = $\frac{1}{8}$ span

Examples of arch structures

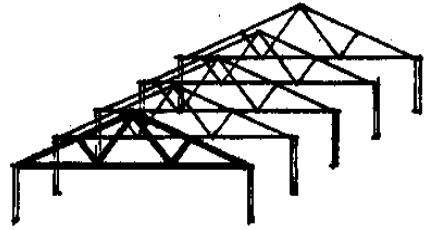
Vector active structural systems

. . . are systems of short, solid, straight lineal members, in which the redirection of forces is effected by vector partition, i.e. by multi-directional splitting of single force simply to tension or compressive elements

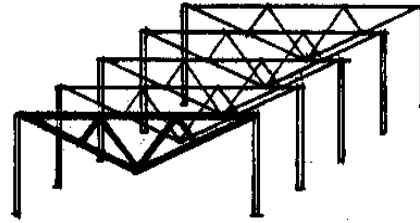
Example of structures:

1. Flat trusses
2. Curved trusses
3. Space trusses

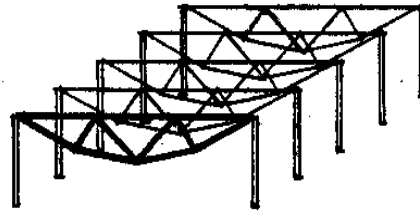
Flat truss systems



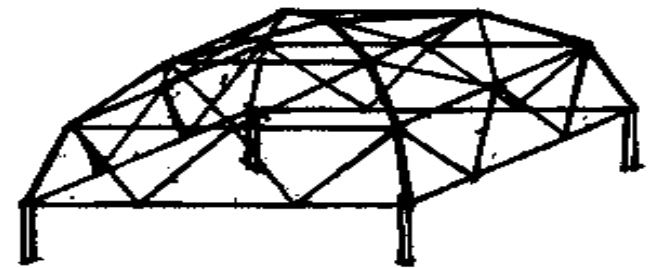
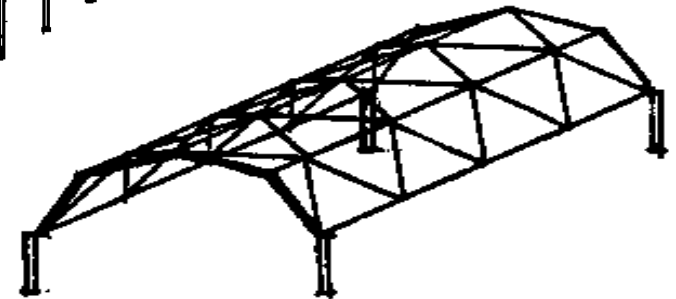
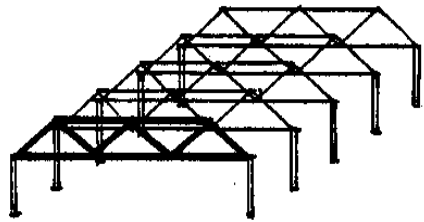
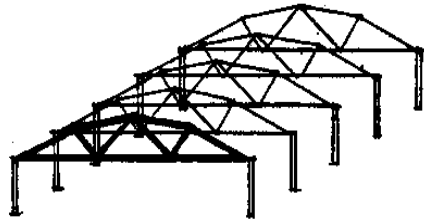
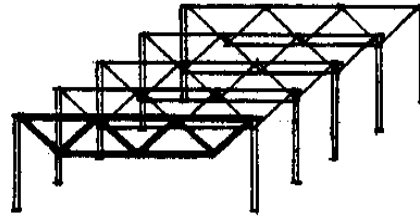
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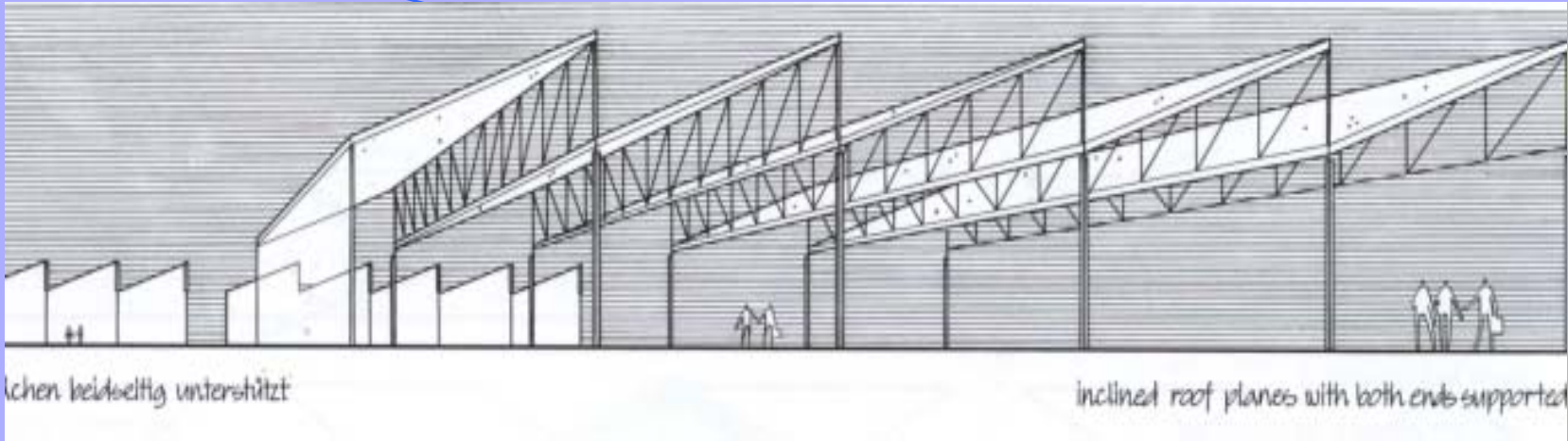
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3

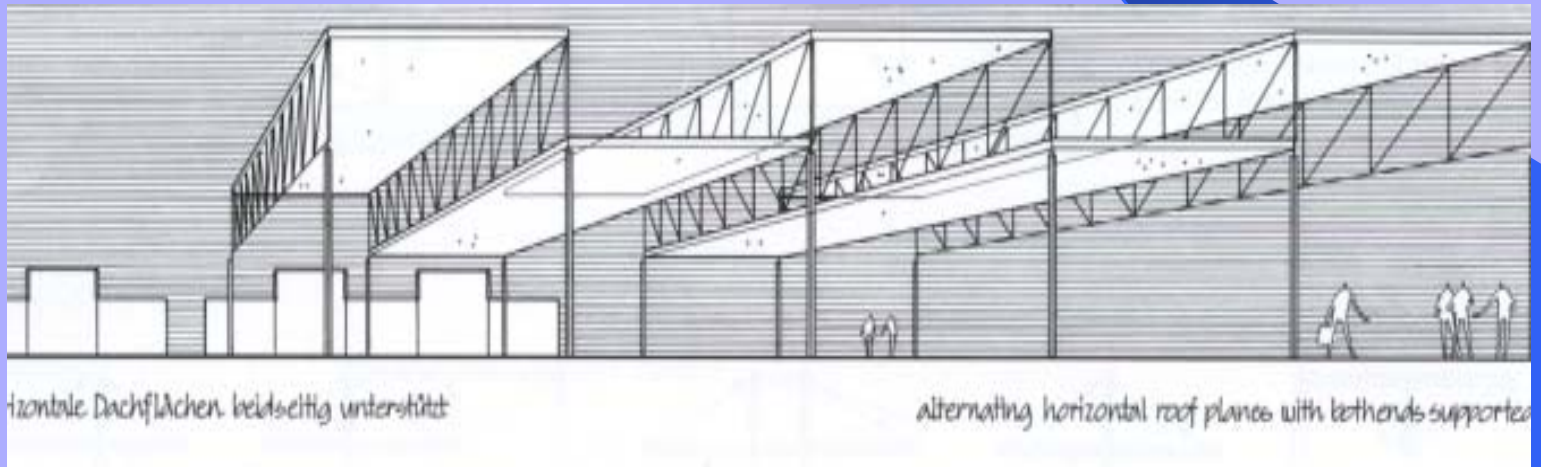


curved truss systems



Inclined roof planes with both ends supported

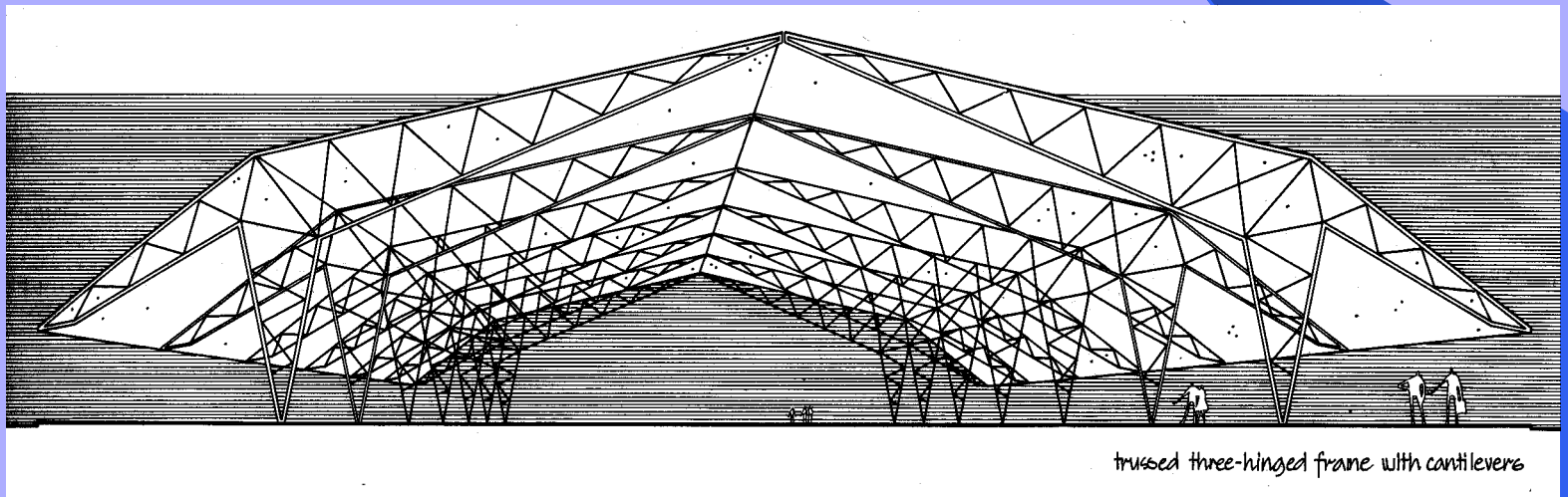
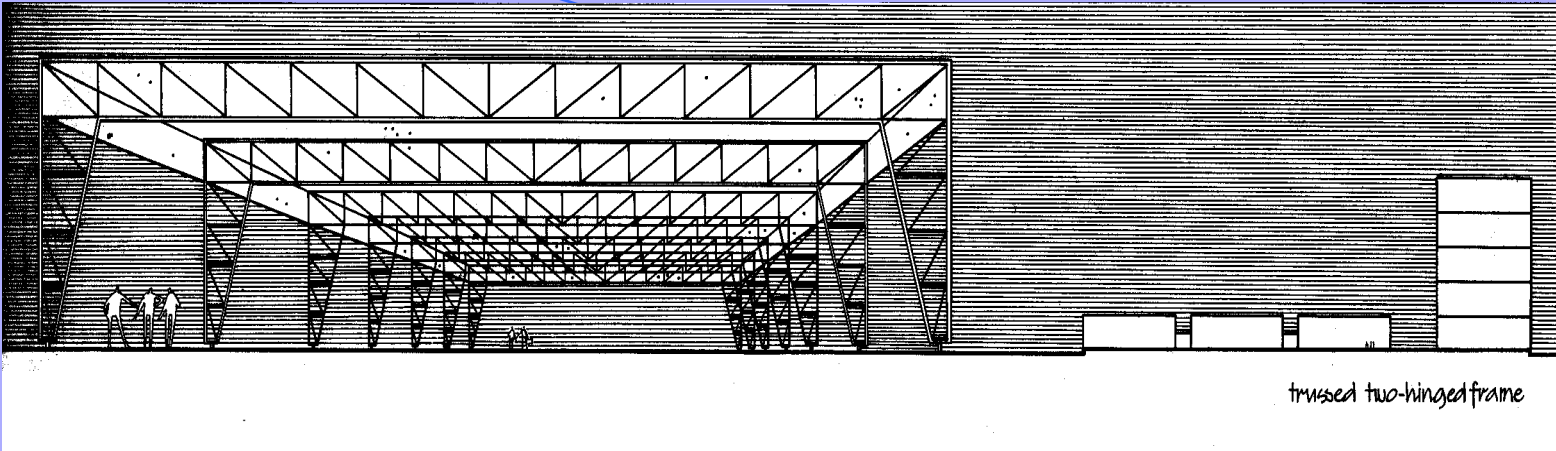
inclined roof planes with both ends supported



Alternating horizontal roof planes with both ends supported

alternating horizontal roof planes with both ends supported

Illustrated examples of flat truss structures



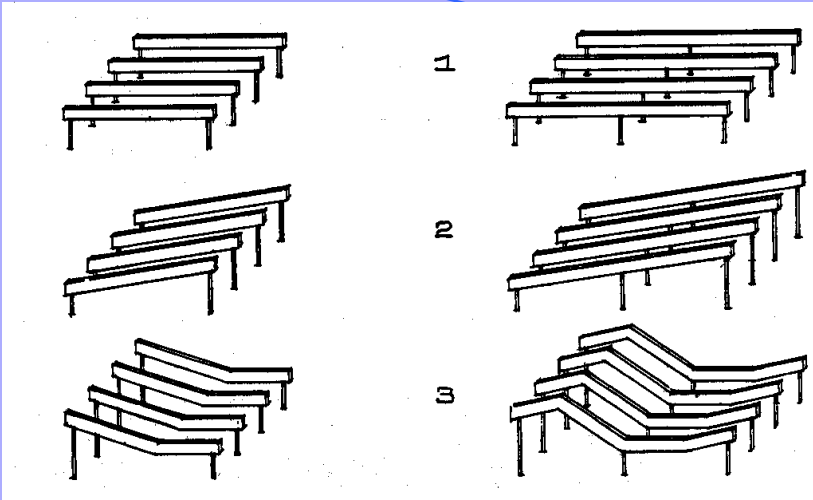
Illustrated examples of hinged truss structures

Section active structural systems

. . . are systems of rigid, solid, linear elements, in which redirection of forces is effected by mobilization of sectional forces

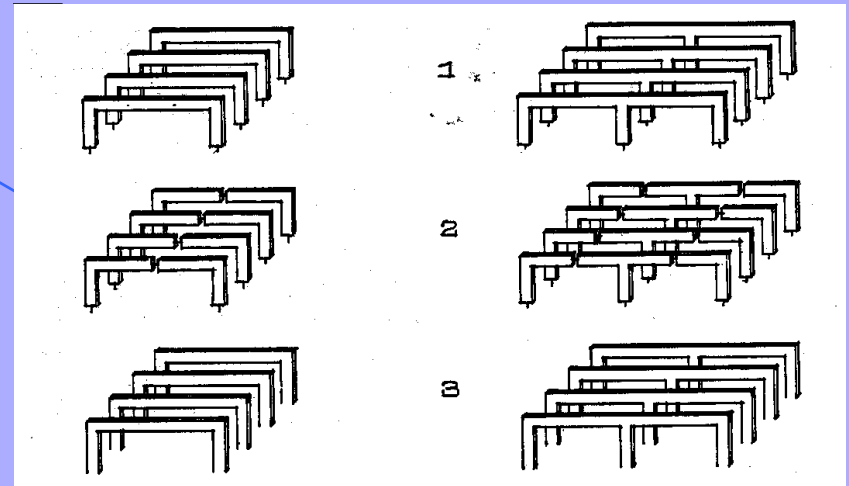
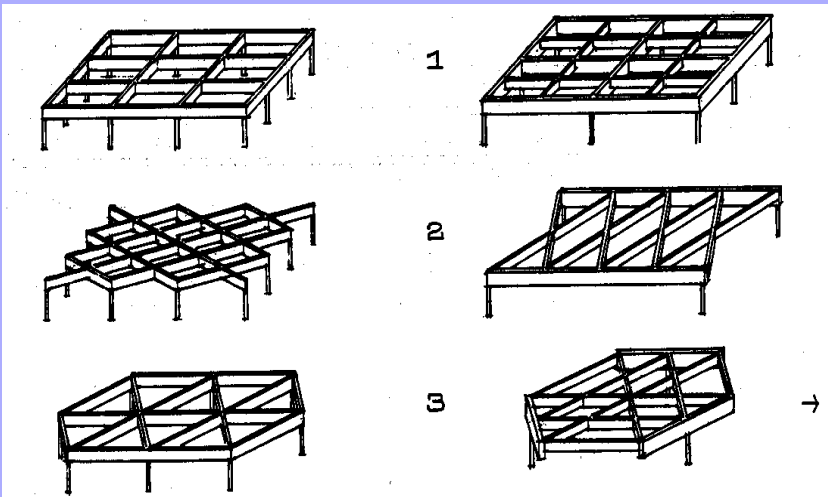
Example of structures:

1. Beam structures
2. Frame structures
3. Slab structures



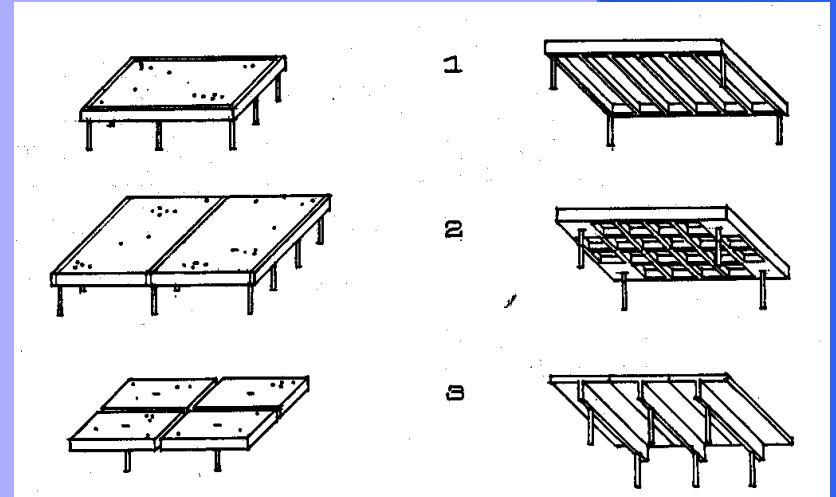
1 & 2 bay beams

Beam-grid systems

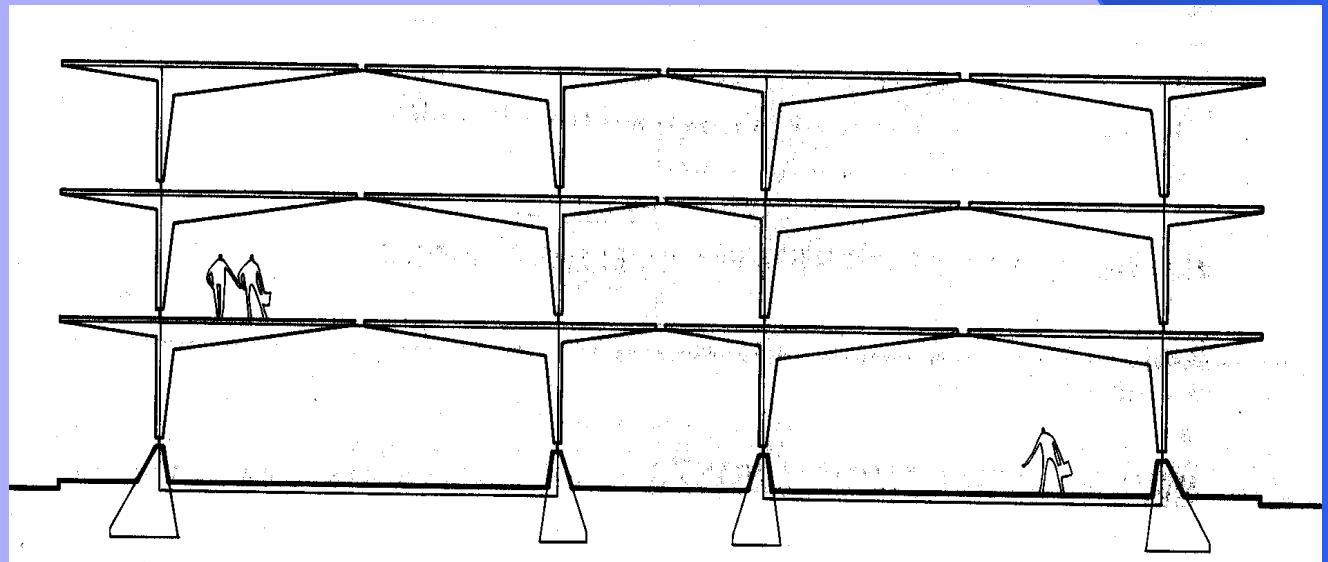
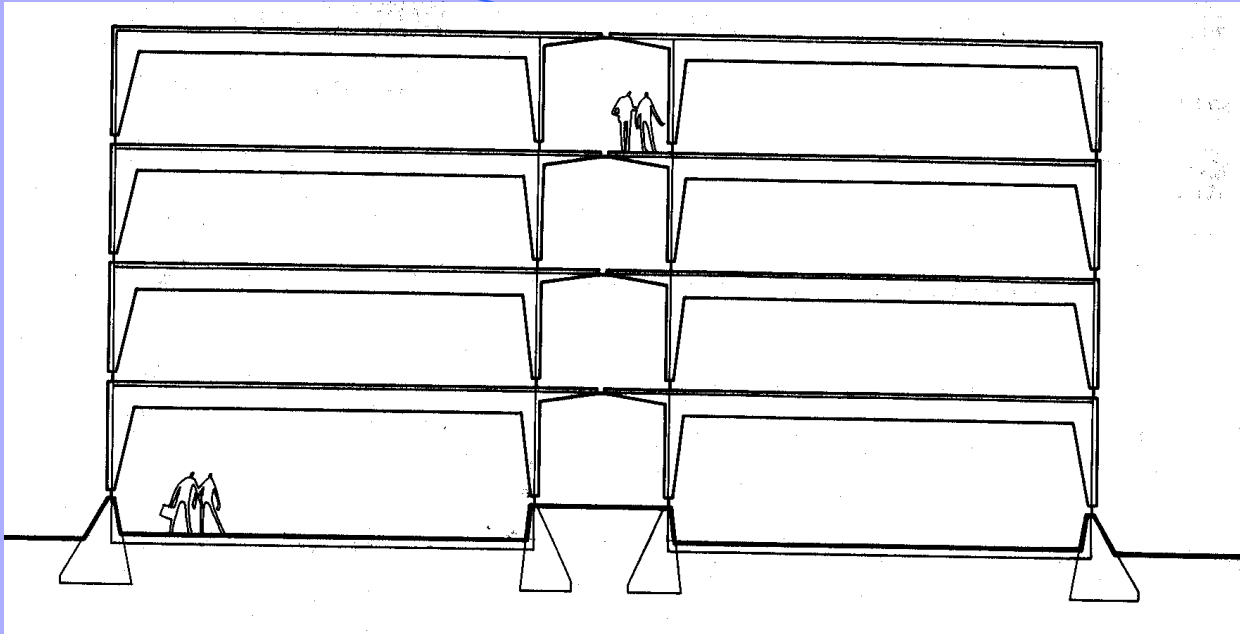


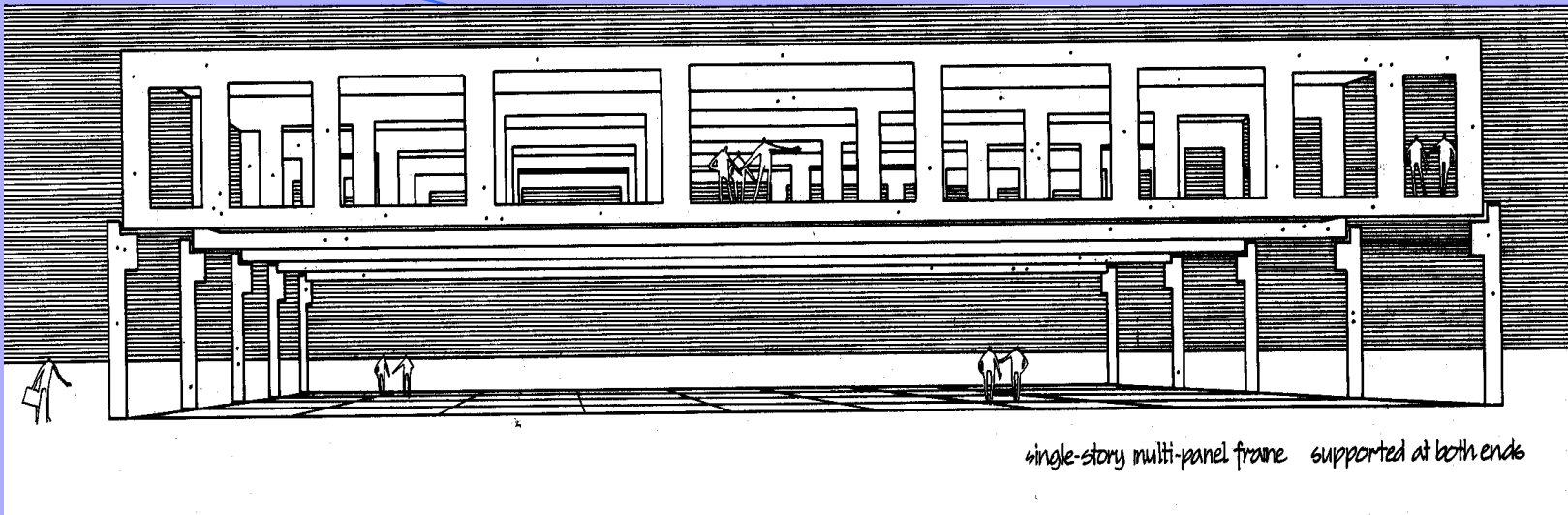
1 & 2 bay frames

Slab structures

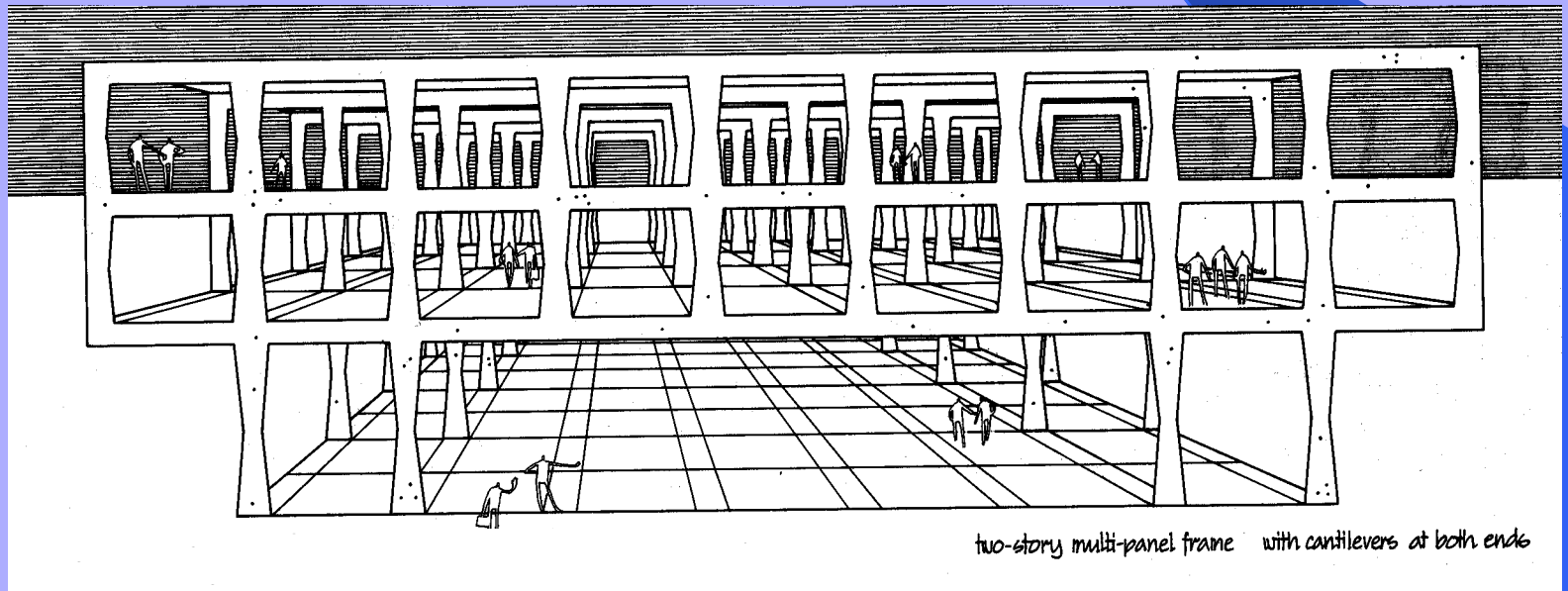


Hinged frame structures





single-story multi-panel frame supported at both ends



two-story multi-panel frame with cantilevers at both ends

Illustrated examples of multi-panel frame structures

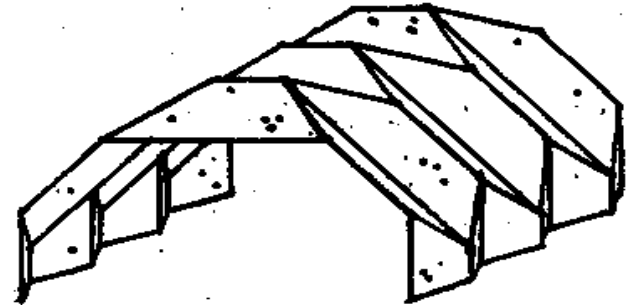
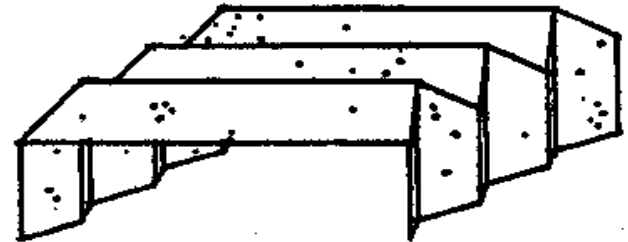
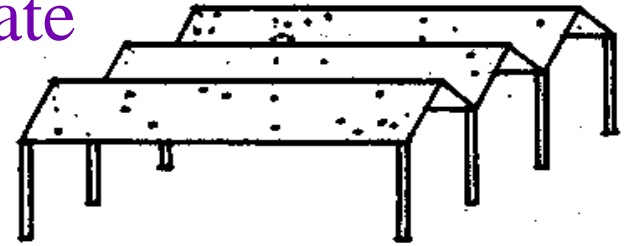
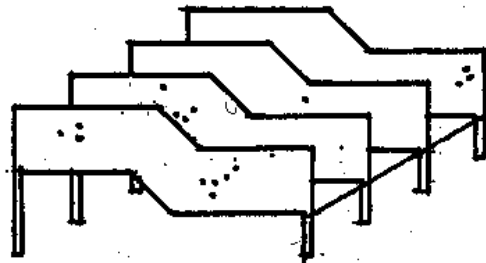
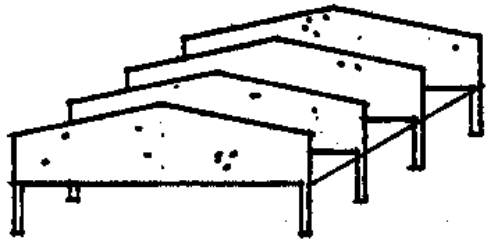
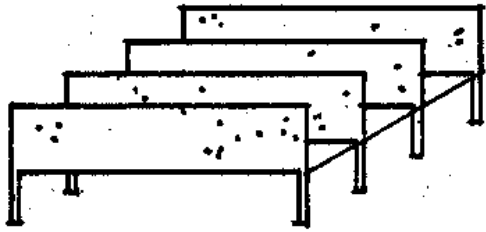
Surface active structural systems

... are systems of flexible or rigid planes able to resist tension, compression or shear, in which the redirection of forces is effected by mobilization of sectional forces

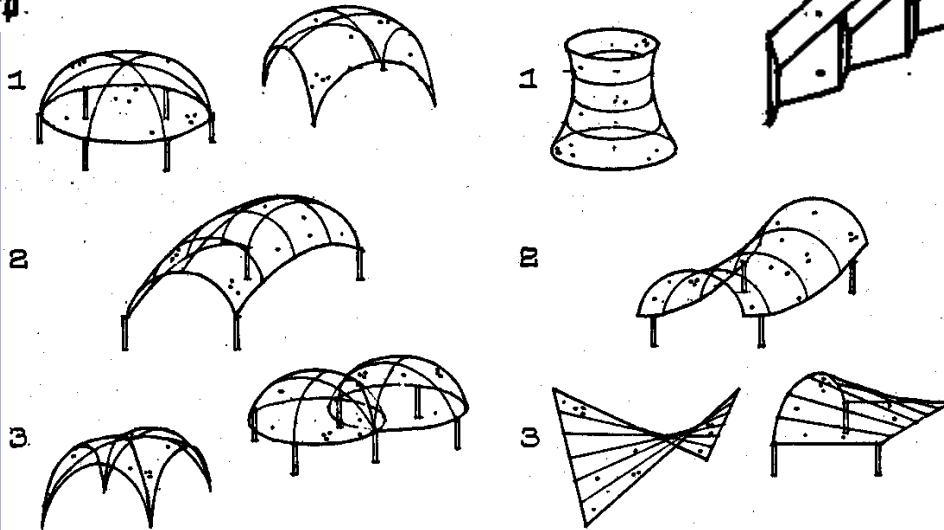
Example of structures:

1. Plate structures
2. Folded structures
3. Shell structures

Folded plate

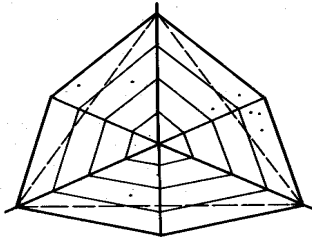


Multi-bay structures

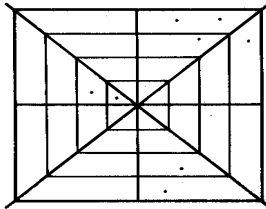
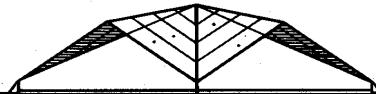
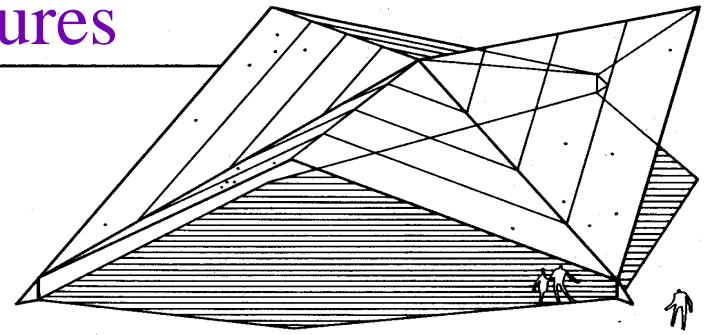


Shell structures

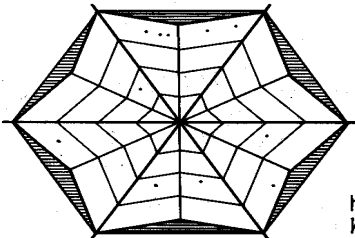
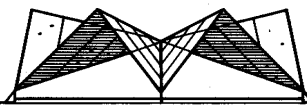
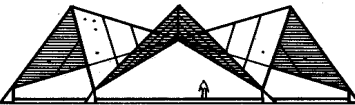
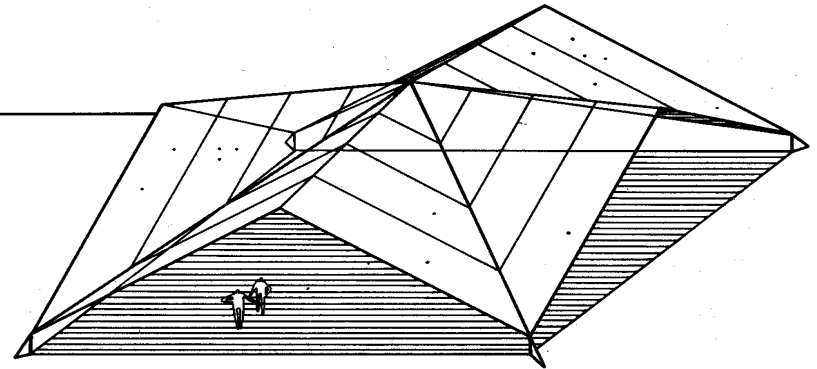
Various forms of folded structures



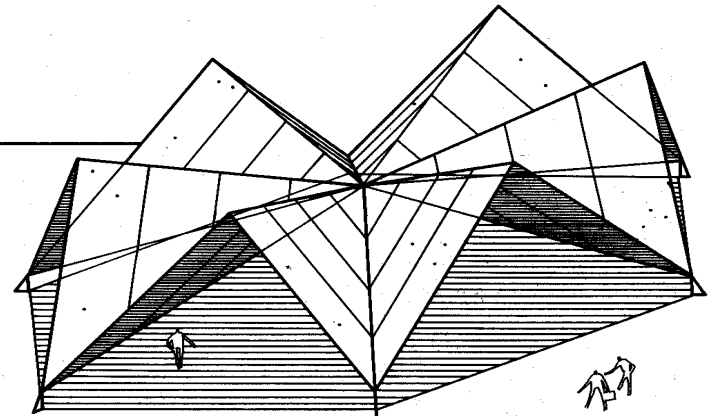
Dreieckiger Grundriß, waagrechte Firstlinien
triangular floor plan, horizontal ridges



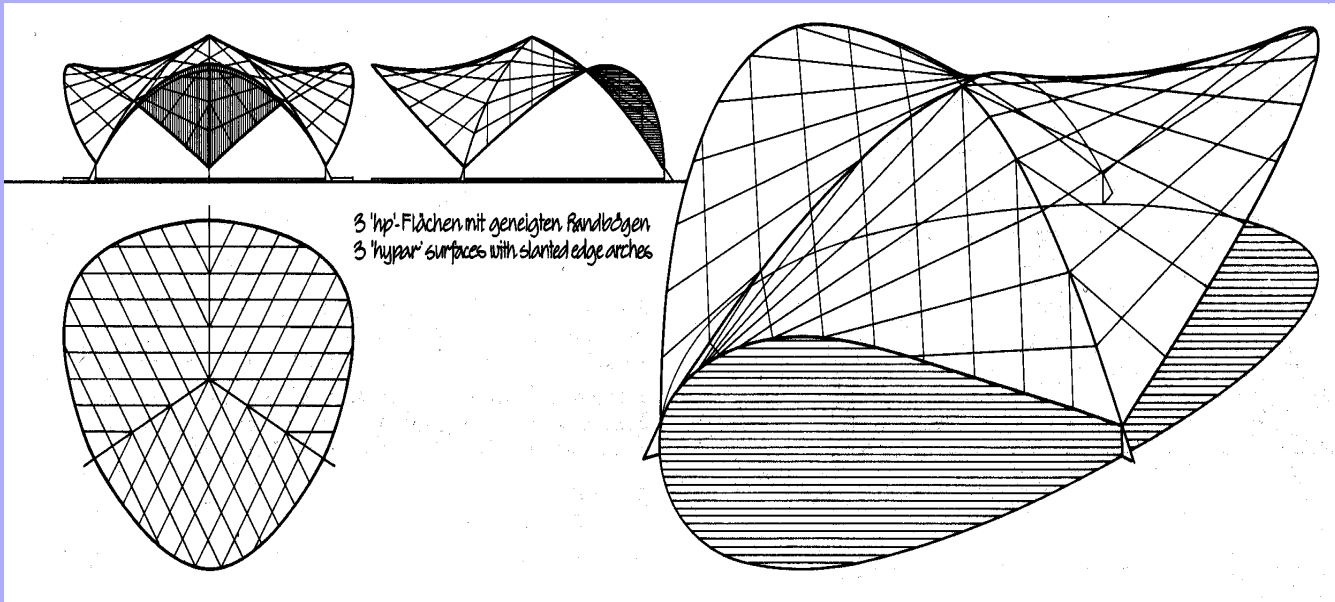
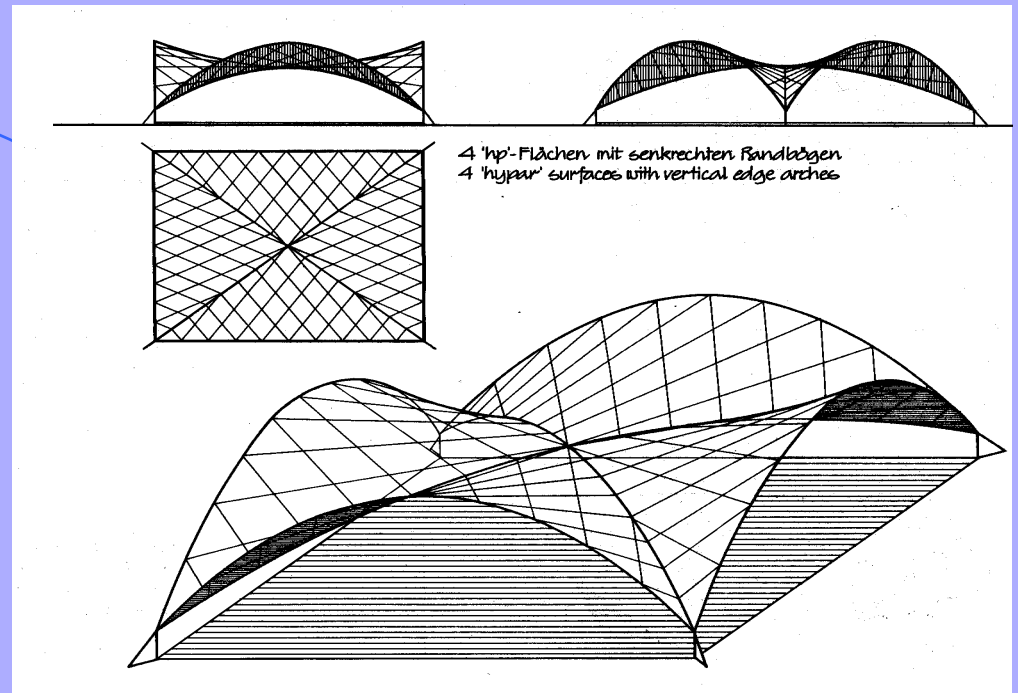
Quadratischer Grundriß, fallende Firstlinien
square floor plan, ridges rising toward center



Hexagonaler Grundriß, steigende Firstlinien
hexagonal floor plan, ridges sloping to center



Examples of shell structures



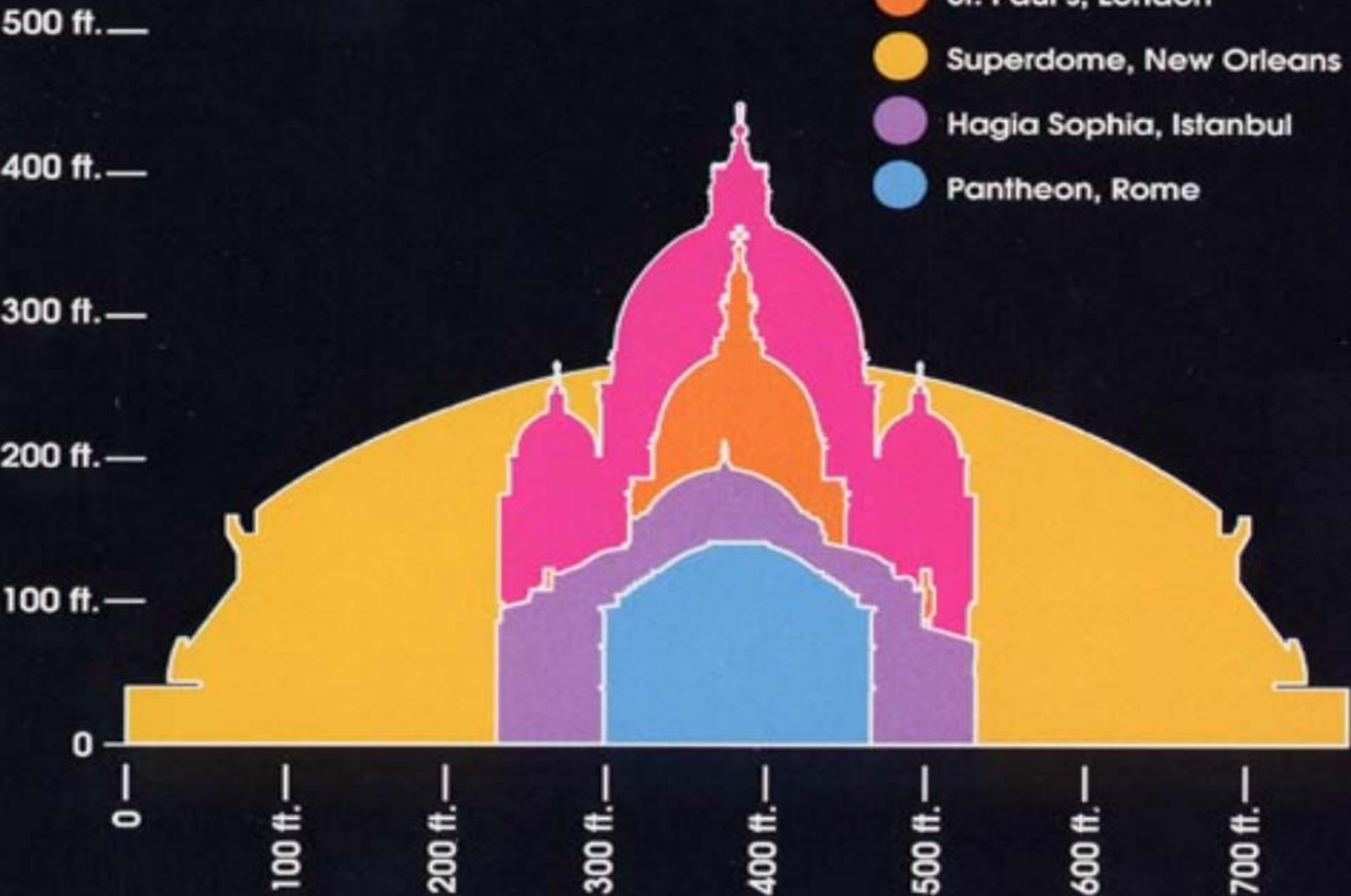
Single Storey Long Span Structure

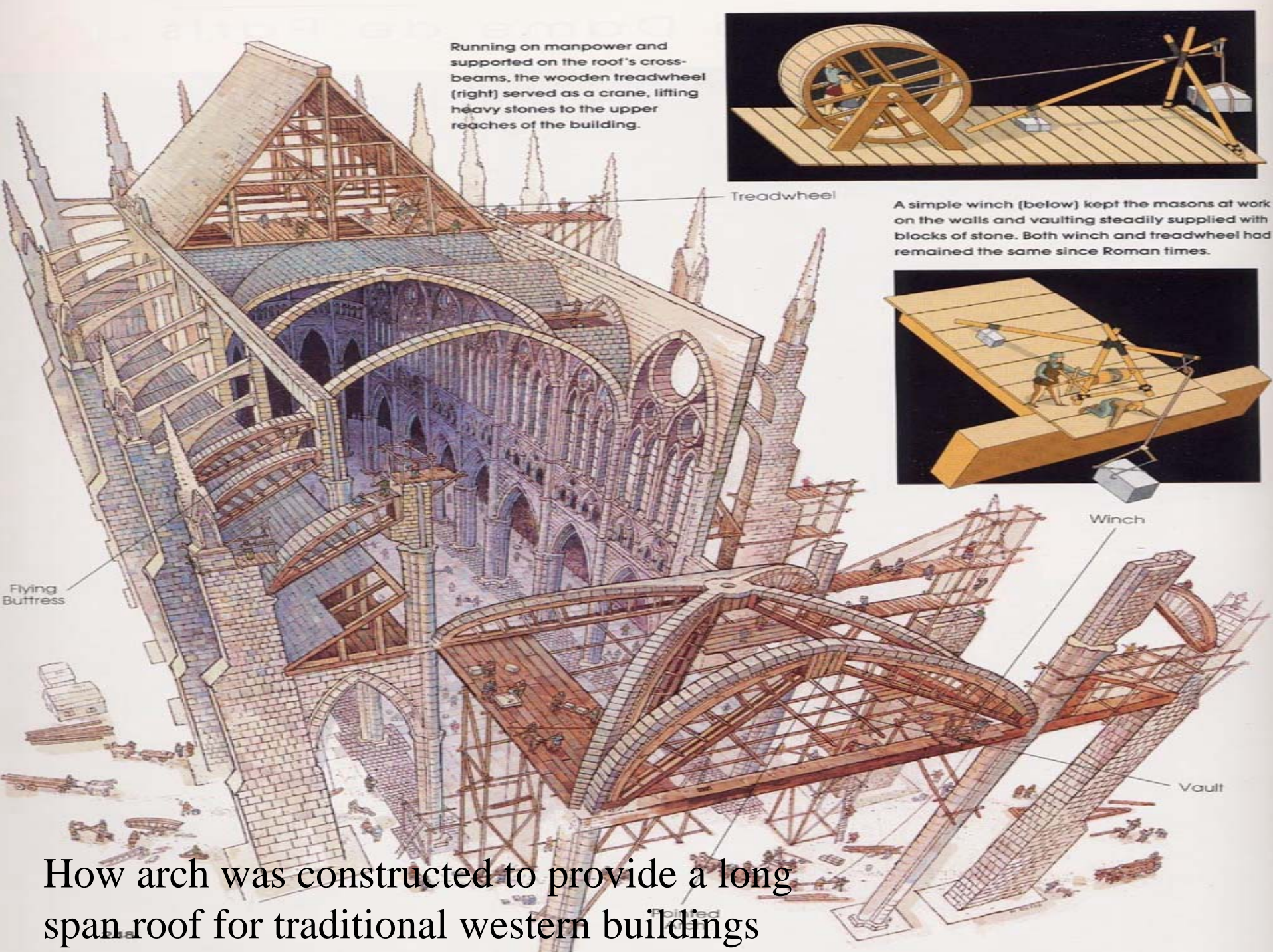
Actual Example



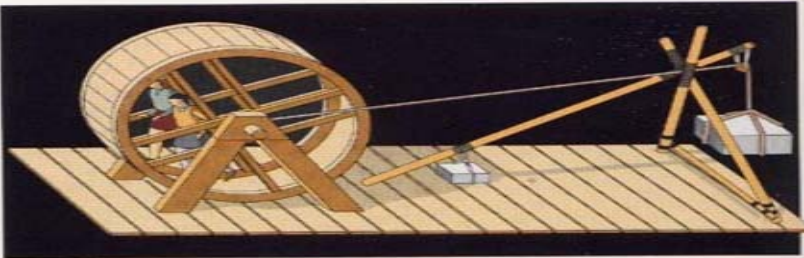
Development History of Long Span Structure

The development of long span structures



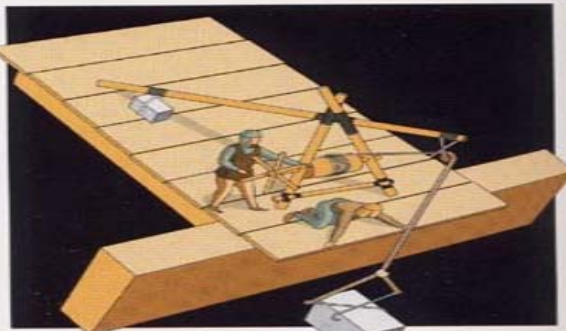


Running on manpower and supported on the roof's cross-beams, the wooden treadwheel (right) served as a crane, lifting heavy stones to the upper reaches of the building.



Treadwheel

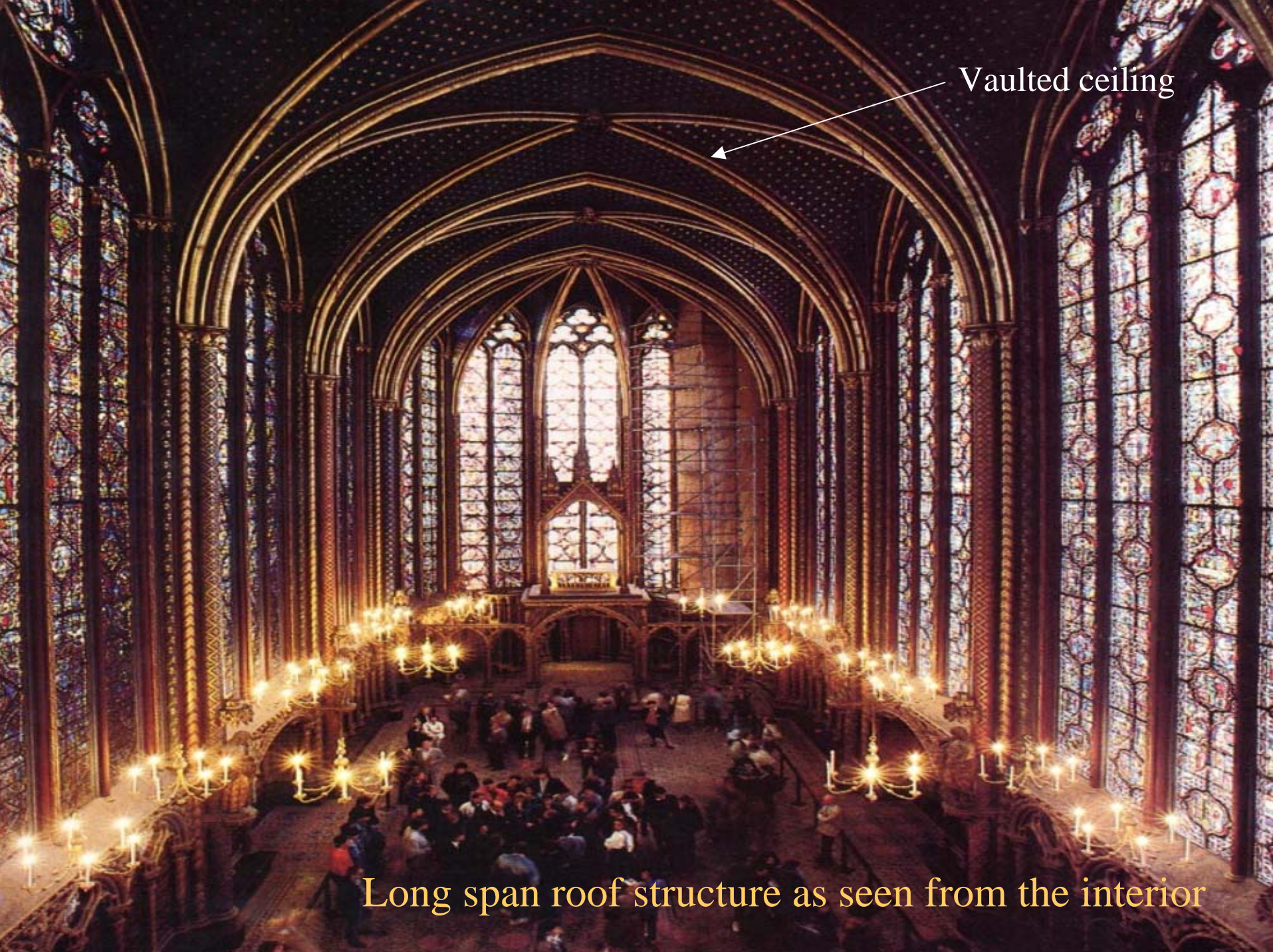
A simple winch (below) kept the masons at work on the walls and vaulting steadily supplied with blocks of stone. Both winch and treadwheel had remained the same since Roman times.



Winch

Vault

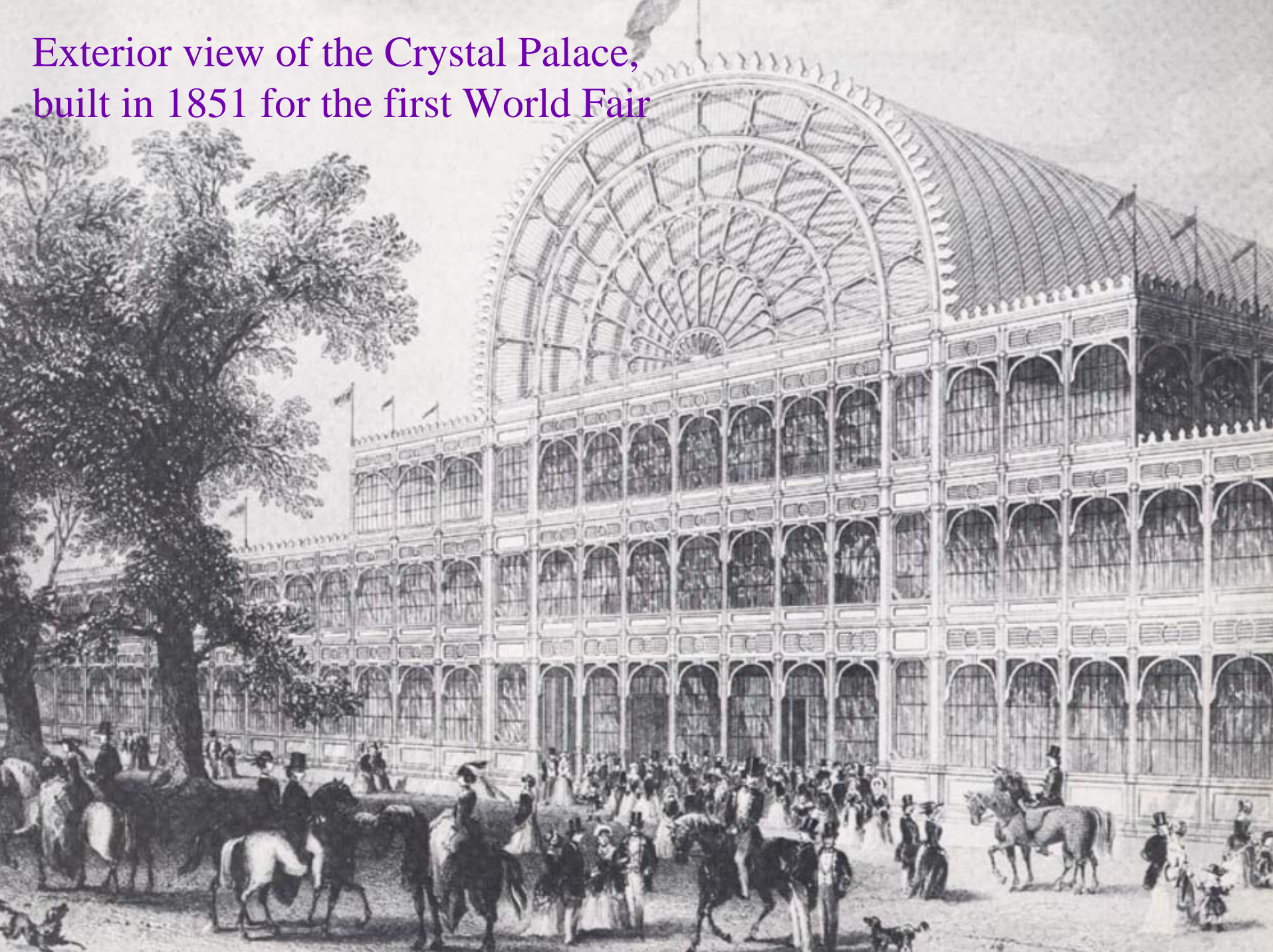
How arch was constructed to provide a long span roof for traditional western buildings

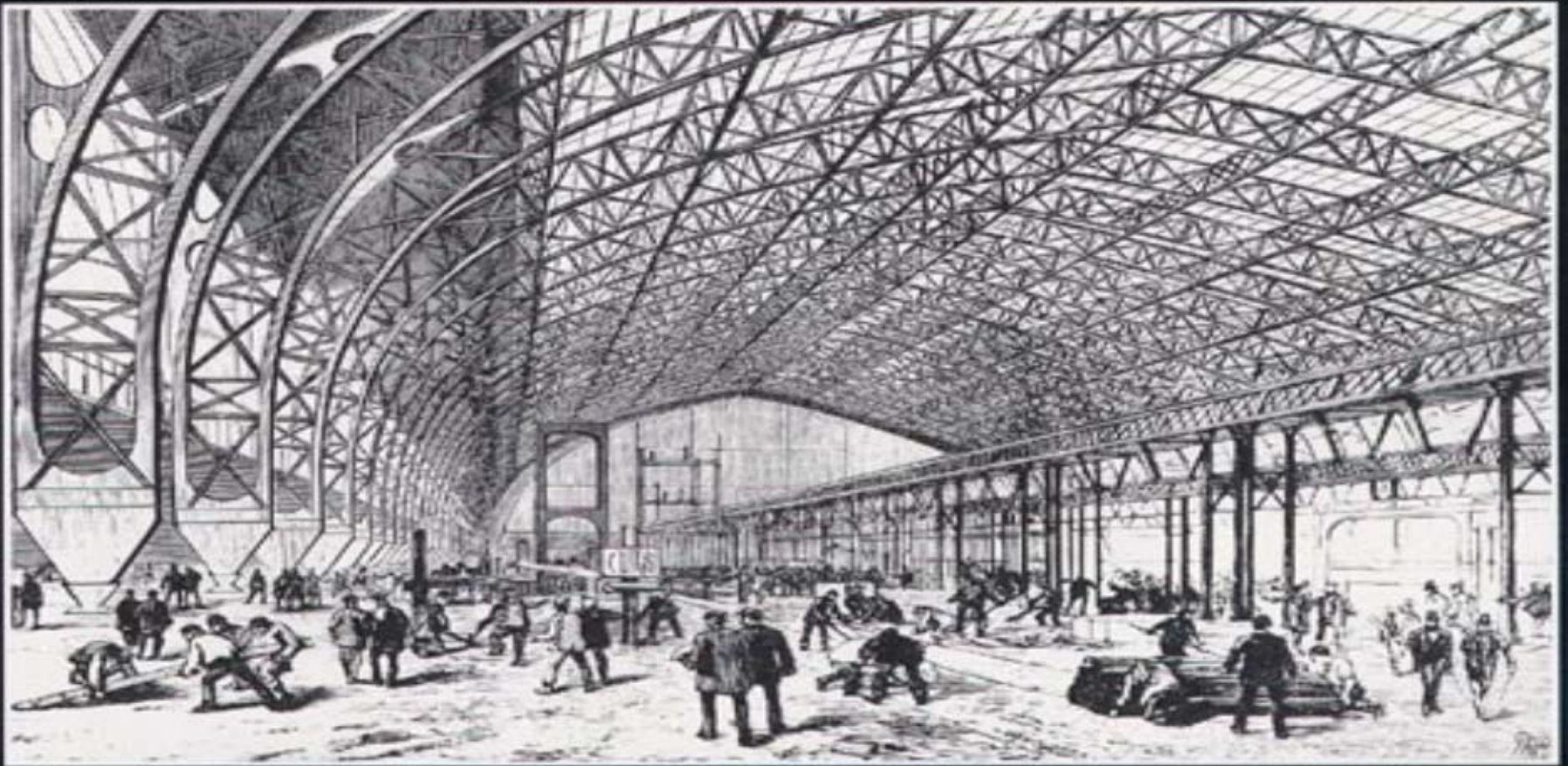


Vaulted ceiling

Long span roof structure as seen from the interior

Exterior view of the Crystal Palace,
built in 1851 for the first World Fair





Designed to celebrate French industrial prowess, the 1889 Paris Exhibition also marked the centenary of the French Revolution. The Gallery of Machines, on the Champs de Mars opposite the Eiffel Tower, was itself an engineering triumph. Framed in the new harder and stronger material—steel—instead of iron like the Crystal Palace, the Gallery's glass panels were fixed to its exterior, shaping a vast inner, seemingly limitless, space. Twenty pairs of hinged girders formed arches apex. The pin supports at the arches' to building to flex if its metal expanded. The strikingly innovative building was a

The Gallery of Machine, constructed in 1889 for the Paris Exhibition



Simple Example in Hong Kong

Span about 35m

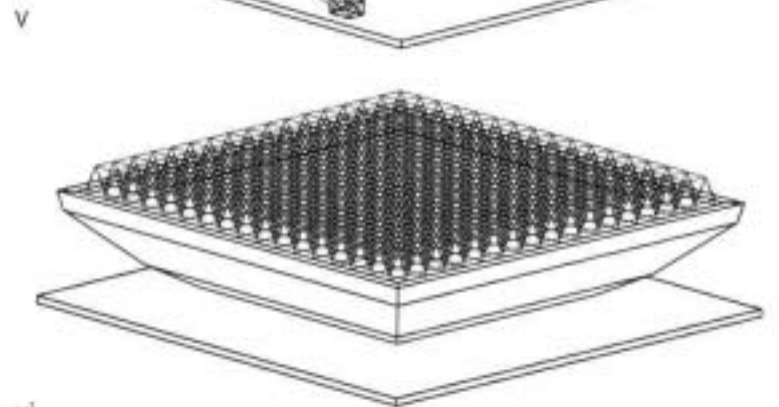
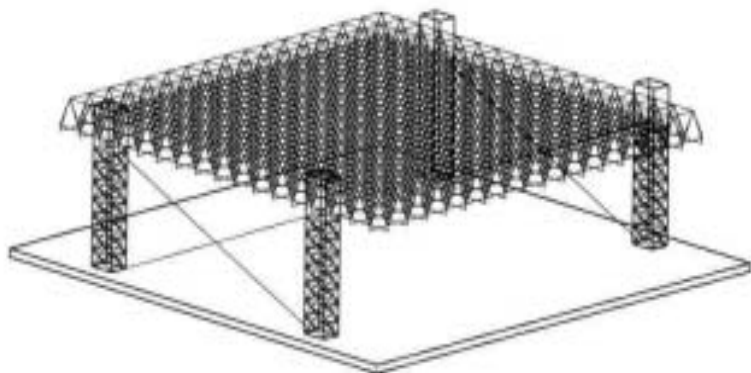
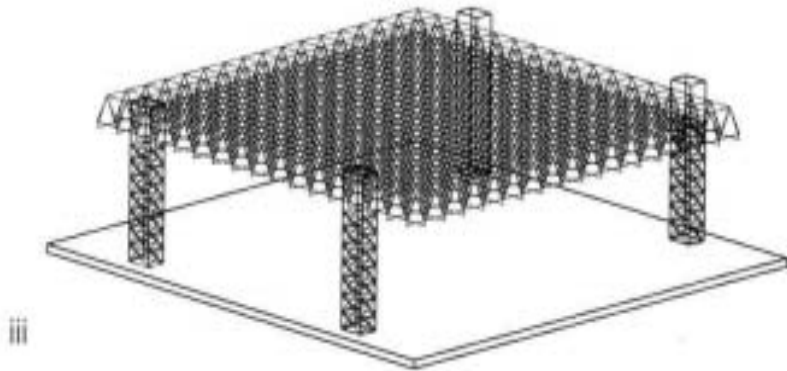
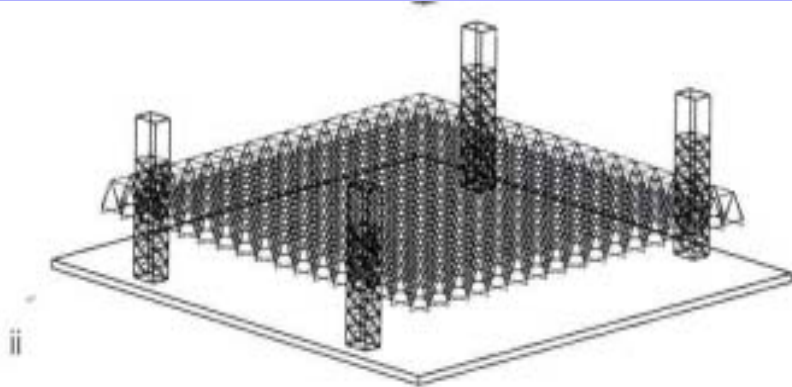


Member Centre of the
Hong Kong Jockey Club

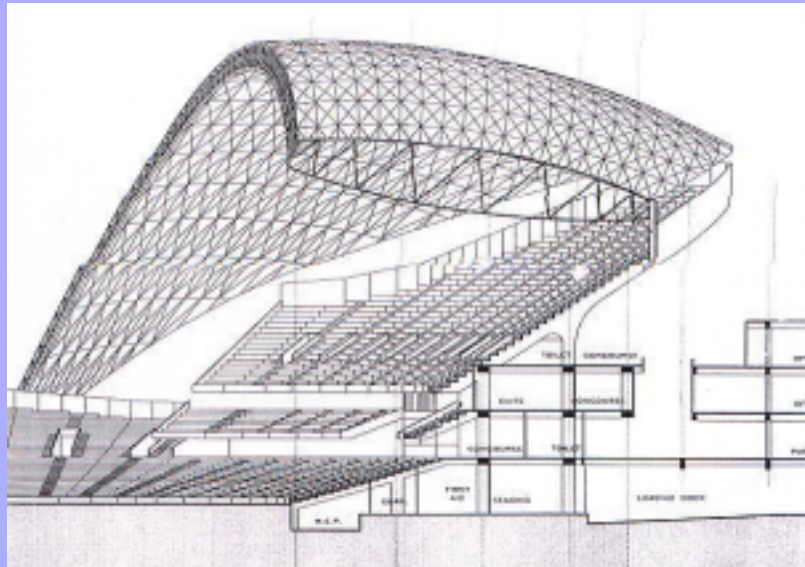
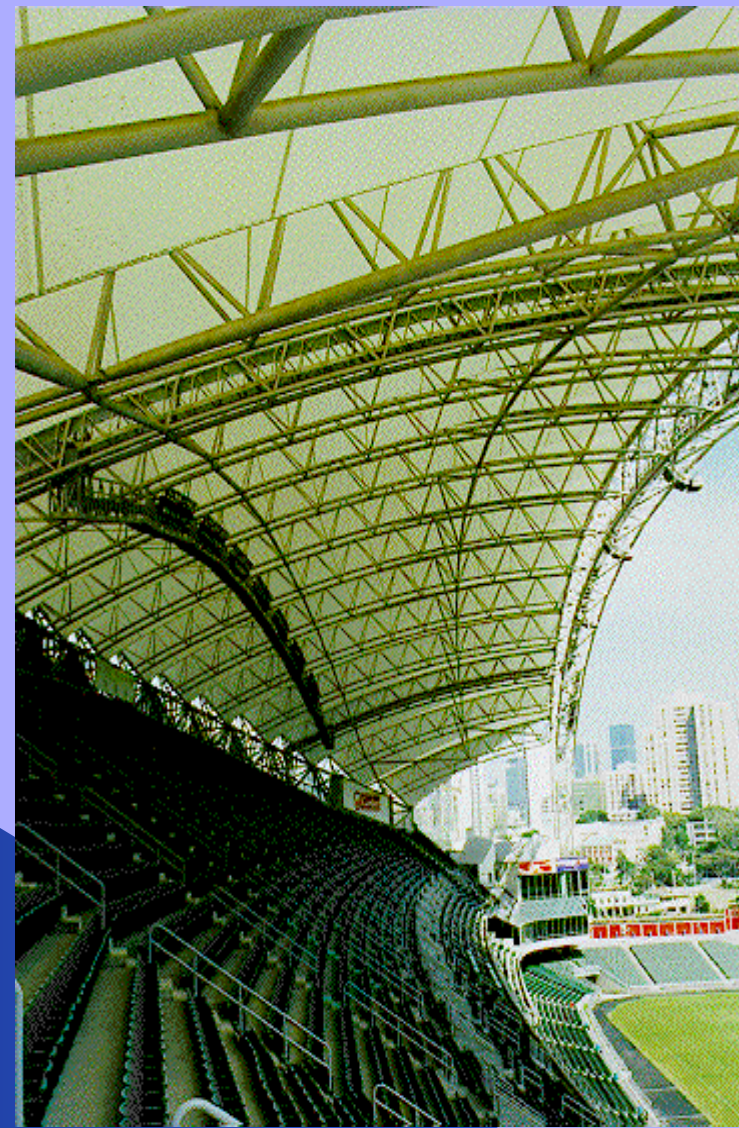


The Hong Kong coliseum





The Hong Kong coliseum

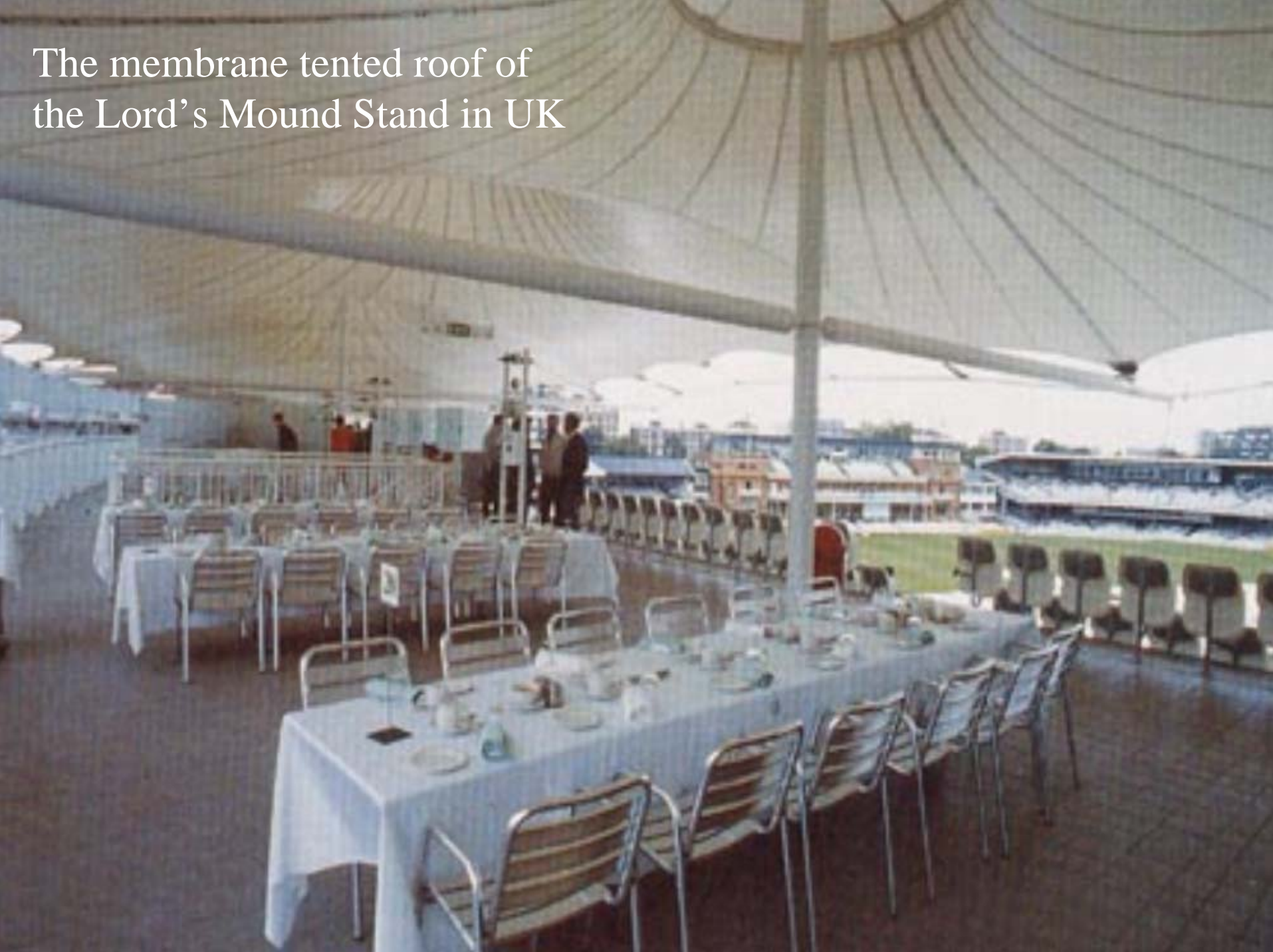


The Hong Kong Stadium

Other Overseas Examples

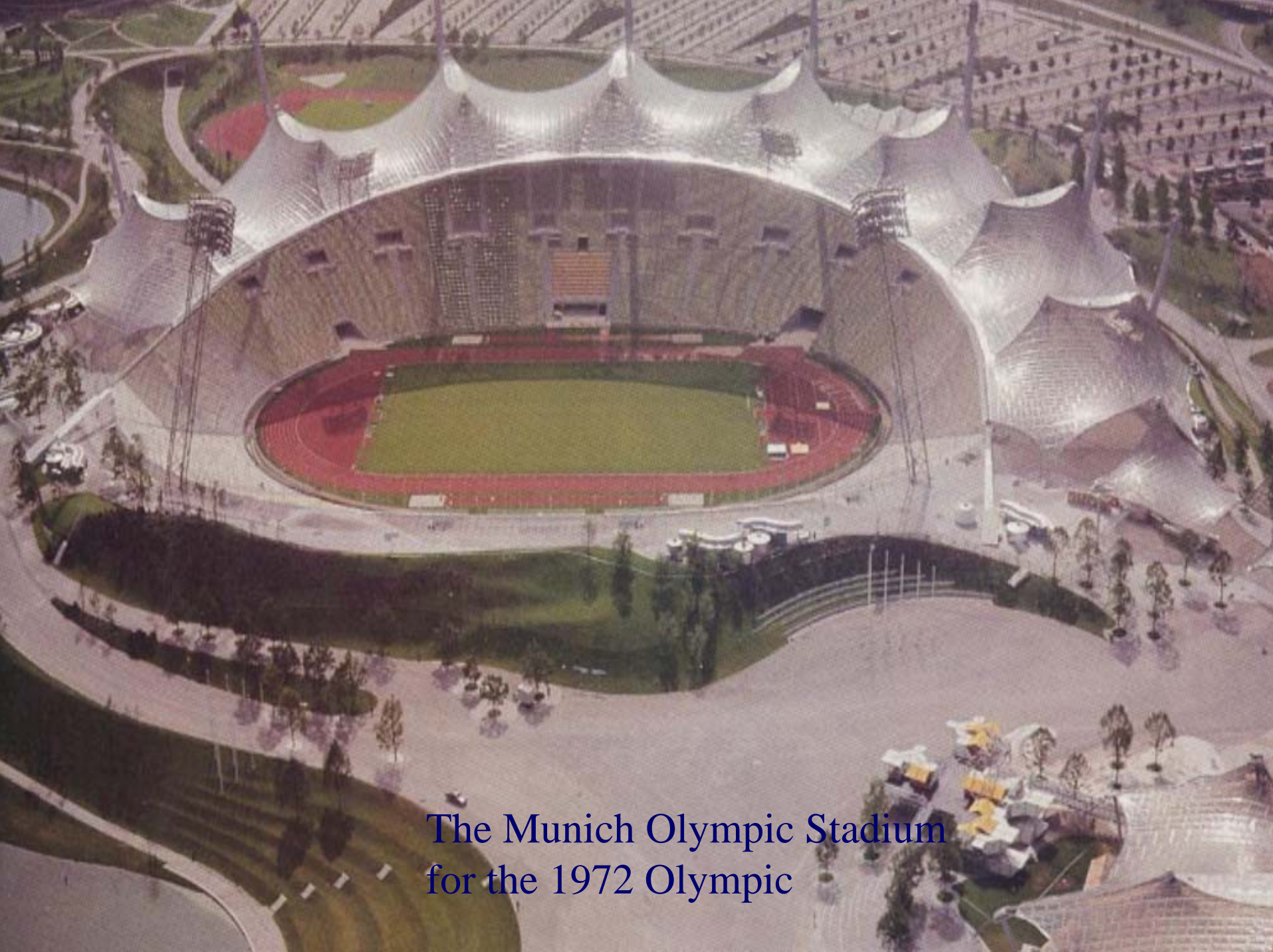
Lord's Mound Stand

The membrane tented roof of the Lord's Mound Stand in UK



Other Overseas Examples

The Munich Olympic Stadium



The Munich Olympic Stadium
for the 1972 Olympic



Detail of the tie member joining nod

Other Overseas Examples

The Melbourne Central







An openable roof operating
on a Rail system





Other Overseas Examples

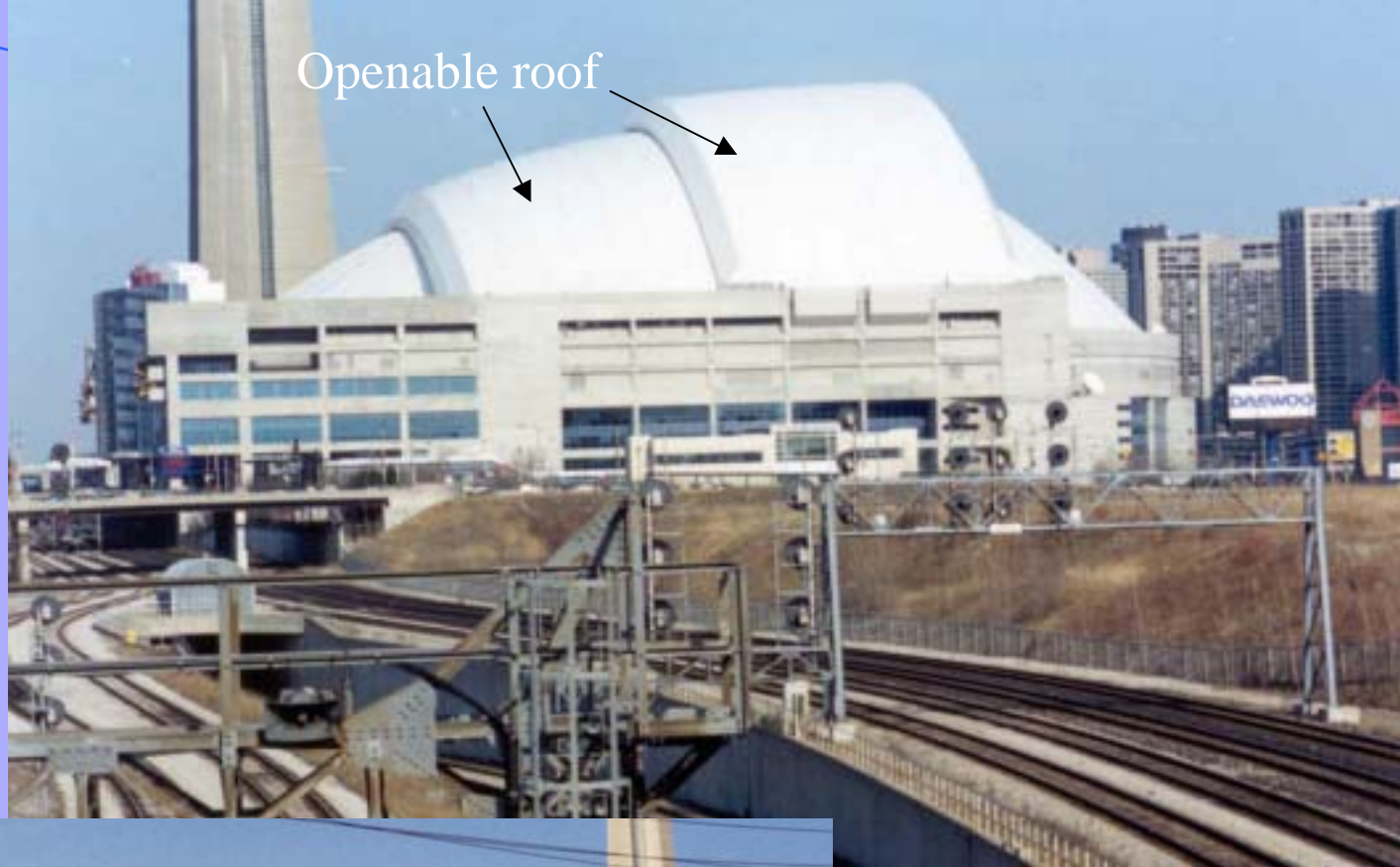
Sky Dome, Toronto

Toronto Tower

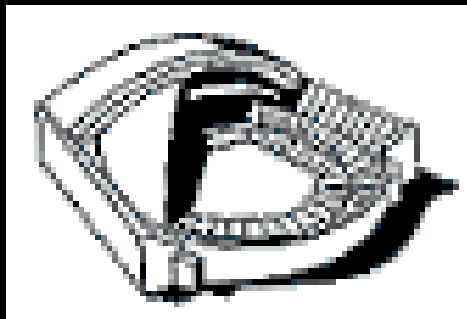
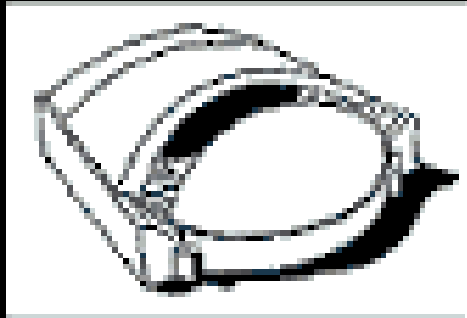
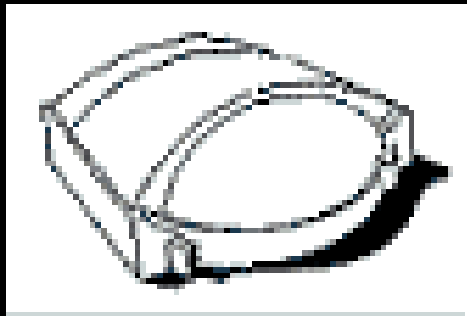
The Skydome



Openable roof

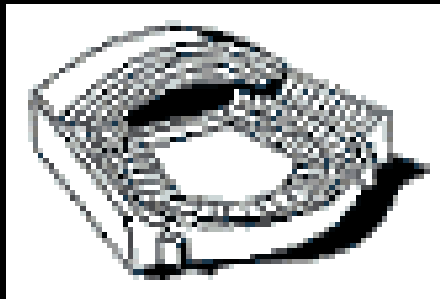
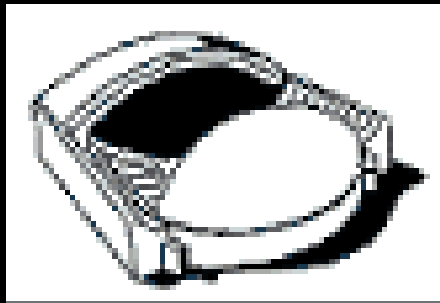






SkyDome is the first and only stadium to have a fully retractable roof. When the weather is good, usually from April 1 - October 1, we are able to roll back the roof, uncovering the complete field area and over 91% of the seats.

- The roof consists of four panels. One panel is fixed, and the other three are moveable.
- Panel One rotates around 180 degrees while Panels Two and Three telescope straight forward.
- The roof runs on a system of steel tracks and bogies. There are 76 bogies altogether, with 10 horsepower motors inside for a total of 760 horsepower.
- It takes 20 minutes for the roof to open or close as it moves at a rate of 71 feet (21 metres) per minute.
- The roof is made up of steel trusses covered by corrugated steel cladding. Covering the cladding (acting as a weather-proofing) is a PVC single ply membrane.
- It weighs 11,000 tons, the same weight as 3,734 automobiles.
- The roof spans eight acres and rises 282 feet (from field level) at its highest point.
- There are 250,000 bolts in the roof.



The Skydome

Features of the roof system

- SkyDome's roof system features a series of 3 moveable panels and 1 stationary panel.
- the roof operates on a system of steel tracks and is powered by a series of DC motors
- roof area is 31,525 sq metres
- weight is 11,000 tons
- span at widest point 209 metres
- height is 85m (from field level to highest point)
- roofing material is PVC on insulated acoustic steel deck
- 100% of the field & 91% of seating area exposed with the roof open
- pen/close time - 20 minutes (21m per minute)

Other Overseas Examples

Charles-de-Gaulle International
Airport, France

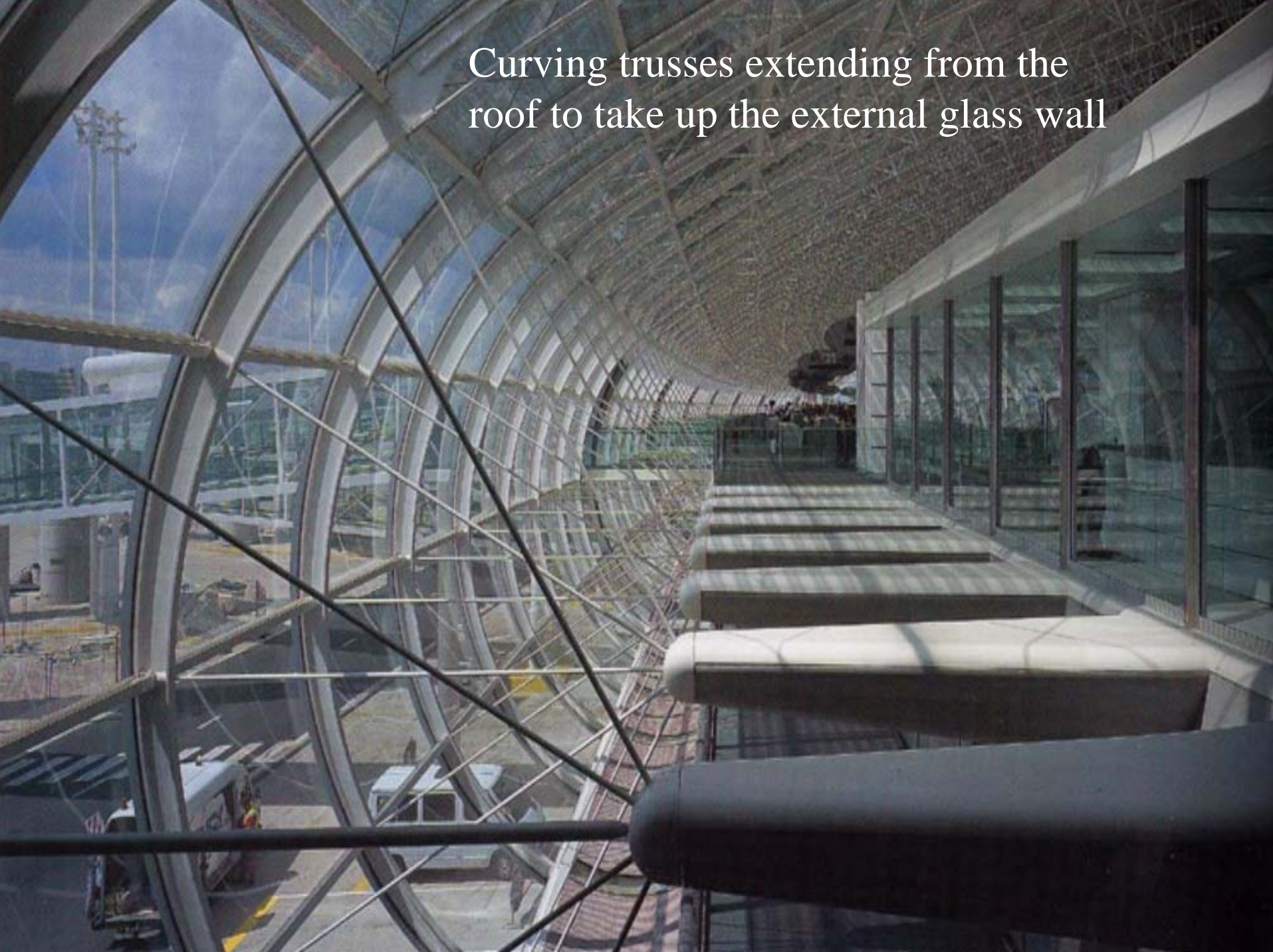
Charles-de-Gaulle
International Airport, France,
completed in 1998



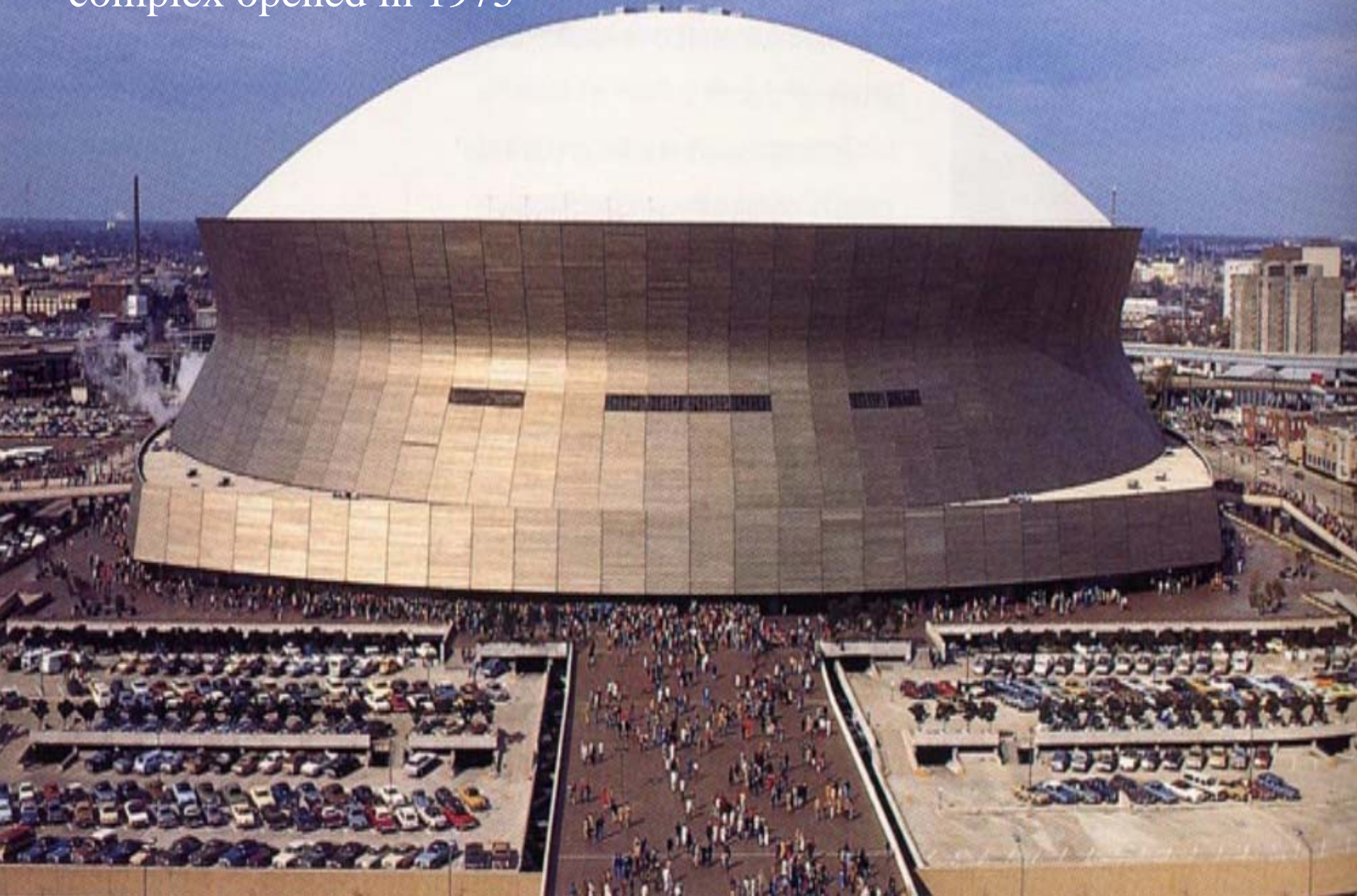
Interior view of the
airport concourse



Curving trusses extending from the roof to take up the external glass wall



The Louisiana Superdome, USA – a 580m clear span sport complex opened in 1975





Erecting the steel trusses for the Superdome, the towering structures in majority are the temporary supporting to facilitate the erection

Other Overseas Examples

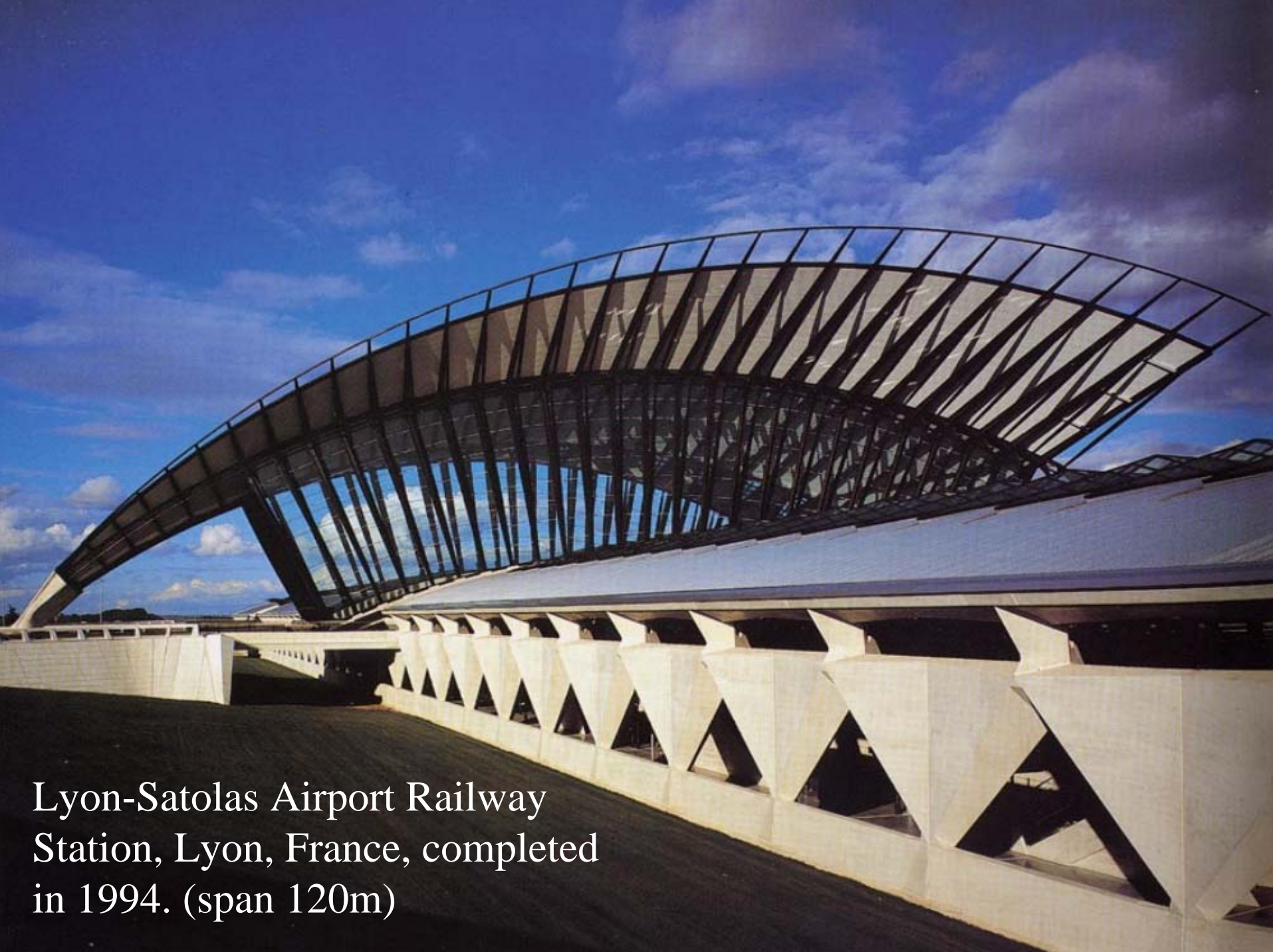
Tenerife Exhibition Central Stadium

Tenerife Exhibition Centre in Spain, a shallow arch structure of 270m span completed in 1995.





85m-span ribbed arch that formed the podium deck of the exhibition space which is constructed by in-situ, post-tensioned concrete



Lyon-Satolas Airport Railway
Station, Lyon, France, completed
in 1994. (span 120m)



Station interior under the 120m span roof

Example in China –

The Guangzhou Olympus Stadium



External view of Stadium



Detail showing the form and shape of the cantilevered roof



Hoisting the cantilever truss



Placing the roof
truss in position





Tie systems

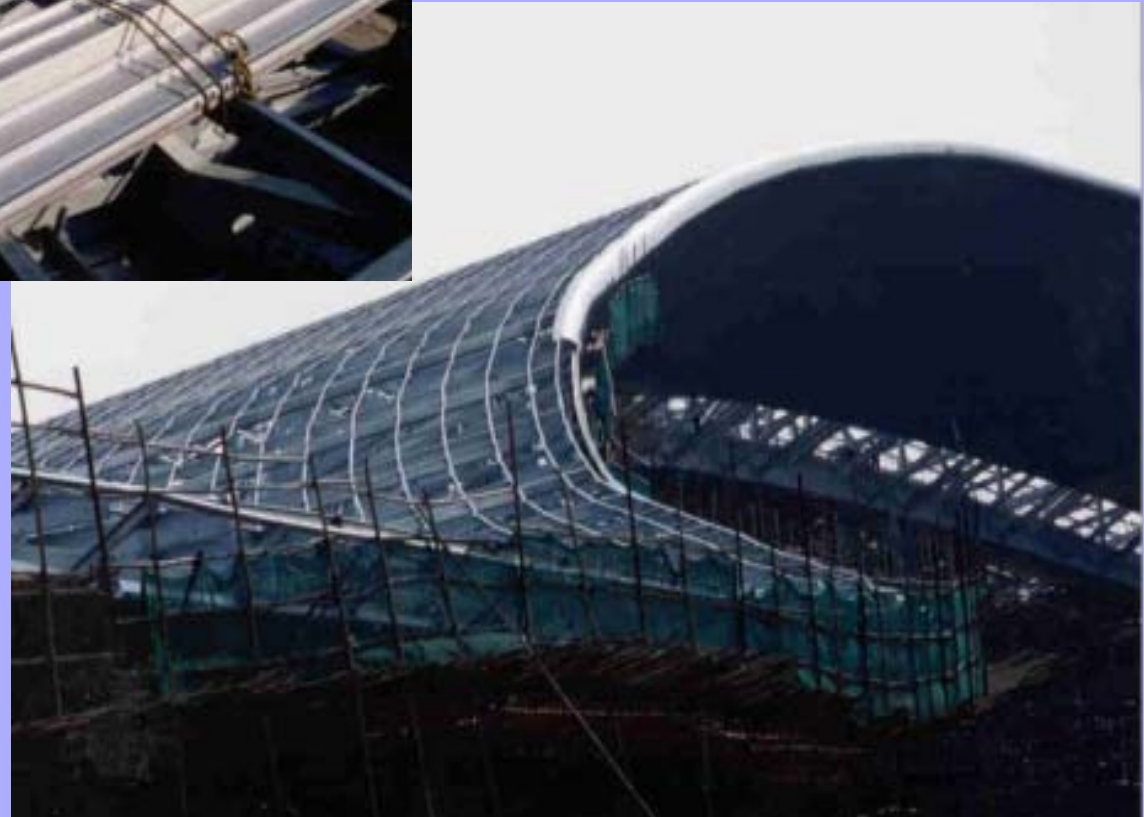
Tie systems to stabilize the cantilevered roof



Enlarged details
of the Tie systems



Decking system of the roof

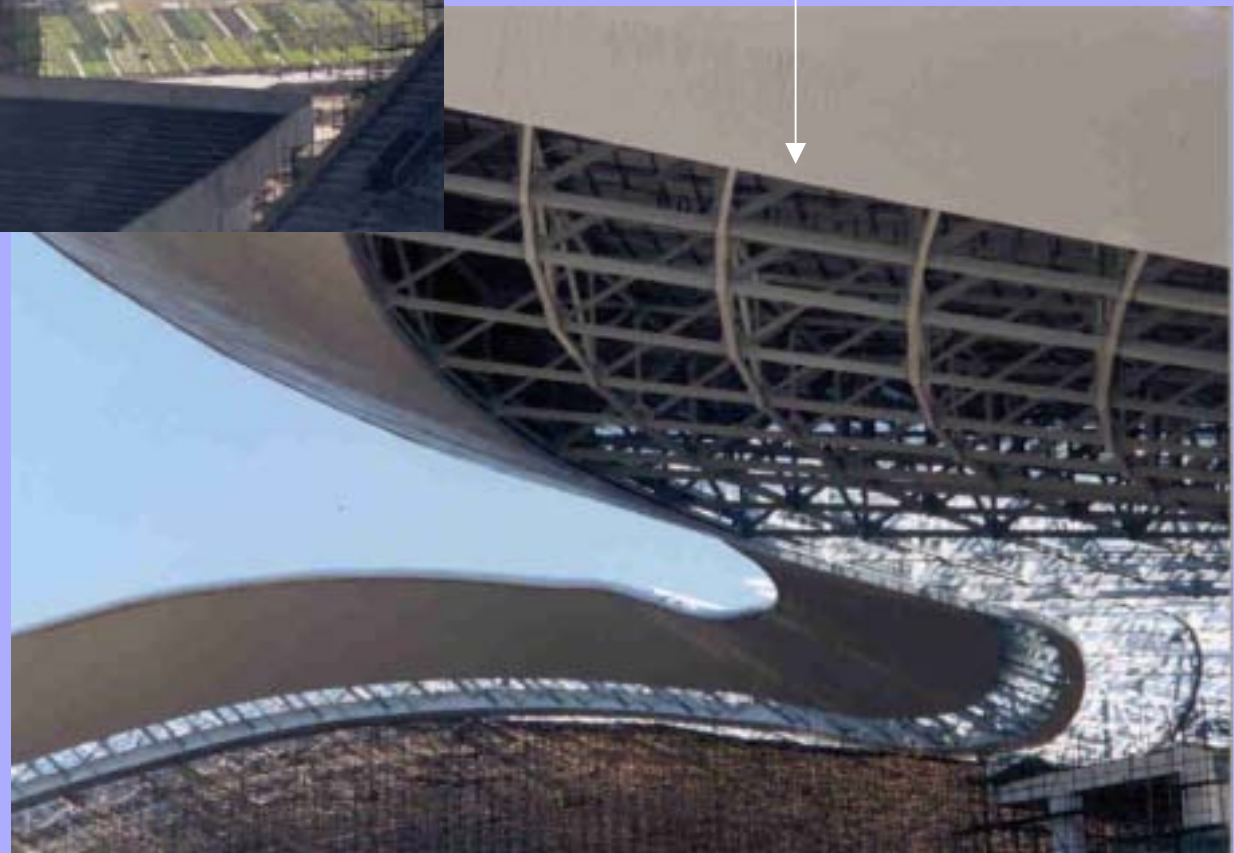


Laying of the
roof deck



Piers supporting the cantilever roof truss

Semi-cladded roof underside





The Guangzhou Gymnasium



The Shanghai Stadium

Other Example of Long Span Structure applied in Buildings

Structure with span larger than 20m can be regarded as long span structure for this span is usually unable to be achieved by ordinary RC structure.

Common Structural Forms for Long Span Building Structures

1. Insitu RC, tensioned
2. Precast concrete, tensioned
3. Structural steel – erected on spot
4. Structural steel – prefabricated and installed on spot
5. Portal frame – insitu RC
6. Portal frame – precast
7. Portal frame – prefabricated steel

Common Structural Forms (Cont.)

8. Cable suspended structures
9. Inflated structure
10. Vaulted or ribbed structure
11. Dome structure
12. Shell structure



Actual Example –
Hangar structure for HK
Aircraft Engineering
Company Ltd. (HAECO)
at Chek Lap Kok Airport







Actual Example –
The Skylight structure of
Festival Walk



The Interior Space under the Sking ring of Festival Walk





Linking structure between the International Finance Center Phase I and II







The deck and roof structure of the HK Convention and Exhibition Centre



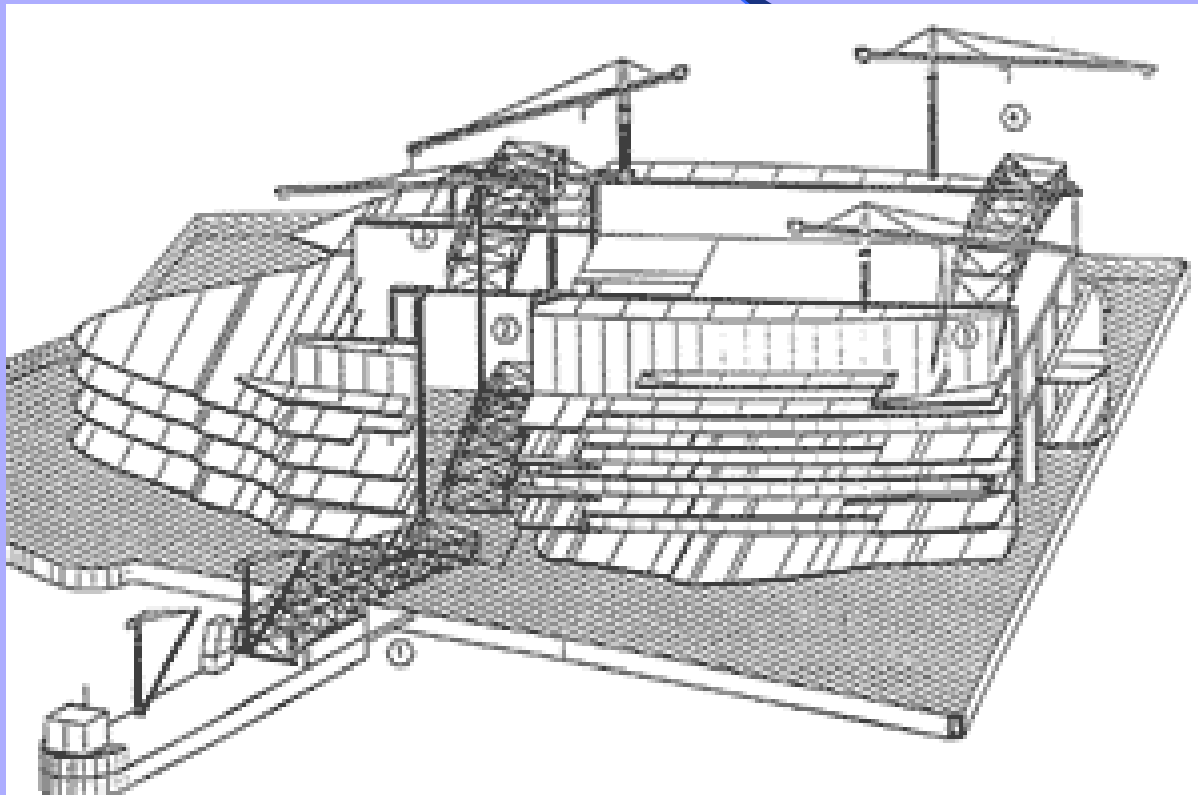
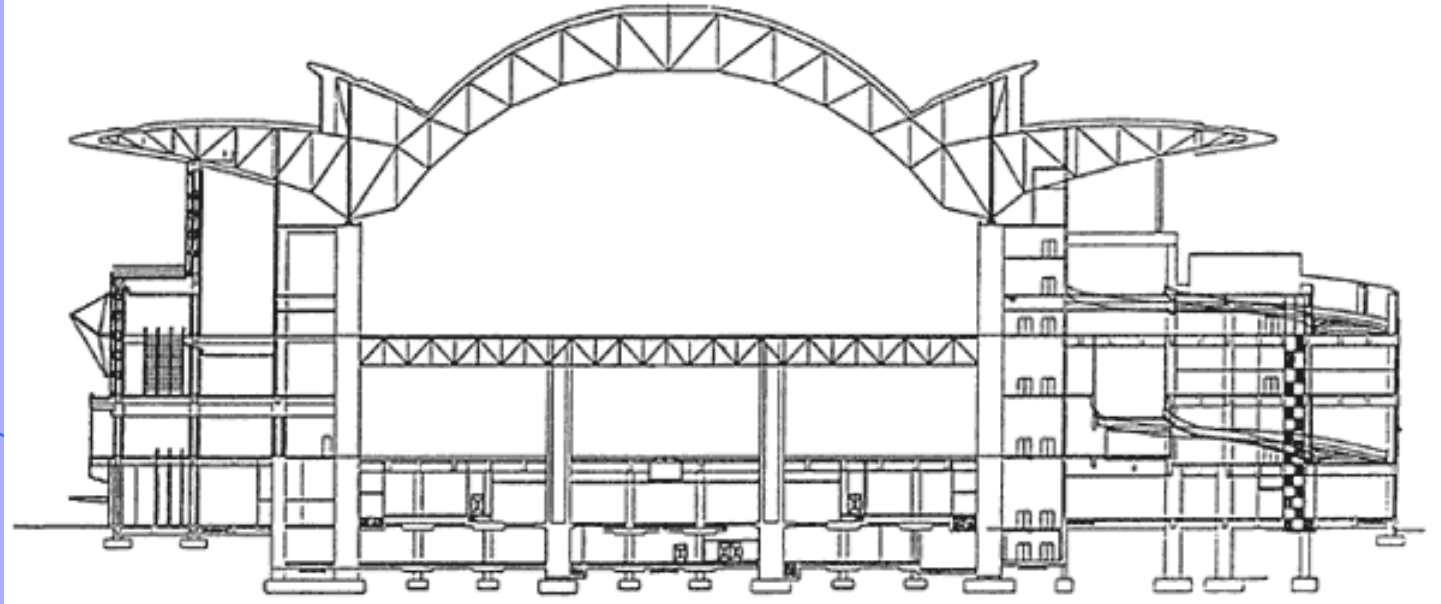


Hoisting of the
80m-span roof
truss



Placing of the roof truss
at the top of the core wall



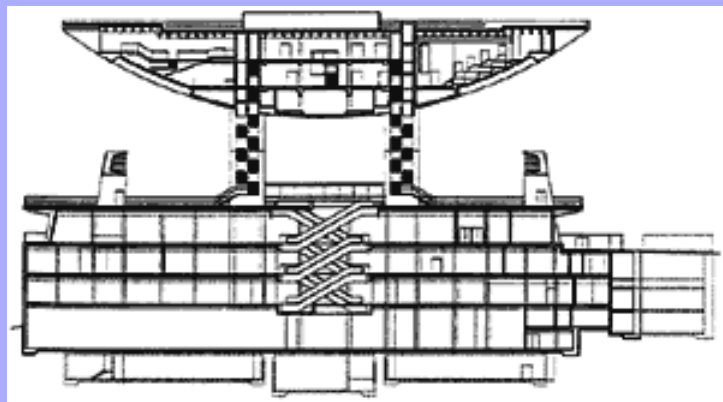
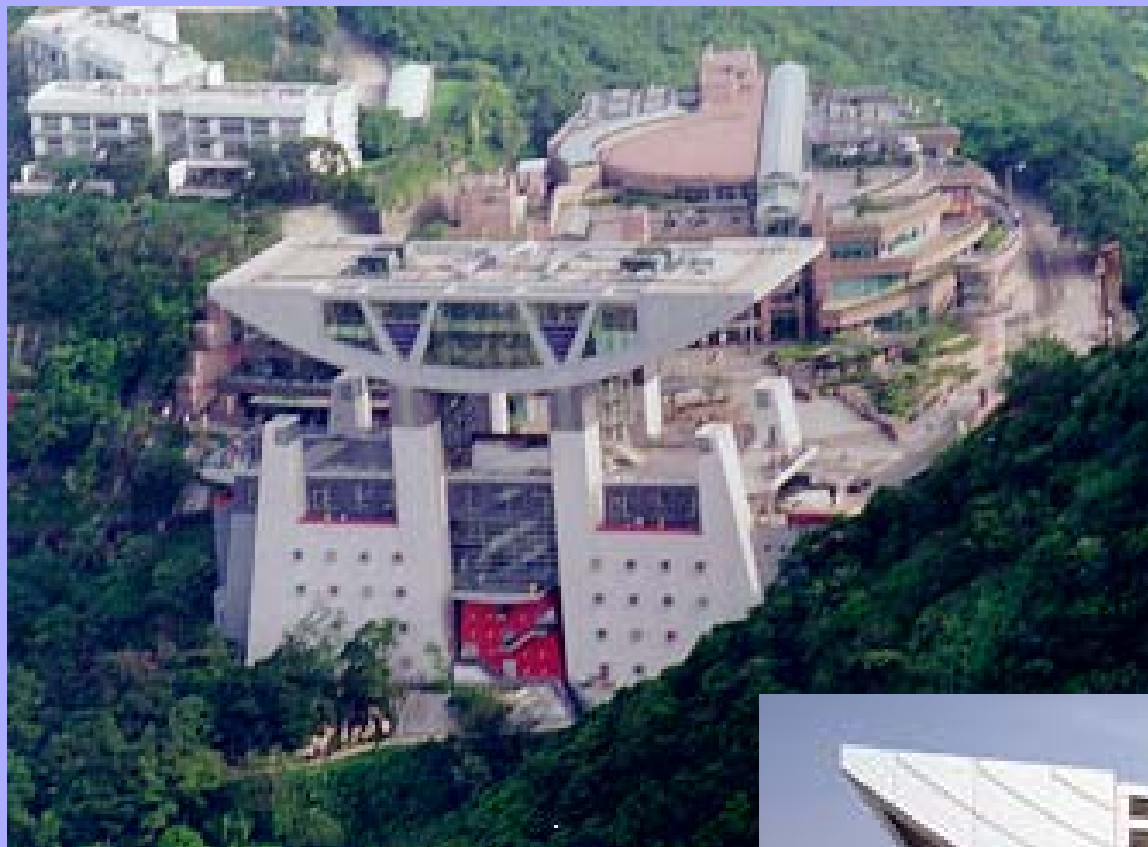




Linking structure
between Phase I and II
of the HK Convention
and Exhibition Centre



The Peak Tower





The New Hong Kong
International Airport at
Chek Lap Kok



The New Hong Kong International Airport at Chek Lap Kok



The Sky Dome, Cyber Port



The Sky Dome, Cyber Port

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