بسمه تعالی

دانشکده هنرهای زیبا
گروه معماری

درس سیستم‌های ساختمانی

(Structural Systems)

محمود گلابچی

تعداد واحد: ۲ واحد (نظری) پیش نیاز: ساختمان های بتنی

هدف درس:

هدف درس عبارت است از:

- آشنایی با سیستم‌های ساختمانی و فرم‌های سازه‌ای مدرن
- درک رفتار سازه‌ها و بررسی تاثیر متقابل فرم و سازه به ویژه در معماری امروز جهان
- آشنایی با تکنولوژی مدرن و مصالح مورد استفاده برای اجرای سیستم‌های ساختمانی جدید

موضوع درس:

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- ارزیابی و مقایسه فرم‌های هندسی متداول در معماری معاصر
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با معیارهای انتخاب سیستم ساختمانی مناسب آشنا خواهند شد.

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سیستم‌های ساختمانی و فرم‌های سازه‌ای زیر مورد بحث و بررسی تحلیلی قرار خواهند گرفت:

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- قوس‌ها و سازه‌های قوسی **Arches**
- خرپاهای مسطح و فضایی **Trusses**

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- قاب‌های صلب — Rigid Frames
- پوسته‌های استوانه‌ای — Cylindrical Shells
- پوسته‌های سهموی-هذلولی (هایپار) — Hyperbolic Paraboloid Shells
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- سازه‌های چوبی — Timber Structures
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- سازه‌های ساختمان های بلند — Hi-Rise Buildings
- سیستم‌های ساختمانی آینده — Future Systems

در بررسی این سیستم‌های ساختمانی رفتار سازه تحت تاثیر نیروهای قائم و افقی (و نیز نیروی زلزله) و شناخت علمی فرم‌های سازه ای مدرن به منظور استنتاج ضوابط مقایسه و ارزیابی علمی این سیستم‌ها و نهایتاً انتخاب مناسب‌ترین سیستم ساختمانی مورد توجه قرار می‌گیرد.

نحوه ارائه درس:

معرفی سیستم‌های ساختمانی فوق‌الذکر با تاکید بر موضوعات زیر صورت می‌گیرد:

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- روش اجرا و مصالح مورد استفاده
- تجهیزات مورد نیاز برای اجرای آن سیستم
- معرفی و بررسی نمونه‌های برجسته اجرا شده از آن سیستم ساختمانی
- تشخیص شرایطی که استفاده از سیستم مورد نظر به لحاظ مسائل طراحی معماری، عملکرد سازه‌ای، خصوصیات فنی، مسائل اجرایی و ویژگی‌های اقتصادی مناسب می‌باشد.

درس به صورت سمینار و سخنرانی و همراه با ارائه تصاویر، اسلاید و فیلم ارائه می‌گردد. دانشجویان با مراجعه به منابع مختلف (کتب، نشریات علمی و فنی در زمینه مهندسی ساختمان و معماری) به مطالعه بیشتر درمورد سیستم‌های ساختمانی و سایر مباحث مطرح شده در کلاس خواهند پرداخت.

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سیستم‌های ساختمانی

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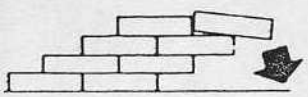
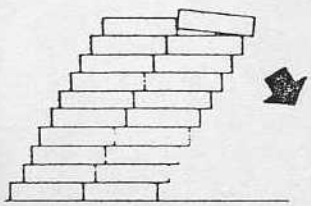
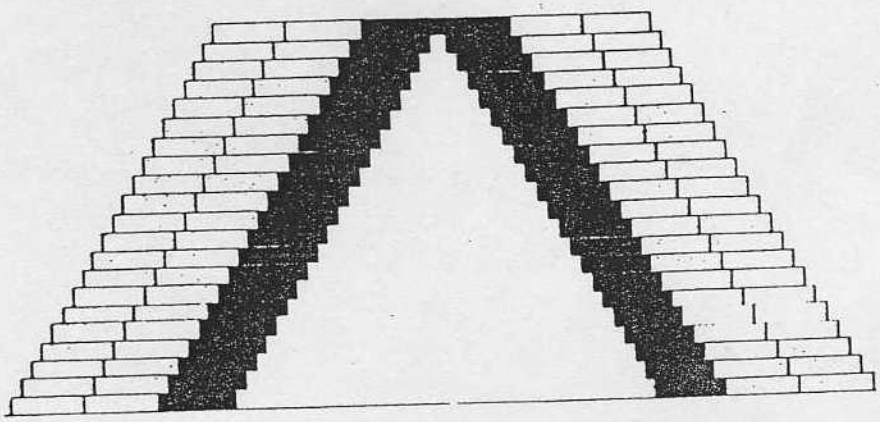
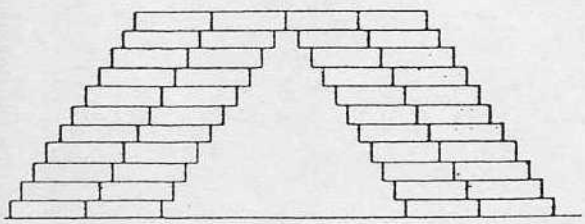
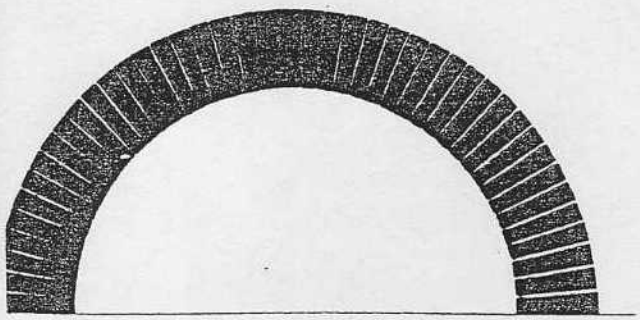
ARCHES

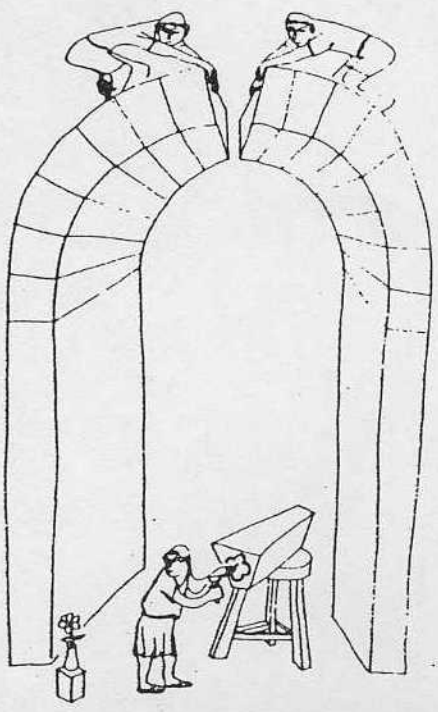












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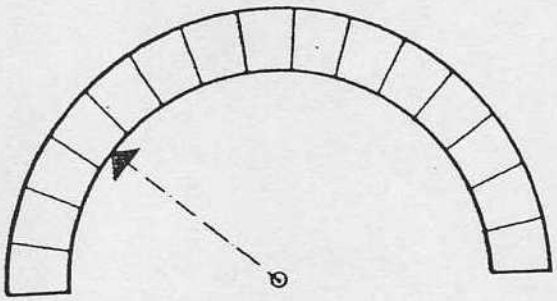
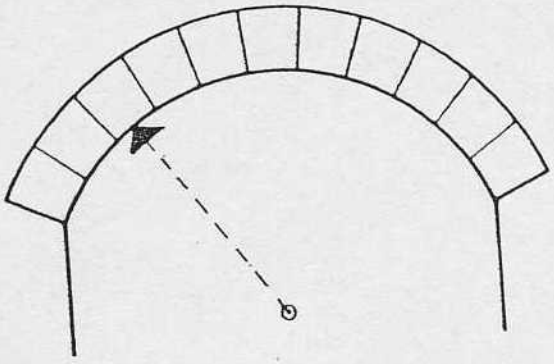
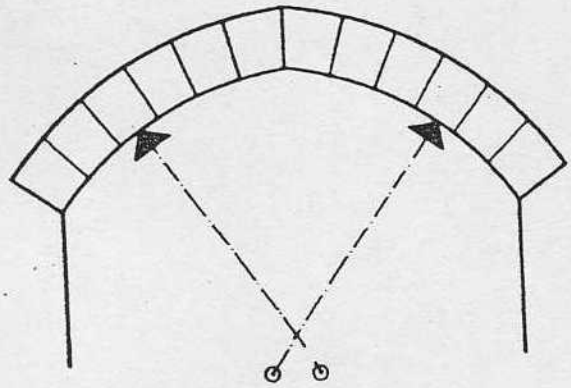
Types of Arches



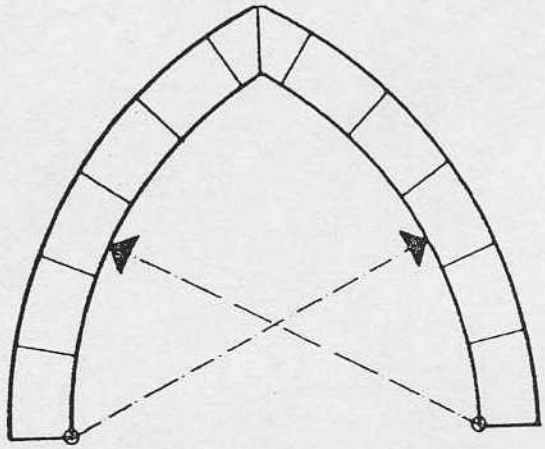
Semi-circular



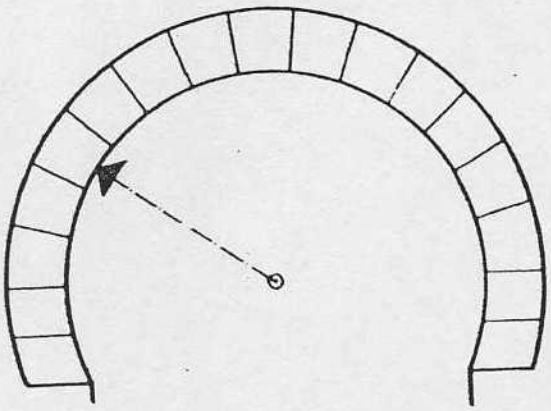
Segmental



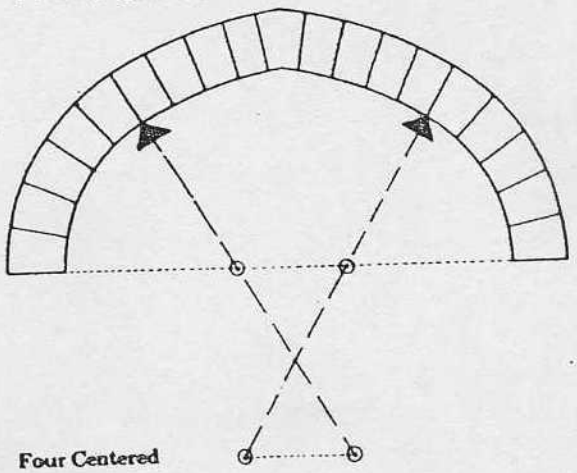
Pointed, Equilateral



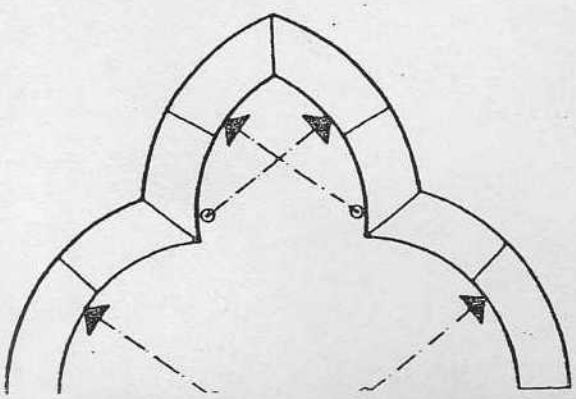
Pointed, segmental

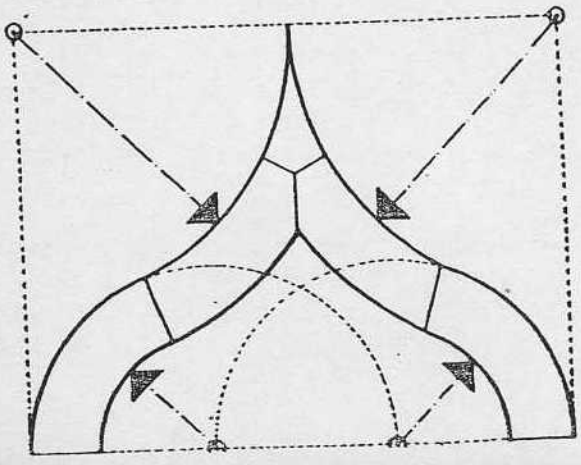


Horseshoe



Four Centered





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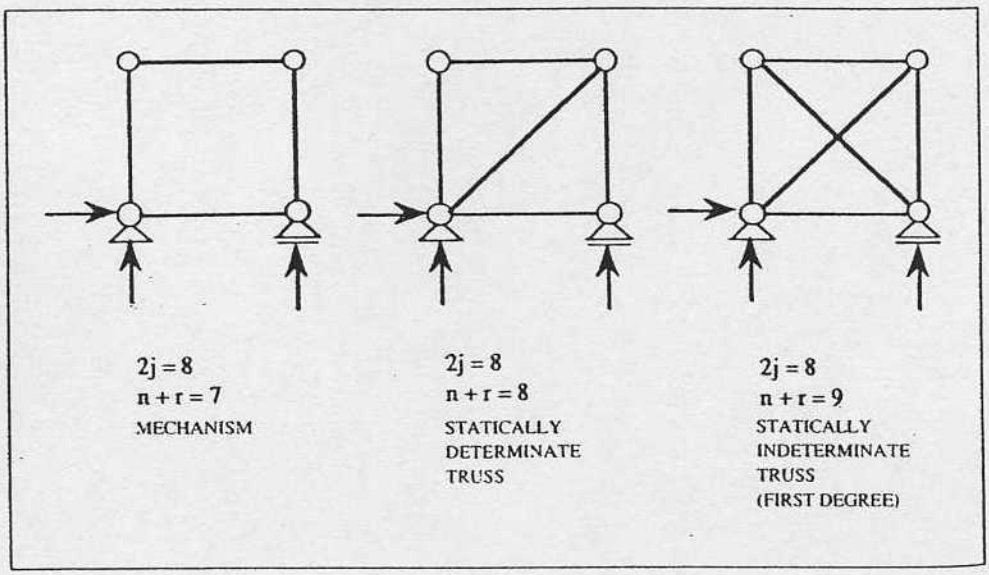
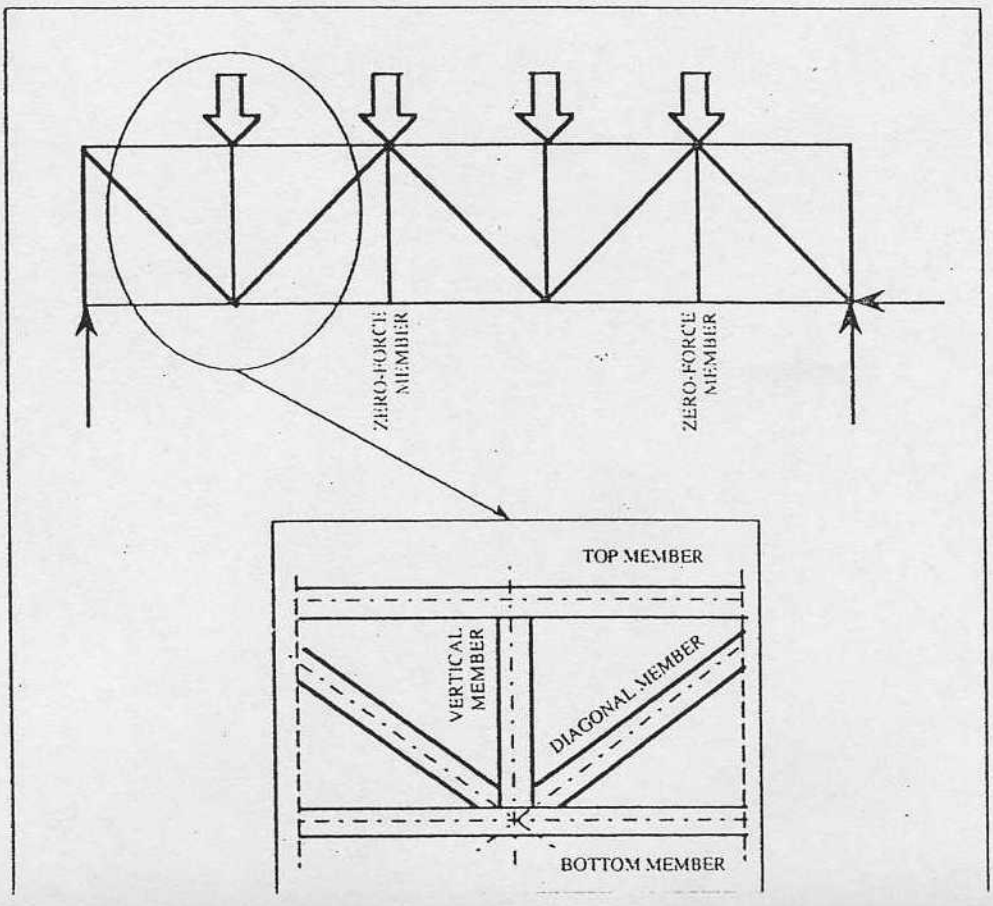
TRUSSED ROOFS



Three structures formed by linear members: mechanism, statically determinate, and statically indeterminate truss.

The terminology of trusses.



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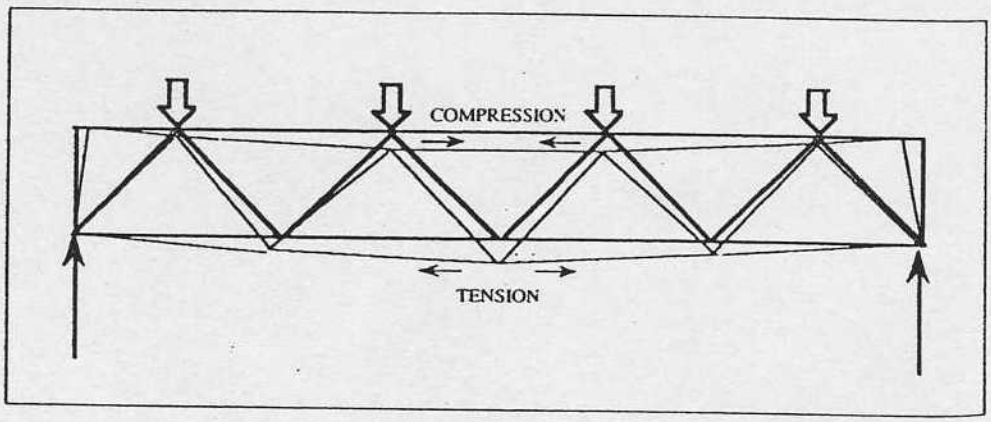
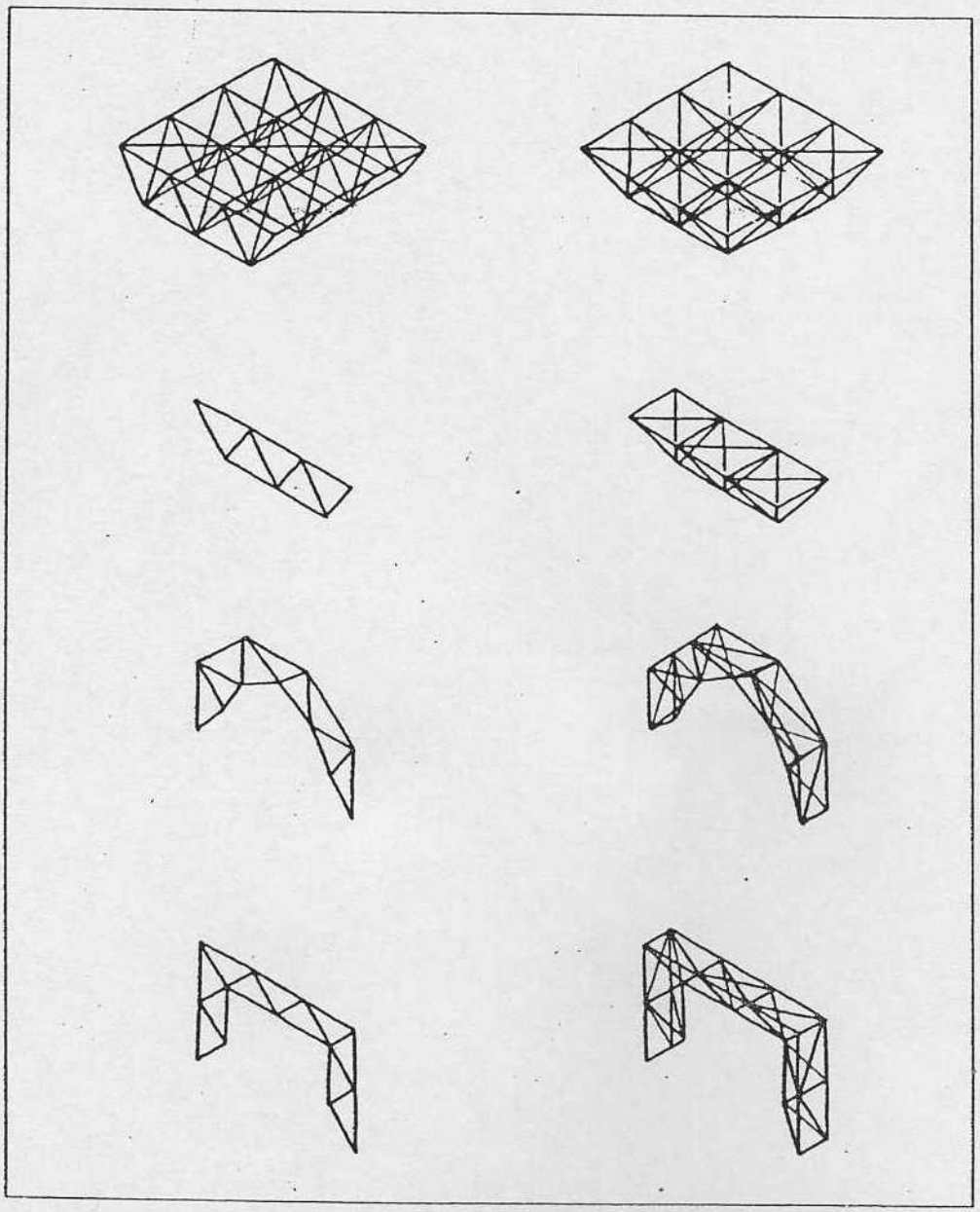


Simply supported truss with compression along the top member and tension along the bottom member.



Planar and spatial trusses.
Left: slab structure of planar trusses, planar beam, arch, and frame.
Right: space frame, spatial beam, arch, and frame.

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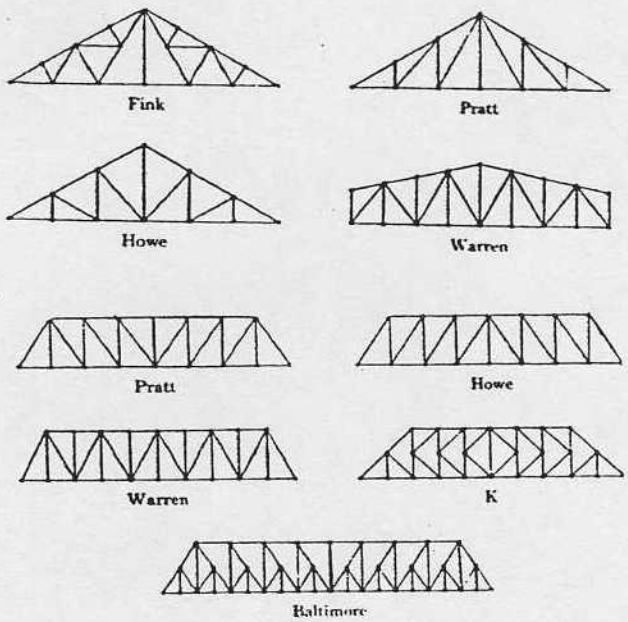
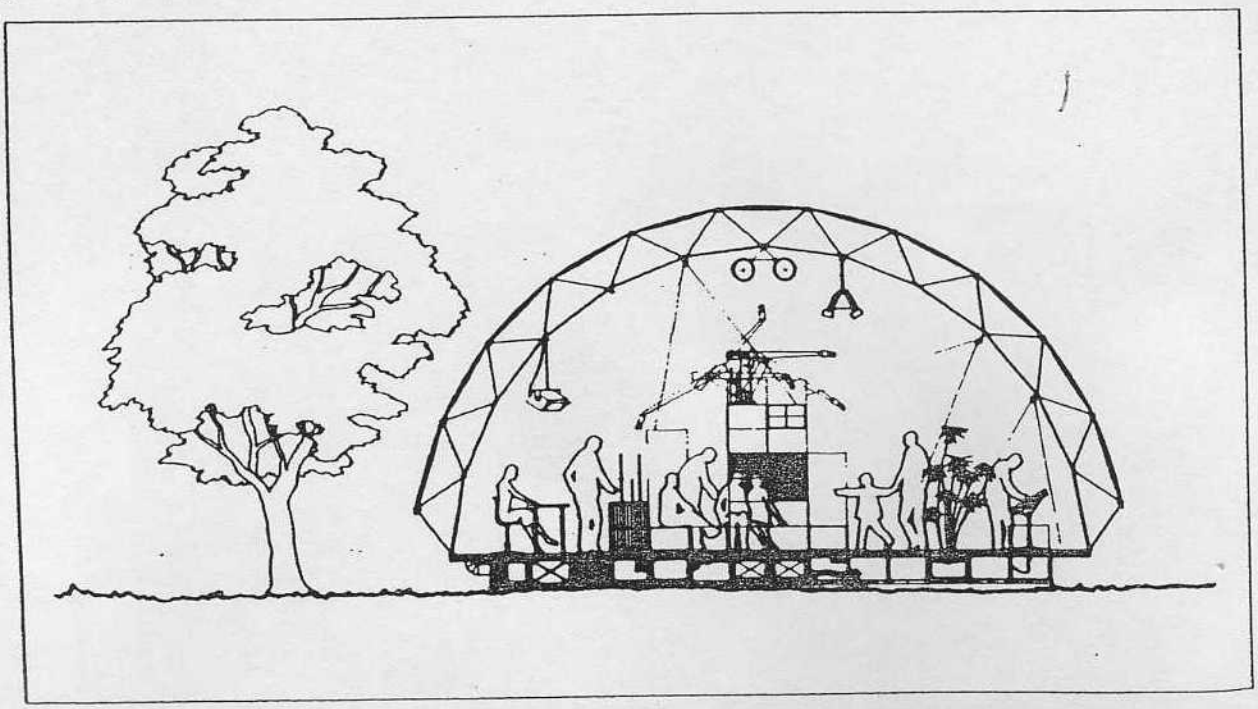


Exhibition Pavillion for IBM. 1982. Architect: Renzo Piano. Arched trusses without linear members. The trusses are established using pyramids of polyethylene. The edges of the pyramids have the required stiffness and function as members.



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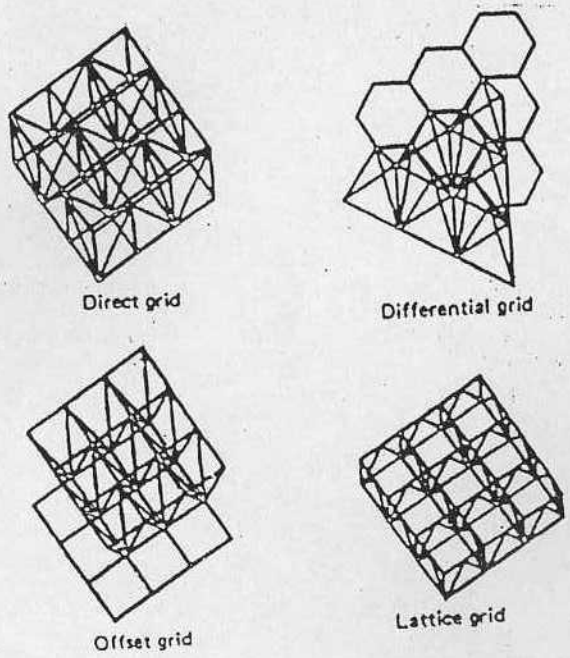
SPACE FRAMES



SPACE FRAMES

INTRODUCTION

The last decade or so has witnessed a growing world-wide interest in space frame structures and, over the years, many have been designed and constructed using a variety of configurations and jointing methods.

Space frame systems owe this measure of interest not only to their pleasing visual character; they also provide the economic answer to many design requirements such as large uninterrupted spans, unimpeded future extensions in any direction and a capacity to carry extensive overhead services. Small size components used in construction also permit fast production methods in the workshop, easy transportation to site and speedy erection.

A survey, embracing an appraisal of these advantages, was carried out to establish the stage of space frame development that had been reached and the lines along which future progress should be directed.

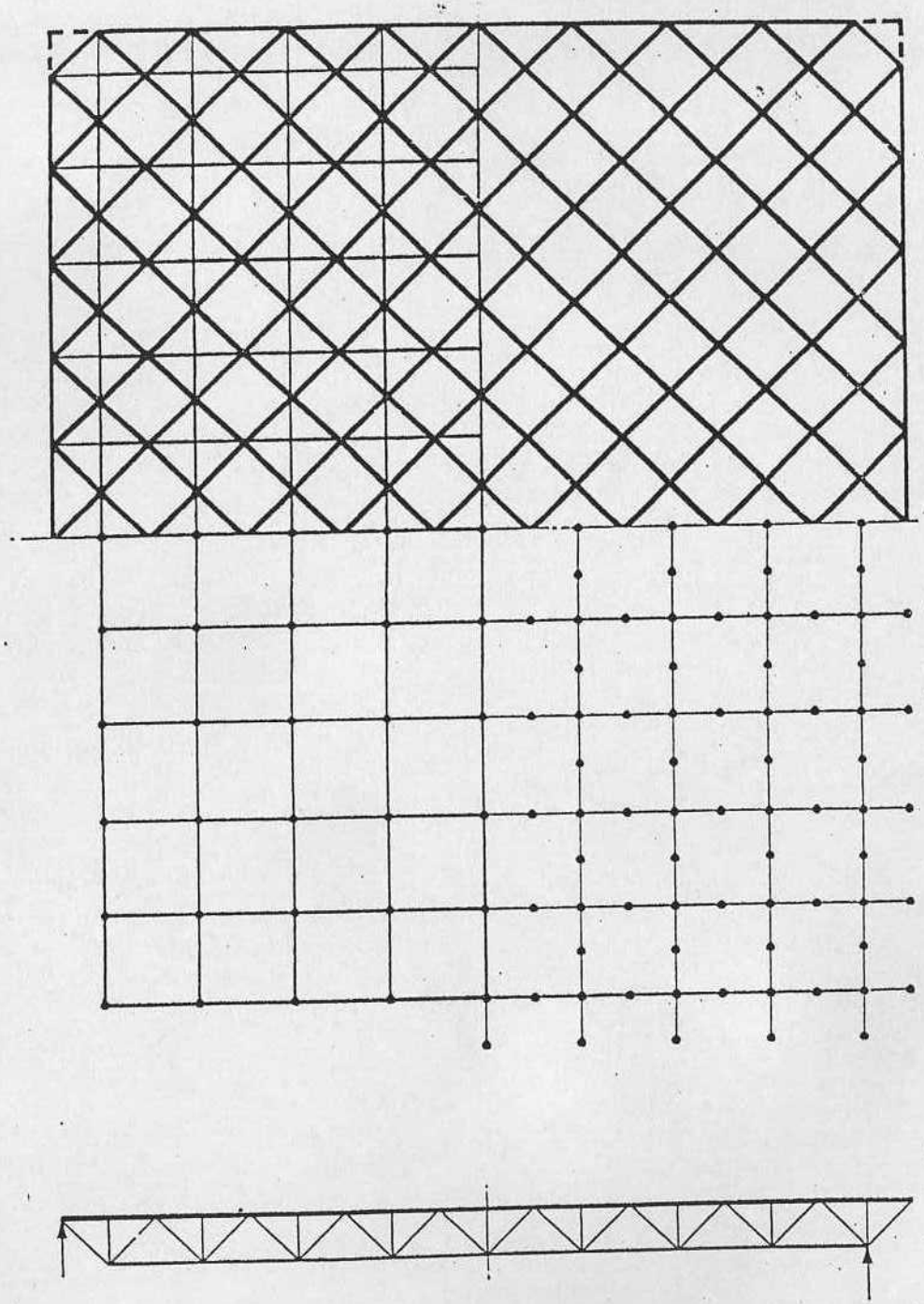
From this survey it emerged that to construct a practical space frame or, more specifically, a two-layer grid, two conditions had to be satisfied; a quick and easy means of calculating the forces in structural members and a readily available method of jointing members together.

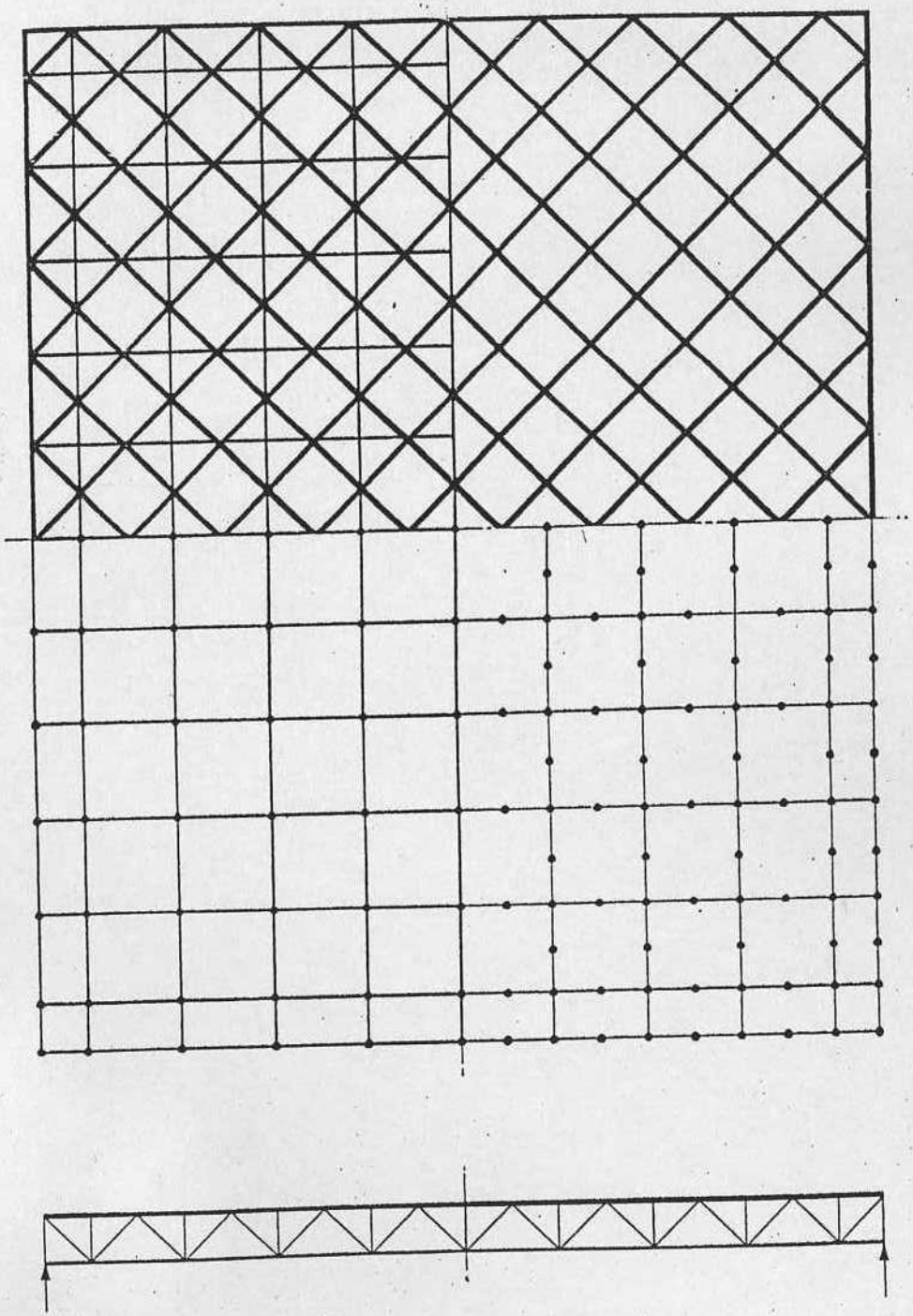
The first condition has been met by a specially prepared computer programme requiring only the completion of a series of data sheets for computer processing; and the second, by the Nodus joint—a 'second generation' jointing system designed, developed and tested by the Tubes Division of the British Steel Corporation.

The engineer is now able to design a two-layer grid, carry out a full structural analysis and then obtain competitive tenders for its construction.

The manual, 'Space Frame Grids' consist of three parts, each covering an important aspect of two-layer grids.

The engineer can only be given a general guide to the design of two-layer grids as the behaviour of this type of structure under various loading and support conditions cannot in many cases be clearly defined without a full computer analysis being carried out. However, guidance can be given on the various grid arrangements that can be constructed using the Nodus jointing system, together with some methods of making a first estimate of member sizes.





A number of factors have a pronounced bearing upon the design of the grid—these are the cladding, the module, the supports and the depth. A compromise between these various aspects usually has to be made by the engineer so that a satisfactory design solution is achieved.

Cladding

The cladding will in most cases be specified by the architect and preferably should not be too heavy or too light in weight. If the cladding is too heavy, then there will be difficulty in obtaining economical prices for large span grids, and, if too light then there may be a penalty under wind load reversal conditions.
Normally, profiled deck-type claddings will be used, as the roof will be substantially flat with only a small rise for drainage, but more economical cladding systems can be used if the roof is set to a monopitch or there is a centre ridge. Advice on claddings and pitch angles should be obtained from the cladding suppliers. However, the type of cladding decided upon will establish the maximum chord spacing or module that can be used. Either circular or square SHS members are suitable for the top layer of the grid but the use of square sections is advised; this will give a better seating for the cladding and will have improved load carrying capacity in relation to the joint size used.

Module

When the maximum allowable span for the chosen cladding has been obtained, a suitable module can be determined which will fit the overall dimensions of the grid. This module must be checked to ensure that it is in a proper relationship to the depth of the grid in terms of the true angle of the bracing member relative to the plane of the chords. If this bracing angle is too low, in the region of, say, 30°, then a large offset or eccentricity will occur between the intersection of the bracing members and the intersection of the chord members. This eccentricity can result in large moments in the chord members under certain support conditions. For grids supported along the edges or near the corners these moments are not significant in terms of controlling the chord size. In the centre of a grid, where the axial loads are greatest, the shear loads are at a minimum and hence the moments will be small, whilst near the supports, where the shear loads are at a maximum, the axial loads are usually low.

Supports

In most cases the position of the supports will have to meet the requirements of the buildings and it is desirable that as far as possible the selected module should fit in such a way that a direct connection can be made to a joint either in the top or the bottom chord layer. If possible, supports at the extreme corners of the grid should be avoided as these tend to give disproportionately high axial loads in the edge chord members and, as it is usual to keep the same size of member throughout either the top or the bottom chord layer, these higher edge loads will determine the basic member size. Support positions slightly in-board are to be preferred. It should be borne in mind that in certain respects a two-layer grid behaves in much the same way as any normal truss structure; for example, the axial loads in the chords will vary in proportion to the depth while certain support conditions, which give counter moments due to cantilever or portal effects, will assist in reducing the principal bending moment.

Depth

It is usually considered that grids can be relatively shallow when compared with more conventional structural arrangements. This is generally true because a grid gives small deflections under load and therefore easily meets the deflection requirement of BS 449. Depths that are small in relation to span will tend to enforce the use of a relatively small module because of the general limits on bracing angles and hence a fairly dense structure will result which will be correspondingly expensive. In general a span-to-depth ratio of about 20 gives good economy when the grid is supported all around its edges but when it is supported near the corners then the span-to-depth ratio should be about 15.

Services

Services are easily supported by grid structures and a considerable load can be carried without any appreciable cost penalty. For instance a service load of one pound per square foot on a roof area of 10,000 square feet will permit a variety of equipment to be fitted to the roof to a total weight of nearly 4½ tons. This will allow equipment which normally takes up valuable floor space to be placed in the roof. Materials handling equipment, monorails etc., are also easily fitted to the roof structure and there is usually no difficulty in catering for nominal point loads to be applied at the joint positions.

RANGE OF GRID TYPES

A wide range of grid types can be constructed using the Nodus joint, as described below. Each has slightly varying characteristics which should be considered in relation to the overall design requirements. When a grid is supported around its edges, and in this sense the supports can be set intermittently at spacing to suit door openings, etc., then the type of grid used is not structurally important. Where, however, the grid is supported near its corners it is necessary, to attain any degree of structural efficiency, that at least one of the chord layers should be set diagonally.

Type 1. Square on square offset

This arrangement is probably the type which has been most widely used. Its main characteristic is that the module of the top layer and that of the bottom layer is the same. This gives a dense appearance and should generally only be used where the loading is exceptionally heavy and where the grid is supported around the edges.

Type 2. Square on square offset set diagonally

This arrangement is similar to Type 1 above except that the top and bottom chord members are set at 45° to the edges of the grid. This type should only be used where the loading is exceptionally heavy and where there are only few supports near the corners.

Type 3. Square on larger square

This grid is similar in many ways to the "square on square offset". Its main difference is that the lower chords are set at twice the module of the chords in the top layer. It will be seen that this arrangement is particularly suited to providing a high level of natural light as there are large openings through the grid which give an unobstructed path for daylight. Monitors can be fitted into alternate grid spacings in the top layer if required. This arrangement is suitable where there are supports around the edges and where normal loads are to be carried. It should be borne in mind that the axial loads in the lower chords will be roughly twice the value of the loads in the upper chords.

Type 4. Square on larger square set diagonally

This grid arrangement is similar to Type 3 above except that the top and bottom chord members are set at 45° to the edges of the grid. Its characteristics are also similar but it is particularly suitable when the supports are near the corners.

Type 5. Square on diagonal

This grid arrangement is generally more efficient than those described above. The top chord layer has members set parallel to the outer edges but the bottom chord layer is set diagonally which results in the lower chords being set at a module $\sqrt{2}$ times that of the top. This grid, due to its open arrangement, gives little obstruction to daylight and monitors can be set in alternate modules. The arrangement with the mansard edge is best when the supports are around the edges whilst that with the cornice edge is suited to either support around the edges or near the corners. There are alternative arrangements of this grid type; that shown in the diagrams has the edge members only meeting at the corners of the bottom layer but it can be re-arranged to give a diagonal chord member also meeting at this point. If possible this latter arrangement should be avoided as no standard Nodus joint is available for this condition.

Type 6. Diagonal on square

In this arrangement the top chord members are at 45° to the edges of the grid, whilst those in the bottom layer run parallel. Structurally this is possibly one of the most efficient grid arrangements but with the top chords running diagonally the cladding will need special trimming which will tend to reduce this saving.

Grid Edge Profiles

There are three types of grid edge profile as shown in Fig. 1.

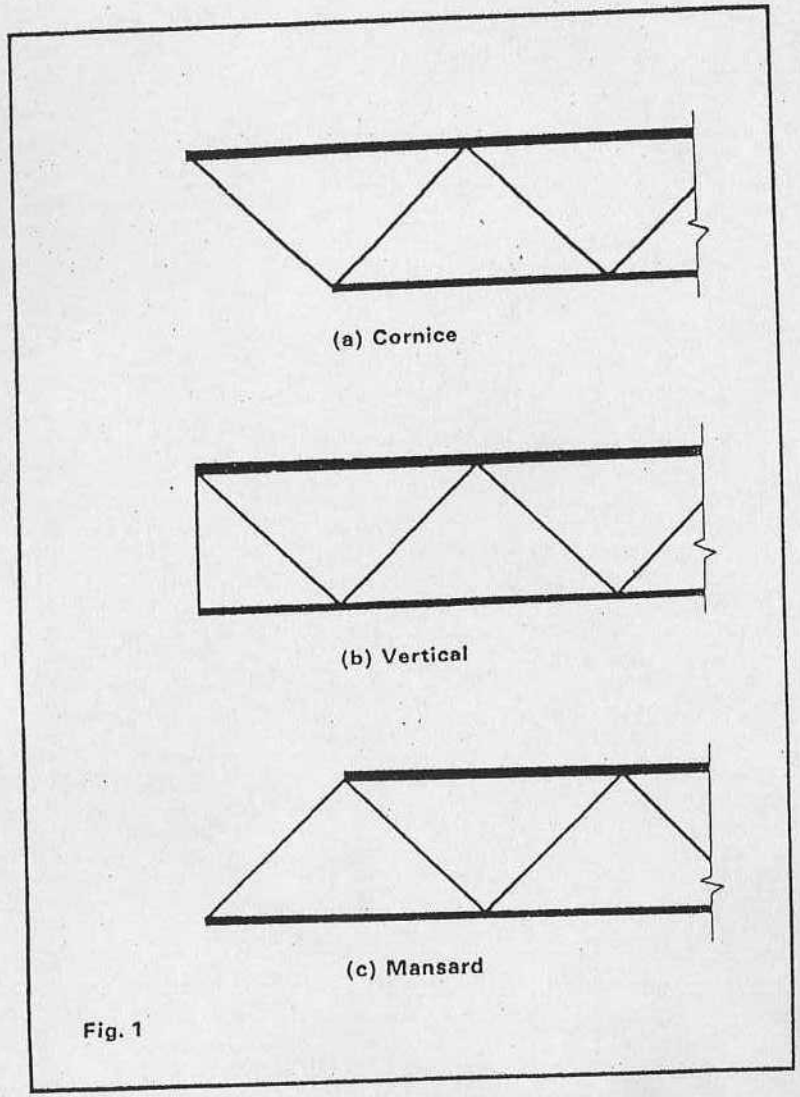


Fig. 1

Each grid arrangement will naturally generate one or more of the profiles indicated in the Type diagrams which follow.
When a desired edge profile cannot be generated by the required grid arrangement then ancillary steelwork should be used.

Each of the standard grid arrangements (Types 1-6), together with the available edge profiles, are shown individually on the following pages.
They are designated by a reference to the grid type and edge profile eg:
Square on diagonal with a Mansard edge is: Type 5c
In order that the arrangement of members in each layer can be clearly defined the method shown in Fig. 2 has been adopted.

Key Diagram

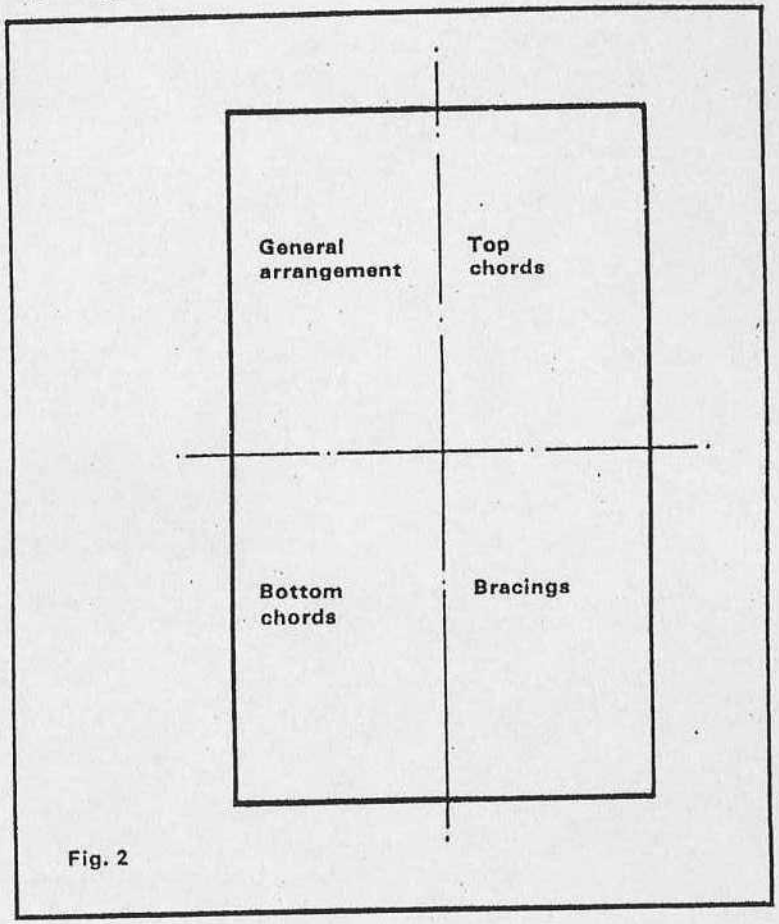
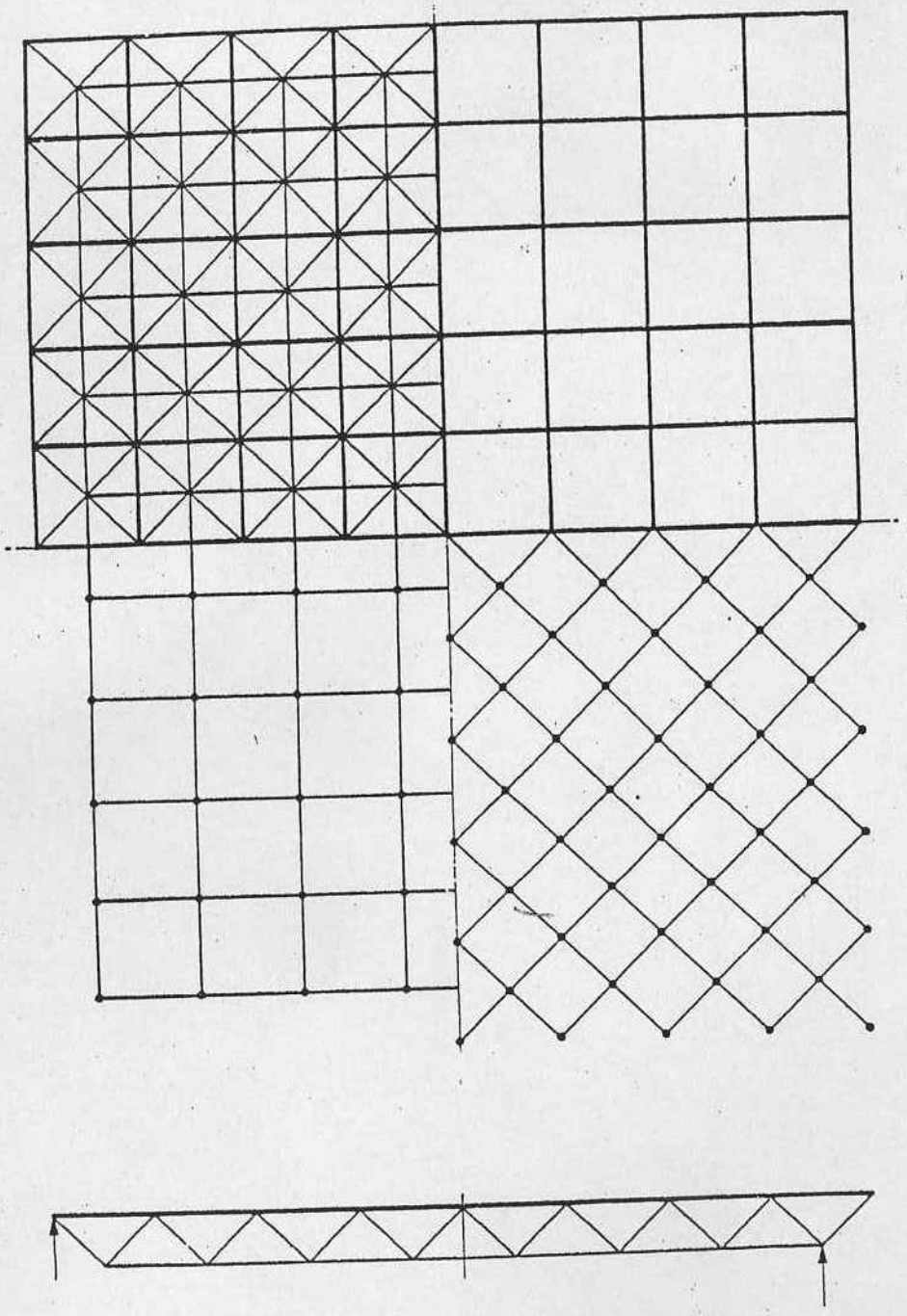
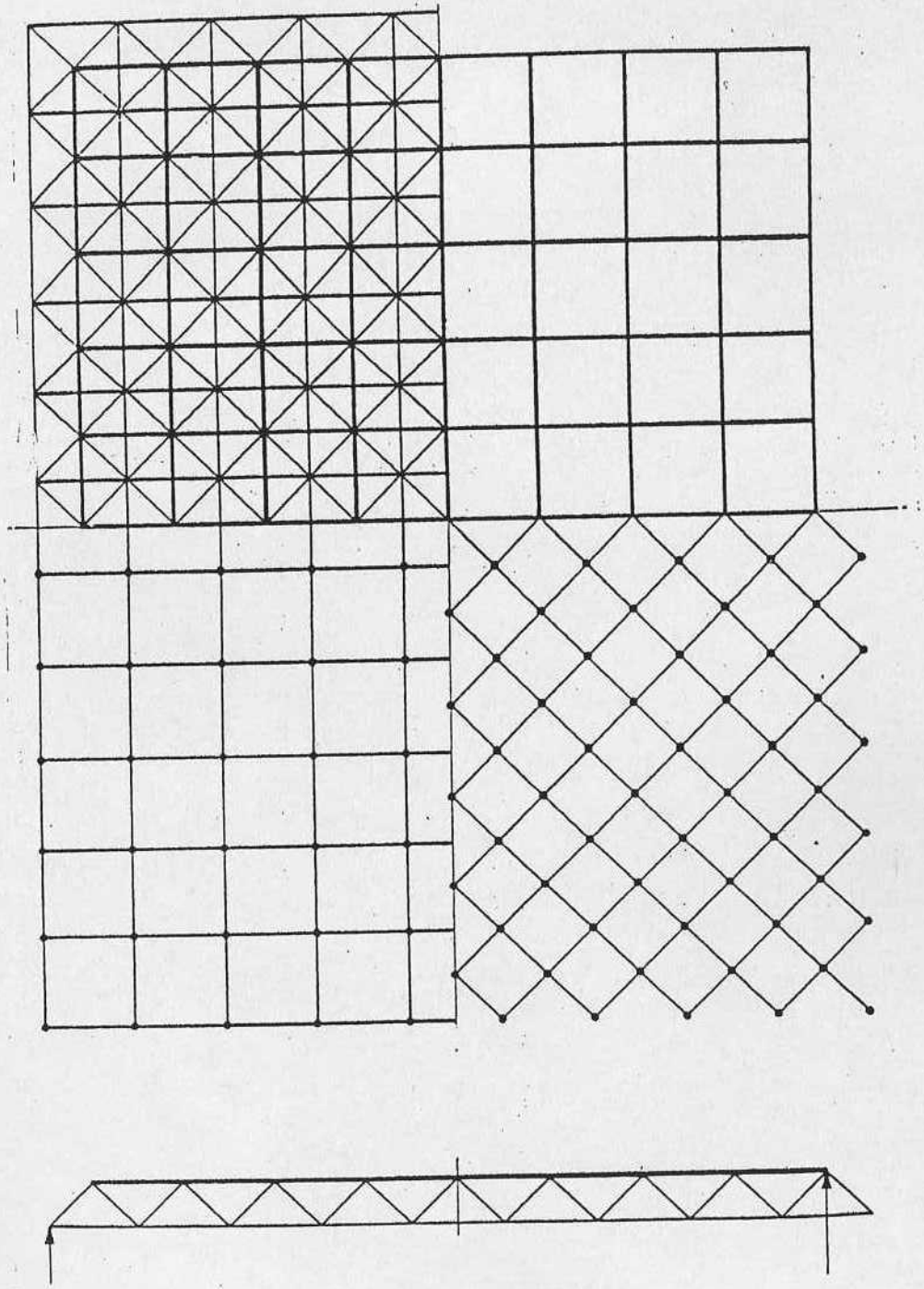
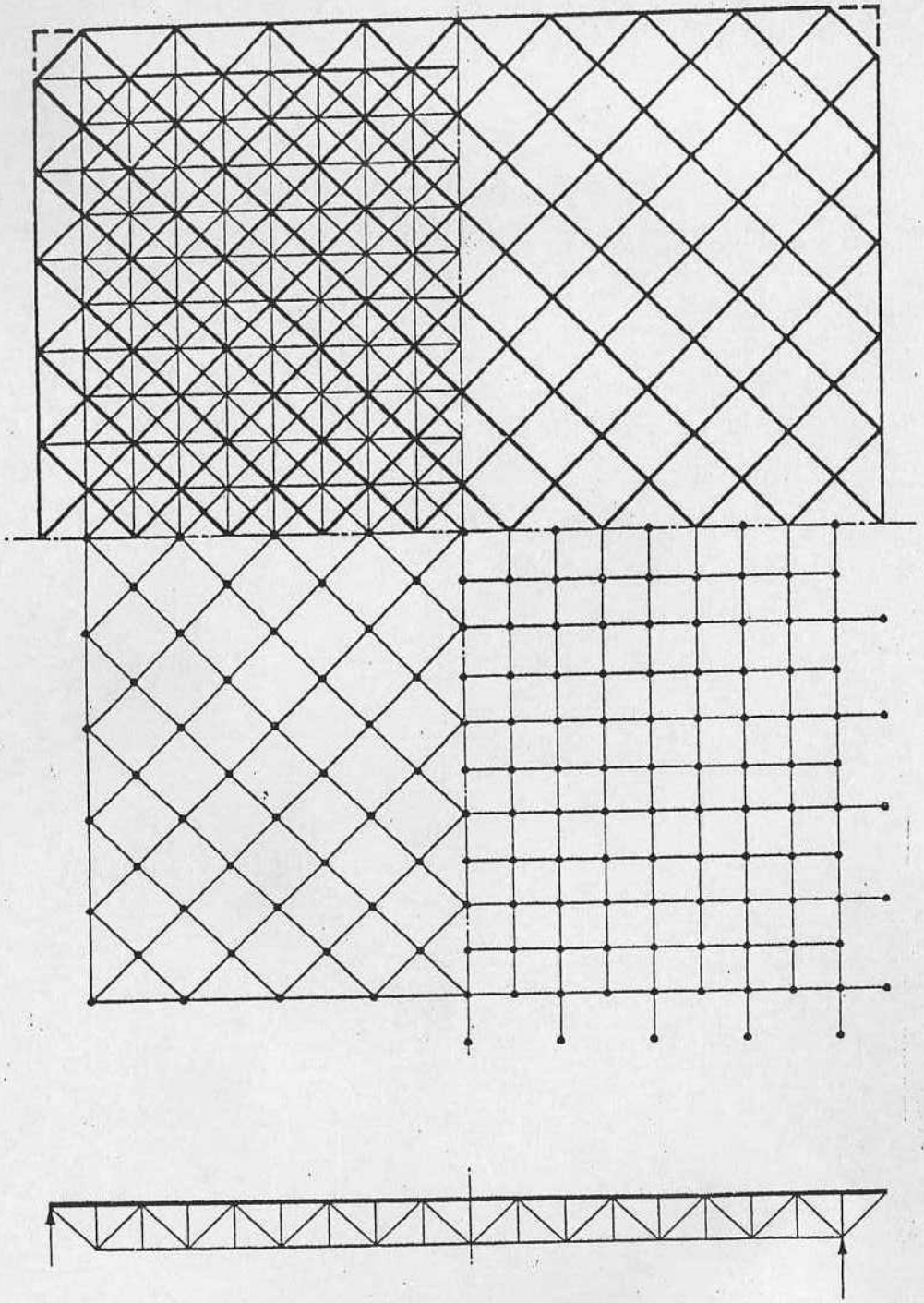


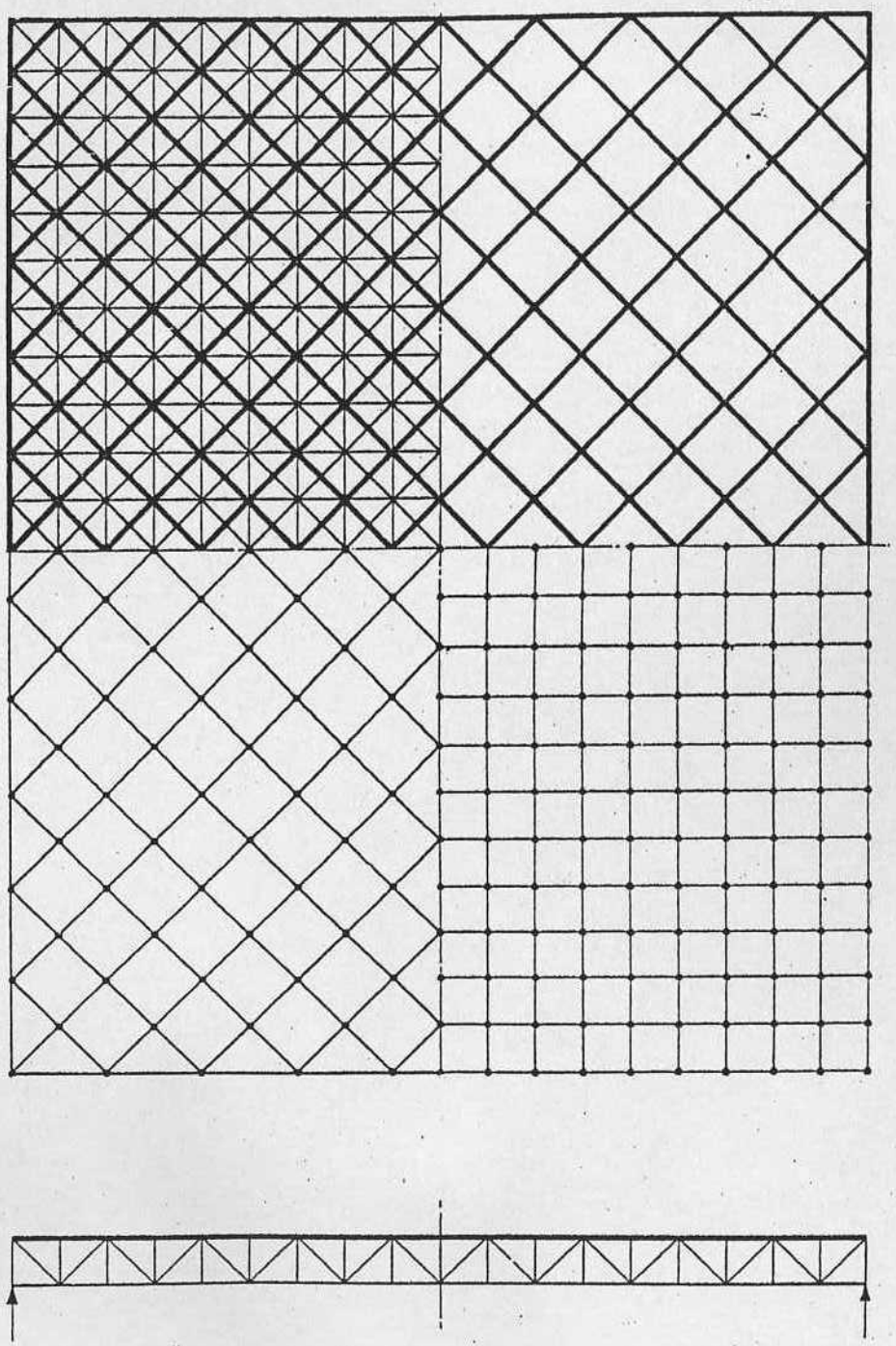
Fig. 2

TYPE 1a—Square on square offset, Cornice edge

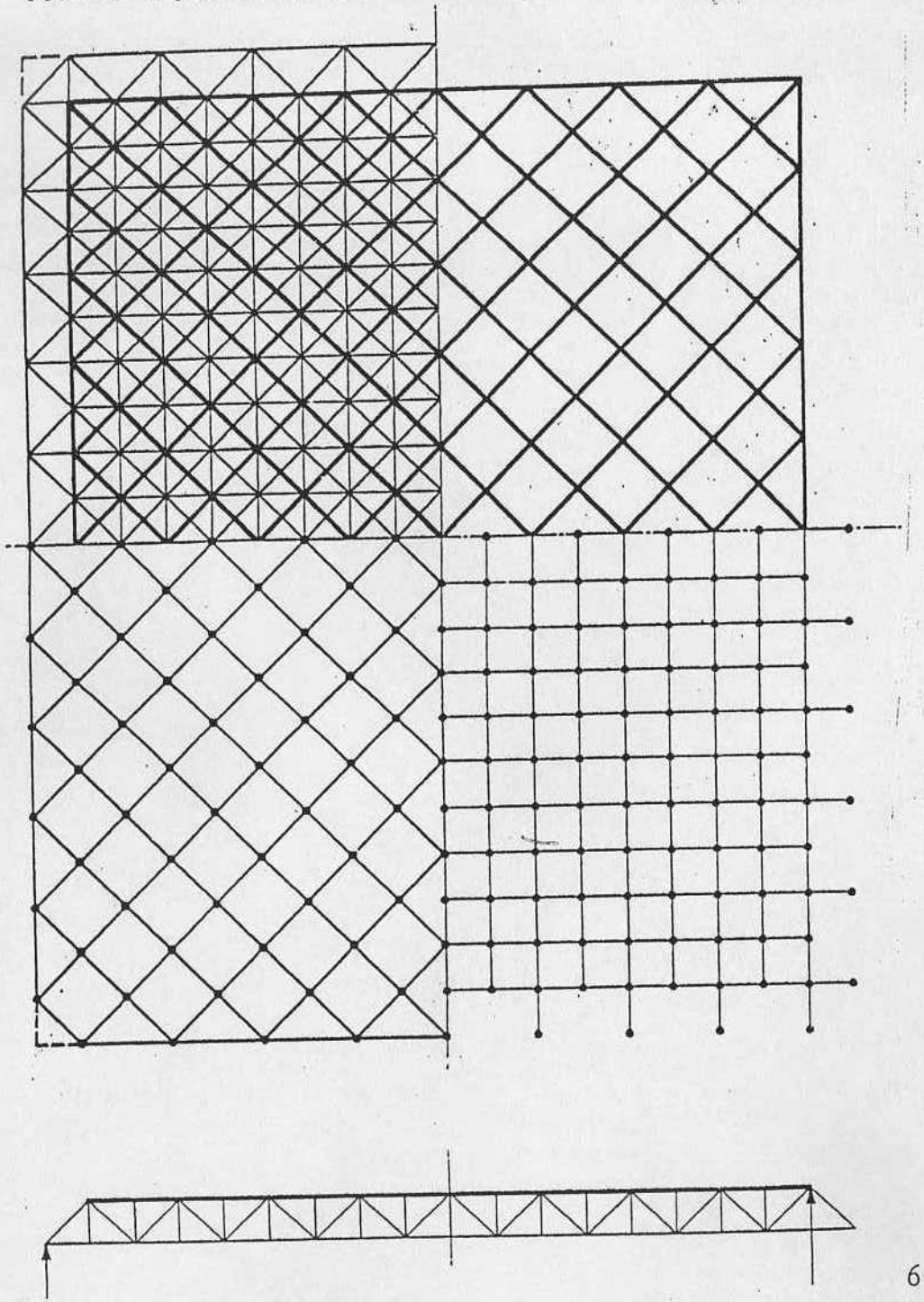


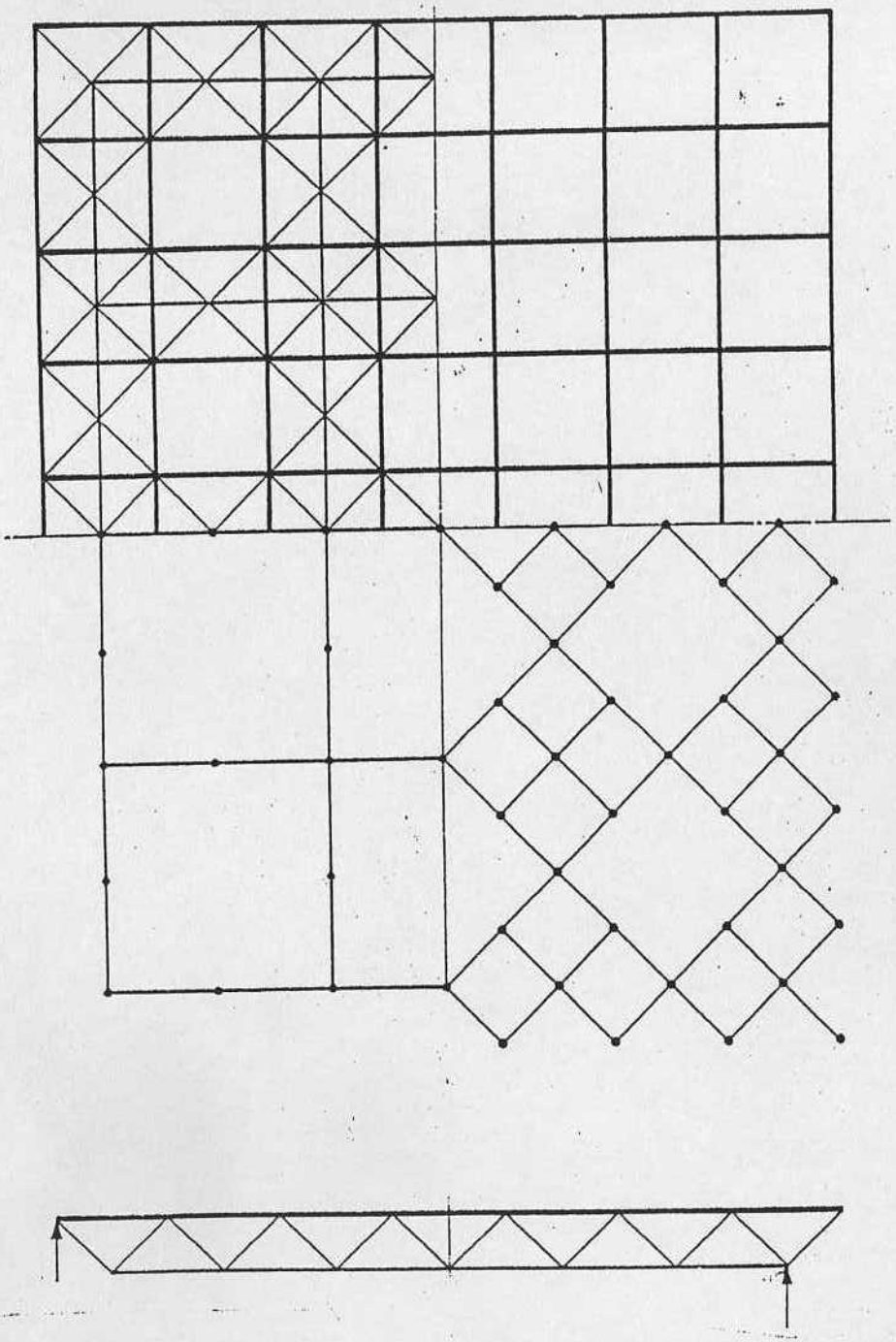




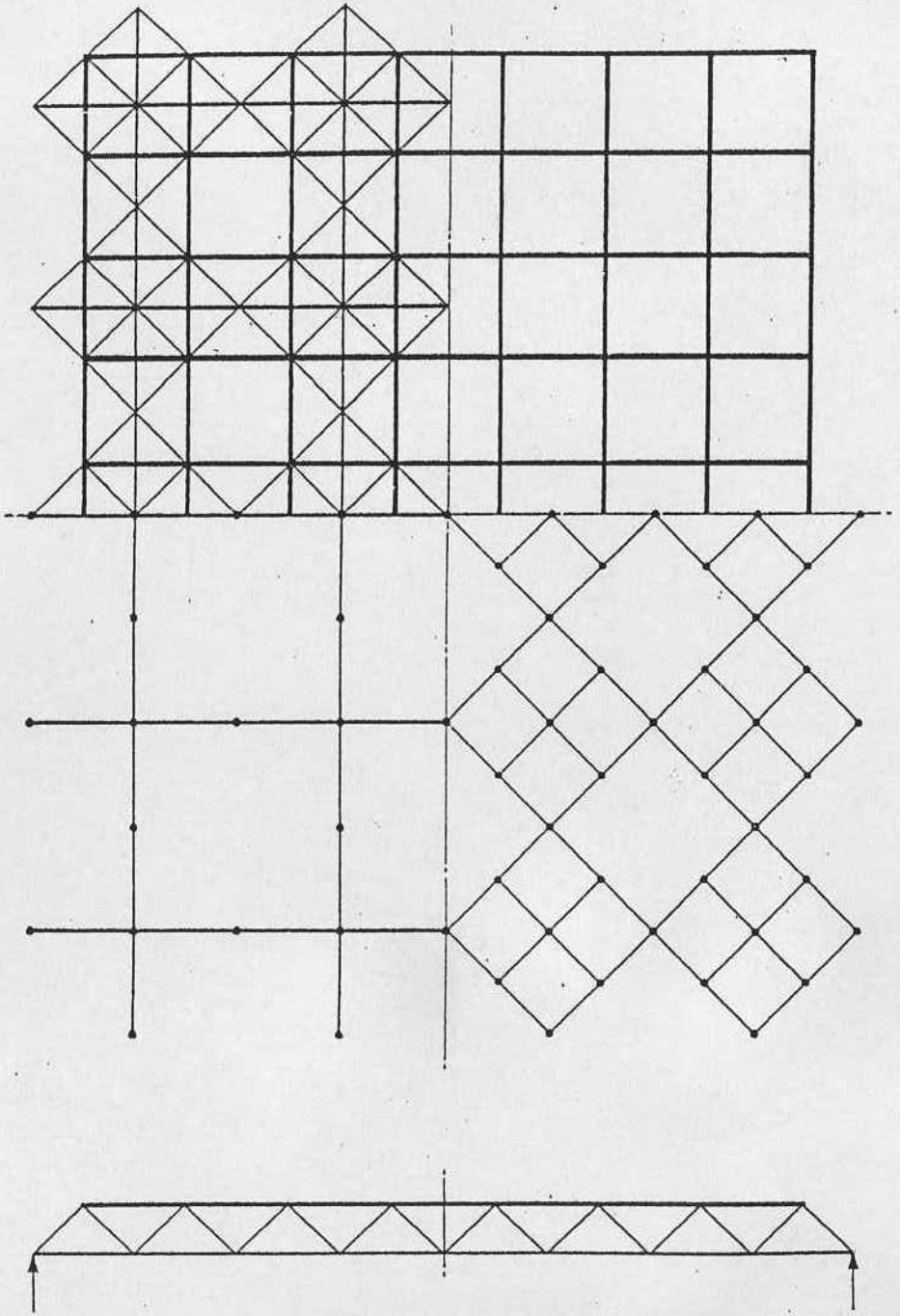


TYPE 3a—Square on larger square, Cornice edge

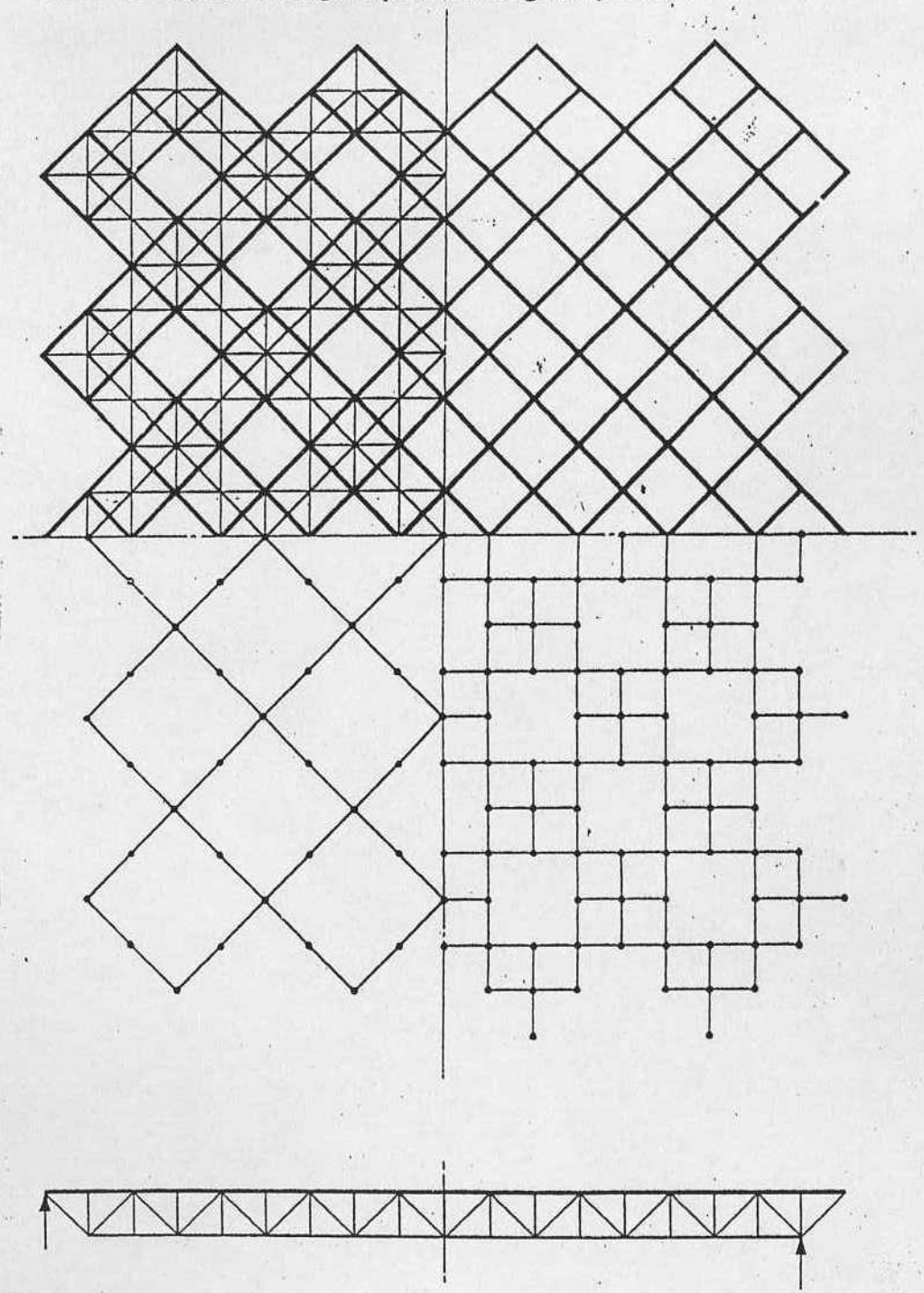




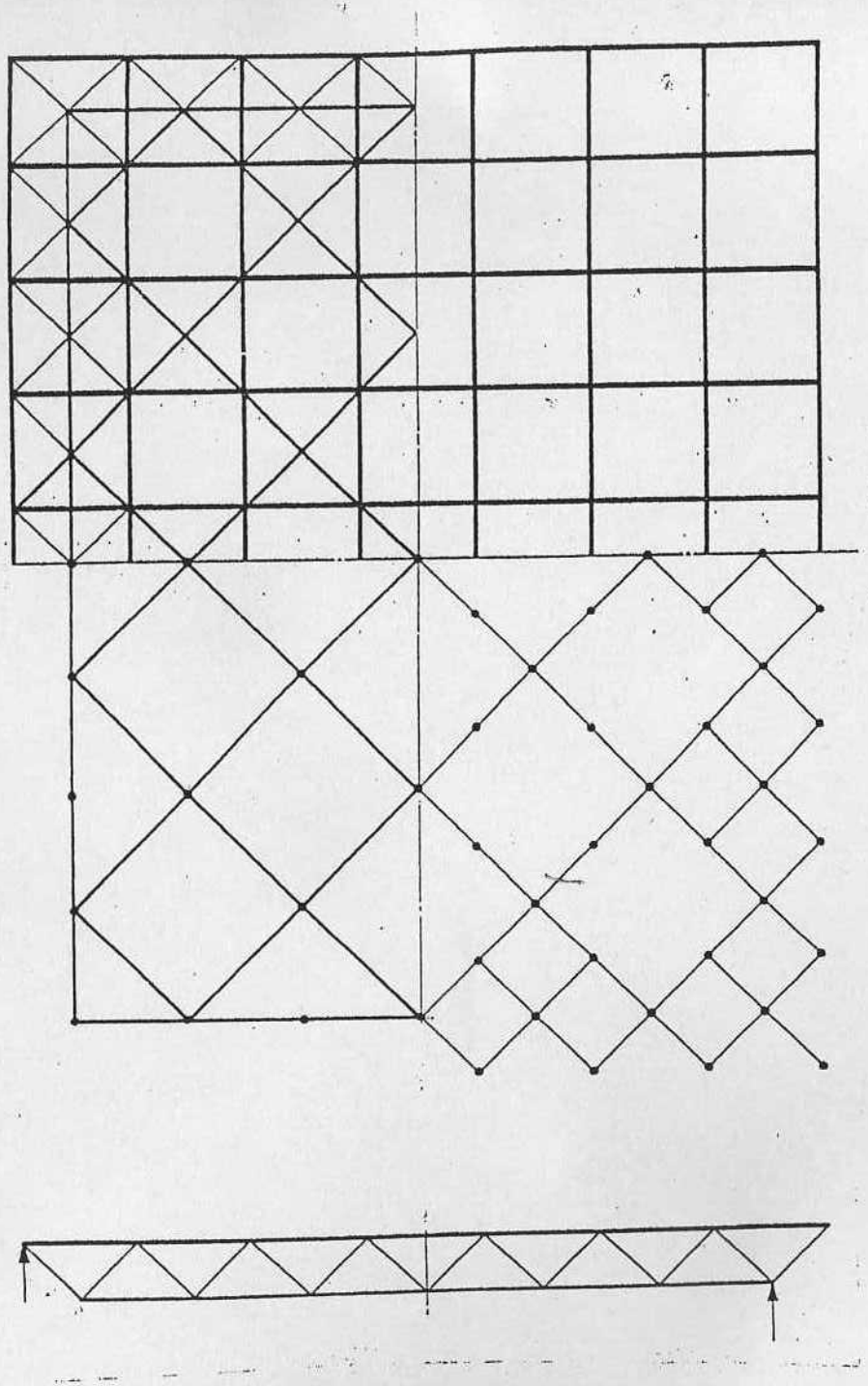
TYPE 3c—Square on larger square, Mansard edge



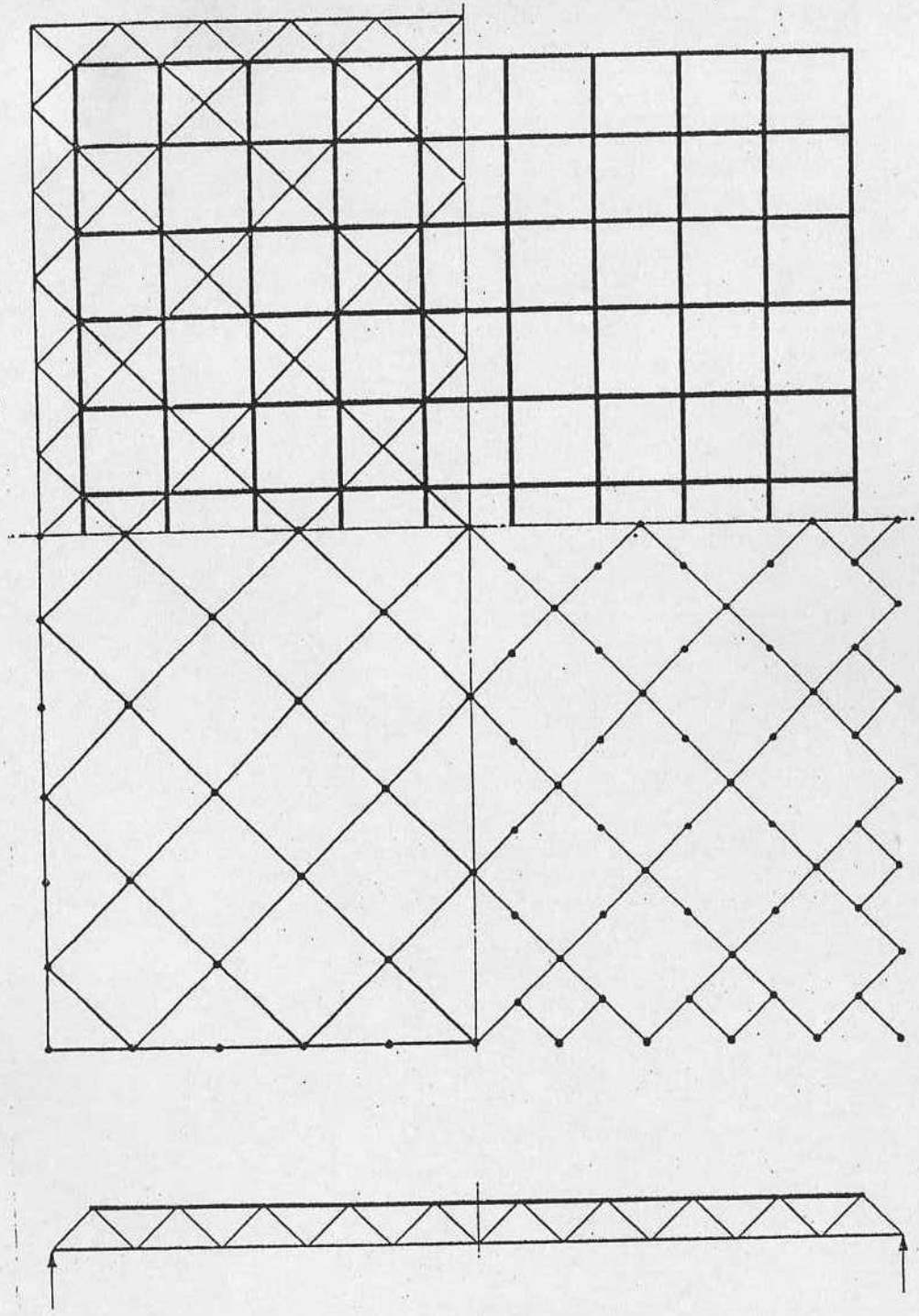
TYPE 4a—Square on larger square set diagonally, Cornice edge



TYPE 5a—Square on diagonal, Cornice edge



TYPE 5c—Square on diagonal, Mansard edge



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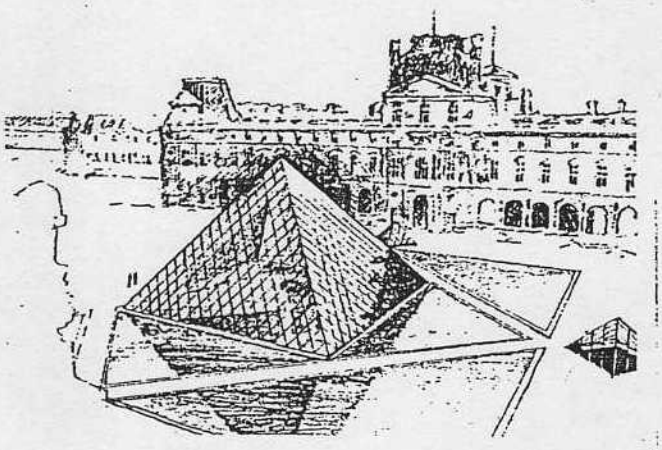
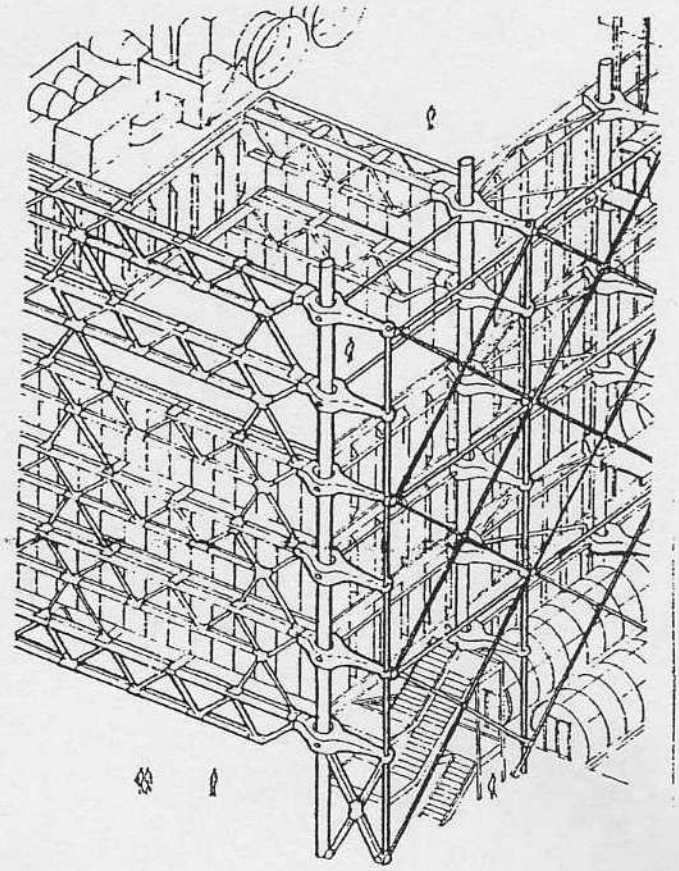
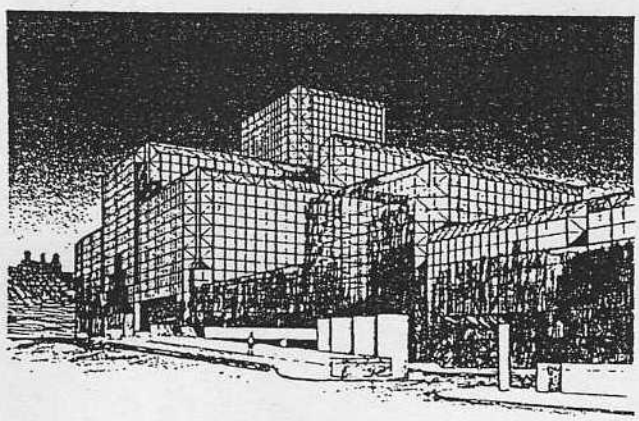


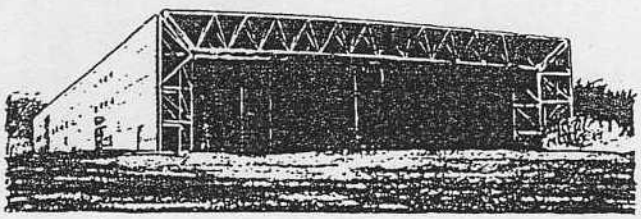
Addition to the Louvre Museum



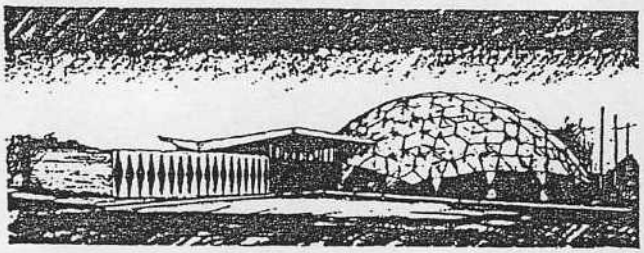
Centre Georges Pompidou



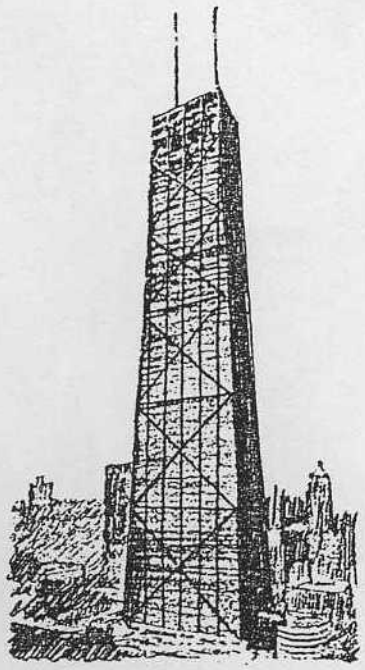
Jacob K. Javits Convention Center



Sainsbury Center



Kaiser Dome



John Hancock Center

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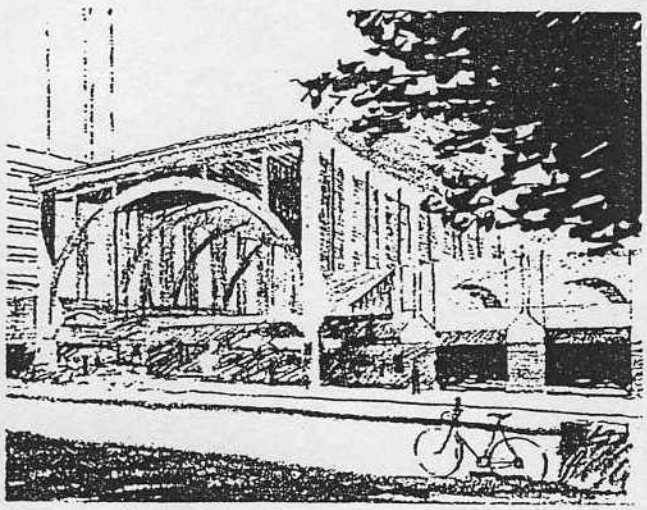
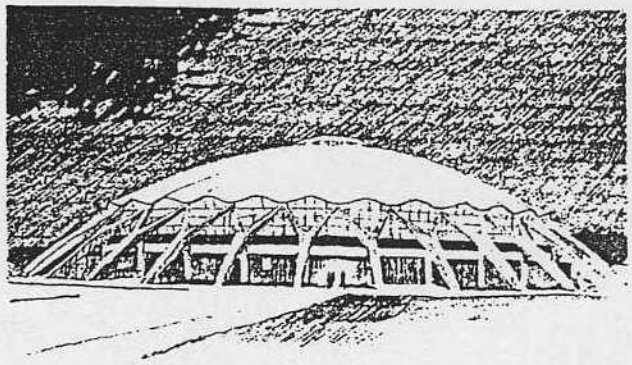
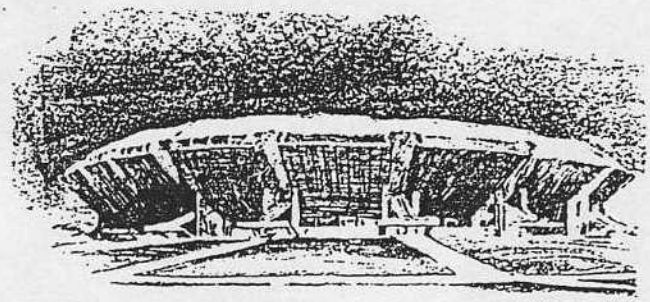


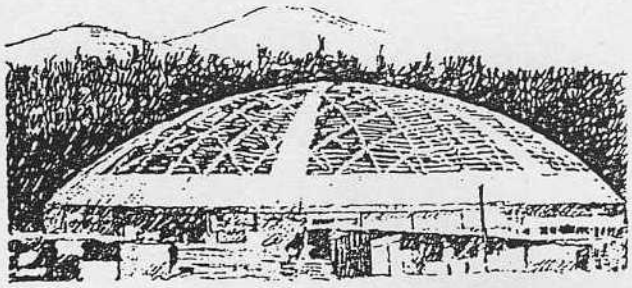
Back Bay Station



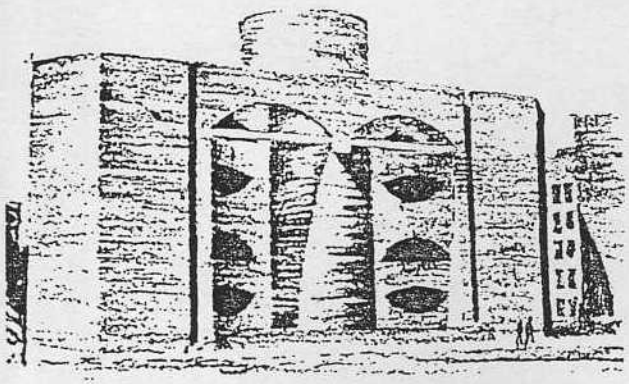
Palazzetto dello Sport



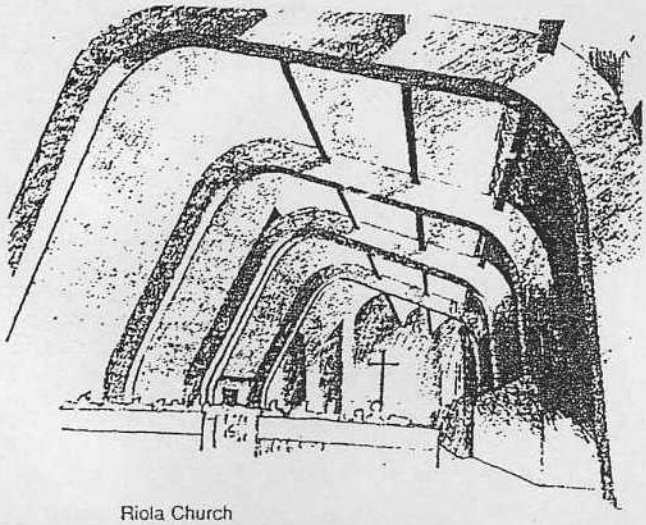
Bari Soccer Stadium



Tacoma Dome



Dormitory, Indian Institute of Management



Riola Church

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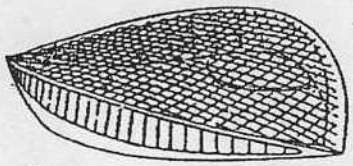
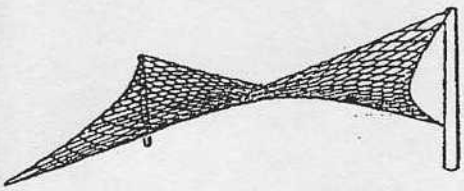
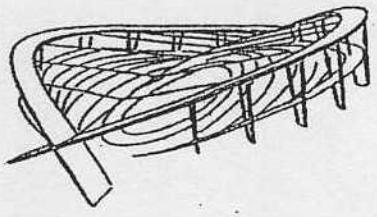
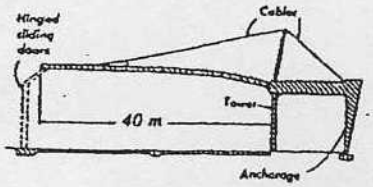


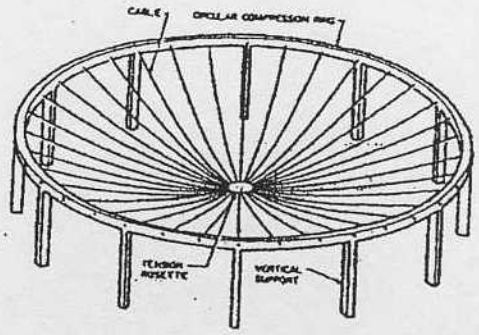


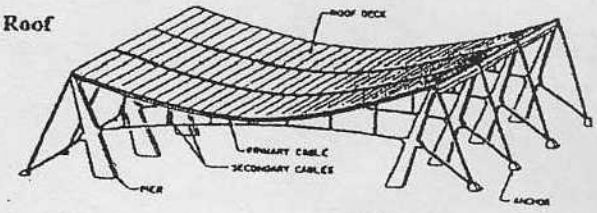


Cable Nets

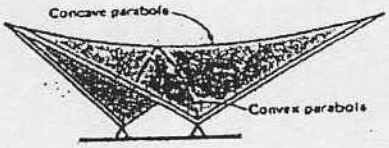


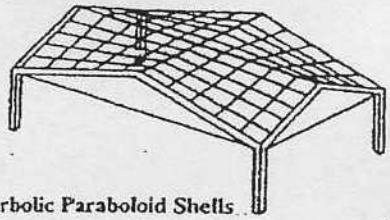
Cable-suspended Cantilever Roof



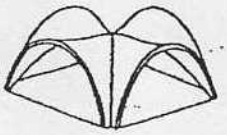


Cable Roof Structures

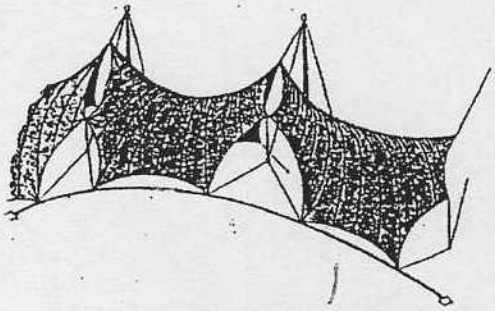




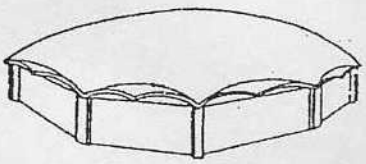
Hyperbolic Paraboloid Shells

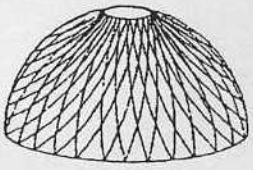


Anticlastic Shells

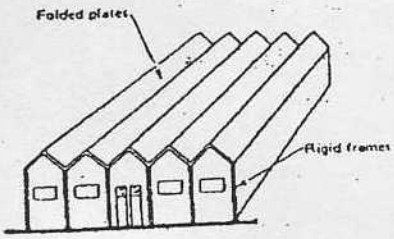


Cable-supported Tent

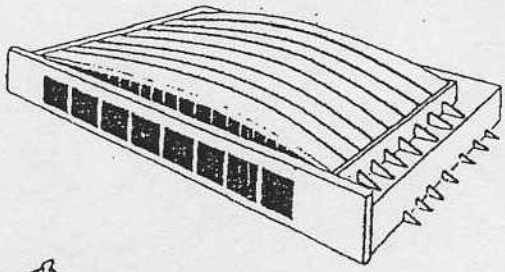


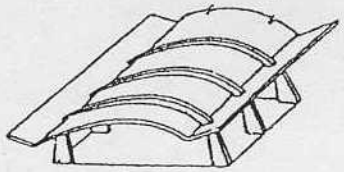


Domes

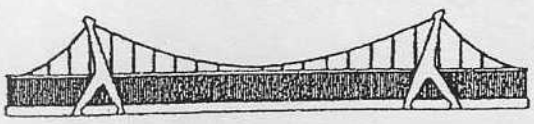


Folded Plates





Translational shells



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دانشگاه تهران
دانشکده هنرهای زیبا
گروه معماری

سیستم‌های ساختمانی

درس: محمود گلابچی

STRUCTURAL SYSTEMS

TENSION STRUCTURES

- **Cable Structure(Suspension Roof System)**
- **Tent Membrane(Cable Supported Tent)**
- **Air-Supported Structure(Pneumatic Structure)**

ARCHES

- **Arched Truss**
- **Arched Grid**
- **Concrete Arch**
  - Reinforced Concrete
  - Prestressed Concrete

SHELLS

- **Cylindrical Shell**
- **Hyperbolic-Paraboloid Shell**

SPACE FRAMES

DOMES

FOLDED PLATES

GRIDS

TRUSSED ROOFS

PRESTRESSED CONCRETE ROOFS

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سیستم‌های ساختمانی

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TENSION STRUCTURES

TYPES AND USES

Major classification of tensile structures include the followings:

Assemblies of single cables

Cable nets

Prestressed

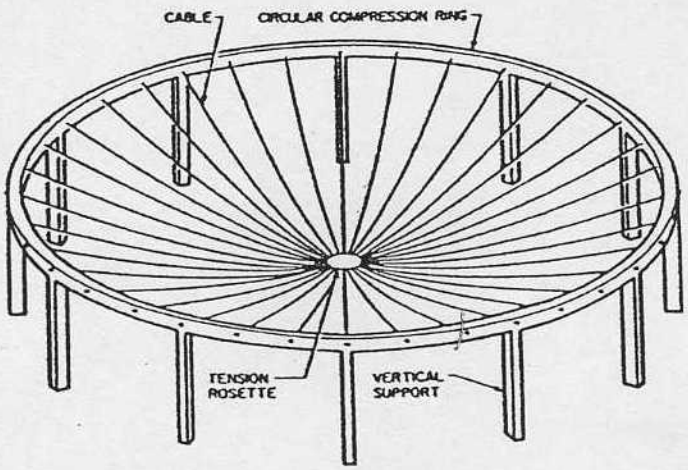
Nonprestressed

Pneumatic structures

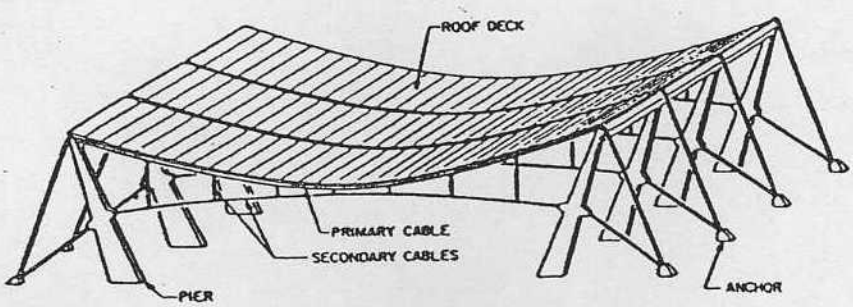
Air-supported

Air-inflated

Membrane structures



(a)



(b)

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TENSION STRUCTURES

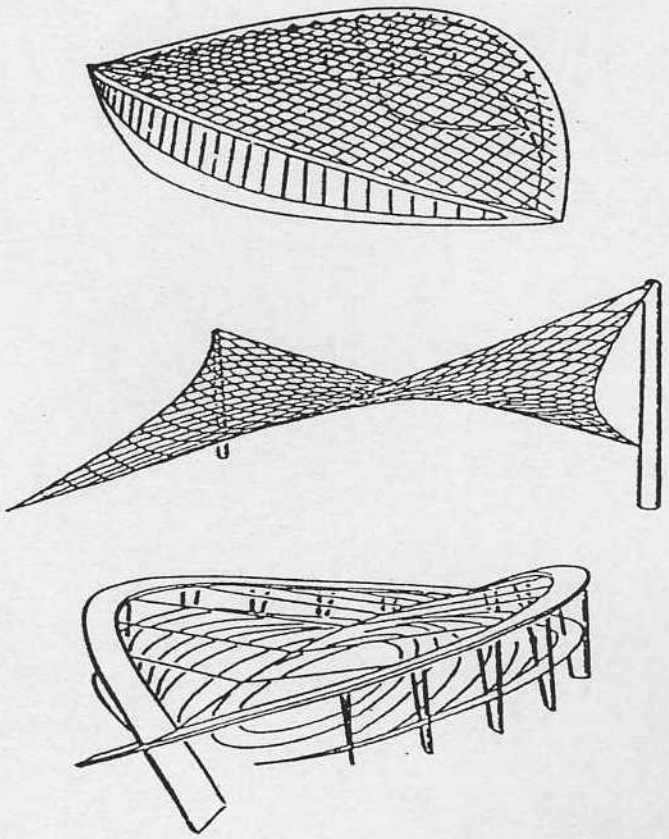

Figure 2. Cable Nets

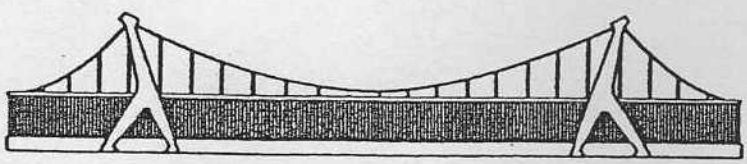

Figure 3. Suspension-bridge roof

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TENSION STRUCTURES

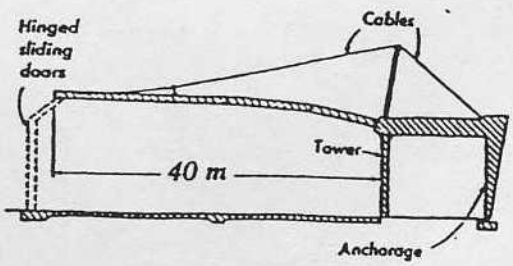


Figure 4. Cable-suspended Cantilever Roof

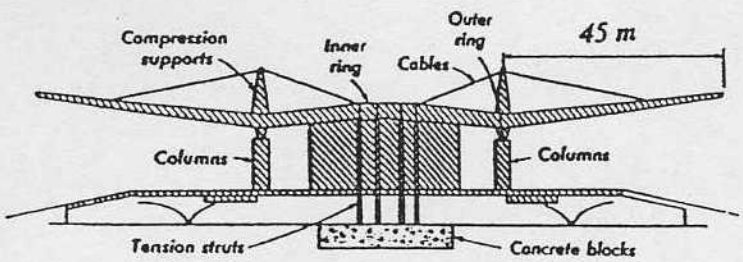
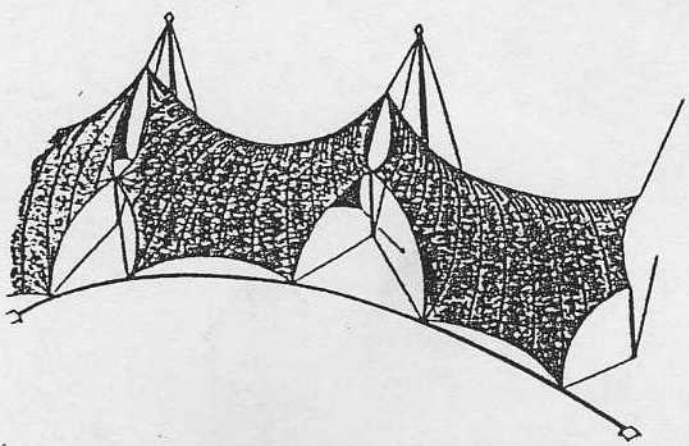


Figure 5. Cable-supported Elliptical Roof



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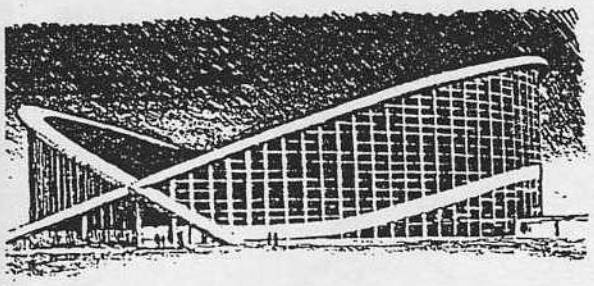
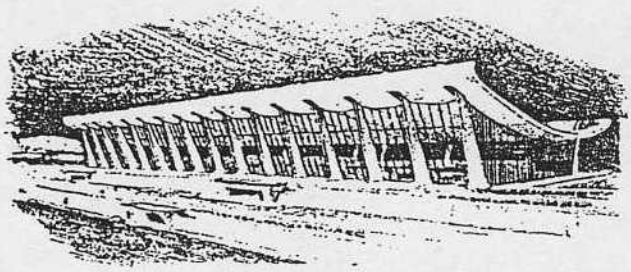
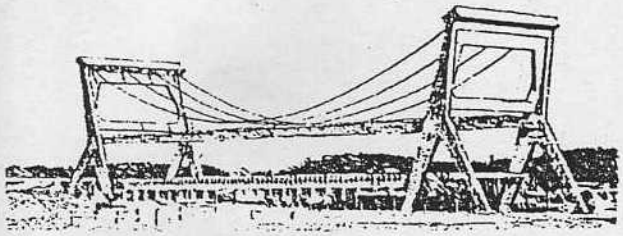
TENSION STRUCTURES



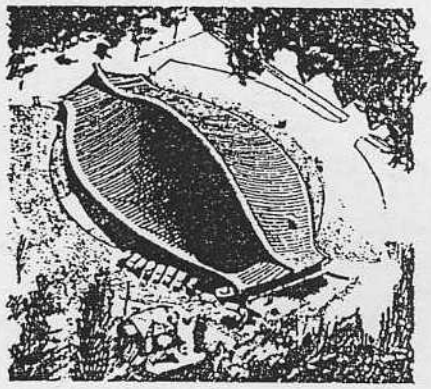
Raleigh Arena



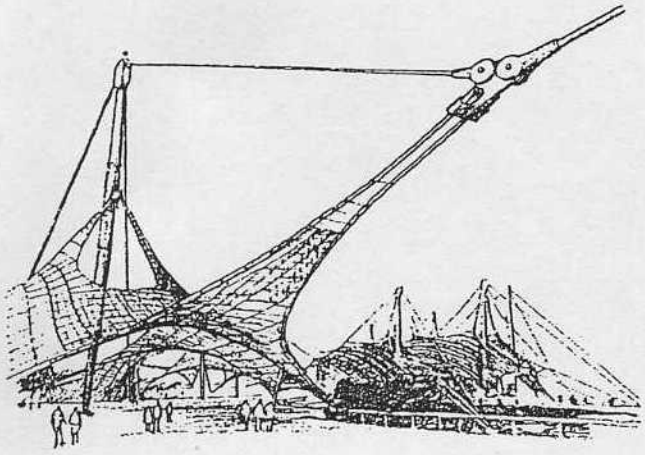
Dulles Terminal Building



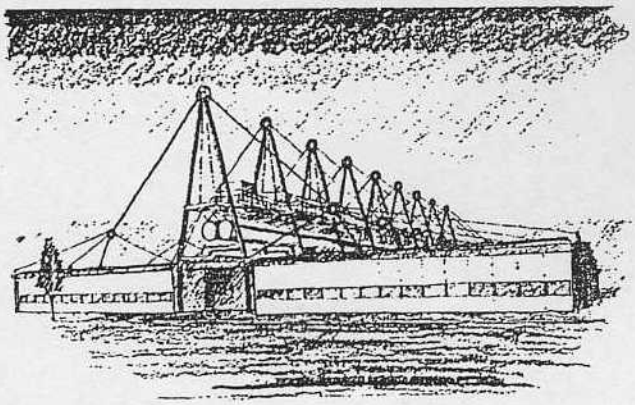
Burgo Paper Mill



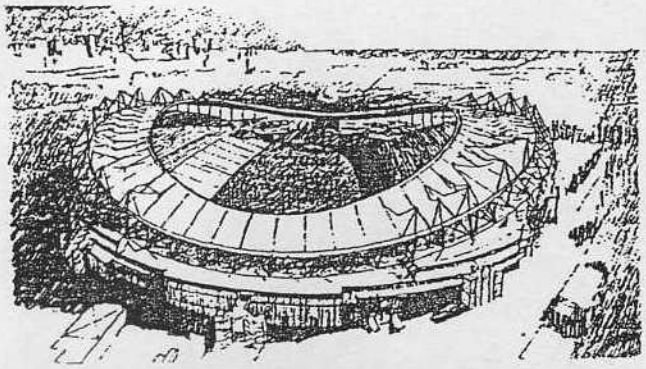
Yale Hockey Rink

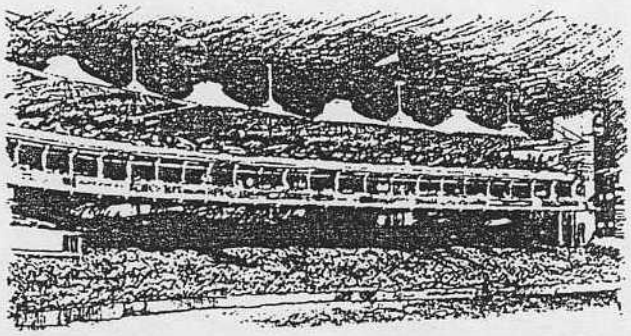


Munich Olympic Stadium



Patcenter





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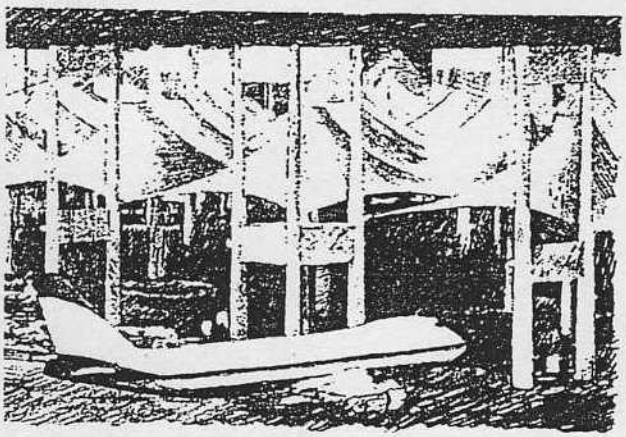
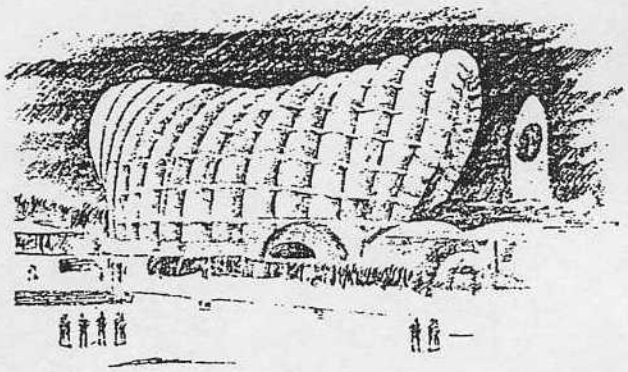
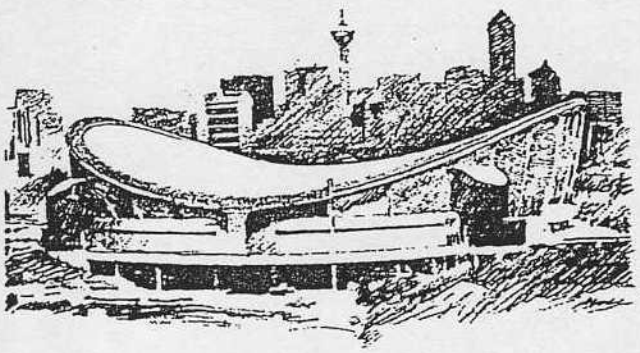
TENSION STRUCTURES



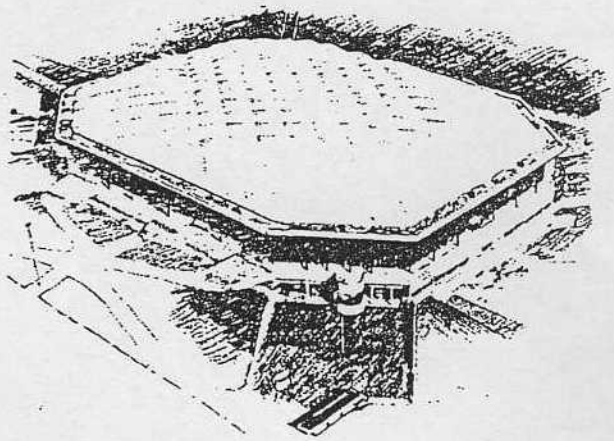
Haj Terminal, King Abdul Aziz International Airport



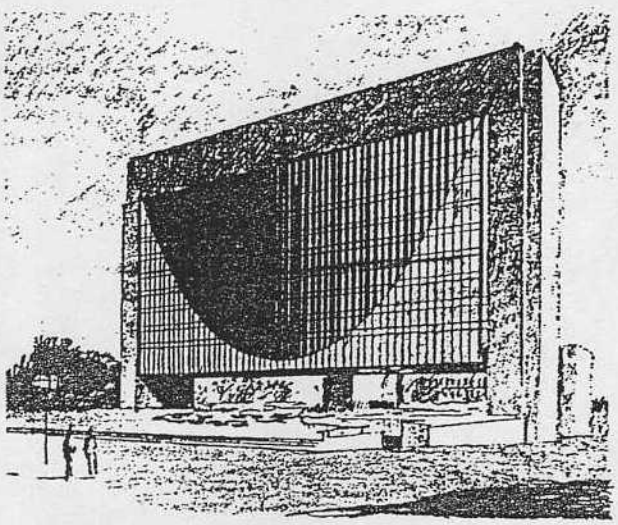
Fuji Pavilion



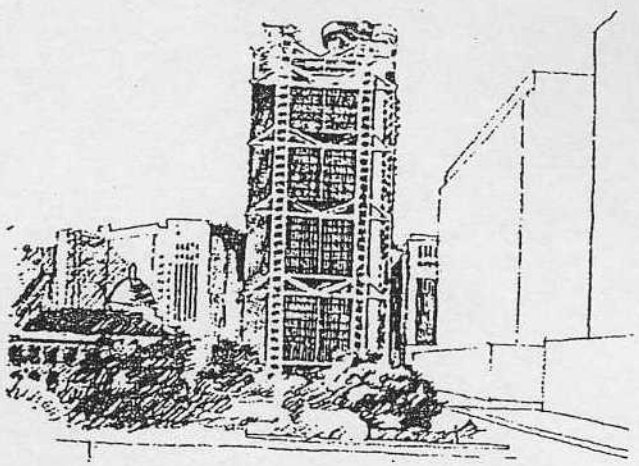
Calgary Saddledome.



Silverdome



Federal Reserve Bank



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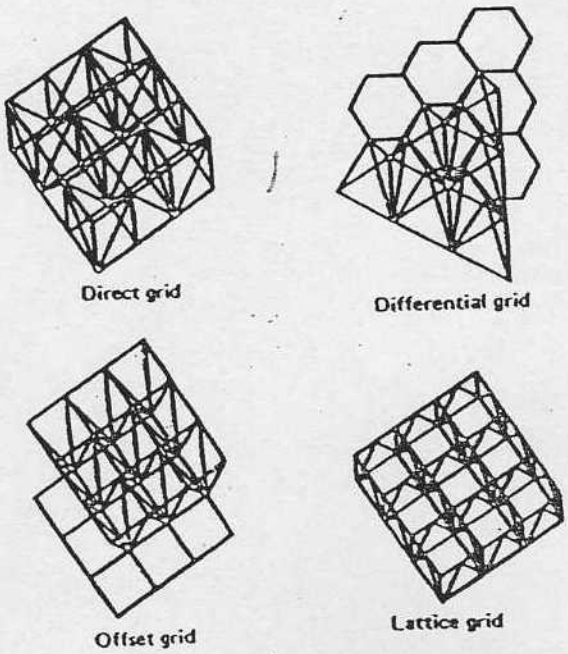
SPACE FRAMES

- **Direct grids:** two parallel girds similar in design with one layer directly over the top of the other.

- **Offset grids:** two parallel grids similar in design with one grid offset from the other in plan but directionally the same.

- **Differential grid:** two parallel grids that may be of different design and therefore directionally different but are chosen to coordinate and form a regular pattern.

- **Lattice grid:** the upper and lower members are braced to form a girder prior to erection.



Types of Space Frames

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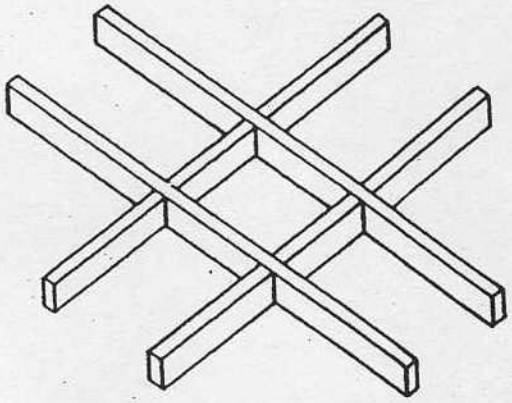
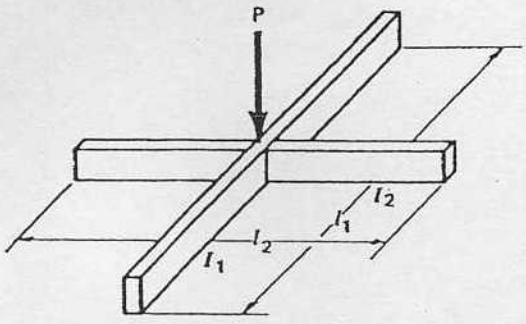
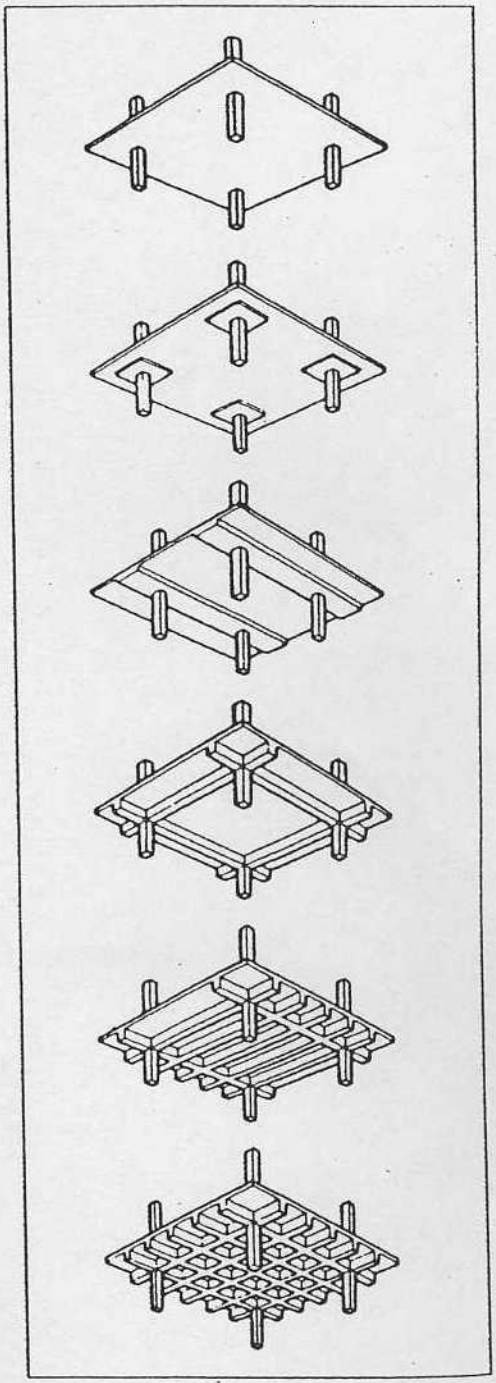
GRIDS



Grid



Grid Study Model



From the top:

Flat slab for spans from 5 to 8 meters

Slab strengthened at the columns. The maximum span is about 14 meters

Slab with underlying beams for a one-way span direction, up to about 15 meters

Beam/slab structure for a two-way span direction of 10 to 20 meters

Underlying beams in one direction for a slab carrying large loads.

Normal two-way slab structure, waffle slab for span from about 8 to 20 meters

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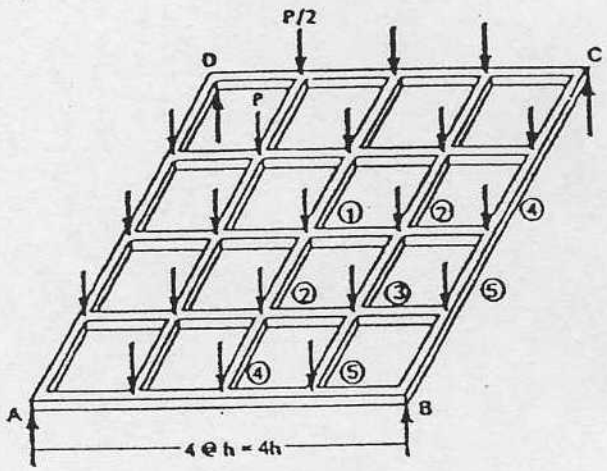
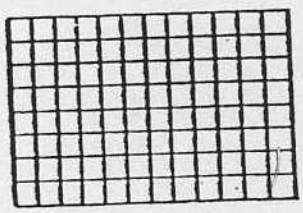
دانشکده هنرهای زیبا
گروه معماری

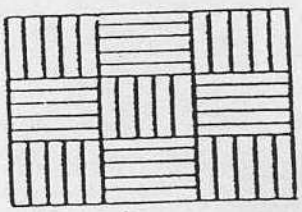
سیستم‌های ساختمانی

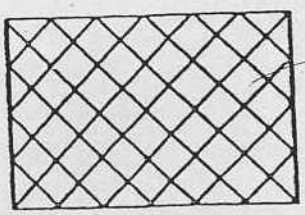
درس: محمود گلابچی

GRIDS









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گروه معماری

سیستم‌های ساختمانی

درس: محمود کلابچی

SHELLS, DOMES AND FOLDED PLATES

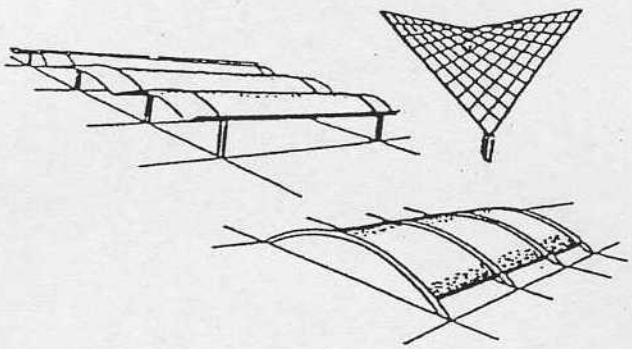
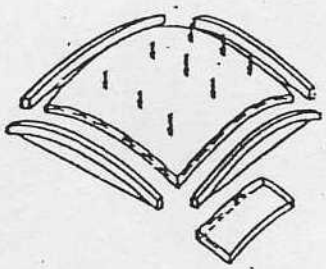
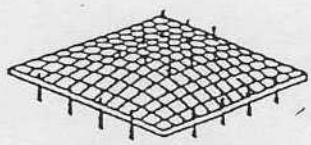


Fig. 1. Shell Systems





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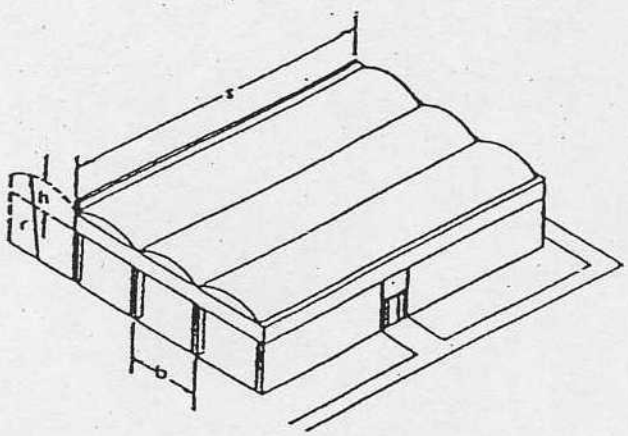

Fig. 3. Developable Shells

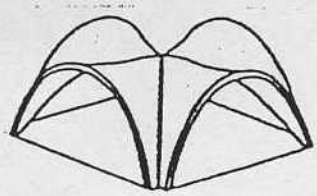

Fig. 4. Anticlastic Shells

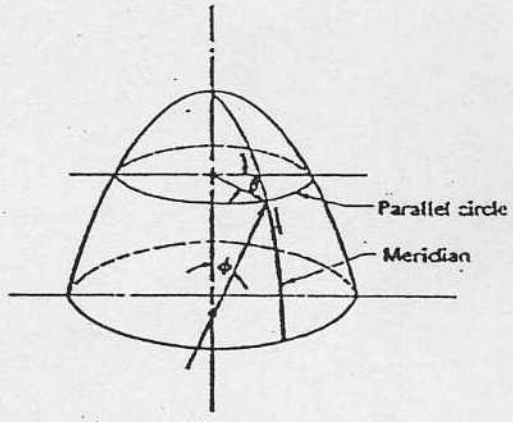

Fig. 5. Rotational Shells

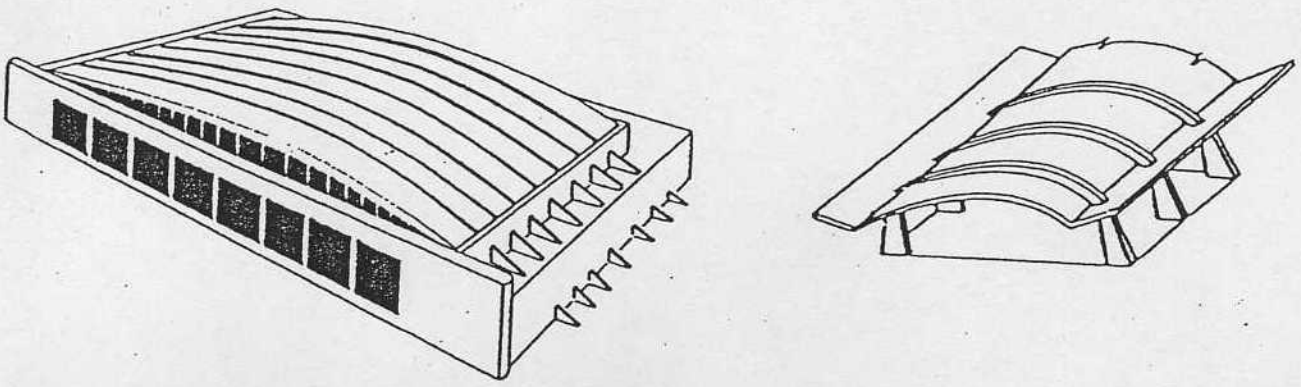

Fig. 6. Translational shells

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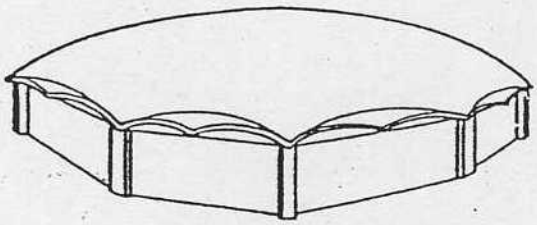


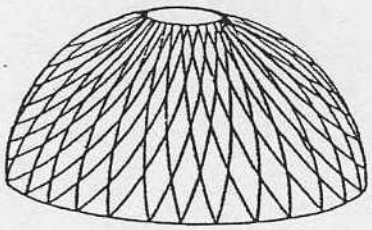
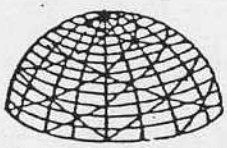
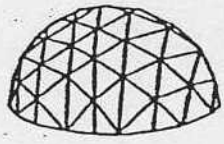


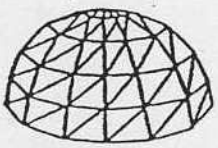
Fig. 7. Domes



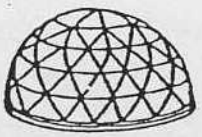
(a) Radial rib-type dome



(b) Geodesic dome



(c) Schwedler dome



(d) Zeiss-Dywidag dome

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SHELLS, DOMES AND FOLDED PLATES

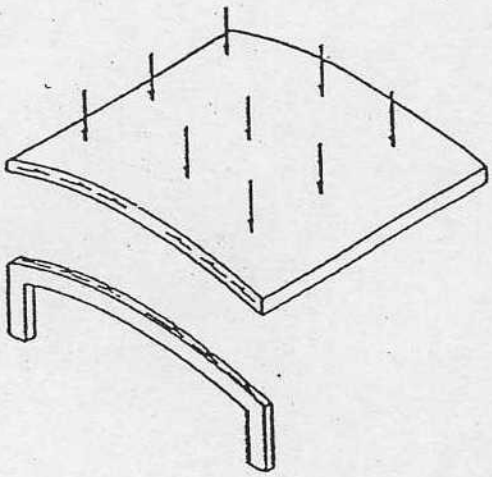
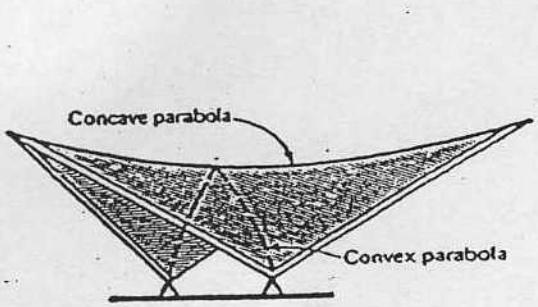


Fig. 9. Cylindrical Shells



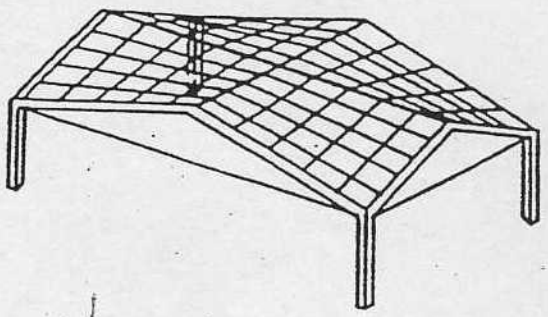


Fig. 10. Hyperbolic Paraboloid Shells

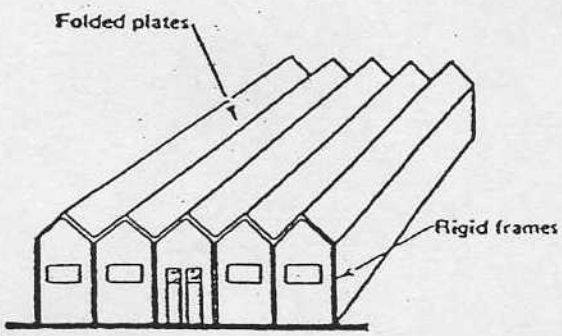


Fig. 11. Folded Plates

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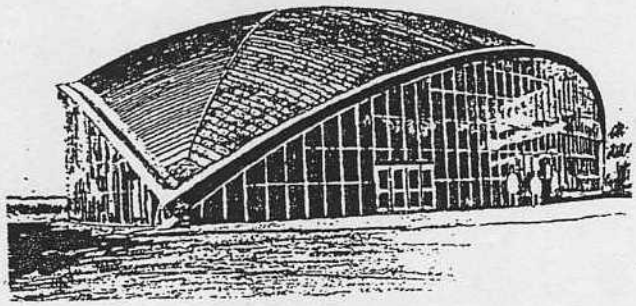
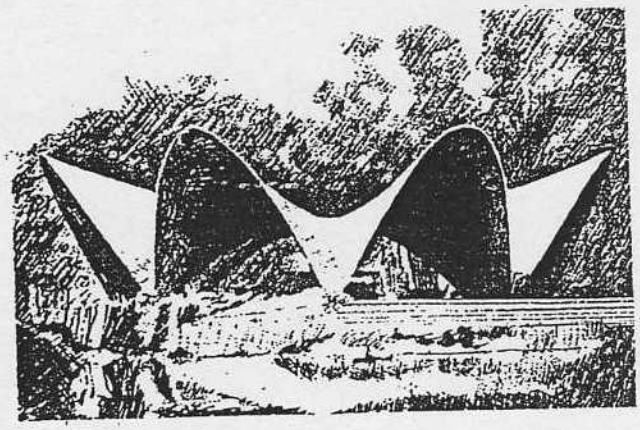
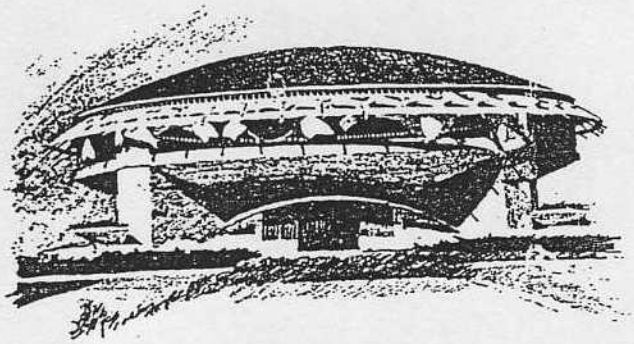


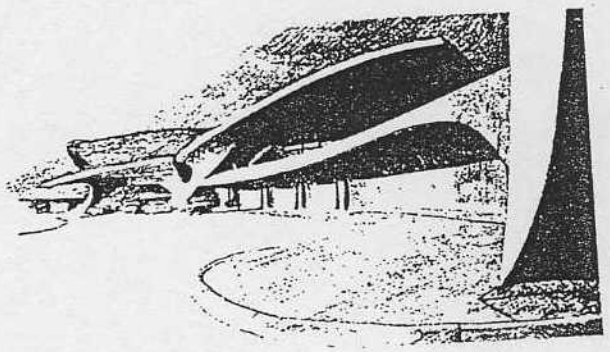
Kresge Auditorium



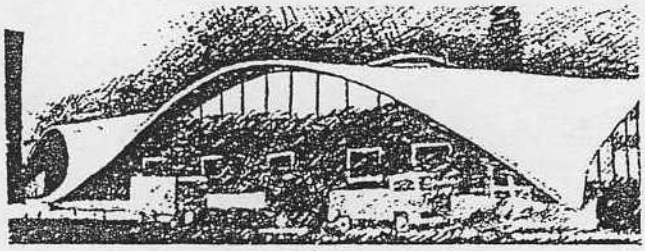
Los Manantiales Restaurant



Annunciation Greek Orthodox Church



Trans World Airlines Terminal



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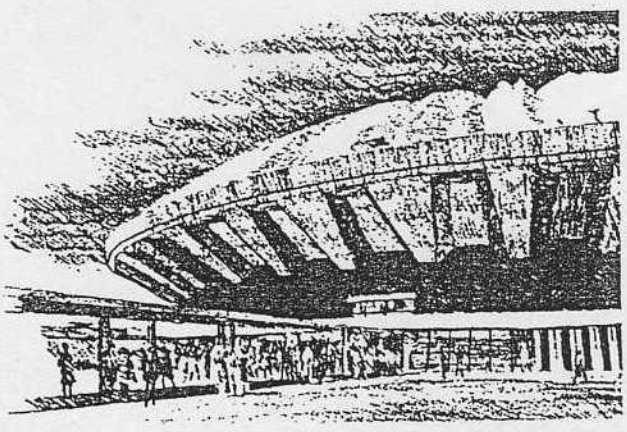
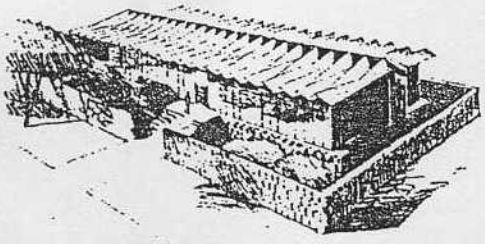


Illini Hall



American Concrete Institute