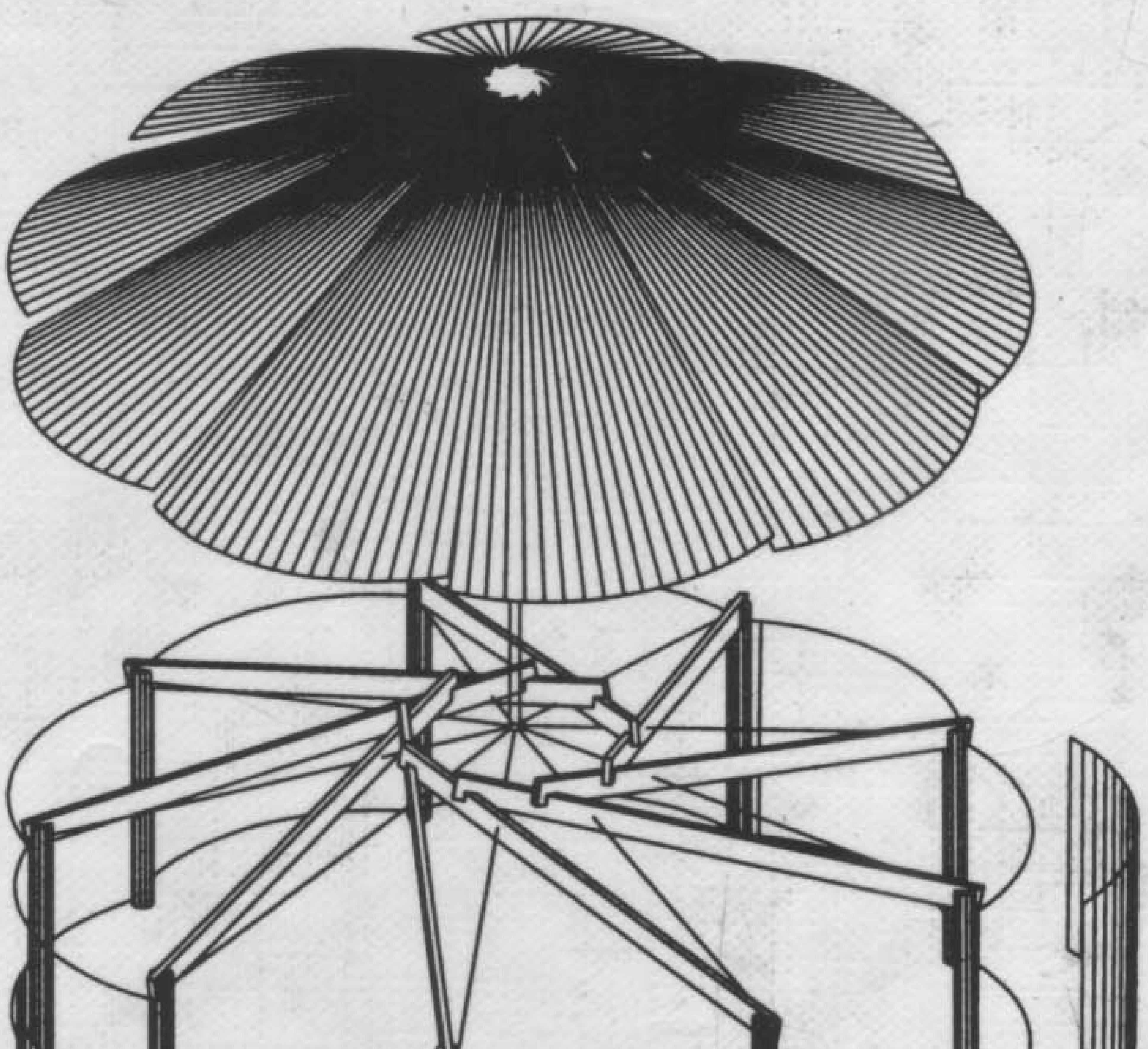
Mobile and Rapidly Assembled Structures II

Editors: F. Escrig and C.A. Brebbia



Computational Mechanics Publications

New ideas on deployable structures

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Abstracts

Deployable structures usually are synonym of temporary and reusable structures, but they are also transportable, easy to erect, reduce working time at the site, are built under factory conditions and accuracy, and are easy to store.
These last characteristics can be also useful for improvement permanent edification's construction,
we have been developing deployable structures for both ideas. Structures very easy to transport, and fast erection for short period of time use as ESTRAN 1, temporary building as the Venezuelan Pavilion and permanents structures were we use deployability as a building method.

Estran 1.

This structure was designed as a ephemeral cover, easy to transport from one location to another. Its fast erection allow very short periods of utilization.
Two versions of this structure have been designed, one is built by three parallel arches joined together by fourteen connections or arms. Starting from a packet of 1x1x4,20 Mts. this structure deploys in two directions to produce a vault of 14 Mts. wide, 8 Mts. long (112 m2) and 500 kg (Fig. 1) of weigh. The second version make it possible to produce in few minutes a roof of 186 m2 with a weigh of 900 kg. The structure is formed by two high arches with an internal diameter of 16 m, and two low external arches with a diameter of 12.18 m, all parallel and joined together by 28 perpendicular arms placed on radial planes generated by the rotation axis of the cylinder and the nodes in the arches. Each arch is made up of six scissors-type assemblies formed by rectangular-sections, tubular aluminum elements pivoting on a common axis on the same plane. The arms are also

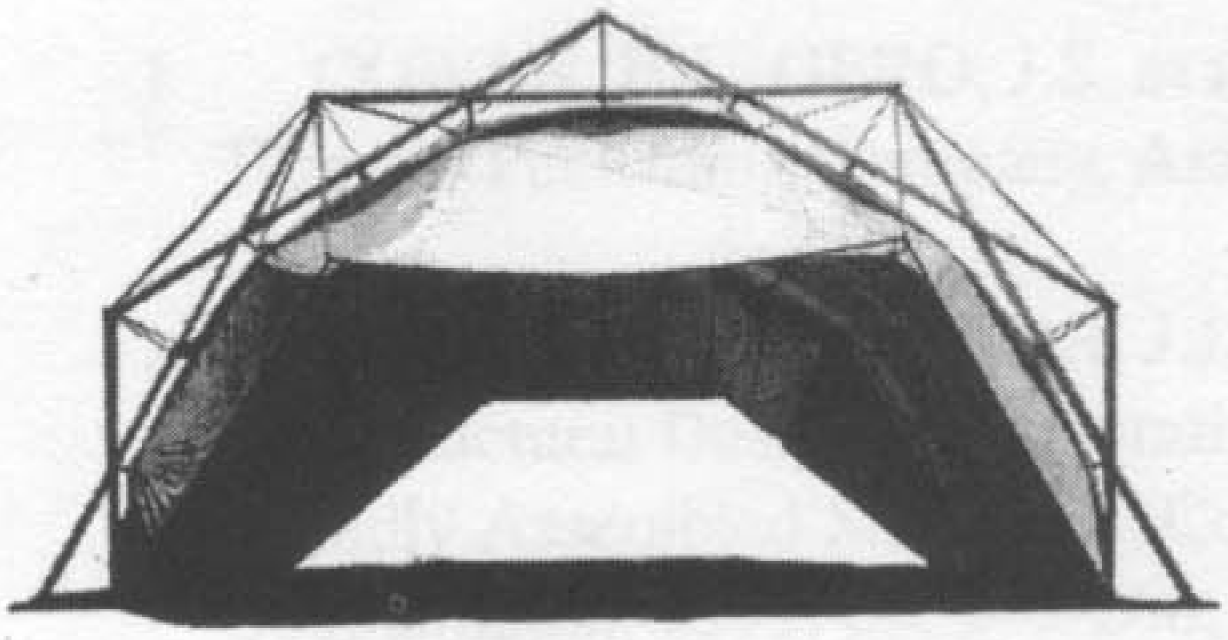


Fig. 1 Front View Estran

connected to the arches by metallic nodes to form a square-based reticule which is triangulated by steel cables fixed on the nodes and provided with tensors to achieve its final stabilization.

The framework consists 100% on painted or anodized aluminum with high resistance alloy. The nodes are made of galvanized steel and are separated from the aluminum components by means of stiff nylon horns to avoid their galvanic corrosion which at the same time reduce the friction between both mobile pieces.(Fig. 2) The difference in the arches produce

Fig. 4 Inside view Estran

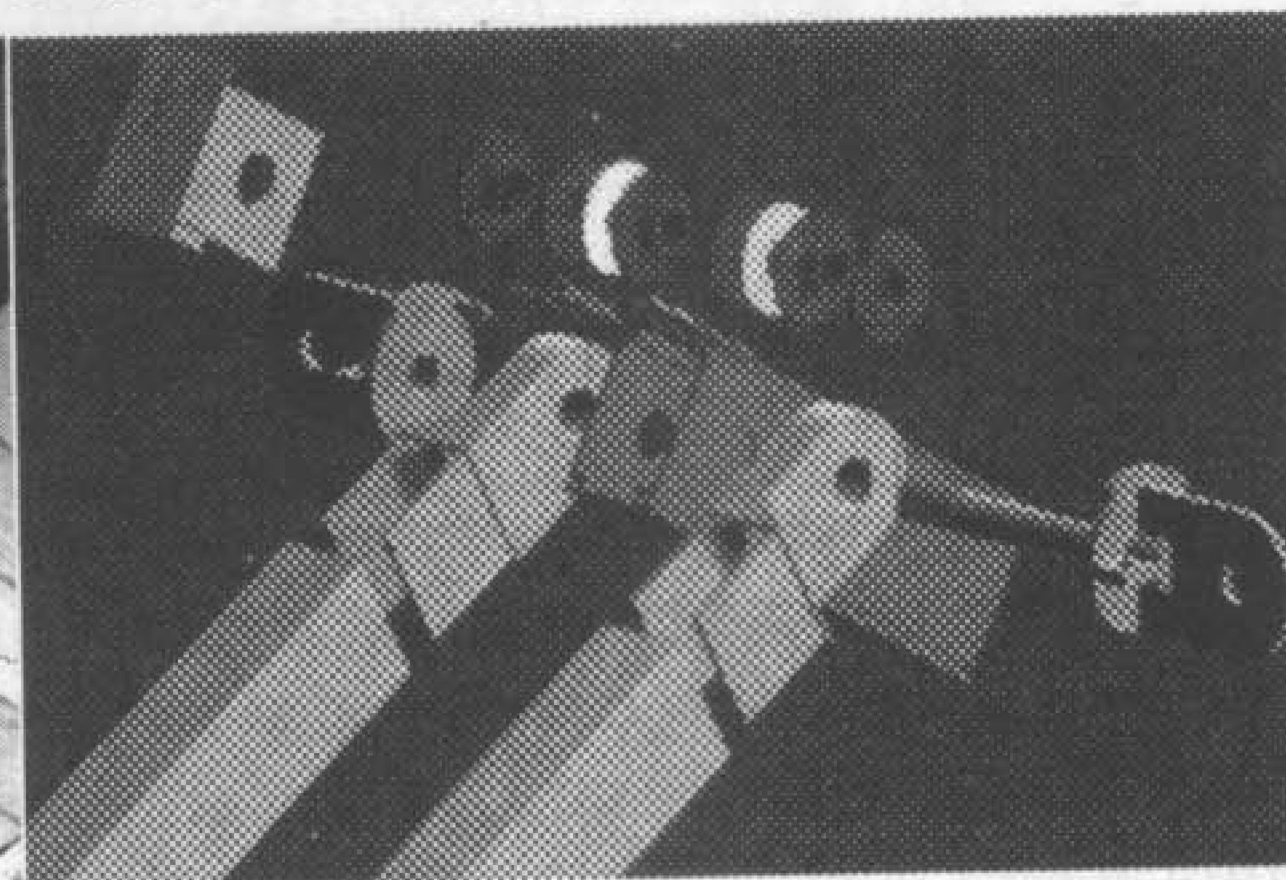


Fig.2 Node

a curvature in the shorter axis of the structure, giving more strength to the assembly.
The structure is transported as a compact package and is erected to a vertical position by a small crane on the transport vehicle; with the aid of four operators (Fig. 3). The ends of the package are pulled diagonally and simultaneously until the structure begins to curve, the roof is hung and the unfolding is complete with the crane lifting the structure to its final position. This operation takes about 5 minutes. The bolts, which stop the reticule structure from returning to its folded position, are put in place, the structure is fixed to the connection plates on the ground. The securing of the struc-

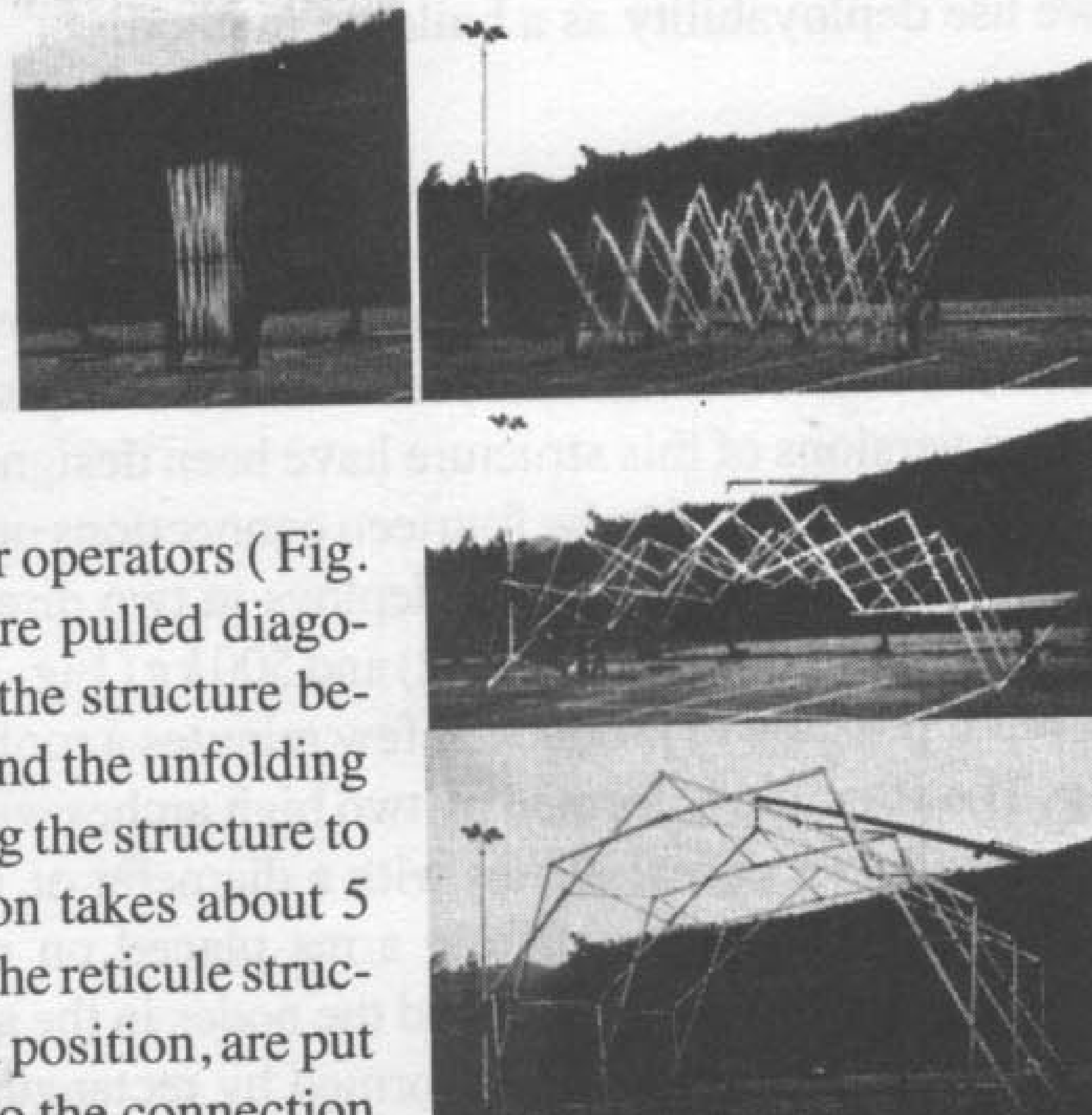


Fig. 3 Deployment Process

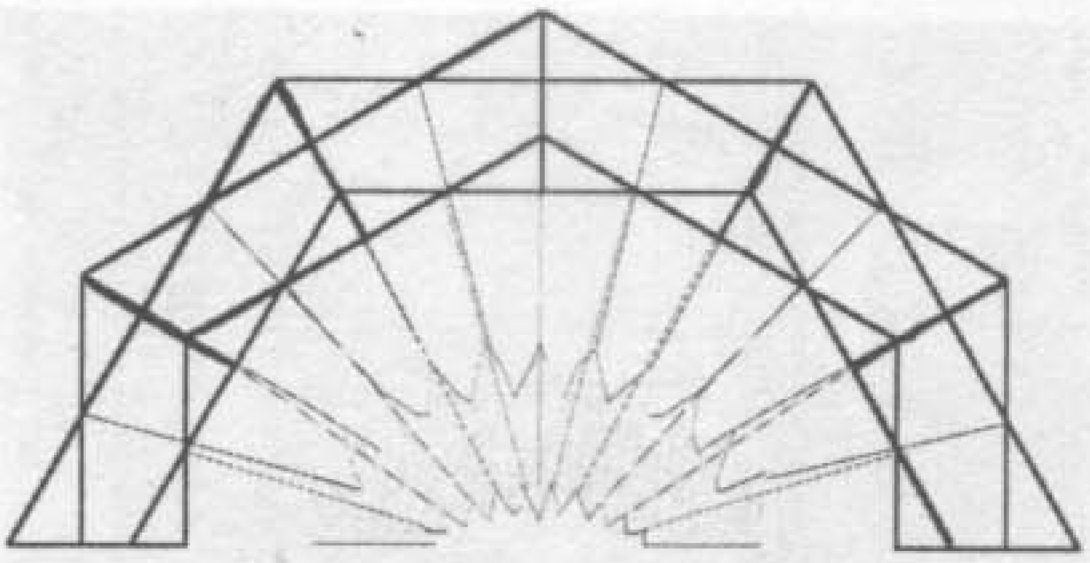


Fig. 5 lifting of cover

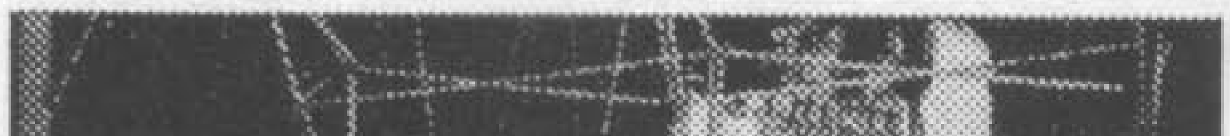


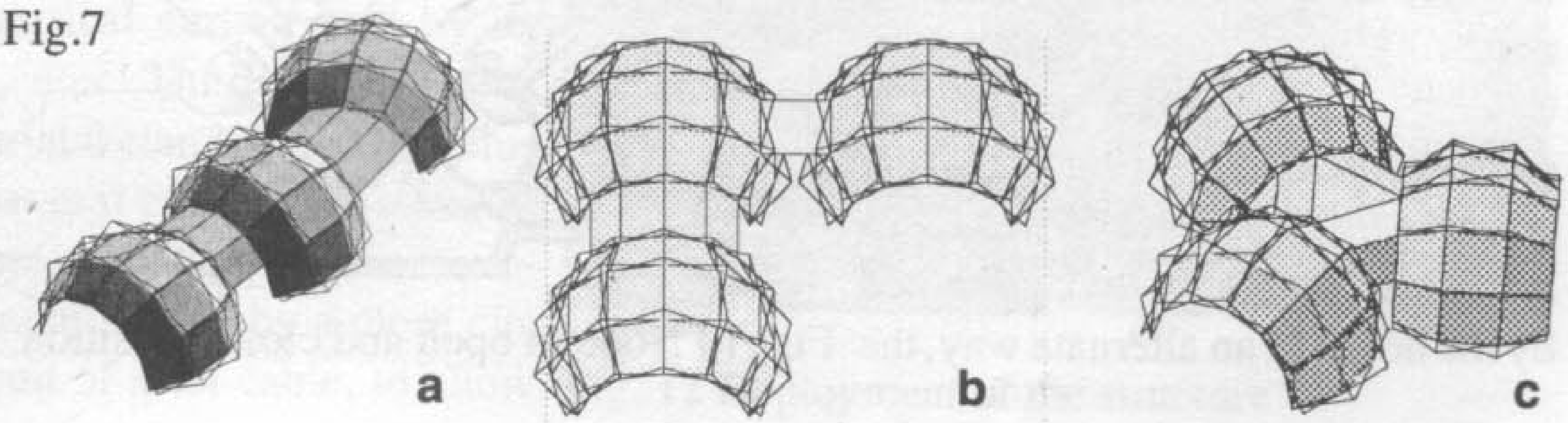
Fig. 6 View of lifting operation

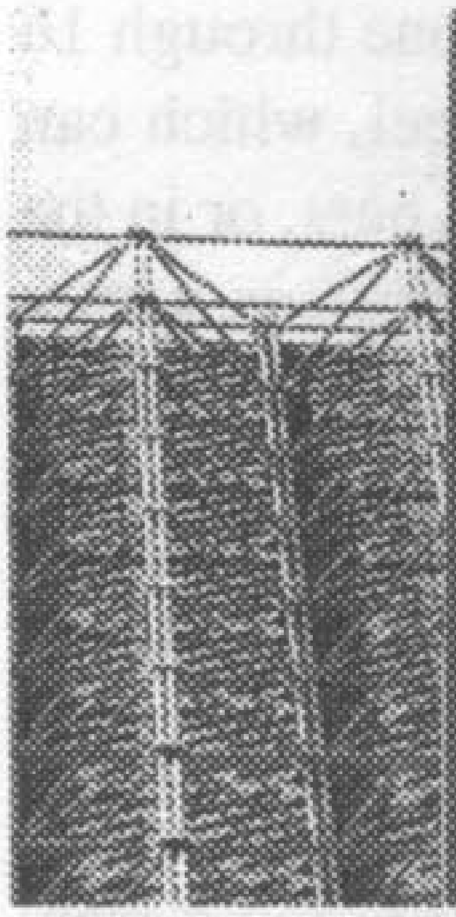
ture to the ground is done through 16 plates of perforated steel, which can be nailed using 25 mm bars, or in the case of floors with rawlplugs with a 250 Kg capacity. If the surface cannot be perforated, the structure is secured by means of bags full of earth, sand or water which give the structure stability when tied to it.

As a cover we use a pug-coated polyester canvas that is hung from the structure (Fig. 4). One of the problems we have been studying is the hangings of the canvas roof. The first method we used was hanging the roof when the structure is half way open, in this position the operator can easily reach the hanging points. The roof is then lifted with the rest of the structure. Although this seen to be a fairly quick method, the roof interfere with the fixing operation so it can not be done from below the structure, the operator has to climb the structure and work from above it , which make the process too slow. The second method we have used is lifting the canvas with the help of pulleys (Fig. 5), once the structure is totally fixed. The pulleys and the lifting lines are placed on the structure before this is fully expanded (Fig. 6), so the lifting operation is done at grow level this reduce the time of placing the roof a lot, but it will be shorter once the whole process will be done from the grown.

Several combinations are possible with ESTRAN 1.1. Two or more modules can be connected. This connection is made by means of pretautened canvas placed between the modules; this covered Area can be completely lineal, that is, connected to modules aligned to each other (Fig. 7a). Another combination with ESTRAN 1.1 is that of connecting the modules laterally, either through the lateral-

Fig.7





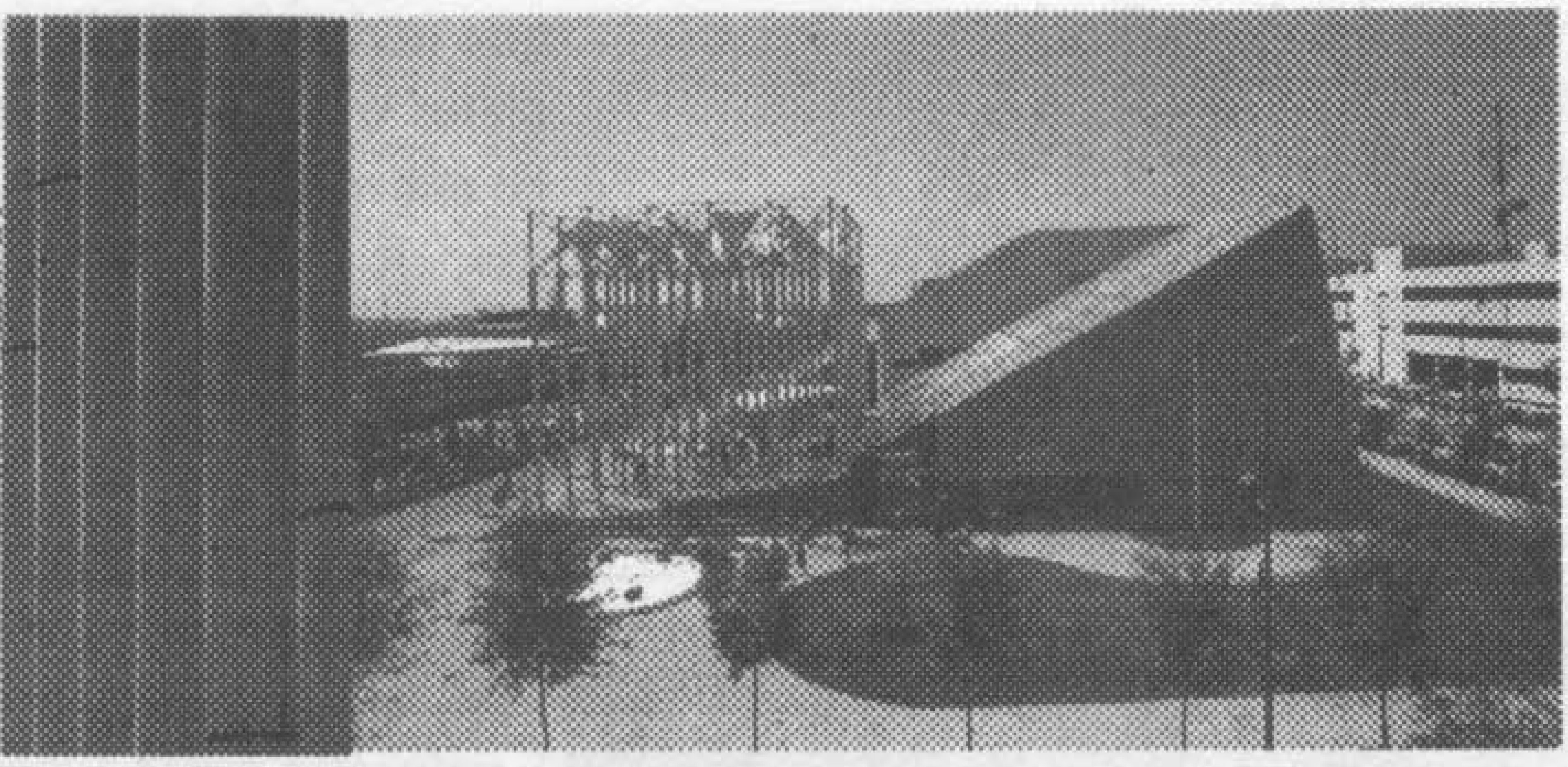


Fig. 9 View of structure   Fig.8 Venezuelan Pavilion at Expo´92 Seville

central axis of each module or forming a lineal corridor (Fig. 7b). A third way to increase space is through a central canvas module formed by the radial union of three modules (Fig. 7c). This creates a covered walkway between the spaces.

The Structure of The Venezuelan Pavilion

The structure of the Venezuelan Pavilion as a difference with ESTRAN this structure was designed for a more permanent use although still light and transportable this accordion like structure of 2000 sq. meters was deployed in two day and the roof added in two weeks, was continually in use for more than 14 months and folded back so we must considered this structure as a semi-permanent one.

The structure is a net made by parallel trusses, (Fig. 9) connected among themselves through hinges, that allow for accordion-like movements, permitting the whole structure to fold in one direction. All the components of the net are circular-sectioned and standard in production. The node is the most complex element since it requires connections in different directions (Fig. 10). It is made up of two pieces: the node-hinge and the staple. The node-hinge permits the bearing to be assembled, receives the transversal elements that give stability to the structure in its final position and the accordion-like movement. The staple is set after the structural net is opened. It is the piece that keeps the node in position, keeping the structure from closing again, and it also permits the closing elements to be fixed.

The trusses are made up of continuous tubular elements, on which the node-hinges are fixed at 2-meter intervals. The diagonals are tubular elements, flatten at the ends, that are bolted to the node leaves. The trusses are related parallelly and are united by the nodes in an alternate way, the

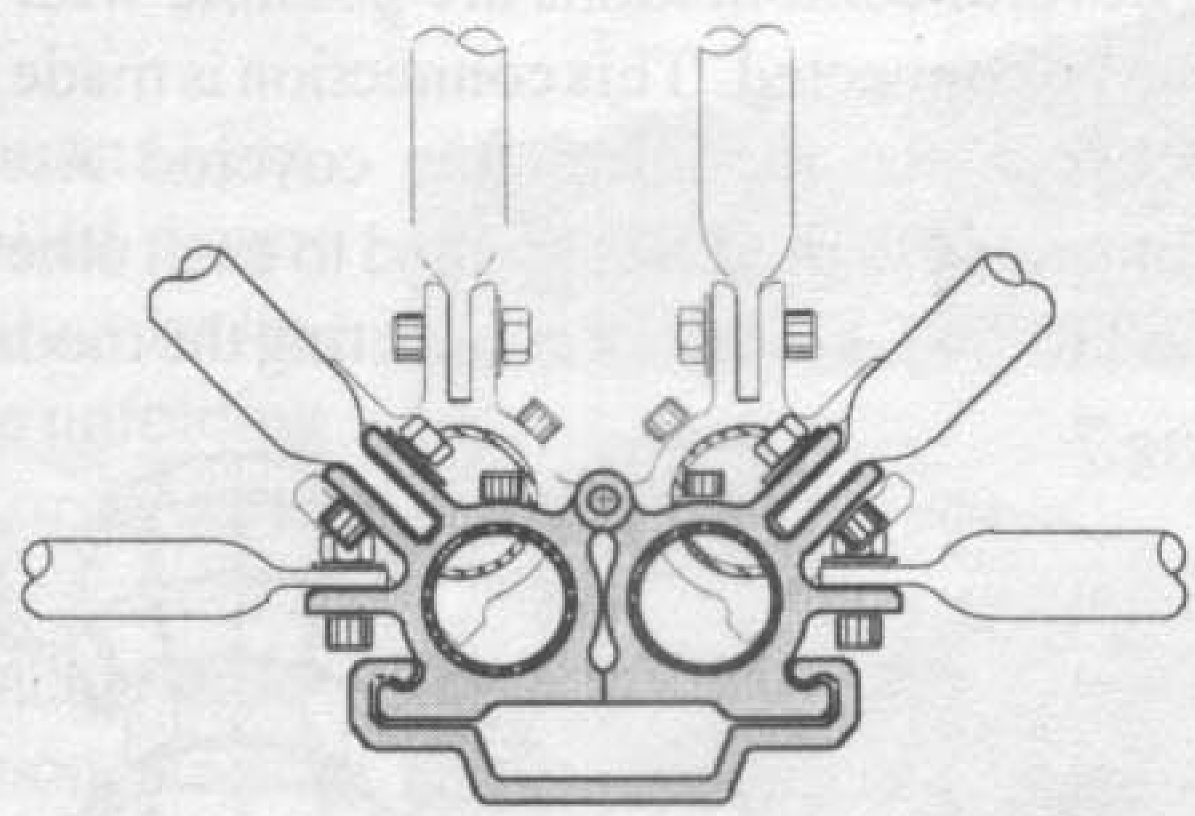


Fig. 10 Node in open and closed position

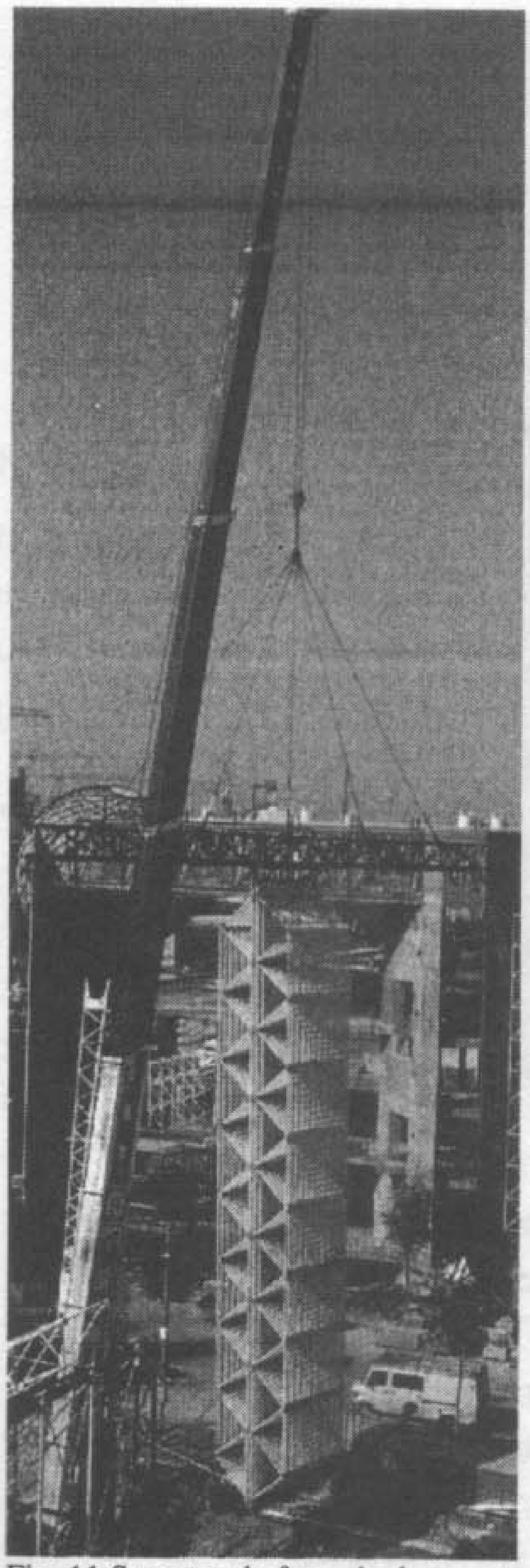


Fig. 11 Structure before deployment

first bearing is connected to the second at the inferior string, and the second with the third at the superior string, and so on, so that the bearings can rotate 45 degrees with respect to the other, to extend or fold as an accordion, forming a package to be shipped to Seville. The trusses are 1.40 meters high in vertical position, going down to a meter when it is unfolded to 45 degrees.

The transformable structures are systems of varying positions, to make its transport easier; thus, its components have a predetermined shape to unfold and connect that depends on the final shape to be adopted. In the case of the Pavilion of Venezuela, the net covers an audiovisual room, which has the geometrical shape determined by the requirements of the projection system.

The result is a triangular section whose highest point (19 meters) corresponds to the top, being made up by two planes, the superior plane that goes from the square to the top, 32 meters long, and the rear plane that goes from the top to the rear bearing, 18 meters long.

Since the superior plane presented an intermediate support, the projection room, the mounting process was divided into two stages. Stage A that covers the waiting Area and the projection room, and stage B that corresponds to the audiovisual room, using the top and the projection room as rotation axis. The first stage was made up by a group of 12- meter-long trusses, and the second stage by two groups of 18-meter-long trusses, united by one of the extremes corresponding to the top.

In both cases the packages are hanged from the rut beam that makes the unfolding easier,(Fig. 11) a movement similar to that of opening a vertical curtain held by its center. This beam is a horizontal element that contains several Trolley type containers, with independent movement, united by a close circuit of steel cable, to allow

Fig. 12 Deployment of the structure

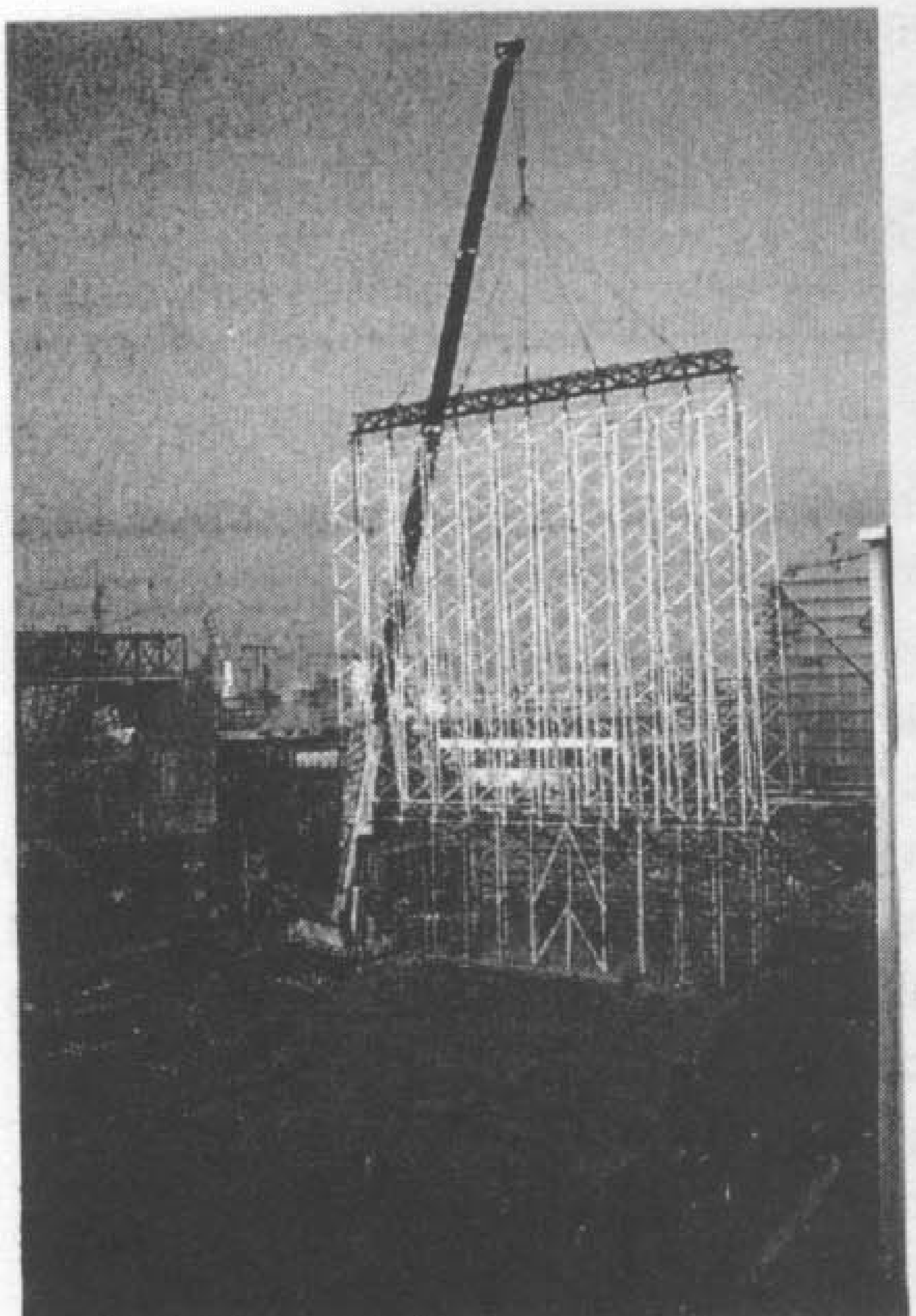
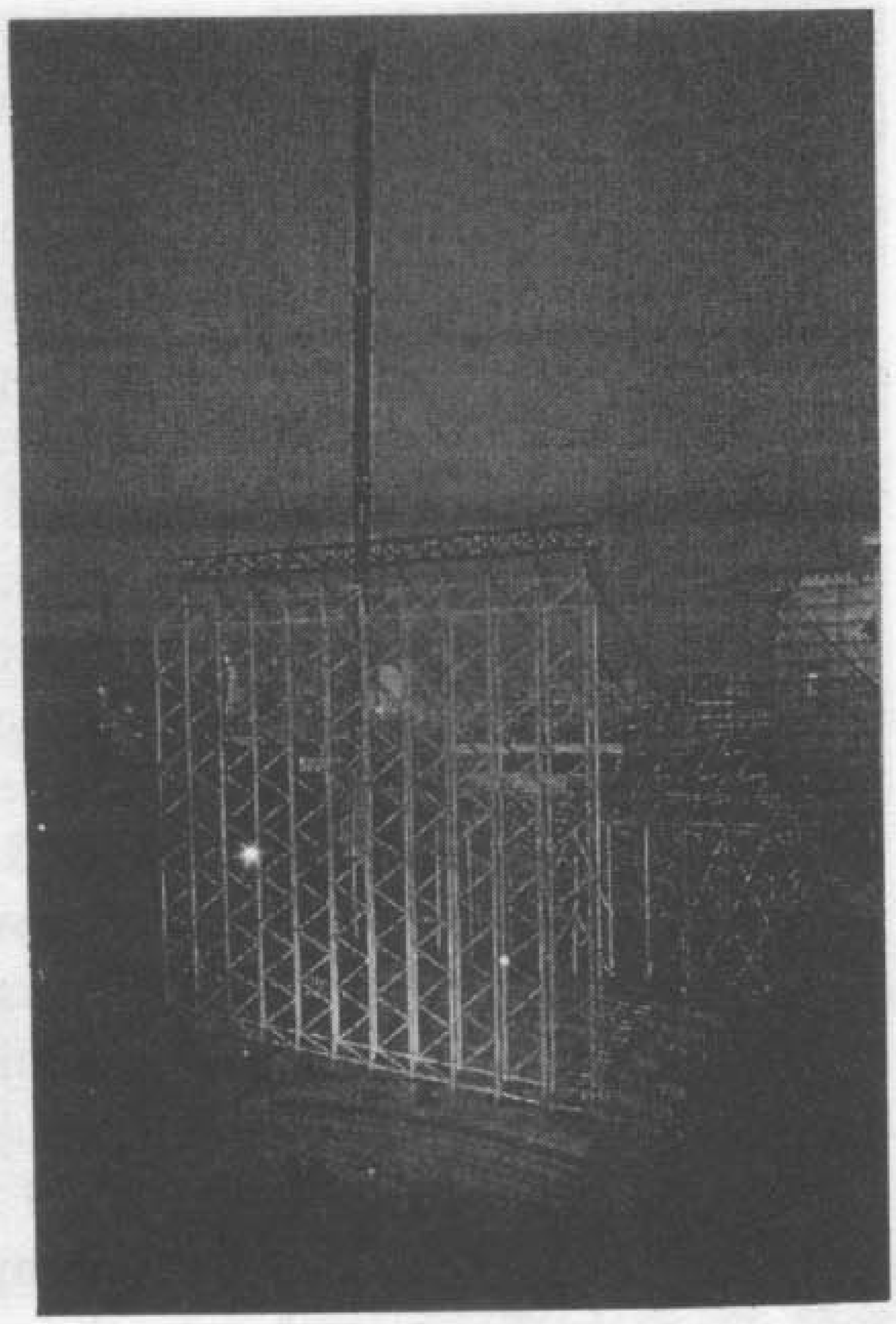



Fig. 13 Placing the structure

for the symmetrical movement and the balance during the process of moving the whole structure in one direction (Fig. 12). Once the structure is suspended and unfolded, it must be fastened to avoid its refolding. This movement is restricted through the use of staples in the nodes. Some tubular perpendicular elements are used as well in the trusses to guarantee the side stability of the structure and the aperture size.

Subsequently, the net is put into place, already set on its final position. In the case of the first section, this is put on top of the anchors on the square, inclining it until it reaches the projection cabin. Likewise, the second section was set the same way, which included, as it was mentioned before, two planes folded on themselves by the top, from which the structure was suspended and unfolded to make it rigid, through the use of staples and transversal elements. Subsequently, the structural net was moved vertically until the extreme of one of the two planes rested on provisional supports put over the projection room, which keep the bottom seam in place and permit its rotation.

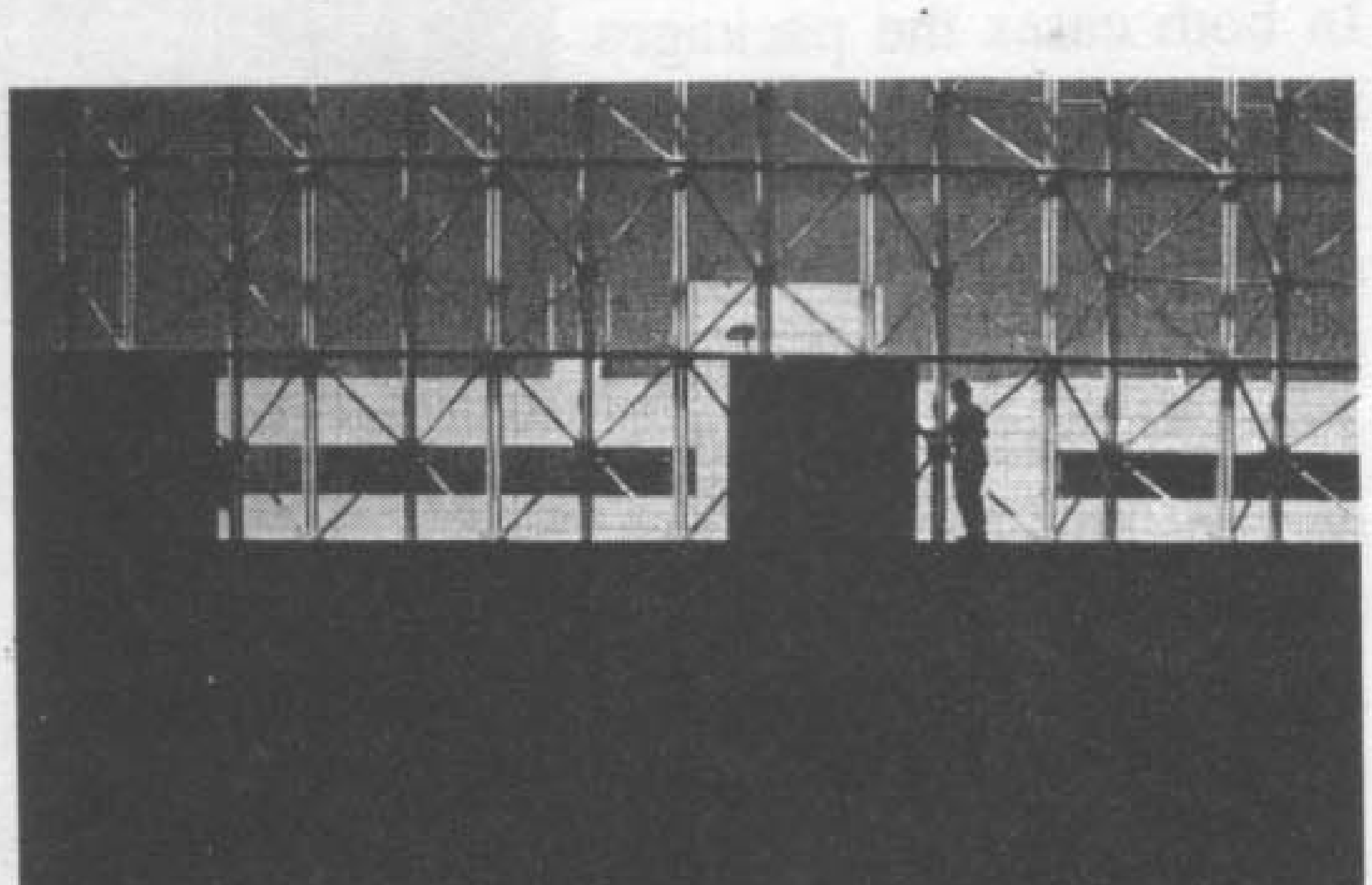


Fig. 14 positioning the panels

Then the rut beam was moved, inclining the struc-

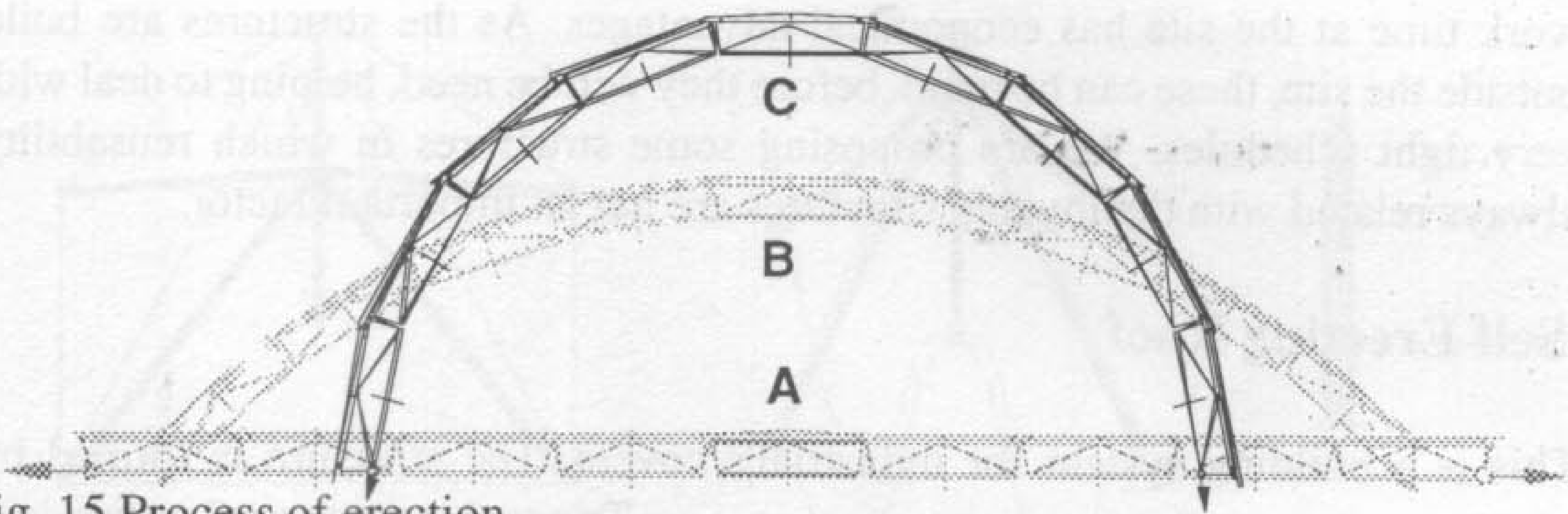


Fig. 15 Process of erection

ture to the rear wall. This movement permitted the two planes to separate, forming an inverted "V". Finally the other plane extreme is taken to its final position on the anchors on the rear wall. (Fig. 13) Finally both nets are connected and the provisional supports from the projection room are taken away.

A system of light panels is added to the structure, consisting of "sandwich" type, 50 mm. panels. Each panel is composed of an exterior molded surface, made of polyester resin reinforced with glass fiber 3 mm. thick, with a light gray gel coat finish, and an interior surface made up by a galvanized steel sheet, 0.7 mm. thick, covered by a film of dark gray polyvinyl chloride. The interior is made of rigid polyurethane foam. The panels are suspended from the structure nodes through adjustable bolts. These bolts support tubular elements, on top of which the panels rest. (Fig. 14) The bolts permit to adjust and level the covered surface after the panels are hanged and does not permit the water from the rain to stagnate. Likewise the panels have an external molding that distributes this water on the top better.

In the Pavilion building, it is not clearly established the difference between the cover and the façade due to the geometry adopted and the use of similar components for each case; thus for its description we will refer to top plane A and the rear plane B, which correspond to the transformable structure of the cover, and the planes C, which correspond to the vertical laterals that complete the prism.(Fig. 8)

The experience with the Structure of the Venezuelan pavilion show the advantages of using deployable structures technology as a building method. Some of these advantages are that Structures are build with small tolerances, good finishes and control over the production process, a simplifies erection process and reduced

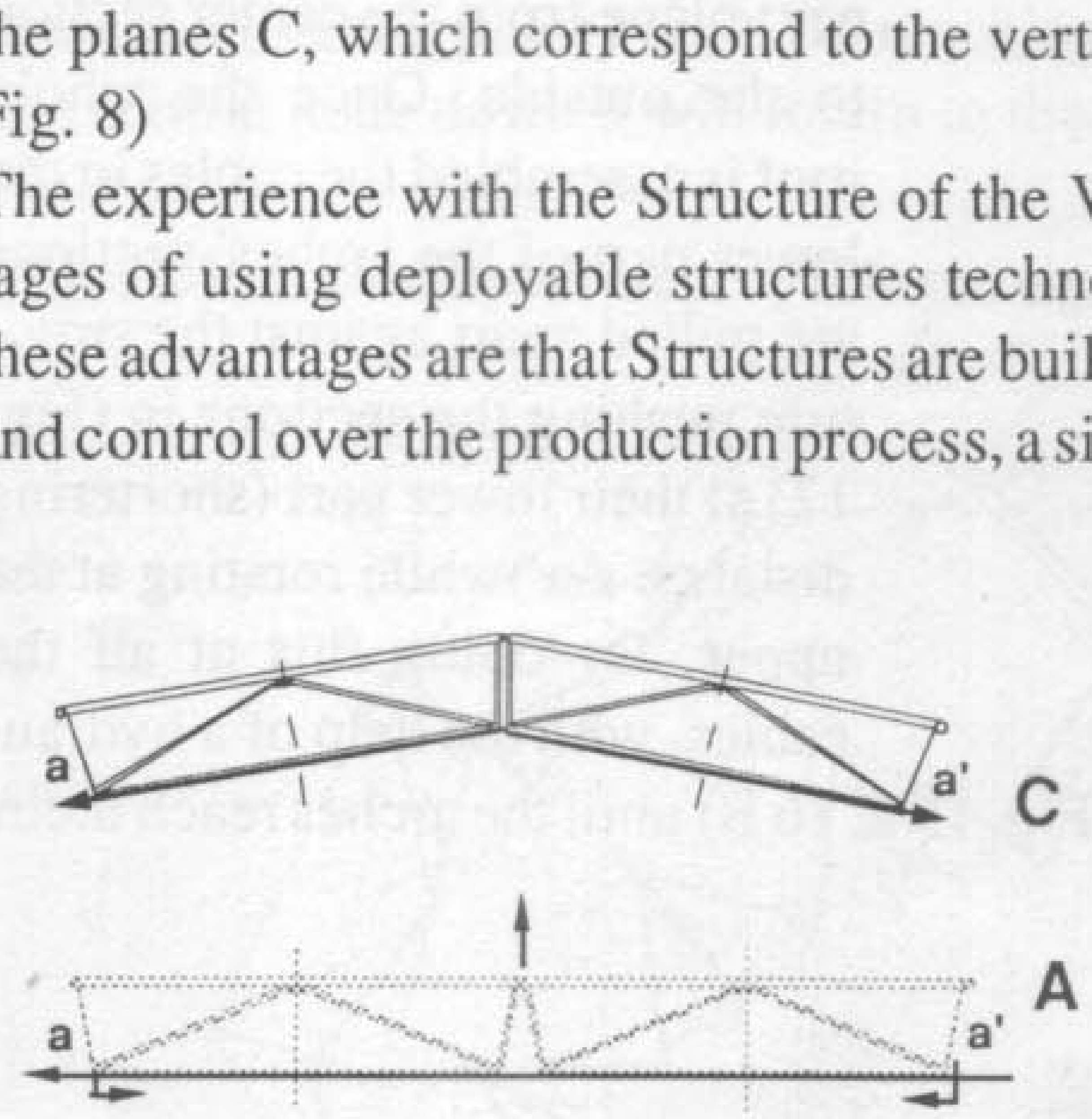


Fig. 17 Scheme of system

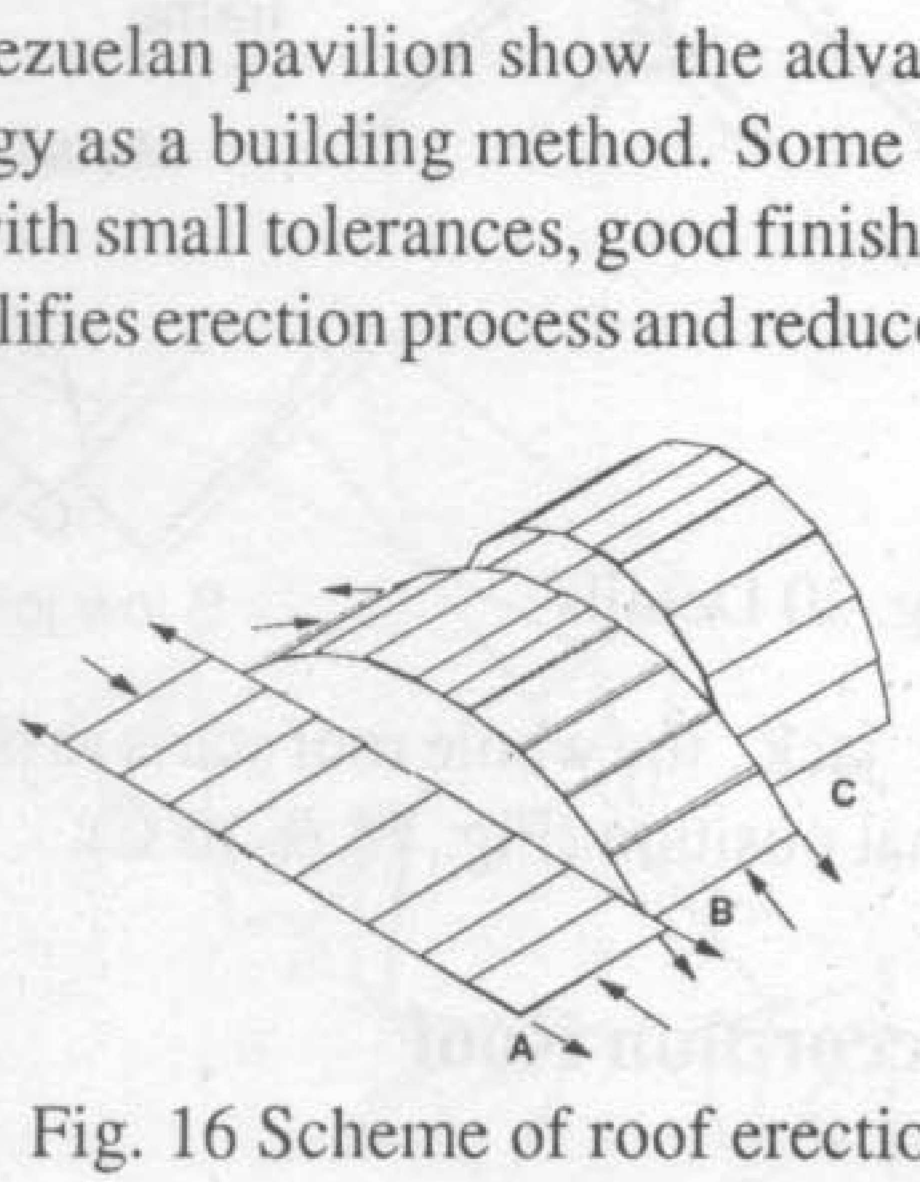


Fig. 16 Scheme of roof erection

work time at the site has economical advantages. As the structures are build outside the site, these can be build before they will be need, helping to deal with very tight schedules. We are proposing some structures in which reusability always related with deployable structures are not an important factor.

Self Erecting Roof

This is a building system for industrial's covers. The structure is formed by Triangular shape steel arches, join by tubular elements whose support a metallic roof. The steel prefabricated structure is assembled on the floor (Fig. 15 & 16 A), The arches are made out of 7 sections join by a steel bar that form a hinged in the upper plane and a steel cable that run through a lower tubular element. Each section is connected by tubular elements perpendicular to the arches with the same section in the next arch (The arches are flat at this point (Fig. 15 & 16 A)) and so on until the total length of the building is completed. Each group of sections created independent planes whose are covered with metallic sheets that overlap the next plane from the center section to the outside. Once the whole roof is assembled the cables in the lower part of the arches' sections are pulled apart against the structure pushing the sections in (Fig. 17) at their lower part (shortering distance a-a')while rotating at the upper. By doing this at all the cables, with the help of a hydraulic jack , the whole roof starts to rise (Fig. 15 & 16 B) until the arches reach theirs final position (Fig. 15 & 16 C).

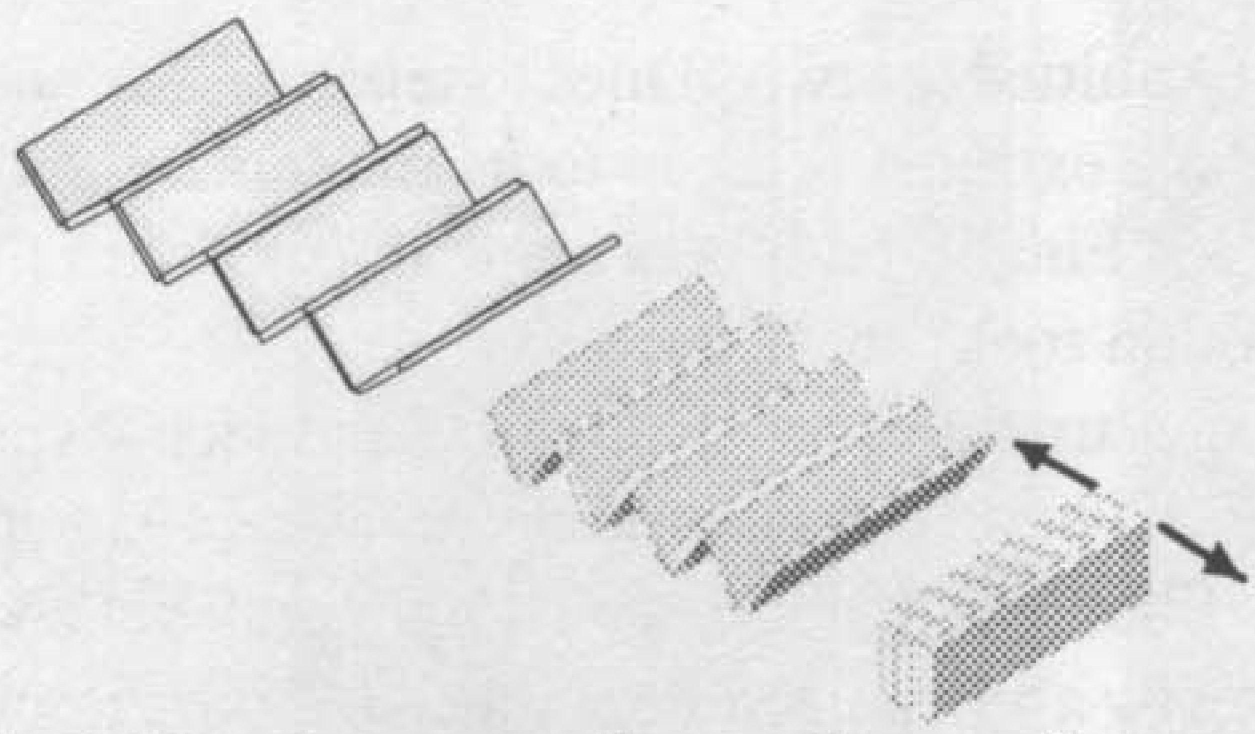


Fig. 18 Deployment of accordion roof

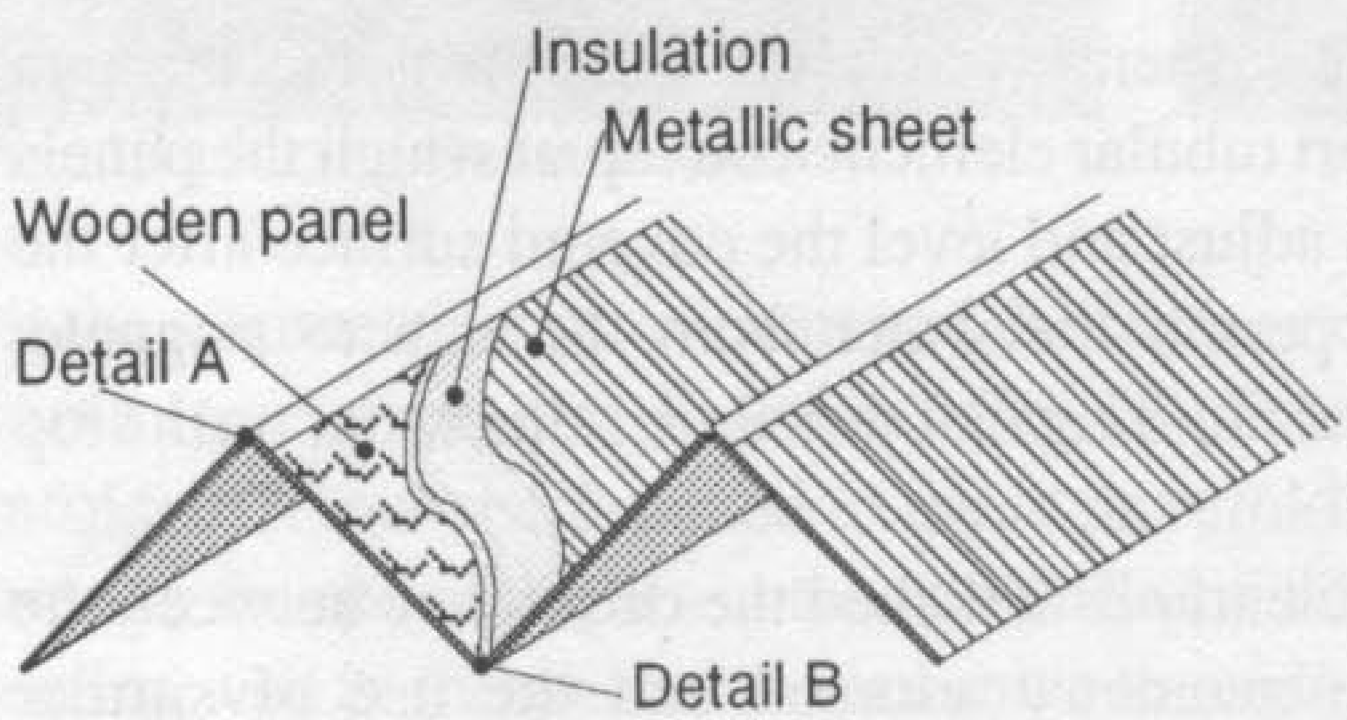


Fig. 19 Elements of panels

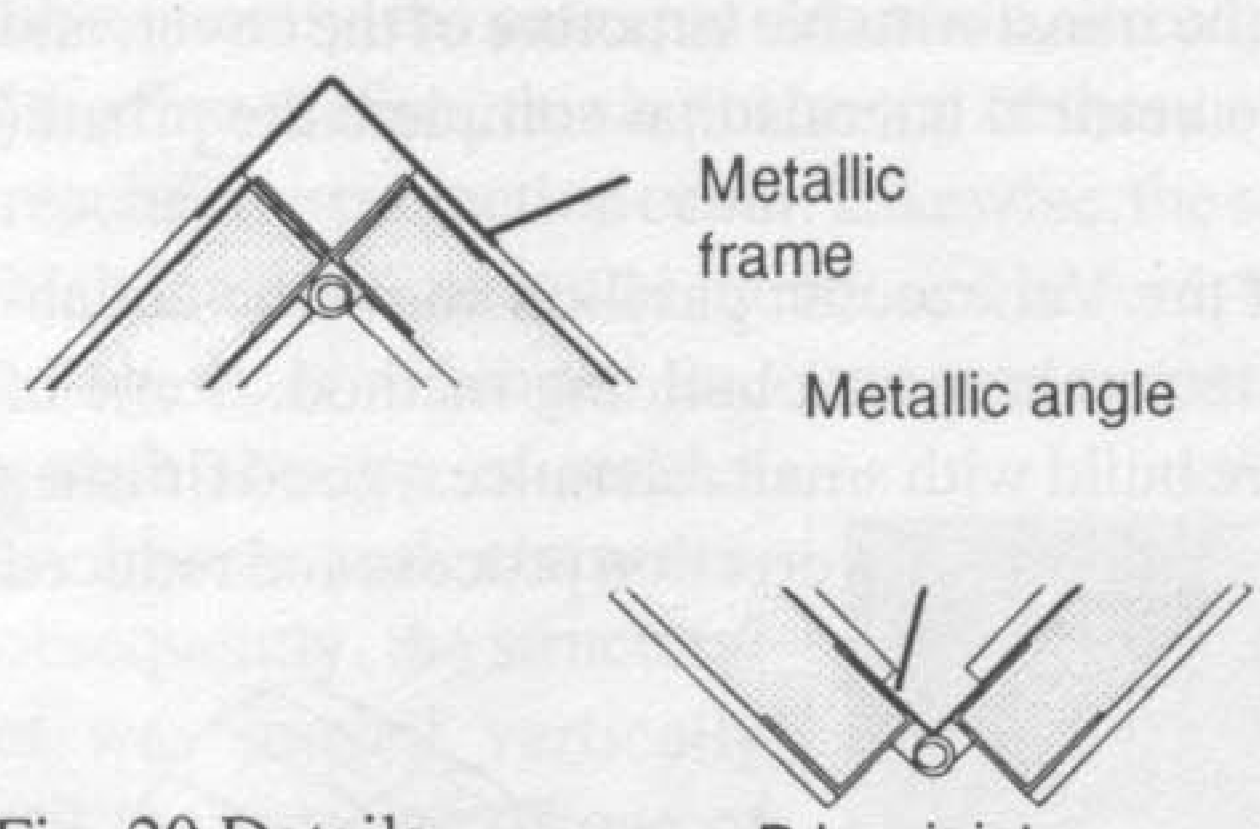


Fig. 20 Details

Accordion Roof

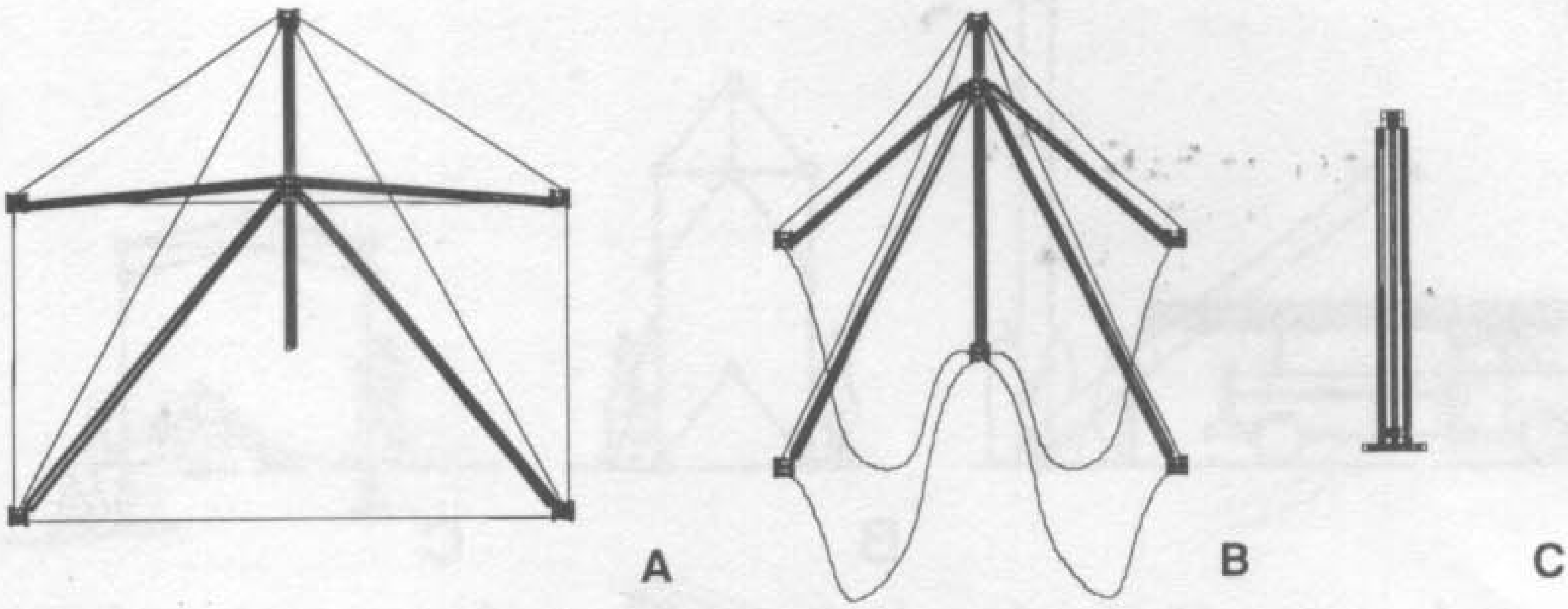


Fig. 21 Deployment process of basic unit

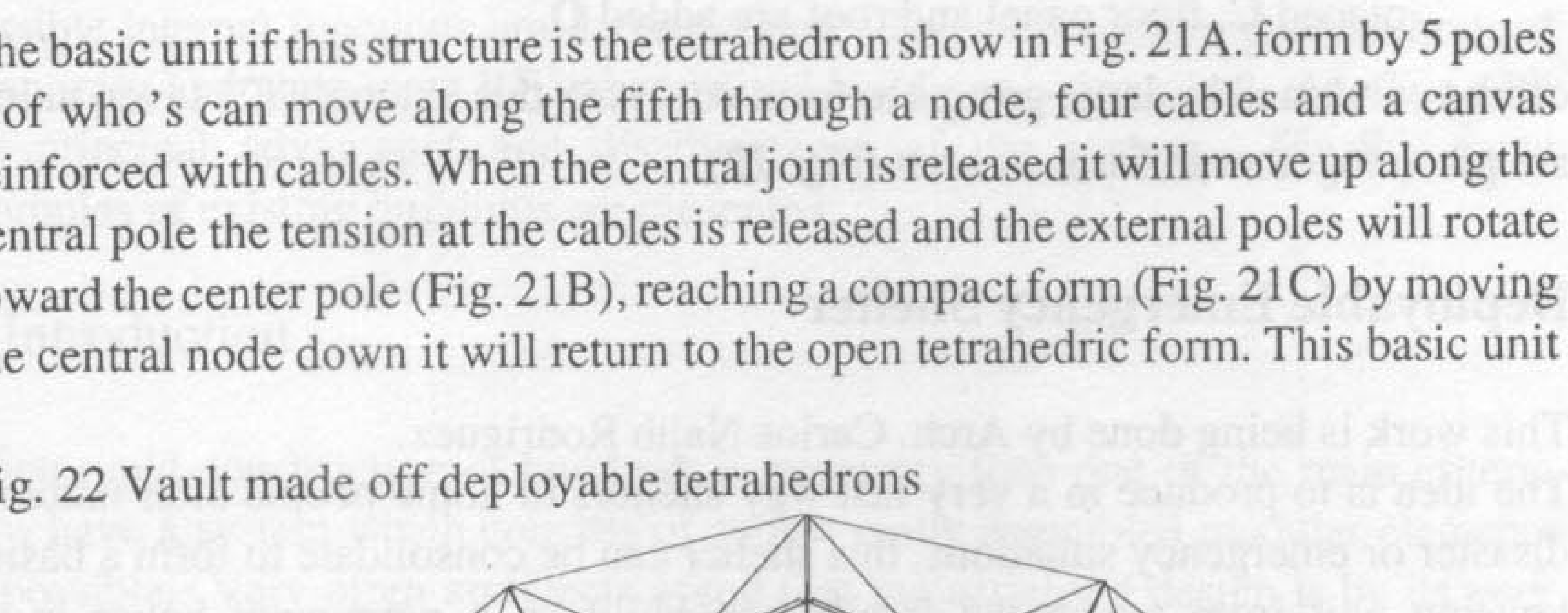
It is a system for medium span Roof. Where a prefabricated and totally assembles Roof made out of light panels is transported to the site, place on the structure and unfolded in one direction (Fig. 18).

The panels are made of a metallic frame, the exterior face is covered with a folded metallic sheet, the interior is a wood in panel with the internal finish and between an insulation, every thing forming a compact sandwich. (Fig. 19). The panels are joined by hinges in an alternating way so to allow the panels to be parallel to each other and rotated 45 degree to unfold in one direction between each panel there is metallic angle a rigid one in the high connection and a flexible one in the low connection, making the whole watertight (Fig. 20).

Deployable Tetrashedrons

The basic unit if this structure is the tetrahedron show in Fig. 21A. form by 5 poles 4 of who's can move along the fifth through a node, four cables and a canvas reinforced with cables. When the central joint is released it will move up along the central pole the tension at the cables is released and the external poles will rotate toward the center pole (Fig. 21B), reaching a compact form (Fig. 21C) by moving the central node down it will return to the open tetrahedric form. This basic unit

Fig. 22 Vault made off deployable tetrahedrons



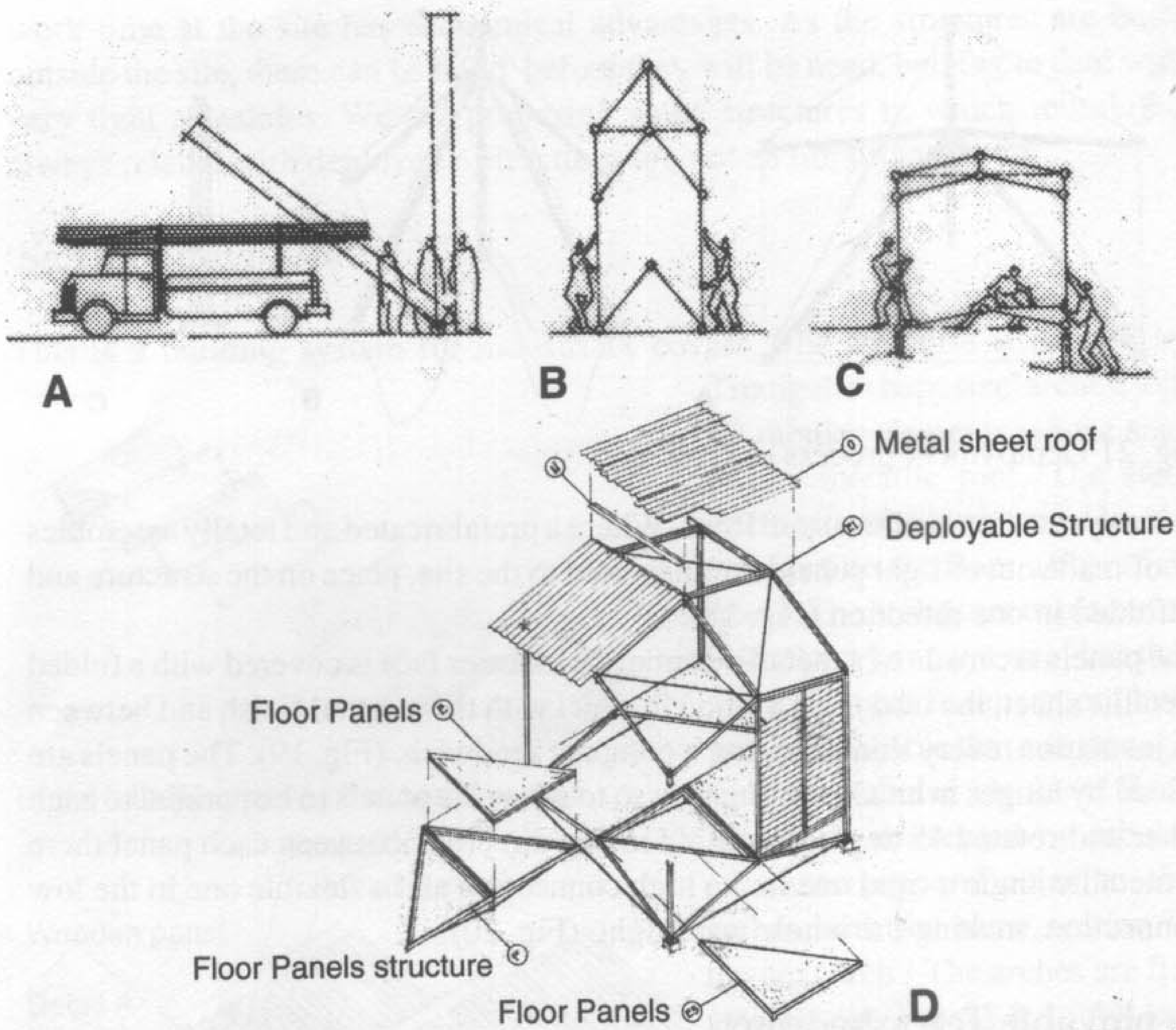


Fig. 23 Deployable structure is transported **A**, the structure is deployed **B** and placed **C**, floor panel and roof are added **D**.

can be combined in large groups to form covers in this example (7) seven units are place together to form an arch (Fig. 22).

Deployable Emergency Shelter

This work is being done by Arch. Carlos Najib Rodriguez.
The idea is to produce in a very fast way shelters to home people after natural disaster or emergency situations, this shelter can be consolidate to form a basic housing unit from which the family can build up a permanent house in a progressive way. Given answers to the natural dynamic of the progressive low cost housing construction used in the developing countries.
Its a building system based on a Deployable Steel Structure with very cheap Mobil connection's whose are fixed by incorporating the enclosing panels and floor panels. The basic module can be combined to generated bigger shelters or to build the basic housing unit.

References:

1. Instituto Experimental de la Construccion. *Pabellon de Venezuela Expo '92*, Ex libris, Caracas, Venezuela , First edition 1992.