Roof structure of the new hangars by the International Fiumicino Airport (Rome): design, model tests

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Roof Structure of the New Hangars by the International Fiumicino Airport (Rome) (Design, Model Tests)

La structure des nouveaux hangars à l'aéroport international de Fiumicino (Rome) (Projets, essais sur modèle)

Dachausbildung der neuen Hallen im internationalen Flughafen von Fiumicino (Rom) (Entwurf, Modellversuche)

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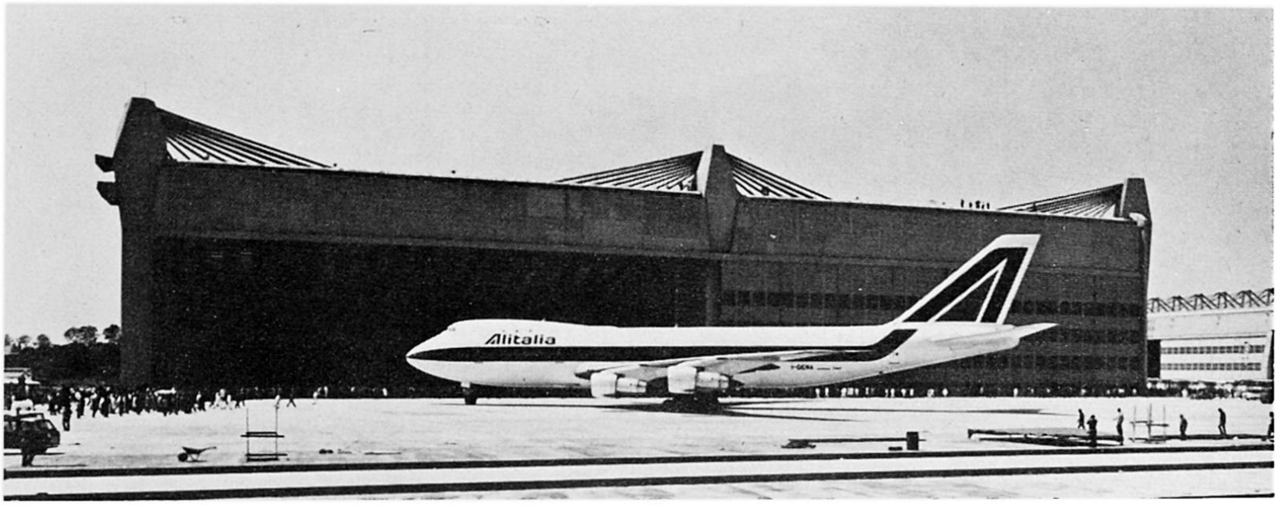

1) DESIGN

1.1) General (Introduction)

The new structure, including workshops and stores, recently accomplished at the "Lennardo da Vinci" Airport in Fiumicino (Rome) is mainly developping all around the two main hangars designed for the housing and maintenance of the new jet Boeing 747. Actually the hangar shape and size perfectly cope with the shape of the aircrafts. This peculiarity guided the design towards the realization of large entrance openings, while on the opposite side the structures have been adequately reduced down to a large protruding "corridor" in which the bow of the aircrafts finds its place. Such solution has allowed the siting of shops, stores and operating centres in the back, also using the space resulting between the two corridors of both hangars.

As far as the vertical dimensions of the two hangar rooms are concerned, the great height of the B747 vertical rudder size has guided to a dissymmetric roof structure reaching its highest point at the entrance side, see in correspondence of the jet tail.

1.2) The Hangars

Each hangar consists of two adjacent rooms of different shape:

- one back room (the before mentioned "corridor") housing the aircraft bow, parallelepiped like, 45,00 m in length, 20,00 m in width and 16,40 m in height;
- one front room, housing the bow central and back part, the wings and tail; 78,25 m wide, 74,50 m long and varying in height from 20,00 m to a max of 30,00m.

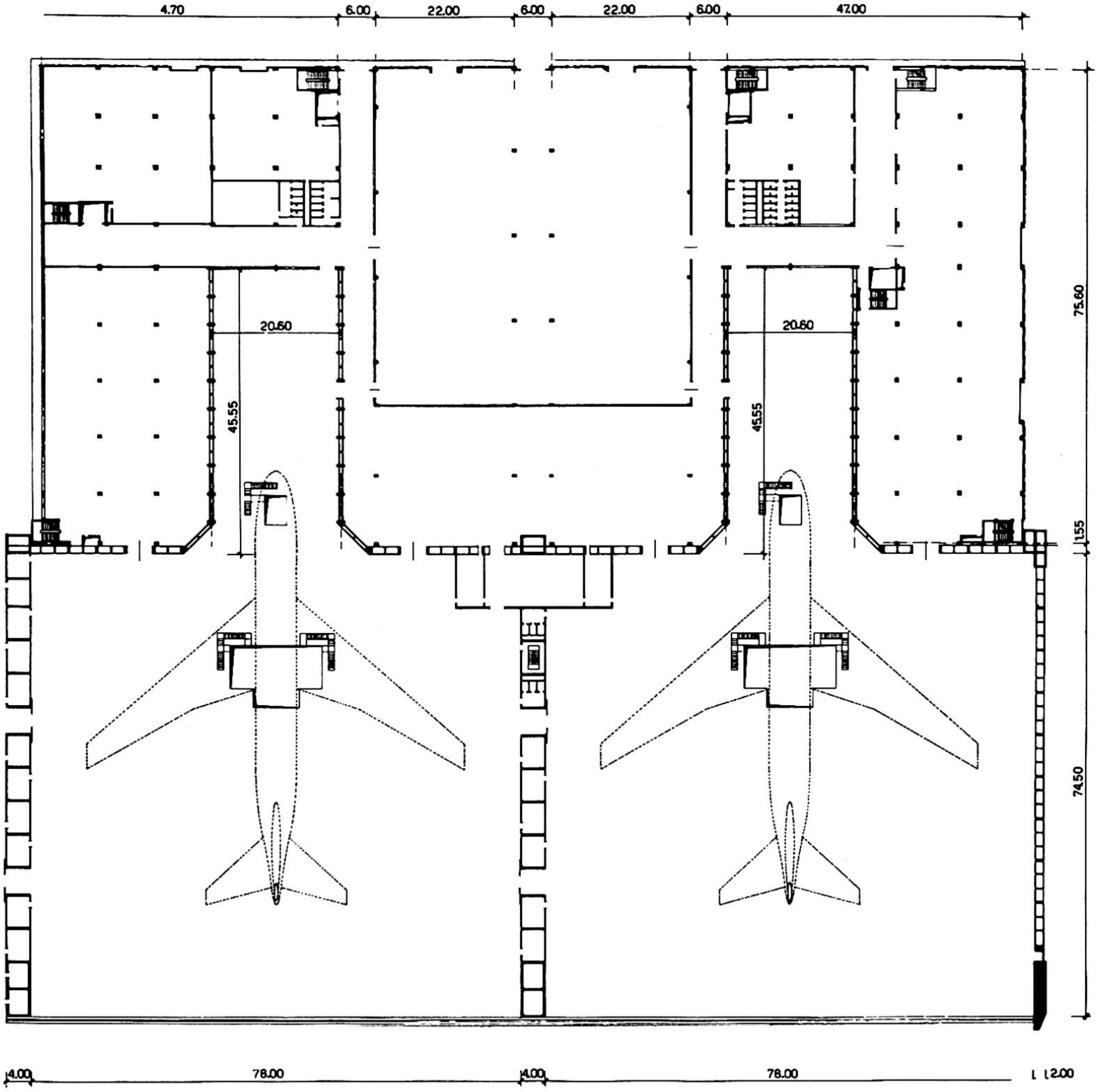

Fig. 2 Plan

The two rooms are closed all around by means of reinforced concrete walls, with exception of the entrance wall consisting of a large sliding door. The walls have also a static function: in effect they transfer to the foundations all actions originated by the roof.

The rear room has a flat ceiling consisting of a number of parallel prestressed concrete beams spaced 4,50 m and joined by precast concrete slabs. The main roof, on the contrary, is made by a steel concrete suspension structure anchored by

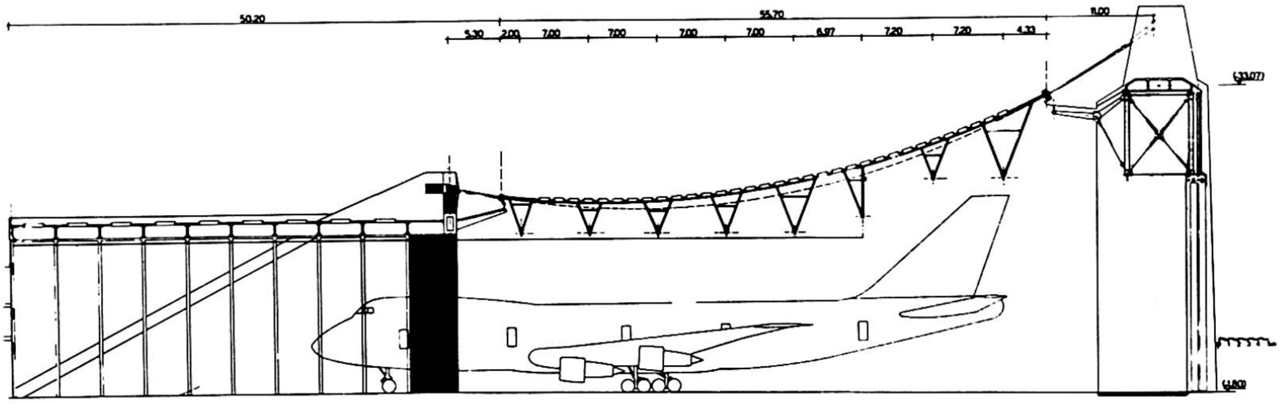

Fig. 3 Longitudinal section

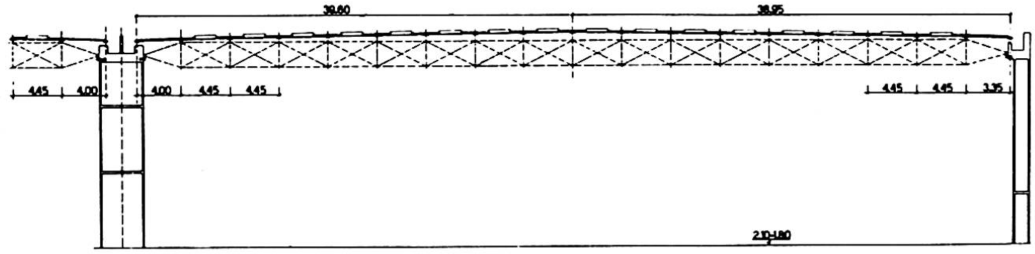

Fig. 4 Transversal section

means of ties to the walls at points A,B,C,F,G,H,(see Fig. 4 and 5).

In correspondence of these points are transmitted vertical and horizontal forces to the walls either longitudinally and transversally. All these forces are transferred to the foundations either through the walls themselves and through the transversal connections. In effect on the front plan are placed two connections: one at pavement level, consisting of a prestressed concrete beam resting on the ground; the other, at 31,00 m of height consists of a reinforced concrete box compression strut resting on a truss steel girder which, at the sa me time, gives support to the large sliding door.

In the back, the transversal connection is given partially by the rear con crete walls and partially by a reinforced box beam, placed between points C and F.

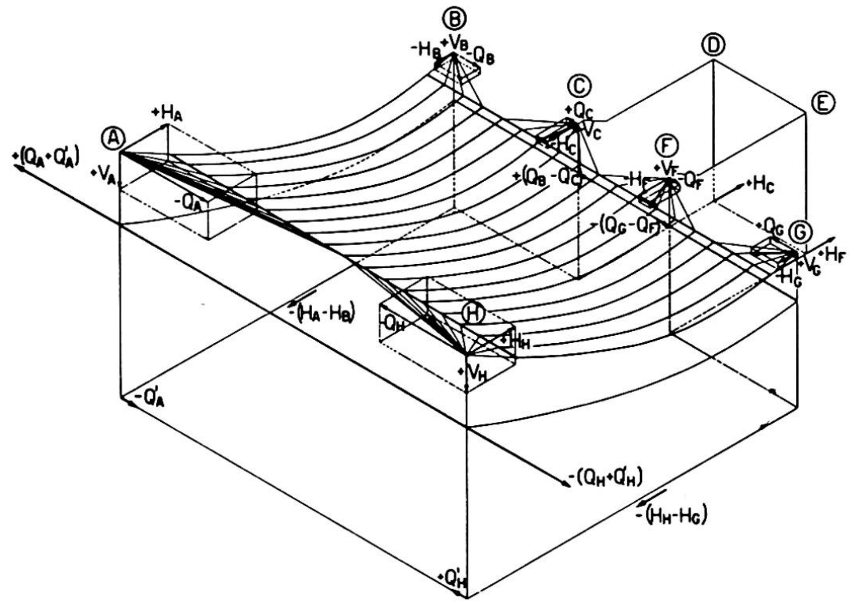

Fig. 5 Static schema of the structure.

1.3) The suspension roof

The roof structure of each hangar consists of 19 prestressed concrete cable-like members, directly supporting the roof plates and linked, at both ends, to two transverse beams also of prestressed concrete of variable cross section.

The resistant members and transverse beams are, then, linked to the walls by means of two series of prestressed concrete tendons fanning out from points A and H in the front, and from points B,C,F and G in the rear. The whole suspension structure, whose structural members are the cable-like members, the cross beams and the fans of tendons, is represented in Fig. 6.

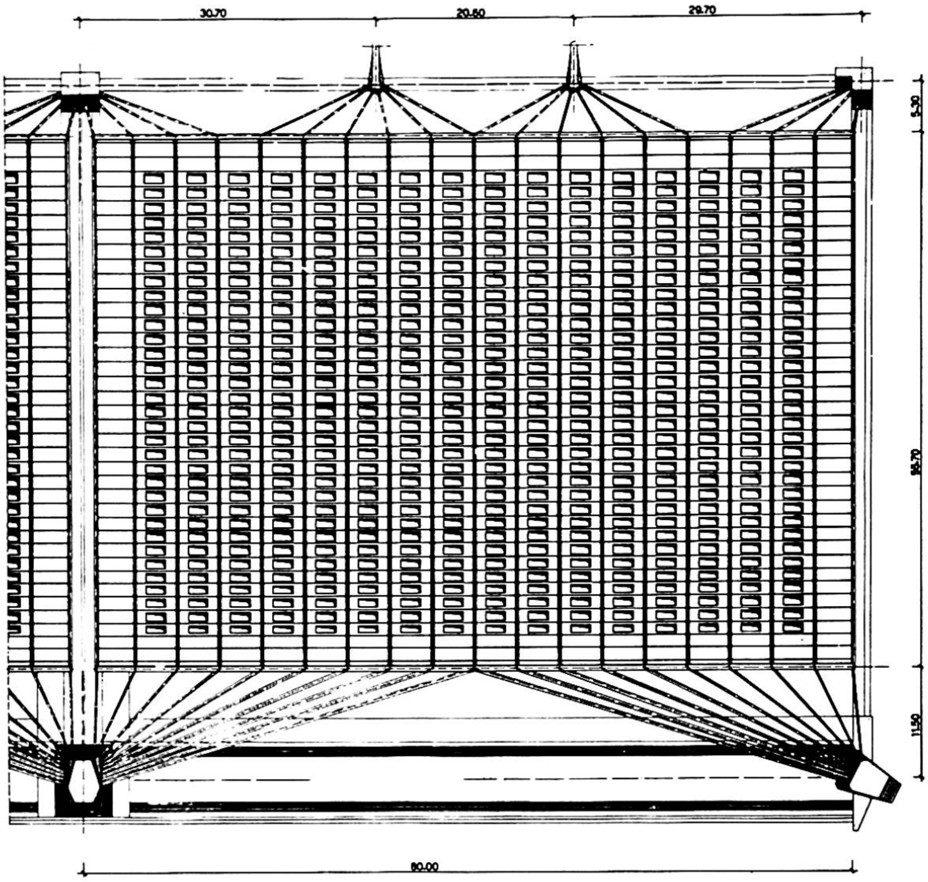

Fig. 6
Plan of the roof

The cable-like members (40x15 cm) are spaced 4,45 m and support the pre-cast roof plates. These plates allow also the light to pass through because of a central rectangular hole covered by a dome of acrylic resin. Each cable-like member is prestressed by means of three high tensile steel tendons consisting of eight 1/2" strands each. The fanning tendons are also of rectangular cross section: moreover, owing to the different values of the forces to which they are subjected, both the cross section and the number of prestressing cables are different from tendon to tendon.

The two end cross beams are sited in correspondence of the joints between cables and ties. Both beams are horizontal and present a rectangular section which is constant for the rear beam and variable for the front beam. Eight more cross-beams are hanging from the roof. They are truss steel beams of triangular section with two upper and one lower chord; such beams are intended to distribute along the roof the heavy concentrated loads of the bridge cranes. The ten cross beams provide a very efficient connecting action between the cable-like members of the roof.

The suspension structure is in the shape of the catenary of the dead load with different values of the tension in the various cable-like members. These members owing to their small thickness as referred to their length, can be considered perfectly flexible, that is, without flexural rigidity, and so they can undergo any change in their center-line curve.

It has to be pointed out that the structure is a one-way system of cables: therefore, the stability of the roof against the wind suction is due to the dead weight only, which is considerable because the plates of the actual roof are also made of concrete. Hereunder are given some values on the design loads:

- dead load of the roof including plates, cables, cross beams, crane beams, 230 kg/m^2;
- overload 120 kg/m^2;
- wind load 100 kg/m^2.

1.4) Construction techniques

It has been already told that the initial tensile structure is in the form of the dead load catenary, for given values of the stresses in the various members. For the erection was used a steel tube scaffolding, following the structure shape, which supports the whole roof. Then the prestressed elements have been subjected to tensioning beginning from the cable-like ones, then the cross and finally the fan-like tendons.

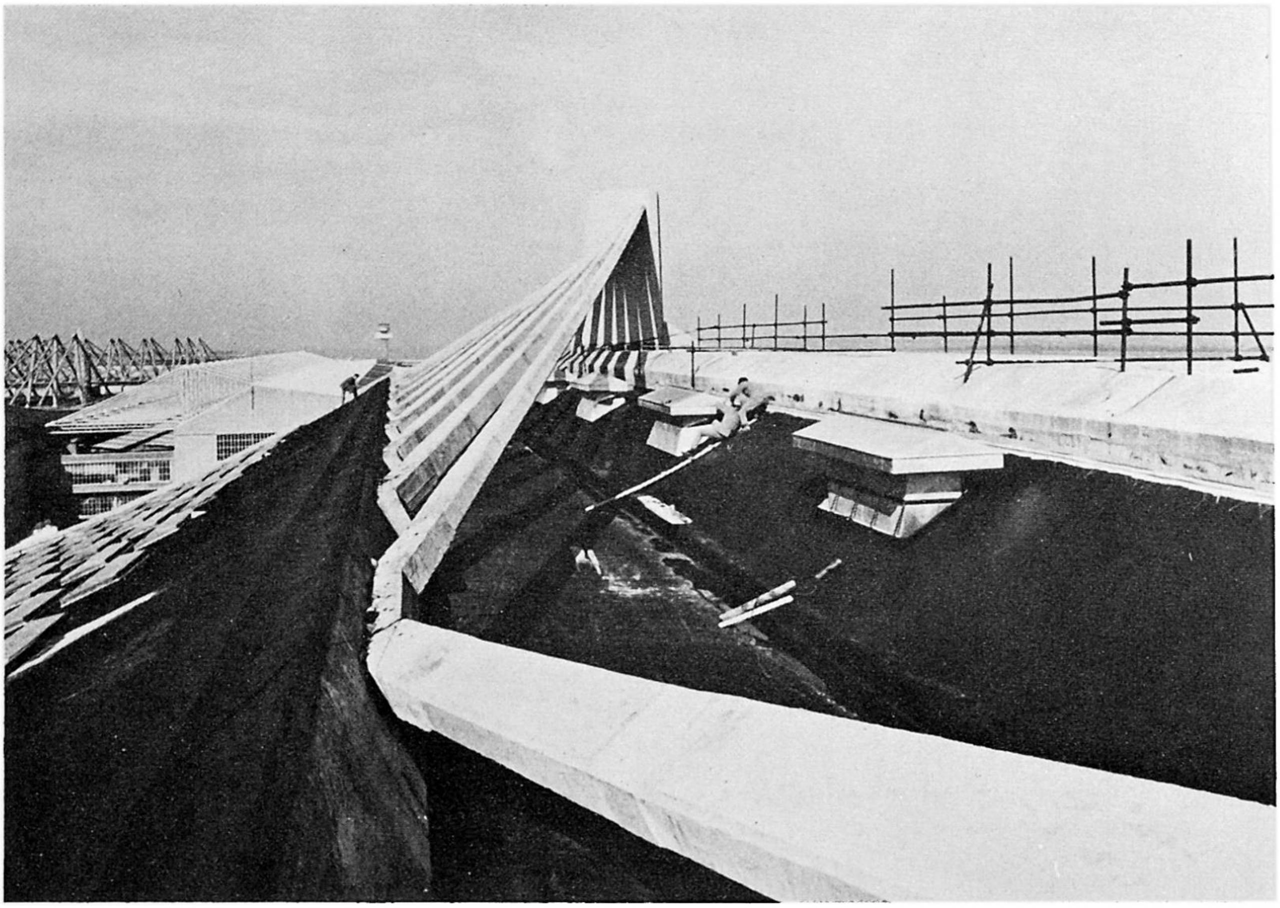

Fig. 7 View of the fan-like tendons.

2) TESTS ON MODEL

2.1) General characteristics

As it has been previously pointed out, the actual structure is composed of prestressed concrete members, precast concrete plates and steel trusses. In the model the corresponding elements were made respectively of steel, aluminium and an aluminium alloy called anticorodal.

The same alloy was used for the two cross beams.

The reasons of the heterogeneous choice of materials follows from the requirements due to the similitude laws, as well as the technical ones (assemblage) and the necessity of having, in the proper places, space enough for applying the straingauges.

In order to establish the sizes of the model various elements, following the mechanical similitude, it has been assumed the value 0.35×10^6 kg/cm^2 for concrete in the actual structure; 2.1×10^6 kg/cm^2 for the steel elements of the model, and $E = 0.7 \times 10^6$ kg/cm^2 for the aluminium ones. The anticorodal modulus of elasticity was determined by preliminary tests on the actual laminates which were to be employed in the model.

As far as the various structural member sizes are concerned, the mechanical similitude laws have been taken into account starting from the representative equations of the problem. If ϕ is the force-ratio and λ is the length one, we obtain the following relationships:

$$\sigma_m = \frac{1}{\lambda}\sigma^* \; ; \quad A_m = \frac{1}{\phi}\frac{E^*}{E_m}A^* \quad \text{(tendons)}; \quad I_m = \frac{1}{\phi\lambda^2}\frac{E^*}{E_m}I^* \quad \text{(beams)}$$

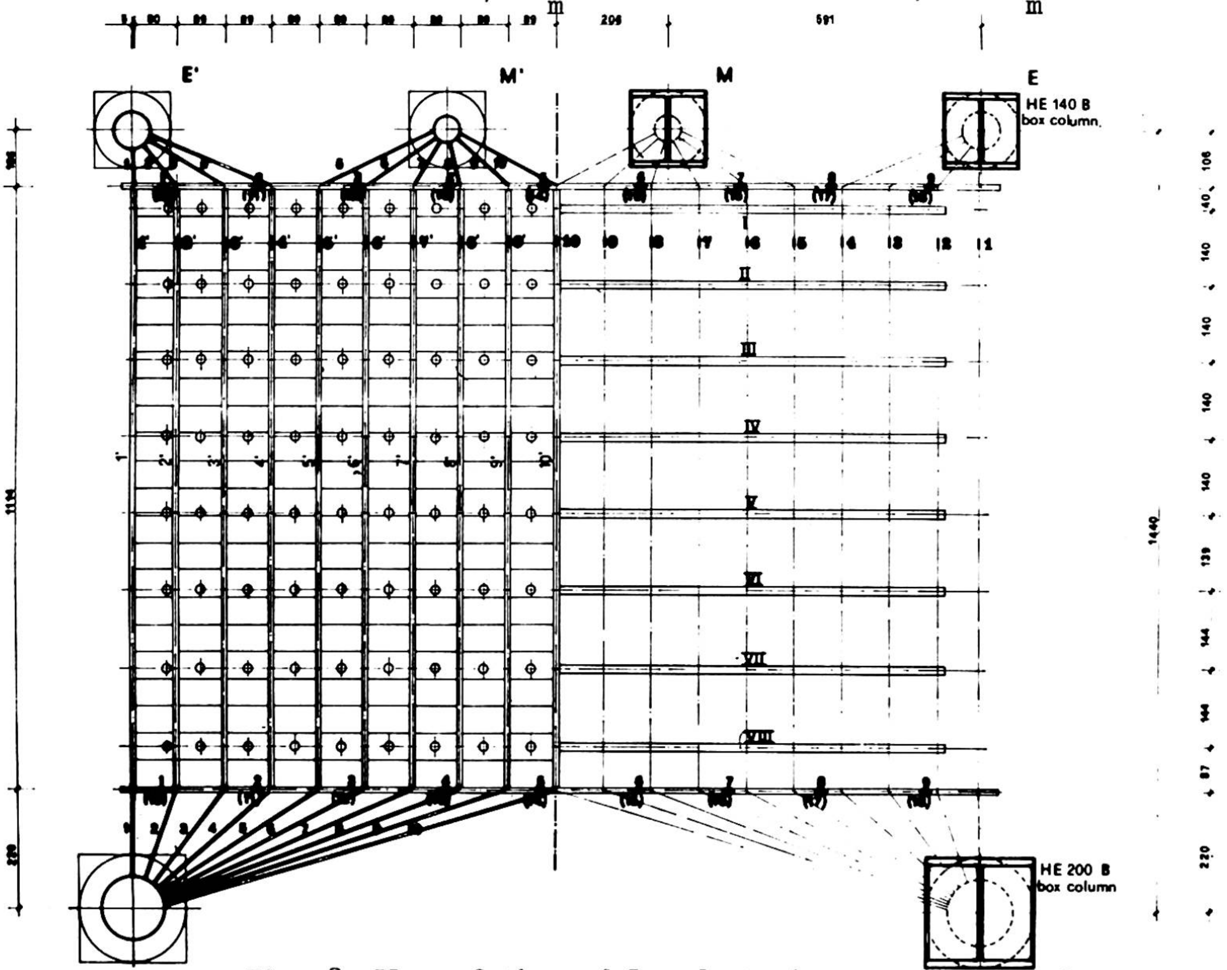

Fig. 8 Plan of the model and straingauges disposition

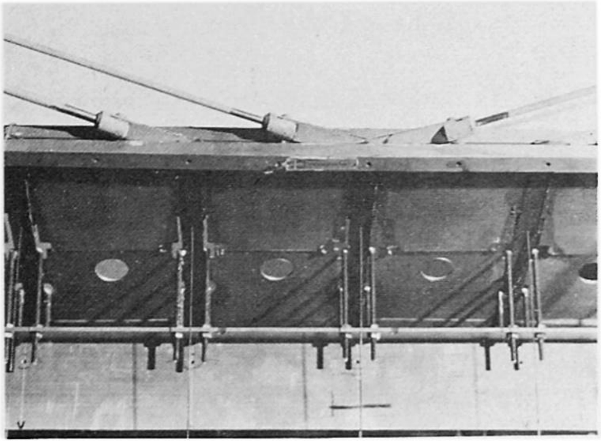

Fig. 9 Model detail

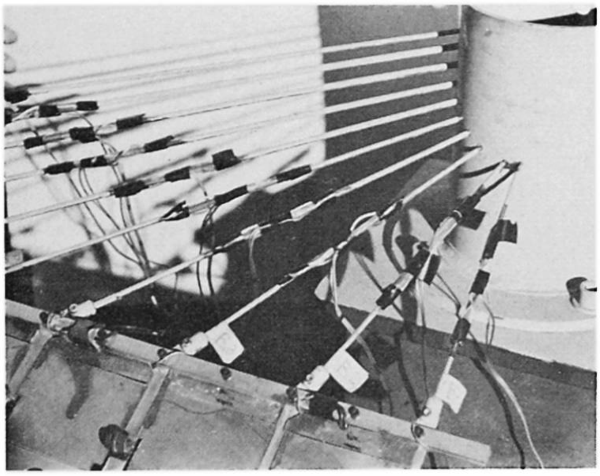

Fig. 10 Model:anchorage of the fan-like tendons

given the size of the actual structure, it has been considered convenient to assume the values: $\lambda=50$ and $\phi=2,200$ from which follows the ratio for the cross sections in tension (cables and tendons):

$$\frac{A^*}{A_m} = 13,200$$

The section has been chosen rectangular, 0.5mmx11.0mm, which is convenient for the application either of the straingauges and of the roof plates. From the previously determined parameters the tendons cross sections-made by steel rods having commercial sizes, which vary in steps of 0.5 mm - were derived. All arising approximations do not exceed a 4% error in diameter.

Both terminal cross beams were constructed by means of two bars spaced 2 mm from each other, assembled by bolts.This composite section, constant in height for the raar beam, and variable for the front beam, has been chosen in order to solve the problem of an efficient connection between the beam itself and the other two structural members converging in every joint. The resulting sections follow the similitude laws either as it refers to

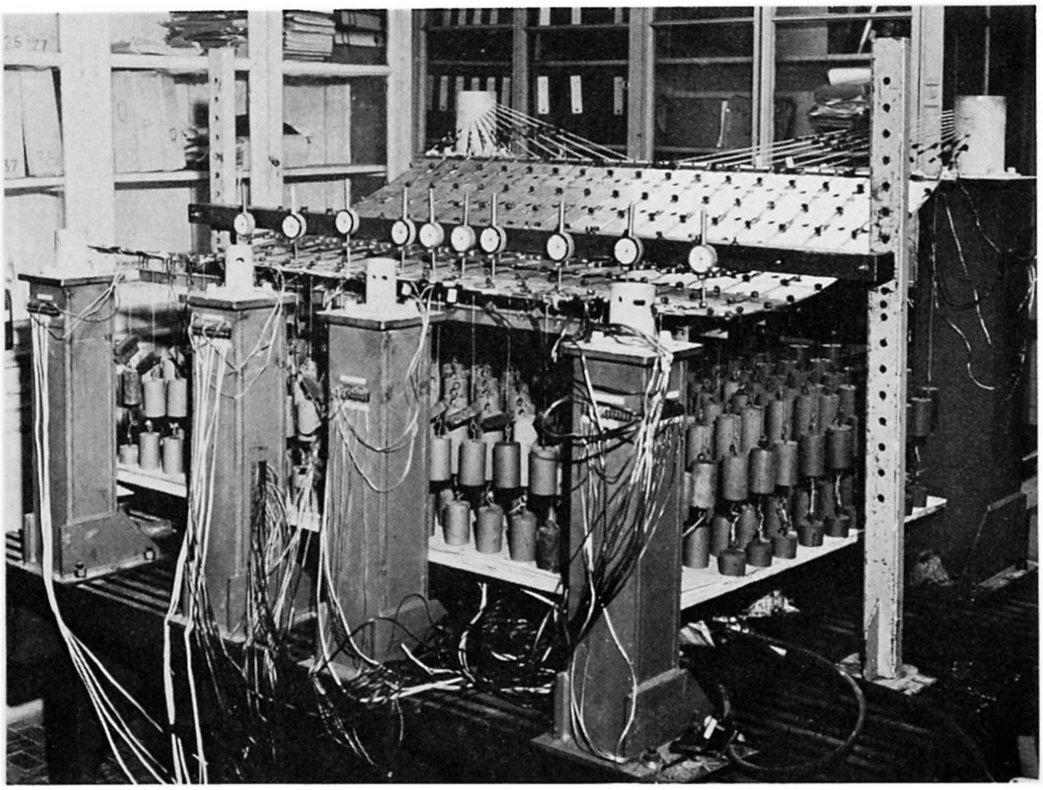

Fig. 11

Model:general view showing deflection gauges and loads.

the areas and the moments of inertia: as a matter of fact, the cross beams are submitted to high axial force.

In connecting the tendons to the outside walls and columns this latter part, (whose deformations are smaller than the roof ones) has not been realized but the tendons fixed to rigid steel tubes.

As it refers to intermediate cross beams, actually consisting of a double steel trusses, they are represented by anticorodal Tees, being impossible to re produce in detail the rather complicated truss structure.

Six linkage head ties (tubes) are fixed to six steel columns of a box profile composed by HEB I beams. Loads are realized by means of iron cylinders, 2.00 kg each for the dead load and 1.25 kg for the live load.

The loading equipment consists of a table raised and lowered by means of four hydraulic jacks, acted by a single hand pump. Through the table raising and lowering action are applied or taken away only the live load weights, while the dead load ones are always suspended to the roof.

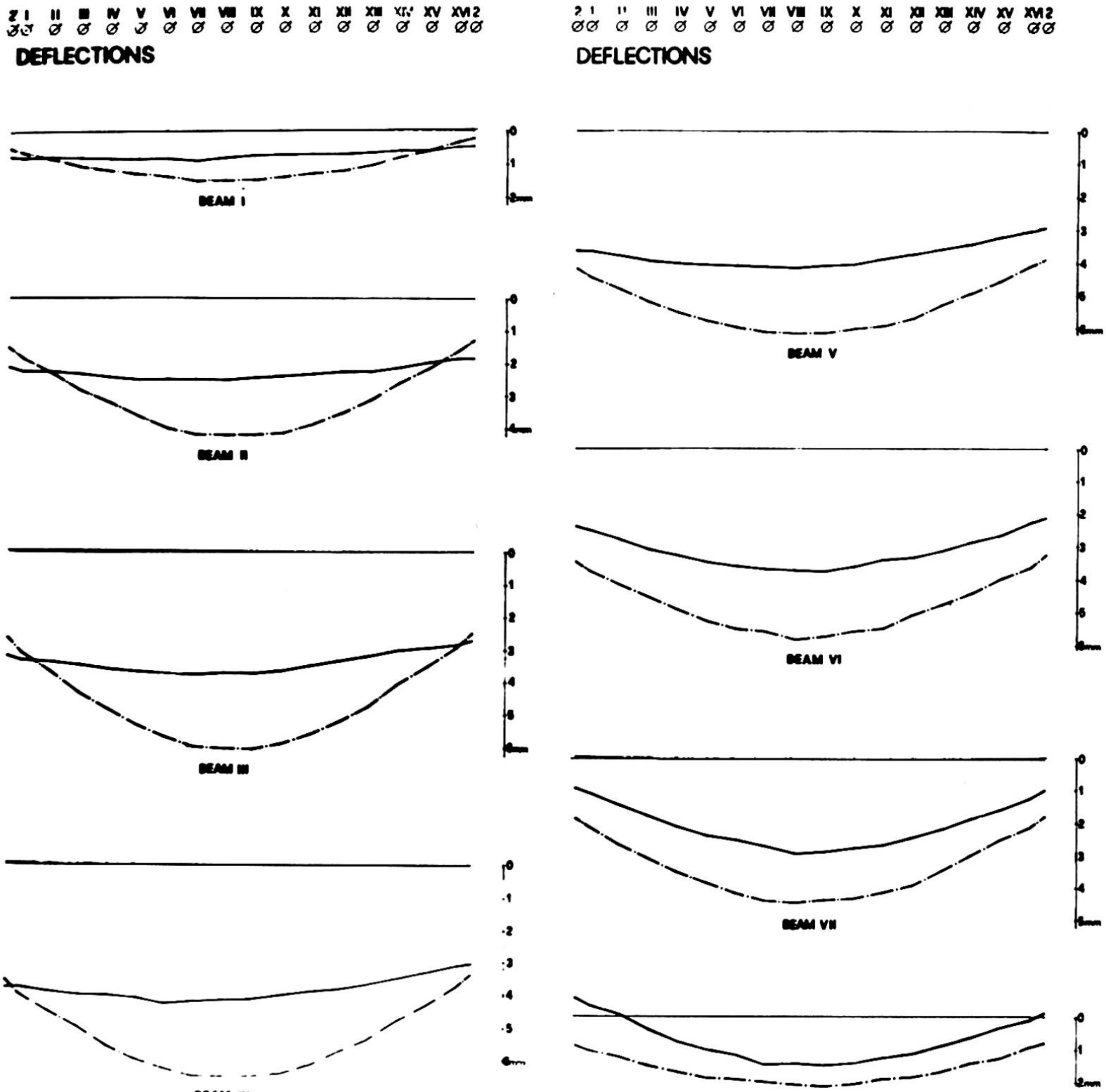

Fig. 12

2.2) Testing and results

The model tests resulted from the application of the live load to the structure already subjected to the dead load.

Two sets of measurements have been taken, one before the roof plates were mounted, the second with the plates in place.

Besides it has been tested the effect of the concentrated loads measuring the effects due to a 3 kg load applied in correspondence of five section every intermediate cross beam.

In the model, taking λ =50, these displacements result in the order of 1 mm.

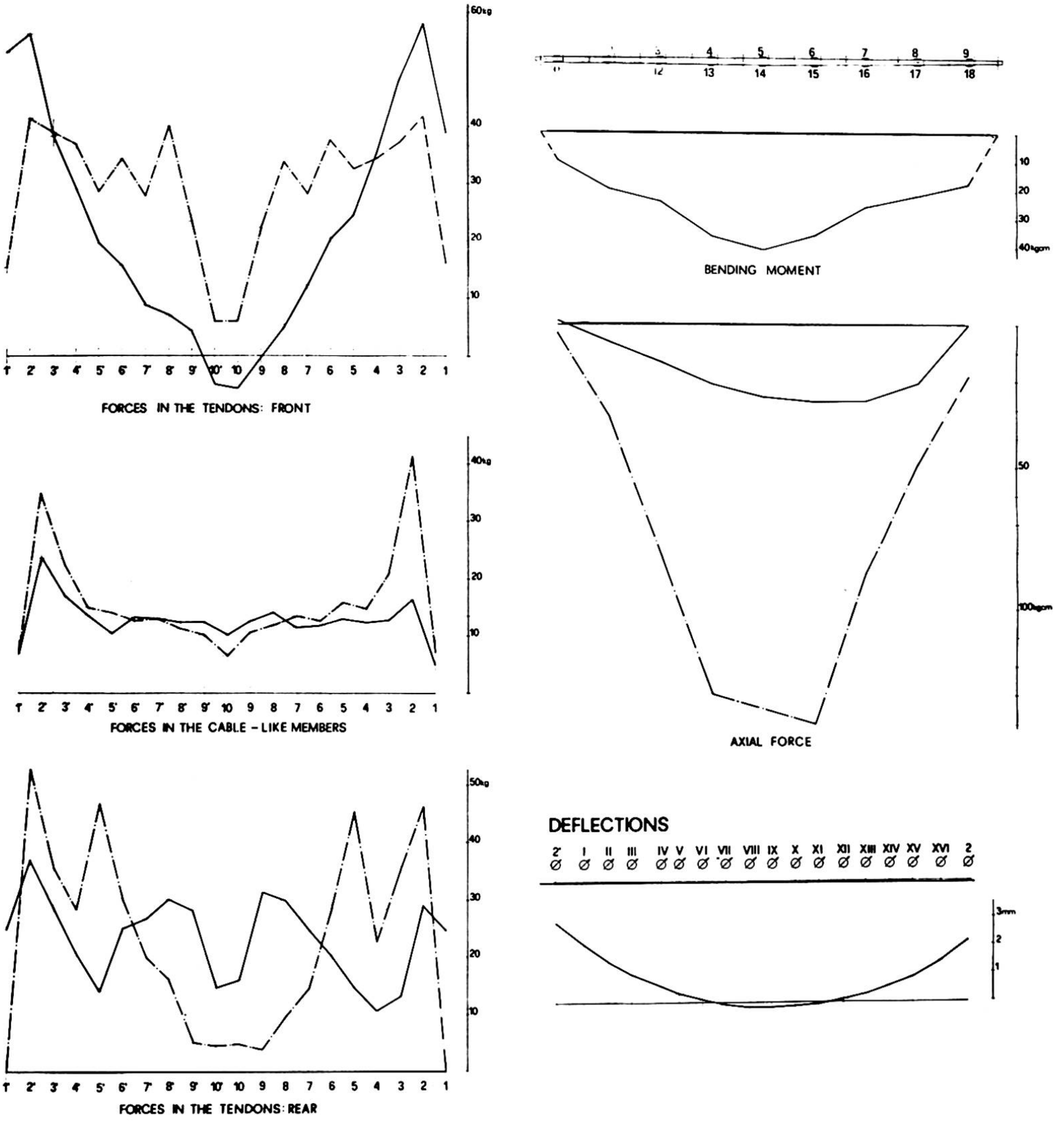

Fig. 13

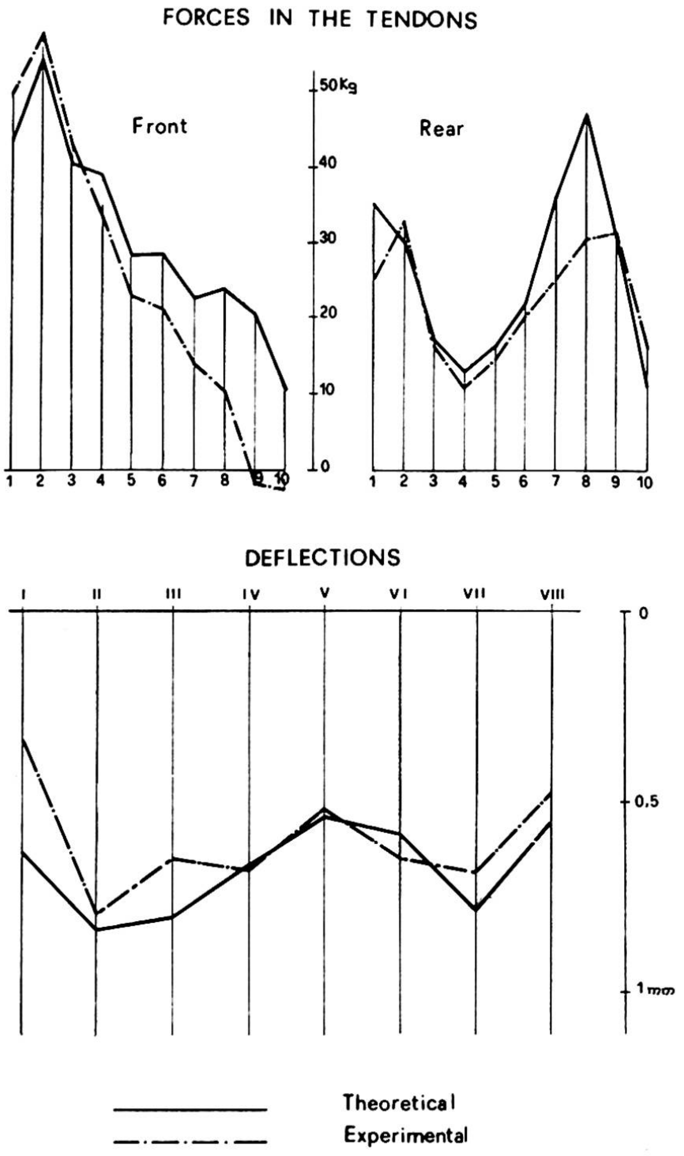

Fig. 14 Theoretical and experimental results

The main results of the model tests are given in Fig. 12 and 13, where the roof deformations (taken in correspondence of the cross beams) as well as the bending moments and the axial force distributions are represented.

In Fig. 14 the main experimental results are compared to the analytical ones, as far as the force distribution among the front tendons and the deflections of the transversal beams are concerned. It is evident the good correspondence existing between the two results.

Summary

The structures of the new hangar housing the jet Boeing 747 at the "Leonardo da Vinci" Fiumicino Airport (Rome) is described. Its main feature is the suspension roof, completely built in prestressed concrete. The structural elements are a series of parallel cable-like members, tied by transverse beams which are suspended to columns by means of fan-like tendons.
Stabilization against wind suction is provided by dead weight only.

Tests were made on a 1:50 scale metal model; details of the design as well as of the construction elements are given. Model tests results are in good agreement with the theoretical ones.