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Artikel: Modification of cantilevered folded plate roof for an aircraft hangar at Bombay (India)

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10. Modification of Cantilevered Folded Plate Roof for an Aircraft Hangar at Bombay (India)

Owners:	*Indian Airlines, Bombay*
Contractors for Hangar:	*B. E. Billimoria & Co.*
Contractors for Modification of Roof:	*Prestressing Corp. of India, Bombay*
Consulting Engineers for Roof:	*STUP Consultants Ltd.*
Work's duration:	*18 months*

Synopsis

The Indian Airlines Hangar at Santa Cruz, Bombay, is a suspended, 62 m long Cantilever Folded Plate Structure in prestressed concrete. This hangar ranks amongst the most outstanding structures built in the last decade.

Originally designed to accommodate Boeing 707 aircraft, it has recently been modified to accommodate the Airbus A 300 – B2 which Indian Airlines is employing on its major trunk routes.

Salient dimensions

The hangar complex measures 151.4 m × 91.4 m in plan symmetrically divided by an expansion joint located at half the diwth, Fig. 1. The 151.4 m length consists of two cantilevered hangars of 62 m each and a service complex of 27.40 m width, Fig. 2. The suspended roof covering the entire area of 151.4 m × 91.4 m is a continuous multiple-folded plate system. The transverse section of the folded plate consists of modules of 7.60 m width having a corrugated plate arrangement with horizontal top bottom plates between webs inclined at 45°.

Modifications

Whereas the greater wing span and the length of Airbus imposed only minor restrictions of positioning and scheduling for maintenance of aircraft in the hangar, the greater tail height was a serious problem because of insufficient head-room below the roof structure. The modifications proposed essentially consisted of making slits or «cut outs» (5.41 m × 1.75 m) at four locations in the roof, Fig. 1, into which the tail of the airbus could be guided while bringing the aircraft into the hangar from the apron.

Problems of creating slits

The slits in the roof structure were to be created in the top flange of the folded plate. Some of the more important problems that had to be overcome are discussed below:

- The creation of the slit would cause discontinuity in the transverse sense by removing the horizontal reaction available at the top flange due to the adjacent folded plate module. This horizontal reaction would have to be substituted.
- The main cantilever longitudinal steel was located in the top flange of the folded plate. The creation of a slit would have to be preceded by the provision of an alternate system of reinforcement.
- The «hat shaped» beam at the tip of the cantilever, Fig. 2, provides an important structural function, by distributing the unequal transverse loads (like wind gusts and live loads) applied near the cantilever tips favourably to all the folded plate modules by diaphragm-action. The cutting-off of a portion of this beam had to be replaced by an alternative diaphragm-system.

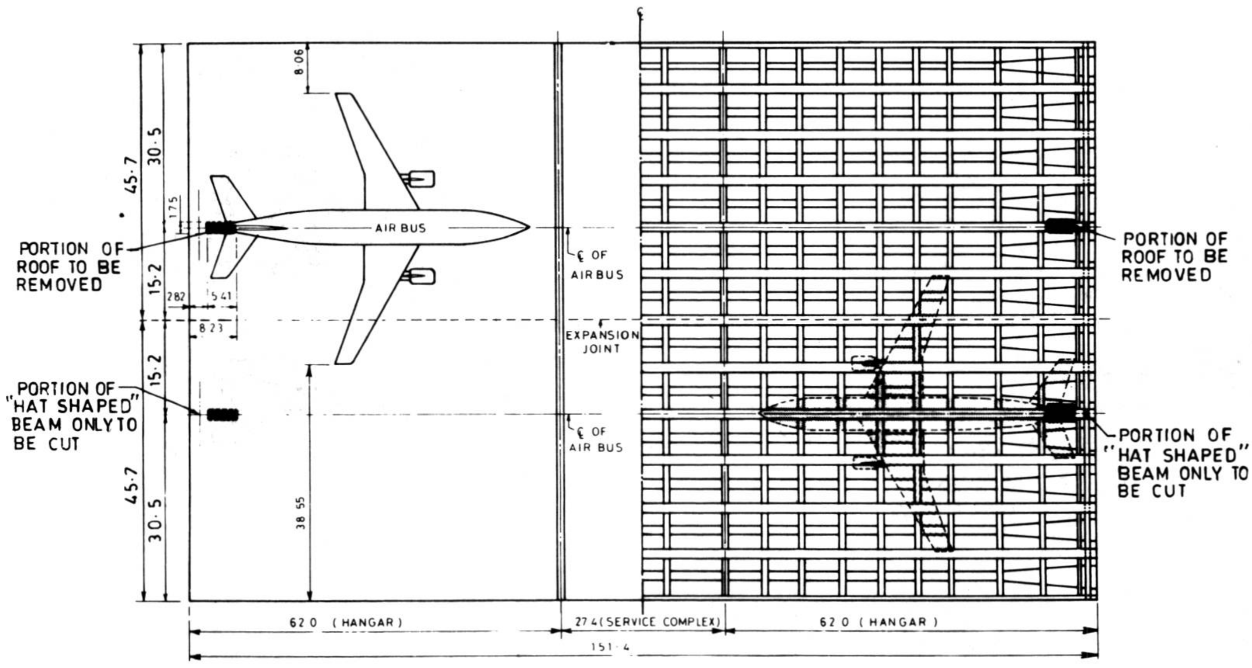

Fig. 1: Plan

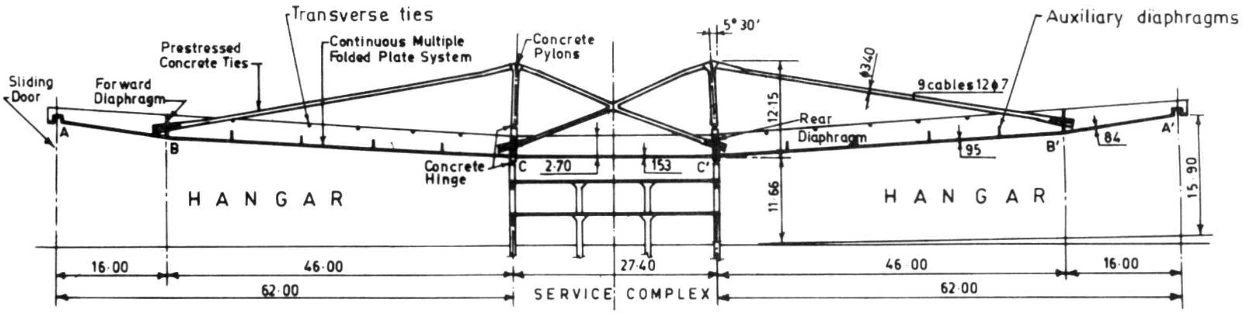

Fig. 2: Longitudinal Section

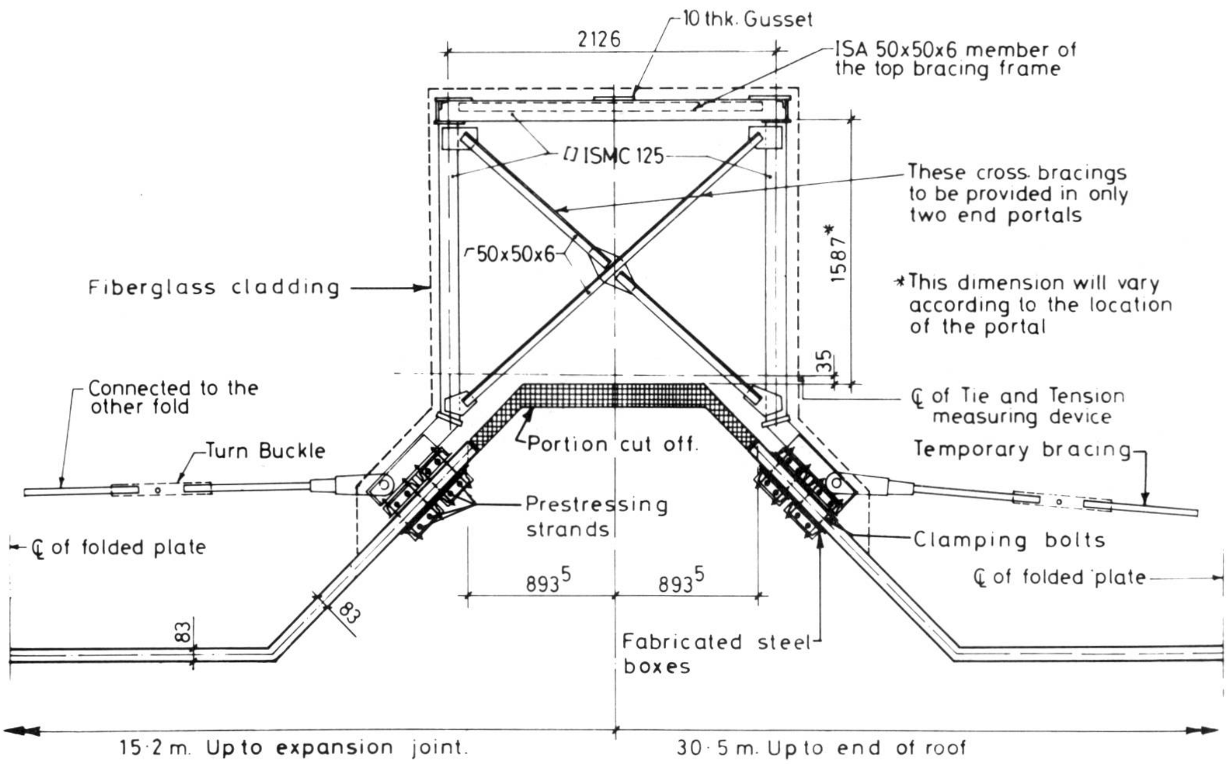

Fig. 3: Cross-Section, Canopy for extending roof at slit

Solution

The solution is shown in Fig. 3. Rigid structural steel portals 1.7 m centre to centre were clamped to the ends of the remaining folded plate concrete by bolts. A pre-evaluated temporary pre-tension was provided at the base of the portal before clamping to concrete, so that on de-tensioning, a positive force would be experienced by the neighbouring folded plate modules.

Prestressing strands were anchored on the end face at the tip of the concrete cantilever and on the other side to specially fabricated steel box anchorages which were clamped to the concrete of the folded plate.

A rigid structural steel frame consisting of a channel section was clamped on either side of the «hat-shaped» beam. The connection was done by means of bolts joining the web of the structural steel channel to that of the «hat-shaped» beam. The rigid frame was kept clear off the folded plate as well as the stiffening steel boxes required for longitudinal action.

Construction aspects of modifications

The success of the modifications proposed depended largely on the creation of a substitute concrete-structural steel composite structure and the ability to transmit large shear forces from the protruding structural steel elements into the concrete. Little published literature of properly conducted tests are available. The consultants had therefore to rely essentially on previous experience with epoxy mortars and the published data of the epoxy manufacturers.

To enable proper transfer of shear from structural steel to concrete, matching of the surfaces of the two was important. This was achieved by a freshly applied thin layer of epoxy mortar and quick clamping of the structural steel by bolts to get an effective pressure of 0.1 N/mm^2 on the epoxy mortar for proper setting.

Special attention was paid to the preparation of both the steel as well as the concrete surfaces which were sand-blasted to make them clean and rough. Since the struc-

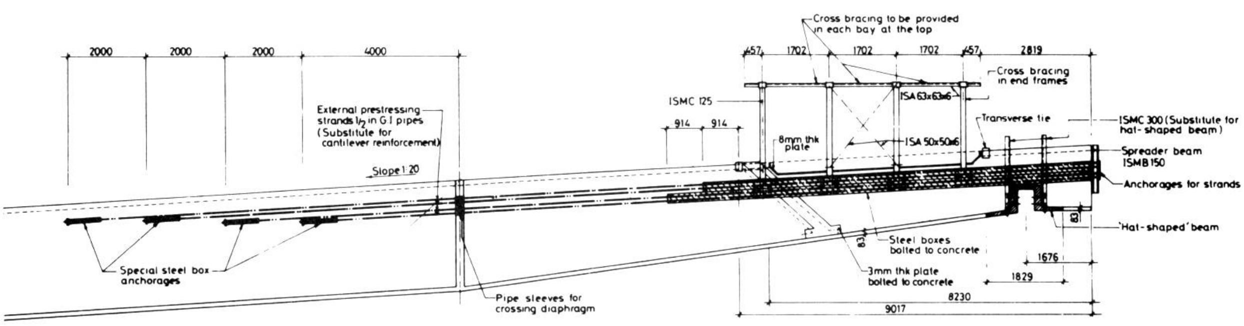

Fig. 4: Longitudinal Elevation

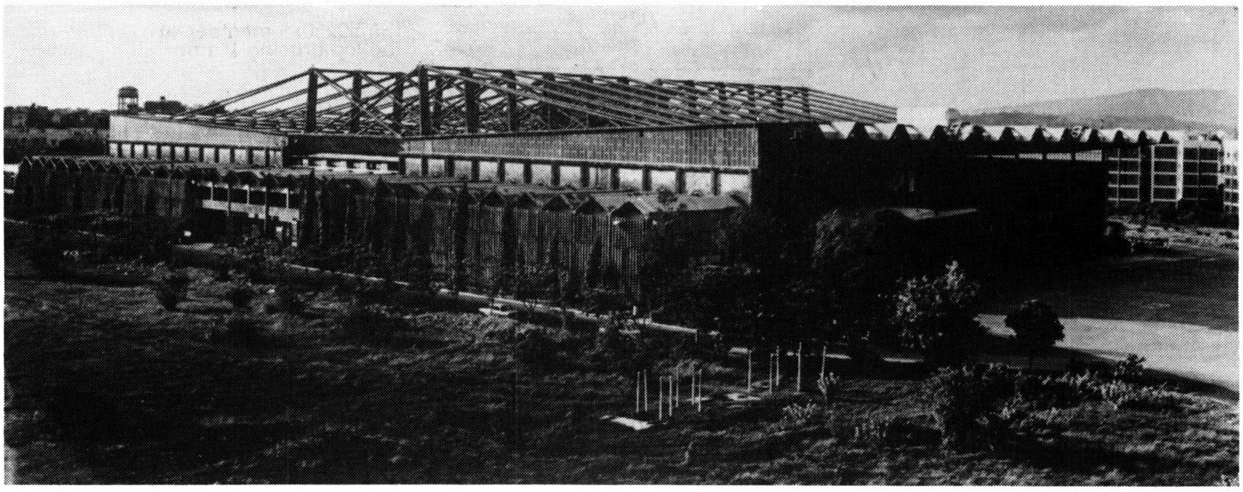

Fig. 5: Completed View of IAC Hangar

tural steel had to be fabricated many weeks in advance of their erection on site, the sand-blasted surfaces were painted with clear epoxy. The consultants have similarly prepared successfully strong surfaces with considerable roughness for many projects where such requirements of heavy shear transfer have been called for.

The transfer of shear through epoxy mortar accounted for only a part of the required resistance. The remaining capacity was derived from the bolts (used for clamping) in bearing. To improve the capacity in bearing, galvanised pipe-sleeves were placed in the holes drilled in concrete and filling-up of the gaps with epoxy mortar. The shear applied from the structural steel to the bolts would therefore first be transferred in bearing of the bolt shank with the pipe-sleeve and thereafter to the concrete. The larger outer diameter of sleeve and presence of epoxy mortar at the highly stressed localized zones increased the capacity in bearing to about two-fold as compared to the bolts bearing against the concrete directly.

Conclusion

The designer should concentrate on re-establishing in a very similar fashion various equilibrium systems which existed in the original structure in as direct and simple a manner as possible. To achieve this successfully, an understanding of the structural behaviour and accurate assessment of stiffnesses and deflections are important.

(M. C. Tandon, C. R. Alimchandani)