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Fig. 1: Overall view of the "Polydôme"

Introduction

The "Polydôme" is a 25 m-span timber shell exhibition hall built to commemorate the seven hundredth anniversary of the Swiss Confederation *(Fig. 1)*. The project was an opportunity to present concrete evidence of research, as well as to demonstrate the possibilities of engineered timber structures using simple material means.

Geometry

The project provided an interesting geometrical challenge, necessitated partly by the fact that timber structures inherently require geometrical precision and partly by the form of the roof.

The floor area of the building measures 25 m × 25 m and the maximum height of the building measures slightly less than 7 m. The walls, which are glazed with the exception of small service rooms located at the middle of the wall, have a maximum height of 3 m.

The roof is geometrically a spherical cap with a radius of nearly 28 m and an effective static height of approximately 10 cm which puts the roof into the Thin Shell class for structural behaviour, relying principally on membrane action to transmit loads to the supports. The roof has eaves which extend out beyond the walls a maximum of almost 1 m. The roof system has circular ribs which follow meridian arcs of the sphere in two orthogonal directions, that is to say that the ribs all have the same spherical centre. The points of intersection of orthogonal ribs at the exterior border form a planar arc which also respects the spherical geometry *(Fig. 2)*.

Fig. 2: Form at the exterior border

Roof Construction

The roof behaves structurally like a stiffened shell supported principally by four concrete abutments at the corners of the building. The abutments are tied together by foundation walls since the abutments resist horizontal as well as vertical forces. Posts having a section of 80 mm × 120 mm are located in the glazed walls of the building to provide minor supplementary vertical support for the shell between the abutments. The ribs and decking of the shell were all built from one standard small-size section of Swiss spruce boards (27 mm × 120 mm) finger-jointed to a maximum length of 19 m.

Each rib consists of two boards separated by the thickness of a board in order to allow one board of an orthogonal rib to pass between them at a point of intersection. As a result, the out-of-plane eccentricity between two orthogonal ribs is acceptably small and the detail at the intersection point of two orthogonal ribs is simple and efficient, with two boards running continuously in each direction and, therefore, no perpendicular-to-grain stress problems. Short filler pieces, the lengths of which vary for different pairs of intersection points, were placed between the separated boards to offset the out-of-plane eccentricity and to prevent local buckling of the individual boards. In addition, the exposed surface area of the individual boards of the ribs is reduced, thereby improving the fire resistance.

The decking is oriented at approximately 45° to the ribs to provide the necessary shear strength in the plane of the shell. Each board is separated by a small variable-width gap in order to fit the spherical geometry. The boards are essentially parallel to the borders and thus mainly in compression. This arrangement results in a more rigid behaviour for the spherical geometry than if the boards were perpendicular to the borders and thus mainly in tension.

The connection at the intersection of two orthogonal ribs consists of a single 12 mm ∅ machine bolt and four 5 mm ∅ screws. The filler pieces and the decking are fastened by 5 mm ∅ screws. The heads of the screws are located on the top surface of the shell and therefore hidden from view on the inside of the building. The heads of the machine bolts, visible on the inside of the building, are spherical.

The shell is covered first by a vapour barrier followed by thermal insulation panels, notched on one side in order to adapt to the spherical geometry. This is covered by a waterproofing membrane in the form of a foam material sprayed on to a thickness of 1.5 cm and finished with a thin layer of gel-coat to protect the waterproofing membrane from ultra-violet rays.

Structural analysis

Structural analysis, which consisted of a first-order three-dimensional frame analysis, was carried out to provide an estimate of the structural behaviour. The decking was modelled by truss bars running diagonally between the ribs. Asymmetrical loading was considered in the analysis, although there is little risk of unbalanced snow accumulation. The calculated value of the central deflection under a total uniform load of 150 kg/m^2 was 5 cm.

The high redundancy of the structural system gave some assurance that the analysis underestimated the rigidity of the structure, given the high variability of material properties for wood. This proved to be the case, as the actual central deflection of the shell upon removal of the interior temporary supports was of the order of 3 mm under the shell self weight of 25 kg/m^2.

Fig. 3: Layout of the ribs at ground level

Erection

The boards were delivered to the site in lengths of 19 m. No precurvature was necessary since the ratio of the shell radius to the thickness of the boards was approximately 1000 to 1 (the limit in Switzerland for the glulam industry is set at 200 to 1) and so the boards were flexible enough to take on the spherical form. The floor of the building was completed before beginning the erection of the shell in order to provide a flat work surface free from obstruction.

The erection of the ribs began by first laying out one layer of boards in each orthogonal direction at the floor level with holes predrilled at locations along the boards which corresponded to the intersection points of the final form. As the erection proceeded, an increasing number of intersection points took on the spherical form, beginning at the centre of the shell and going out radially *(Fig. 3)*. The ribs were fastened temporarily at these points and the filler pieces, which were field cut because of the variable lengths between the different pairs of intersection points, and two additional layers of boards for the ribs were added in successive stages. Temporary supports were placed at a number of intersection points at various intermediate stages until the points had attained their final height.

The light weight of the boards permitted raising them by means of hand winches supported on temporary portal frames. Thus the use of one or more cranes was avoided, thereby reducing the cost significantly.

When the ribs had reached their final form, the border beams and wall posts were fixed in place *(Fig. 4)* and the decking fastened. The fastening of the boards for the decking commenced at the borders, resulting in four triangular sections, the joints of which were located along the two main diagonals of the shell. Four skylights were installed at the central region of the shell where the in-plane shear forces were negligible.

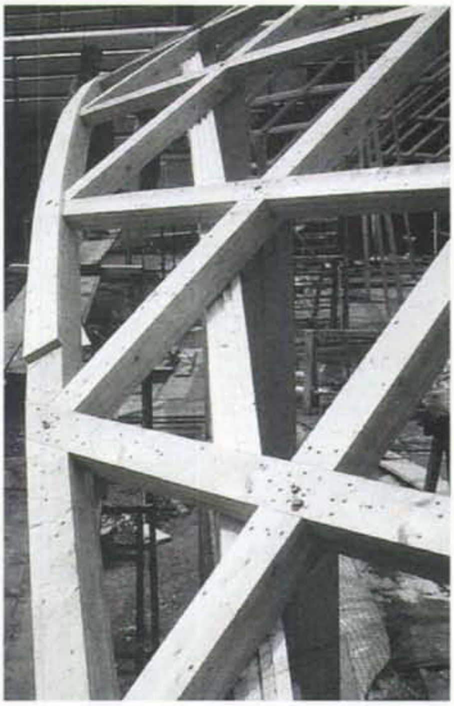

Fig. 4: Detail of border beams

Architect:
Dan Badic & Associés, Morges

Timber Engineer:
Bois Consult Natterer, Etoy

Contractor:
Jules Sallin & Fils, Fribourg

Service date:
1991