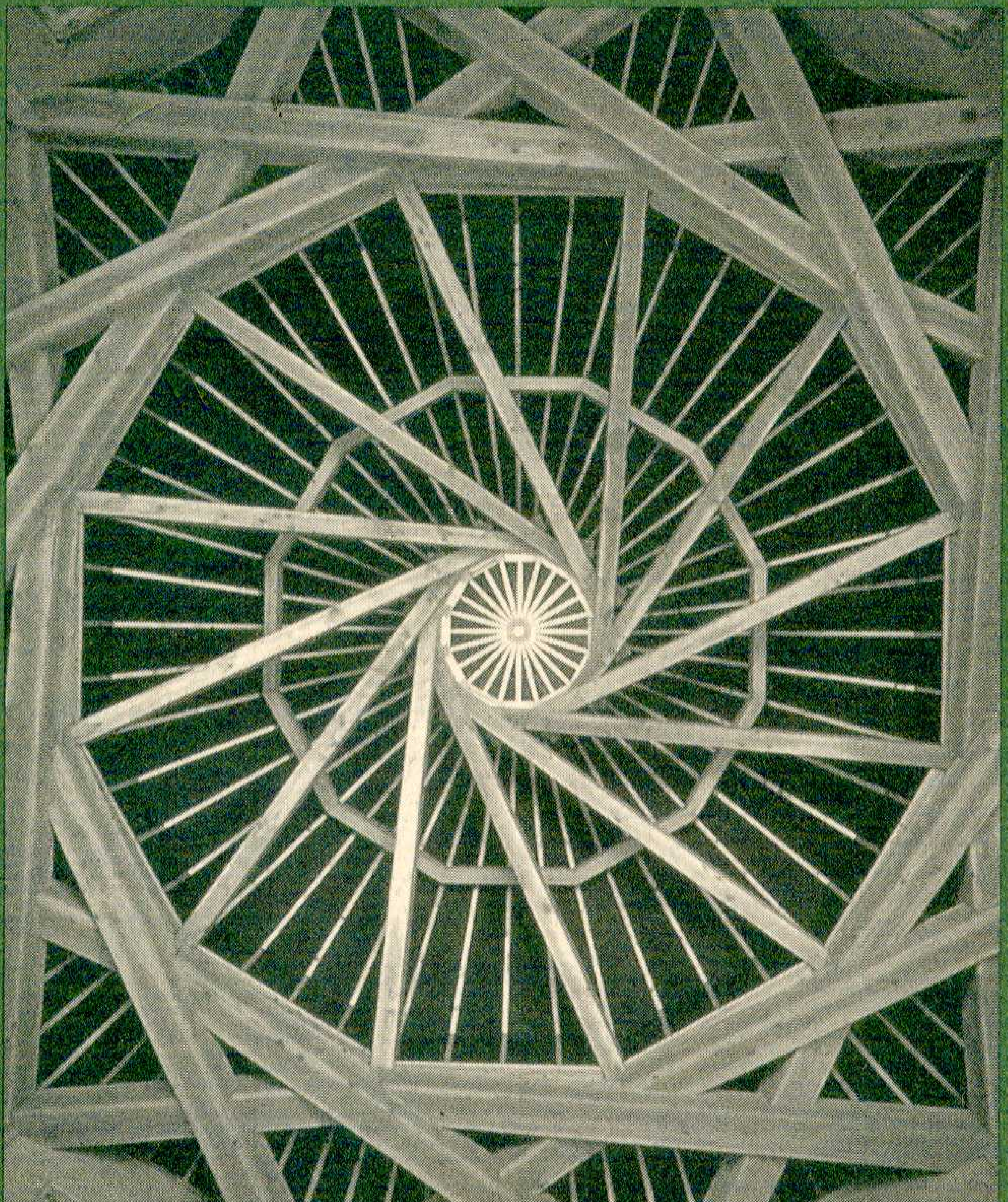
Götz Gutdeutsch

Building in Wood

Construction and Details



Birkhäuser

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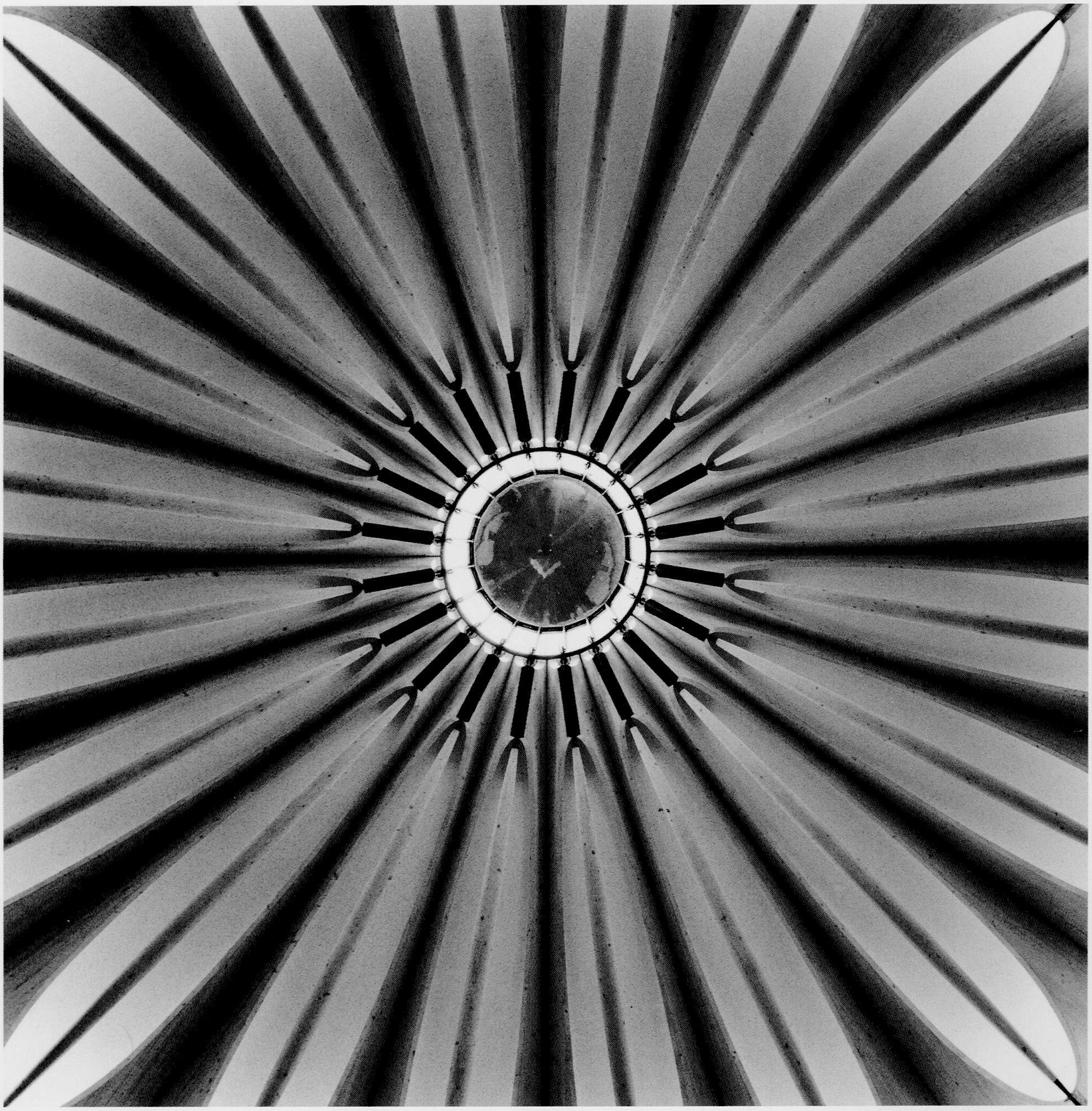

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About this Book

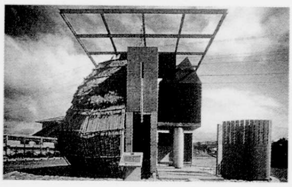
Wood and stone are the oldest building materials known to mankind. Both are natural products and both were originally certainly used only in their natural form: stones either rounded by the action of water or with sharp edges, wood still in the shape of trunks and branches. While stone is hard, rigid and permanent, wood is soft, warm and, even after felling, still organic. Wood breathes, swells and shrinks throughout its entire life; it is almost as though the felled tree lives on in our boards, planks, beams and columns.

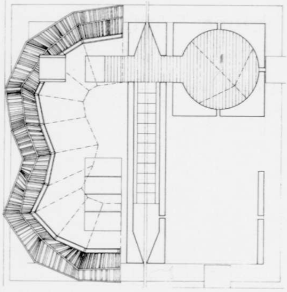
Mythical Beginnings | Trees were regarded as living beings by our prehistoric ancestors. They felt a kinship with the trees who, like them, stood upright. They witnessed their growth, their active response to the changing seasons, their fight for light as well as their death and decomposition, and saw this as an allegory on their own lives. Our ancestors also observed how each year the trees generously bestowed thousands of seeds and fruits on them, how they provided shelter and protection for countless birds and animals, how they were firmly anchored in the ground but flexed defiantly in the wind. In many cultures trees evolved into a symbol of life itself, which found expression in numerous myths and legends. By contrast, modern man and modern woman, with their scientific viewpoint and rational explanations, regard trees as merely functional objects: as suppliers of firewood or building materials, as climate regulators or windbreaks, at best of aesthetic interest to artists or nature-lovers.

History | But even today, when we use wood for building purposes it appears as an almost alive and very complex material. Just the fact of the dissimilar swelling and shrinkage characteristics in different directions and the different strengths along and across the grain, make wood an extremely sensitive building material which needs to be treated carefully by experienced hands. For centuries guilds of carpenters and joiners were the highly esteemed guardians of the knowledge and secrets of woodworking. A building culture which over generations altered only marginally, developed and refined the techniques needed for the optimum use of wood in various structures. The converse was also true: buildings were adapted to meet the possibilities and properties which wood offered; at that time, no designs were put forward which were not “buildable”!

Things began to change in the 18th century. After the light-hearted and florid but, in terms of construction, completely non-productive Rococo period, the "Architecture of the Revolution", practised by such architects as Etienne-Louis Boullée (1728–1799), for the first time proposed "unbuildable" designs – structures with huge, geometric forms. At the same time, however, a new building material emerged: iron, both cast and wrought, which for the first time could be produced economically in large quantities. Iron was stronger than all building materials previously known and, furthermore, possessed the agreeable property of being isotropic, a major contrast to wood with its so very different properties dependent on direction. So it is easy to understand how iron – and later concrete and steel – triumphed as a building material. This new material presented just so many more opportunities. The attempt at an aesthetic return to the traditions of the Romantic period, in particular the English Arts and Crafts movement, failed to halt these developments. As methods of analysis and construction improved, methods which of course preferred homogeneous materials, so wood retired from the scene of the innovative engineers and architects. Only in low-tech, low-cost buildings and in romantic imitations did wood survive the unstoppable concrete and steel boom of this century.

Wood lived on too in regions where the economic production and processing of the new materials was not possible, either because of the lack of a qualified workforce or the lack of the necessary division of labour. Several larger countries have tried to solve this problem by force – with dubious success. These were perhaps also regions and cultures in which the social structure was not so geared up for quantitative growth. For whatever reason, in such regions wood was given the chance to gradually adapt to changing living standards and customs.





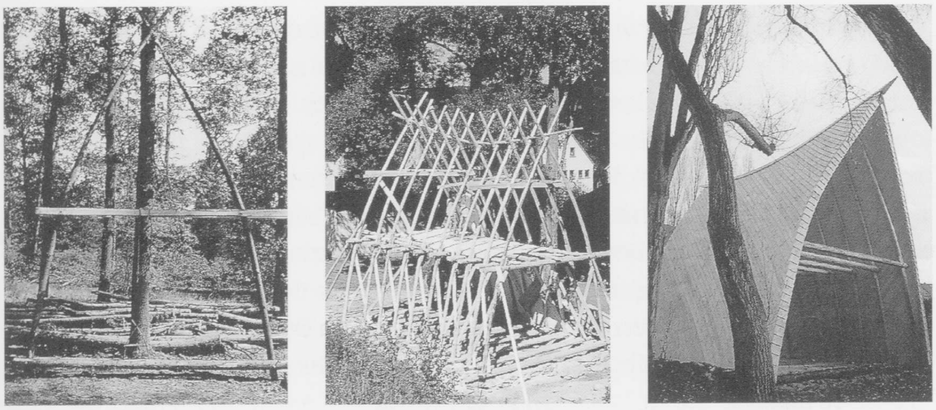
Benson and Forsyth, "Monument to Time", Oshima, 1992. Exterior view and plan.

New Uses | Of course, the rediscovery of wood in the industrial countries has been helped by the growing awareness that our unrestrained plundering of nature cannot continue if we are to preserve those things fundamental to our existence. Materials which can only be produced with enormous amounts of energy and which are difficult to recycle must be reduced to the absolute minimum. Wood suggests itself as an obvious alternative. As it grows – in the form of a tree – it regulates our climate, stabilizes the water content in the soil and in the air, and is the primary element in a balanced biosphere. When a tree dies or timber is disposed of, the wood, through rotting or combustion, is returned to the natural cycle without any additional energy input.

Modern Needs | Wood stands opposed to today's matter-of-fact computerized calculations and aspiring demands. However, we are living in an age in which the disparity between technology and nature is acknowledged, and to tackle this is regarded as a vital task of our time. In Oshima in Japan the London-based architects Benson & Forsyth have erected a structure which symbolizes this current theme magnificently: the "Monument to Time" (1992). Aligned with the Polar Star and intersected by flights of stairs, this building illustrates two different and separate construction principles. On one side are cylinder, cube and pyramid, representing the intellectual approach, on the other side the hand-crafted construction favouring natural materials, in this case Bamboo, that "Oriental" wood. Two worlds, separated and yet neighbours, are united within the circle of rough stones which surrounds the structure and provides its foundation; a new interpretation of the Taoist yin and yang symbol.

Tradition | So how can wood be reasonably and sensibly integrated into our high-tech construction industry? Many fundamental studies and experiments involving wood as a building material are being undertaken throughout the world – many outside the glare of publicity. At Wiesbaden University in Germany for instance, where as part of a special research programme the architect Professor Johannes S. Fritz and his students have erected structures built entirely from stripped tree trunks. Here, investigations are being conducted into the undisturbed strength of the timber and the stability of curved trunks in order to discover new forms of timber construction and hence new architectural approaches. At the same time, the architect Kazuhiro Ishii has built a puppet theatre using solid timber members with the traditional, "impressive" dimensions. He has created a framework of such structural and constructional complexity that it hardly fits into the pattern of modern structural analysis – it could only have evolved out of an old building tradition.

In Hungary a group of dedicated architects is trying to develop or stimulate a native Hungarian style of architecture which uses the indigenous timber in an "organic" manner. They and their vigorous proponent Imre Makovecz are following in the footsteps of the Hungarian architects of Ödön Lechner (1845–1914) and Károly Kós (1883–1977). This group is represented in this book through Dezsö Ekler and his structures for the summer-camp in Nagykálló – evidence of the durable impulses for today's architecture provided by traditional and "primitive" forms of timber construction.



Johannes S. Fritz,
Experimental tree-trunk construction, 1990.

Timber-frame Construction | Throughout the world the American "timber-frame system" has become accepted for smaller building projects such as housing. This system, which only employs standardized members, originated in America and can be traced back to the old pioneering days. This type of construction is astonishingly widespread – albeit in a multitude of variations. Its small-sized sections enable buildings to be easily, simply and quickly erected, and corresponding standardization permits simplified design calculations. Of course, these small sections do increase the fire risk and that must be taken into account, and the low self-weight of such constructions requires special measures in order to maintain acceptable sound insulation. The requirements vary from country to country and from structure to structure, resulting in the most diverse opportunities for this form of construction. As an example I have selected a housing project in Los Angeles designed by the architect John Mutlow. It is not especially spectacular but fulfils all the needs of its occupants.

New Technology | Certain technological developments are aimed at improving the isotropic behaviour of wood. Bonding pieces of timber together cross-wise results in elements which no longer exhibit the "negative" properties of solid timber. These elements do not split or warp and possess uniform properties in tension and compression. On the one hand, these laminated timbers (glulam) or, when thinner laminations are used, veneer laminated wood panels (e.g. "Kerto"), present a degradation of wood and its natural properties. On the other hand, with this reverence to our high-tech requirements we are often able to employ timber to conquer hitherto unattainable realms of construction. In particular, glulam sections enable us to span the great distances often desirable in modern structures and which would otherwise only be possible in steel or reinforced concrete. This book provides a number of examples of this, in the form of sports centres and bridges.

These examples reveal just how important the connections are in such structures. The enormous concentration of loads at the supports, in the joints between beams and columns, can no longer be accommodated by the timber alone – steel components are required to transfer such forces. This book shows quite clearly how various architects working in different countries have tackled this type of detail. The whole range of possibilities is represented, from meticulous, coherent planning by the designer to the delegation of this whole task to the contractor. This observation is not intended as criticism; I believe that in this transitionary period we must experiment with different approaches. A consensus concerning the appropriate integration of details within the overall construction can only be formed gradually – and in terms of timber construction we are really only in the development stage.

Detail and Whole | A detail is a part of the whole. The details of a structure could certainly be studied and analysed for their own sake. However, they are and remain pieces, integral elements within the overall structure. They have their own language, express the spirits of the architects and engineers, reflect local traditions and building skills, indeed even the local climate and social structure. Therefore, in my treatment of the projects described here I have in each case first outlined the aspects specific to that particular structure. The emphasis might be on a special technical requirement, such as in Darwin College in Cambridge with its still-green oak members, or the brine baths in Bad Dürrheim where a timber structure is essential owing to the aggressive salt-water vapours, or the combined efforts of amateur builders, like in the Nagykálló summercamp or the McMullen summer-house in Ontario. There are high-tech houses which make use of timber for their primary elements, such as the "Heliotrop" by Rolf Disch. Other architects try to deal with tradition creatively and openly, such as the church designed by Walter von Lom or the aforementioned puppet theatre of Kazuhiro Ishii. So, each and every structure has its own personality which is also reflected in its details. This is why details cannot be judged properly when they are separated from their whole. Climate, local building methods, personal design preferences and a host of other factors all play a role, and it is quite legitimate to regard and to categorize even factors like durability, sound insulation, etc. differently. Every structure is a weighted optimization of all the factors, from the function to the cost, from the skills available to the engineering requirements.

Further, I think that the personality of the designer and the builder are an intrinsic part of a structure. Therefore, where possible I have also included original detail drawings by architects, engineers and contractors in my description. These speak their own language and express something specific about the project and its evolution.

Outlook | Today, the most diverse applications of timber in construction are being tested, offered and implemented. Timber in conjunction with steel, plastics and adhesives is becoming more and more widely accepted. Timber as an organic building material, as a bringer of hope for a more environmentally aware technology, would seem to be re-conquering the construction sector to an increasing extent. We find ourselves in the middle of a secular upheaval; this book attempts to record the current state of development by means of a number of examples.

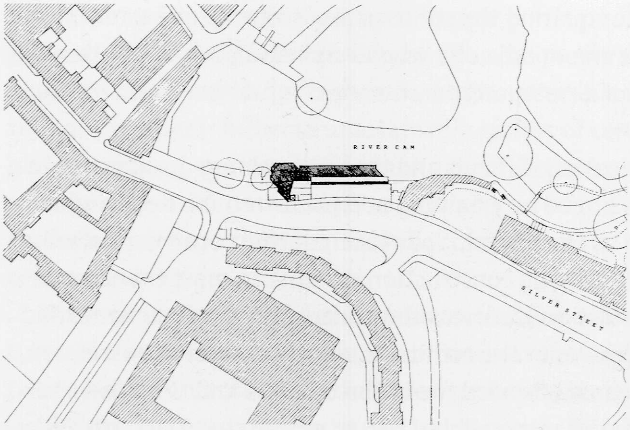
Acknowledgements | Particularly difficult and time-consuming during the preparation of this book proved to be ascertaining and procuring the detail information and drawings as well as the photographs taken during construction, which are often indispensable in clarifying construction systems. In most cases some time had elapsed since the design work was concluded, and the documents had already been sent to the archives or the architects were no longer in possession of the information. My research often led me to the builders and from there to the individual members of staff responsible. I had to rely on the assistance of many others.

Therefore, I should first like to thank all those architects and their assistants who painstakingly provided the answers to my, often, intrusive inquiries and detailed questions. In particular Professor Bernd Steigerwald for the Wilkhahn production plant, Dipl.-Ing. Hans Purkarthofer for the tennis halls in Bad Waltersdorf, Iwona Buczkowska for the housing development in Le Blanc Mesnil and the Collège Pierre Sémard in Bobigny, Mikael Uppling for the KTH sports centre, Anna Brunow for the Rausti sauna, Richard J. Dietrich for the bridge in Essing, as well as Flemming Ibsen, Christian Kandzia and Peter Wöhrle. On other occasions it was only the engineers or carpenters in the timber construction companies who were able to provide more accurate information, in particular Hans Meier (Wey Elementbau) for the Wohlen High School, Walter Bieler, who designed and built the cross-country ski bridge in Pradella, and Lars Serrander from AB Fristad Bygg.

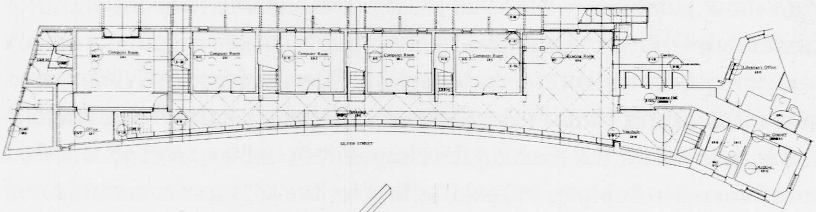
Serious language problems were encountered in the communications with the Japanese and Malaysian architects. Therefore, I am especially grateful to Andrew J. Geddes for his marvellous help with the translations and correspondence, and also to the Japanese architect Toshiya Maeda from the Berlin office of Takamatsu + Lahyani Architects.

Finally, a special word of thanks is due to Ria Stein of Birkhäuser, who read my manuscript and helped me through the difficult initial stages. Tackling and overcoming the problems which arose throughout this project would not have been possible without her constant loyal support and encouragement.

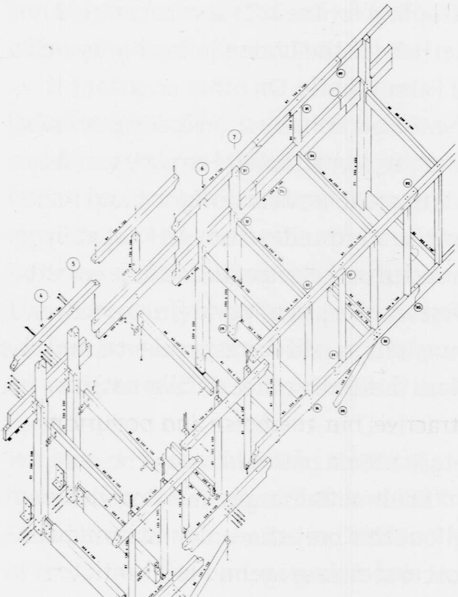
1 | Location plan, scale 1:3000.



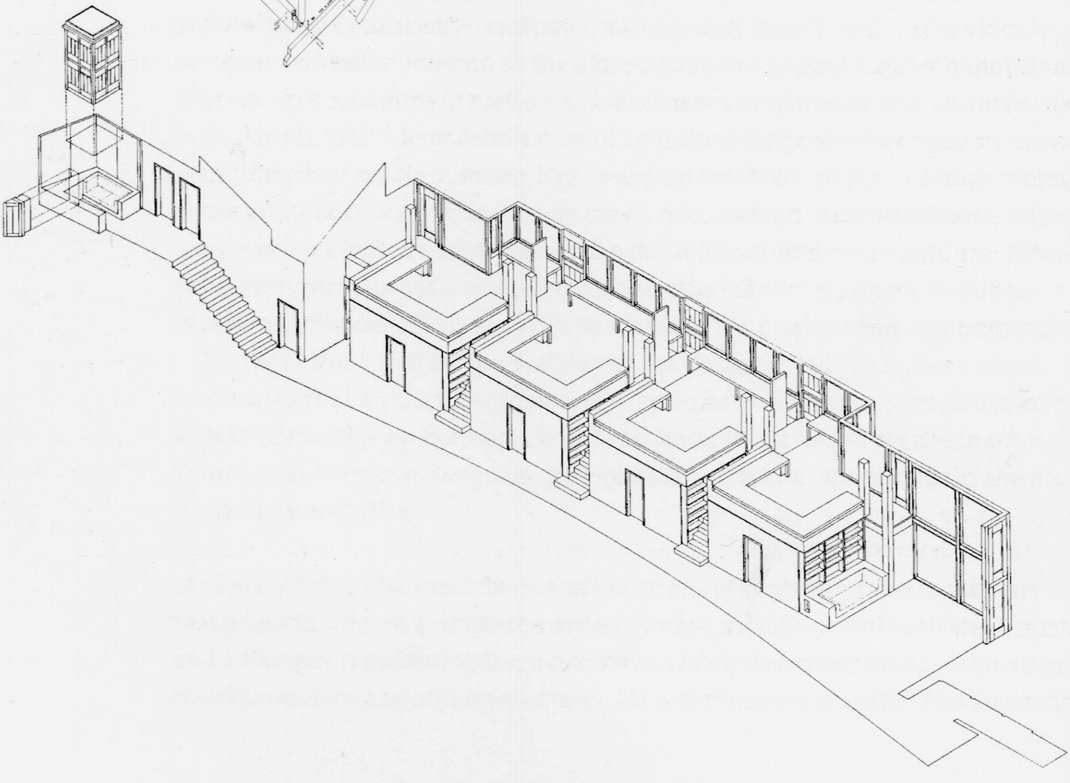
2 | Ground floor plan, scale 1:500. The five computer rooms, each with six terminals and small windows overlooking the river, lie alongside the access corridor. Between these, staircases ascend to the reading and study area. To keep out street noise the slightly curved roadside wall runs the whole length of the building. On right: recreation room and access area.

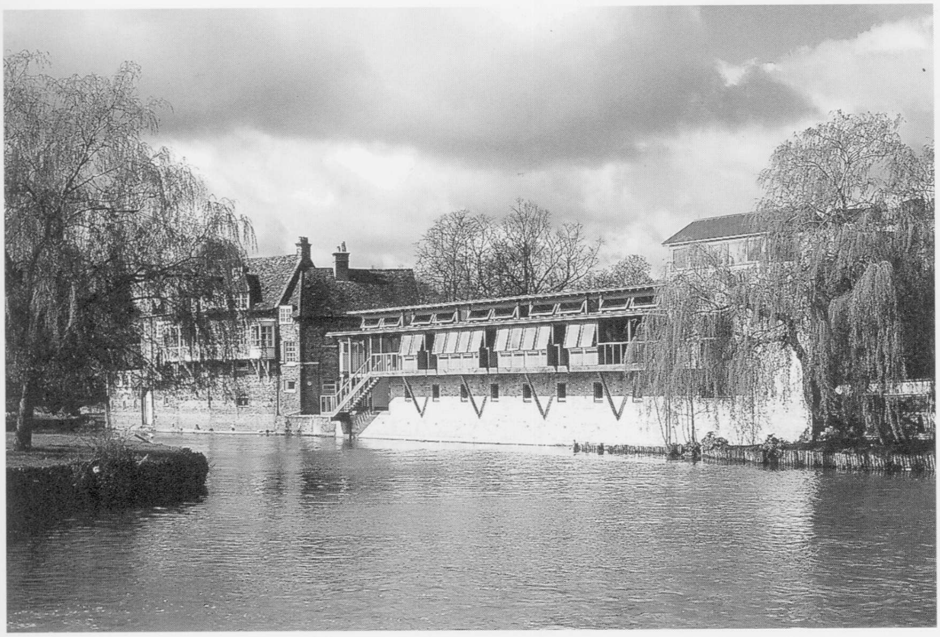


3 | Isometric projection of load-bearing timber construction, scale 1:150. At front and in middle: the fixed points formed by the many twin primary posts, connected by beams at top that cantilever out at sides. These cantilevers carry the suspended intermediate beams.



4 | Isometric projection.





5 | View from riverside.

Darwin College Study Centre, Cambridge

Jeremy Dixon & Edward Jones

Subject | Darwin College is a small postgraduate college of Cambridge University. It comprises a number of old buildings on the River Cam, one of which was once the home of the Darwin family. Hence the name of the college. In 1989 an architectural competition was held for a structure to connect the buildings and provide reading and study facilities for the students. The site itself was exceptionally difficult. Hemmed in by the existing buildings, it was 45 metres in length but only 6 to 8 metres wide between the Cam and the very noisy Silver Street. The south side, facing the mill pond, is very attractive, but the noise and pollution from the street had to be reliably excluded, which was no easy task.

The architects Jeremy Dixon and Edward Jones won the competition with an idea that was as simple as it was effective. On the street side a low continuous wall and on the river side closed-in computing rooms at ground level with the study area above them, open to the river. The load-bearing system was to be of wood. From the tenders received it was seen that, on account of the economic crisis, home-grown oak was the cheapest solution. In the required dimensions, however, it was available only freshly felled and not seasoned. That meant long drying-out times, during which the timber would shrink and move. The problem, therefore, was to find not only a suitable connecting structure but also to create connections between the timbers that could be adjusted and tightened as the drying of the timber took place. The difficult structural analysis was assigned to the building engineers Ove Arup & Partners.

Design | On the street side the building is bounded, optically and acoustically, by a continuous storey-high wall that follows the slight curve of the street. Along the inside of the wall runs the corridor that gives access to the whole building and at the west end leads to a small recreation room communicating with the individual work areas. There are also bookcases there running the whole length of the corridor. On the river side of the corridor a row of four computing rooms is located. Between these, stairs lead to the reading and study rooms above, which are also open to the access corridor with its bookcases. The computing rooms have small windows in the masonry wall, the upper reading-rooms wide strip

Location
Darwin College, Cambridge
CB3 9EU, Great Britain

Client
Darwin College Cambridge

Architect
Jeremy Dixon & Edward Jones, Architects, London
Project Architect
Alison Greig

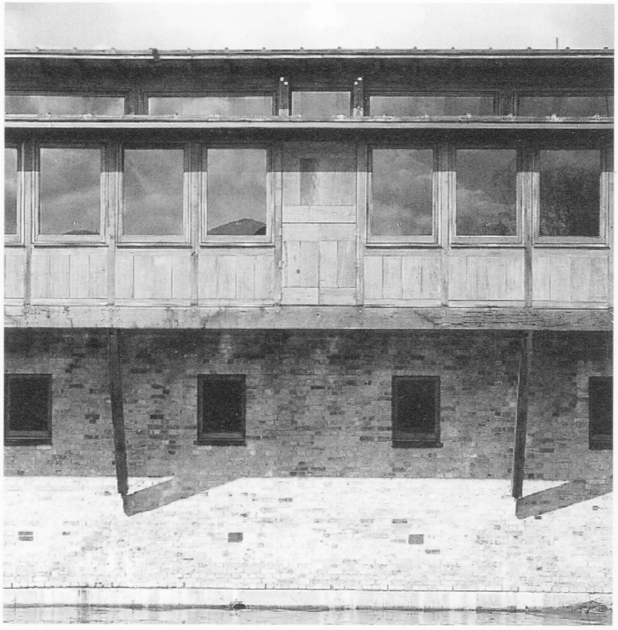
Structural Engineer
Ove Arup & Partners, London
Project Engineers
Roger Hyde, Sarah Maldrum, Peter Ross, Mick White

Timber Construction
Henry Venables Ltd., Stafford

General Contractor
Rattee & Kett Ltd., Cambridge

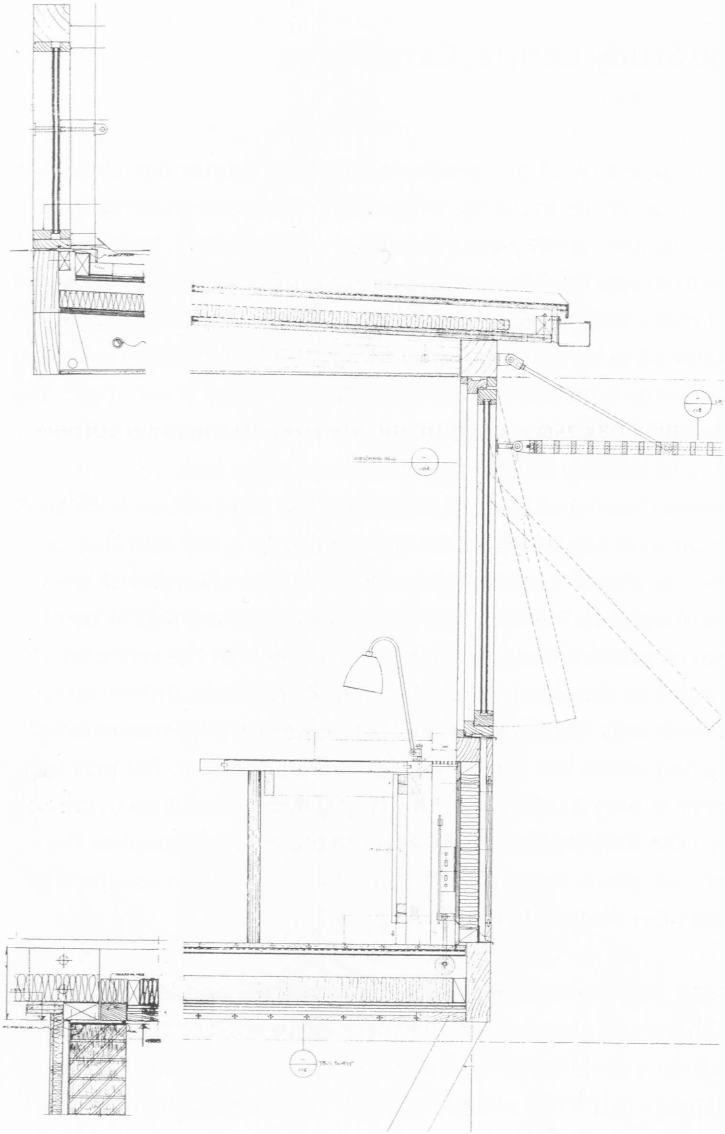
Date of Completion
1994

Costs
The cost of the building came to between 1 and 1.5 million English Pounds and was within the limits of the estimate.



6 | South façade seen from river.

7 | View of access corridor. On left: roadside wall and row of high-level windows. On right: computing rooms under reading and study area.

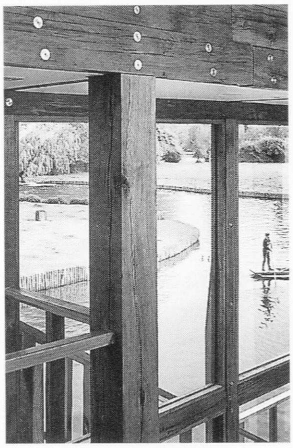


8 | Section of south façade, scale 1:30. Floor construction: load-bearing principal cantilever beams 365 x 150 mm, intermediate cantilever beams 290 x 75 mm – on top 20 mm tongue-and-groove oak parquet, underneath 2 layers of 12-mm chipboard and 20 mm tongue-and-groove oak facing; between beams 100-mm heat insulation layer.
Façade construction: parapet from exterior to interior: 25 mm oak facing on 175 or 75 x 25 mm oak frame on lathing, protective sheeting, 75-mm-thick heat insulation, vapour barrier, 18 mm plywood boarding, window of oak with heat-insulated double glazing.
Flat roof from top to bottom: lead covering, 20 mm boarding, 120 x 50 mm squared timbers, between these 70-mm-thick heat insulation and 50 mm air space, vapour barrier, 20 mm plywood boarding, 150 x 100 mm roof beams, 12 mm gypsum plaster board.

windows opening towards the river and the south. The upper storey also cantilevers out some 1.5 m over the water, forming, as a structure wholly of wood, an impressive contrast to the masonry base.

Above the wall on the street side is a row of soundproof dead lights and over these a pitched roof that rises to a row of windows above the reading area in the upper storey. The pitched roof thus not only amply covers both levels of the corridor and reading area, it also opens up the building to the south, neatly closing it off on the street side. The whole of the interior is predominantly of wood, such surfaces as tables, balustrades, windows and doors being finely smoothed and finished. The structural timbers have been left deliberately rough and fissured, thus offering an interesting contrast to the surfacing wood, likewise all of oak.

In the working area all the windows can be opened by hand. The row of high-level windows, however, forms part of a sophisticated ventilation system combining natural with automatic heating and cooling: at the east end of the access corridor there is a staircase leading to the upper level, as well as a ventilation stack with openings that can be closed by wooden flaps. These and the high-level windows open automatically with a rise in air temperature, thus ensuring air movement without the need for a fan. The automatic control system also closes the flaps against wind and rain. This system provides natural cross-ventilation while keeping out street noise.

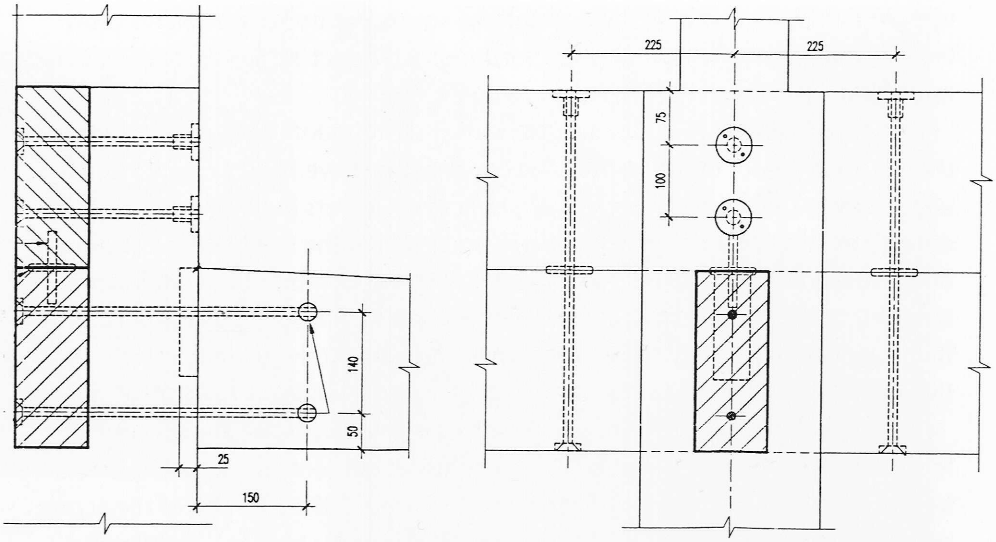


9 | Interior showing primary posts and double beams with screwed anchor bolts and points of support for suspended beams. The windows are also provided with adjustable anchor bolts.

Structure | Only the upper floor is actually a timber construction, the ground floor consisting mainly of the outside walls on the street and river sides. The river wall is reinforced every 5.5 m or so by cross strips of twin masonry walling about 1 m in length and 1.10 m apart. This spacing also forms the basis for the spacing system chosen for the whole of the interior. The double walls are joined under the floor by reinforced concrete slabs 300 mm thick. Placed behind the riverside wall, these concrete slabs not only carry the staircases leading to the upper floor, but also form the foundation for the timber superstructure.

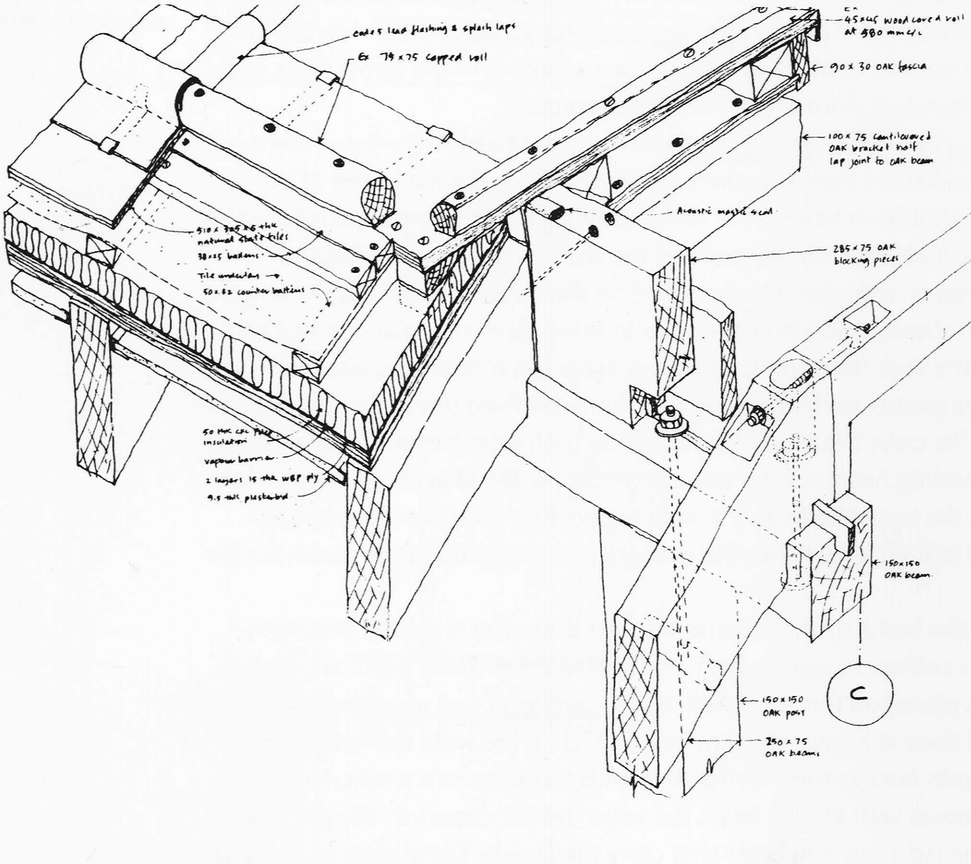
The primary posts are of oak 250 x 250 mm and are fixed to the inner corners of the concrete slabs by steel T-sections and anchored to the back ends of the riverside main cantilever beams. The row of primary posts forms an axis between the body of the building cantilevered over the river on the one side and the pitched roof that sweeps down to the street on the other. Throughout the length of the building stand double primary posts at intervals of 1.10 m and joined together under the high-level windows by two 250 x 100 mm beams, one above the other to ensure greater stability. These thus form the fixed points for the whole construction. The cross beams cantilever out on both sides carrying intermediate Gerber-like coupling beams of the same dimensions. The lower cantilever, which is longer than the upper, looks as if it were supporting these. At the very top, above the row of high-level lights, the primary posts carry the ridge purlin for the pitched roof.

The part of the building that cantilevers over the water is carried mainly by 365 x 150 mm cantilever beams, which are fixed to the primary posts and rest on concrete slabs placed on the outer wall. At the cantilever end roughly 1.5 m from the outer wall there is a 325 x 100 mm head, which in the wide spans between the primary posts is supported further by visible 150 x 150 mm struts stretching from the brickwork wall. On the head, the same distance apart as the primary posts stand the 150 x 100 mm posts that carry the façade. These are connected at the top by the 150 x 150 mm boundary beam and at parapet height by a 100 x 100 mm rail. Between the boundary beam and the above-mentioned continuous twin beams lie the horizontal rafters of the riverside part of the building. 100 mm in width, they display a height of 150 to 250 mm for roof pitch.



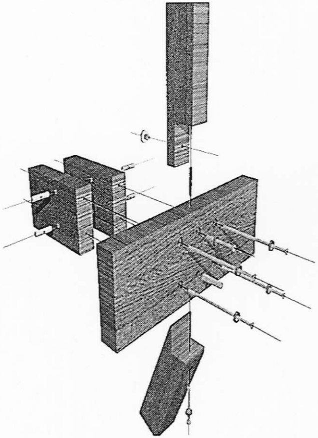
10 | Detail of joint between primary post and twin beam, scale 1:10. The beams are held together and to the primary posts by means of appropriately long screwed bolts. Where the use of lock nuts was not possible anchor bolts were used. The superimposed beams were secured with dowels to prevent lateral movement. The roof beam of the cantilevered section is mortised 25 mm into the primary posts and held secure with screwed and anchor bolts.

11, below | Isometric from roof ridge over south-side high-level windows. From top to bottom the roadside roof surface is built up as follows: natural slate covering of 510 x 305 x 6 mm boards on 38 x 25 mm laths, insulation sheeting, 50 x 32 mm counter-lathing, 50 mm heat insulation, vapour barrier, 2 layers of 15 mm plywood boarding, 250 x 75 mm rafters, between these 9.5 mm gypsum ceiling baseboard in metal frame.

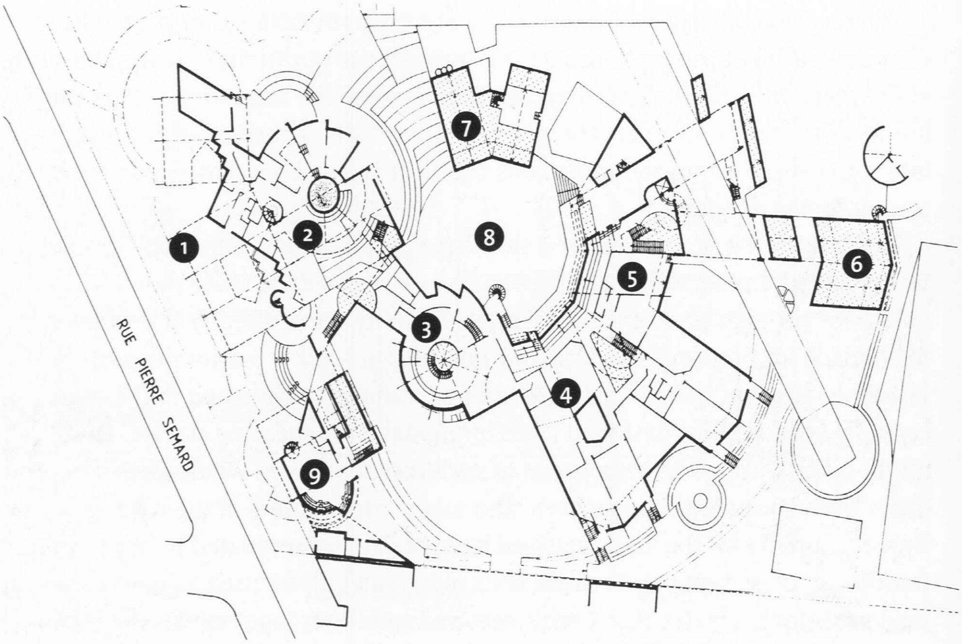


The roadside pitched roof is formed by 250 x 75 mm rafters that stretch from the ridge purlin at the top to a 150 x 150 mm inferior purlin that follows the curve of the masonry wall. The differing distance between the ridge and inferior purlins gives rise to an arched roof surface, which creates a particularly attractive interior. Under the inferior purlin runs the already mentioned roadside row of soundproofed windows.

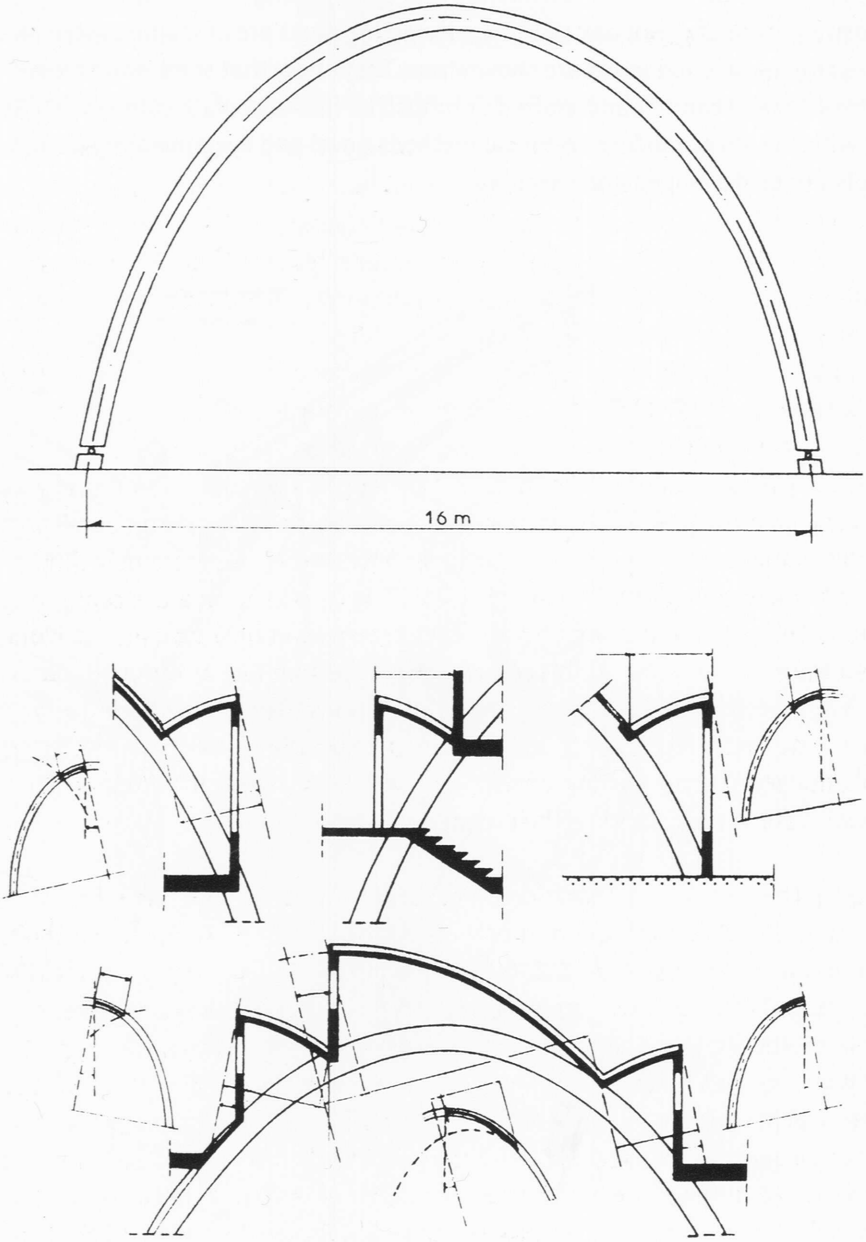
To allow for the slow drying and shrinkage of the timbers adjustable connections had to be used. Although the wood was kiln-dried the three months available were not enough to ensure adequate stability. Consequently allowance had to be made for fissuring, twisting and splintering. For this reason the particularly sensitive rafters of the pitched roof had, for example, to be joined to the two-layer plywood roofing, designed to accommodate any shearing stresses that might occur. During the installation of such components as windows and outer doors the anticipated changes were also taken into account. In the case of all the timber connections the loads involved have been accommodated by appropriate profiling of cross-sections. Because bolts alone can only be used as positioners to hold parts together structural engineers and architects together developed a screwed steel bolt system comprising transverse anchor bolts and cover plates, which proved both statically satisfactory and eye-pleasing. On account of the corrosive nature of green oak all these connecting parts are of stainless steel. A few examples of wood joints are shown here. They show that solid wood cross-sections do not require hand-crafted or industrial nail-and-plate connections and that with the aid of modern technical methods novel and eye-appealing design details can be developed and executed.



12 | Exploded view of beam joint. Rod end anchors were used to connect into longitudinal members, and flush dead end anchors when bolts passed through to the hidden side of a member.



1 | Ground plan of entrance level, scale 1:1000. **1** Administration area; **2** Entrance hall; **3** Library; **4** Classrooms; **5** Science labs; **6** Sports area; **7** Hall; **8** Central courtyard; **9** Art rooms.



2 | Standard arch with examples of dormer window roofs, the curves of which form part of main arch.

3 | View of courtyard. In the background the public gallery in front of the classrooms.

Collège Pierre Sémard, Bobigny

Iwona Buczkowska

Subject | Ever since her studies in Gdansk and Paris it has been the endeavour of the architect Iwona Buczkowska to create buildings and interiors characterised by variety and vitality using standardised building units. In doing this she shows a preference for unusual shapes, in particular for sloped and curved surfaces. She has devoted considerable time and effort to the arch as a basic element of construction.

In 1989 she won the first prize in a competition for a secondary school for 600 pupils to be built in Bobigny near Paris. The prize-winning idea was that of a basic structure of identical wooden arches from which the various floors were suspended, thus leaving the ground floor to a large extent free of columns and posts and creating greater translucency and increased mobility. Used purely as tension elements, the supports on the upper floors were kept extremely slim.

Government rulings for French school building construction are exceptionally rigorous. For access to interiors, for instance, they permit only straight corridors of minimum surface area. In this case, however, the architect attempts to break away from this concept and for the various functions to provide differing qualities of space and lighting, while at the same time creating a lively configuration of unusual room combinations and shapes. With these highly individual ideas she won deserved recognition: the school was built in 1994.

Design | The school administration offices and entrance lie alongside the road leading to the school. Set back at ground level, they create a varied and partly covered-over widening of the sidewalk, leading to the main entrance in the form of a semi-public forecourt. From here one can see into the lower-lying central courtyard. The big entrance hall directly behind the offices offers a first impression of the concept systematically applied throughout the whole of the building: wooden arches with suspended floors. From this hall an amply dimensioned circular arcade leads around the inner courtyard to the various units; first to the round-domed library, then to the classrooms and beyond these to the science and technical labs and, finally, to the hall. Beyond the labs is the sports area and, next to the college entrance, the art rooms.

Location
Collège Pierre Sémard,
85 rue Pierre Sémard,
9300 Bobigny, France

Client
District Authority of Seine-Saint-Denis. Delegated to "Sodédat 93"

Architect
Iwona Buczkowska,
architecte D.E.S.A.,
Ivry-sur-Seine
Design Team
J.P. Conqui, I. Jeangeorge,
T. Krupa, J. Furgalska,
G. Rebboh

Structural Engineer
Monsieur Uhalde

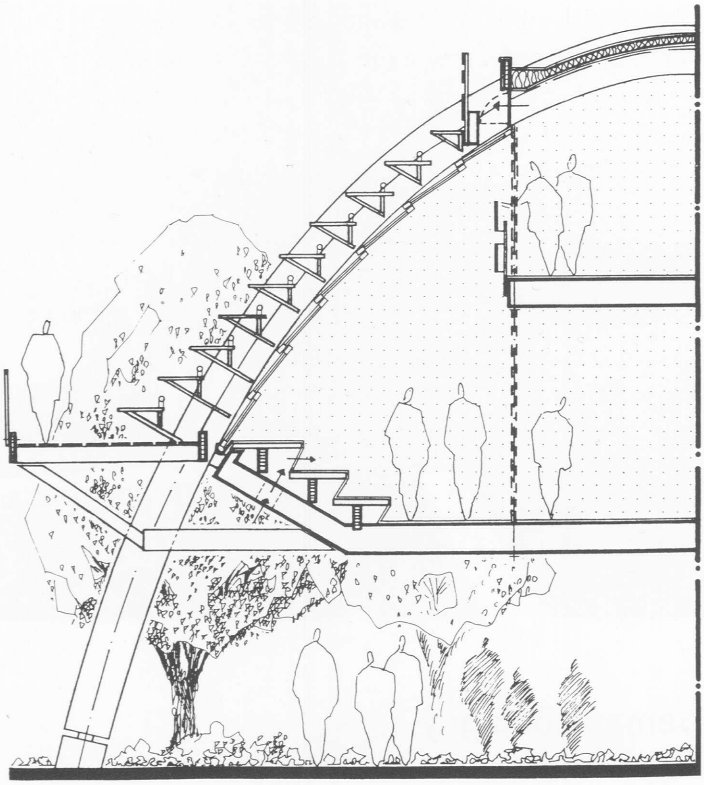
Timber Construction
MARGET

Glulam Beams
GAILLAUD

General Contractor
SICRA

Date of Completion
1994

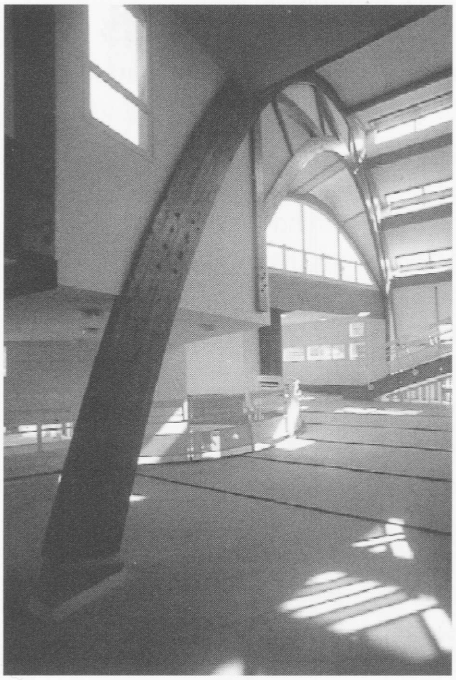
Costs
Total costs amounted to 50 million French Francs.



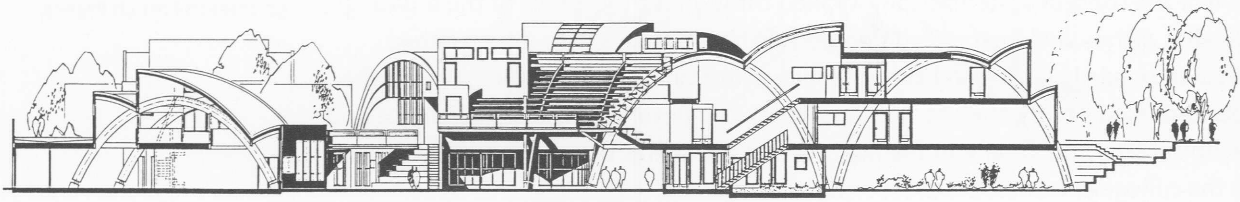
4 | Section through public gallery area before the corridor in classroom unit, scale 1:100.

5 | View of entrance hall.

6 | Art room area. The balustrades are of steel since wood would be too massive.



7 | Section through hall, courtyard and classroom unit, scale 1:500.



The irregular radial arrangement of the structural arches around the central courtyard results in building units that are neither too rigid nor too uniform. The collection of differently shaped spaces and rooms with their interesting views of the surroundings and the interior and the play of light and shade, all of it dominated by the ubiquitous arches, create an almost playful impression.

Structure | The many parabolic arches with their 16 m span and 9 m rise display a 140 x 600 mm cross-section and are of glued laminated wood. As Iwona Buczkowska points out, the same arches of steel would have to measure 400 x 600 mm. Wood is thus of much greater elegance. The distance between the arches is 5.90 metres; arranged parallel, they form the various building units. Between the arches 88 x 303 mm glulam beams with a spacing of some 2.80 m carry the weight of the roof. They support curved 65 x 132 mm glulam timbers, which, some 60 cm apart, form the horizontal roof construction. The outer surface of the roof consists of a shell of two 9 mm layers of plywood, under which are 10 mm gypsum plasterboards. In the spaces between the beams the plaster boards are covered with a 100-mm-thick insulating layer, and between the two is the vapour barrier.

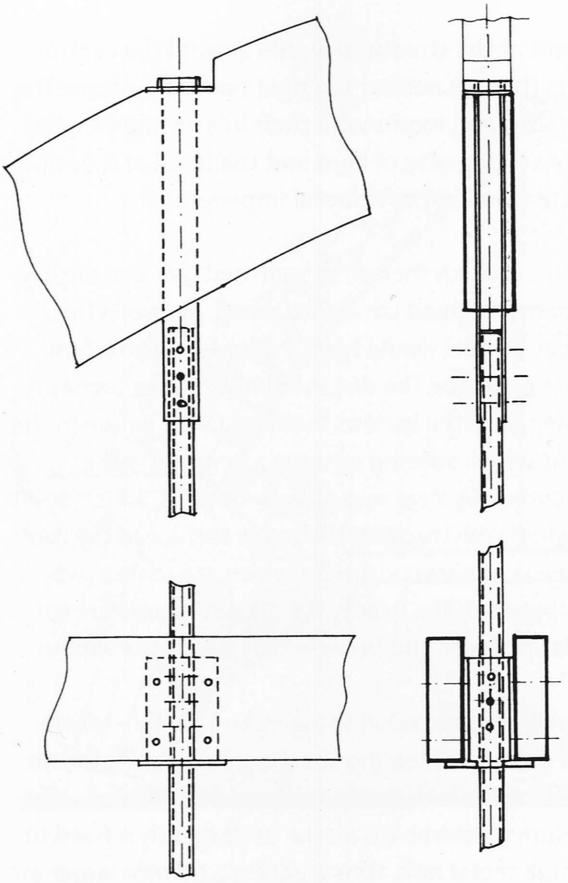

8 | Entrance and administration area.

The actual roofing consists partly of cedar wood shingles and partly – where the roof surface is not visible – of green roof sealing sheeting. As a result, the air space above the insulation is in each case differently designed. Where roof sealing sheeting is used, the gypsum plasterboard on the underneath is fixed to the beams by means of 28-mm-high metal rails, thus creating a 60 mm larger air space between insulation and top surface and ensuring effective ventilation. The roofing shingles are placed on wooden boarding running the whole length of the roof and connected to the plywood covering by 76-mm-high laths. In between is the sealing sheeting, thus creating an air space above the plywood layer to provide the necessary ventilation. There being no need for an air space under the top covering, the bottom gypsum plasterboard is in this case fixed directly to the beams. There are areas under the waterproof sheeting where the air space cannot be ventilated, either because they are too large or the number of windows too small – here the window connections allow for ventilation.

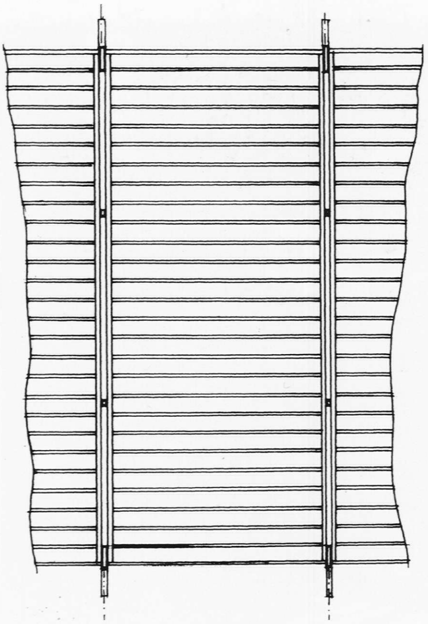
The fenestration is for the most part in the form of saw-tooth-shaped dormer windows that rise from the roof shells. Their roofs, also curved, spring from the main parabolic arches, which made their production easier. The load-bearing components in this case are curved 138 x 220 mm glulam beams which, with a spacing of just under 3 m (1/3 of 5.9 m), are fixed on one side to a main roof beam and on the other to the front of the dormer. Above these, 60 cm apart, are the 65 x 152 mm beams, also of glued laminated timber, which carry the same type of roofing as the main arches.

The entresol floors consist of two principal beams which span the spaces between the main arches and at two places are suspended from them. These 100 x 300 mm beams, also of glued laminated wood, are 150 mm apart. They are bolted at their ends to the main arches and, at two intermediate points, are fixed to the suspension struts. These are 30 x 30 mm steel rods which, for aesthetic reasons, have been sheathed in wood. At a spacing of 5.9 m these principal beams carry the floor joists, on which the floor is laid, consisting of 19 mm chipboard, 20 mm footfall insulation and a second 19 mm chipboard layer as a base for the floor covering. Metal rails 18 mm high fixed underneath the floor joists carry 18-mm-thick gypsum plasterboards for the ceiling. The spaces between the joists are insulated with two 100 mm glass wool layers. Where the outside air is led in underneath, the heat insulation is attached to the floor surface above. In this way the air space is formed on the outside of the insulation, that is, underneath it.

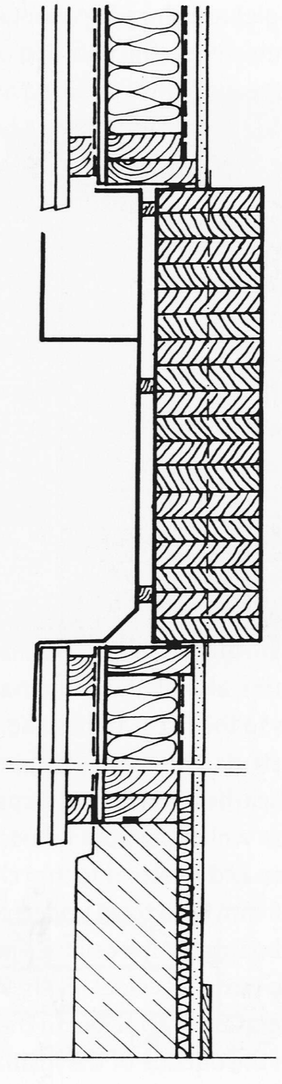
9 | Detail of floor suspension, scale approx. 1:20. Above: main arch with load-bearing connecting sleeve. Below: twin floor beams with steel supports and bolting.



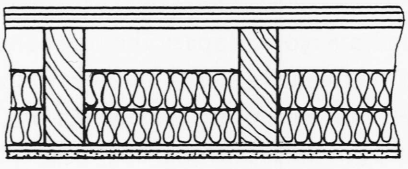
10 | Entresol floor. Ceiling, scale 1:200, showing twin floor beams and between them the floor joists spaced at 50 cm intervals.



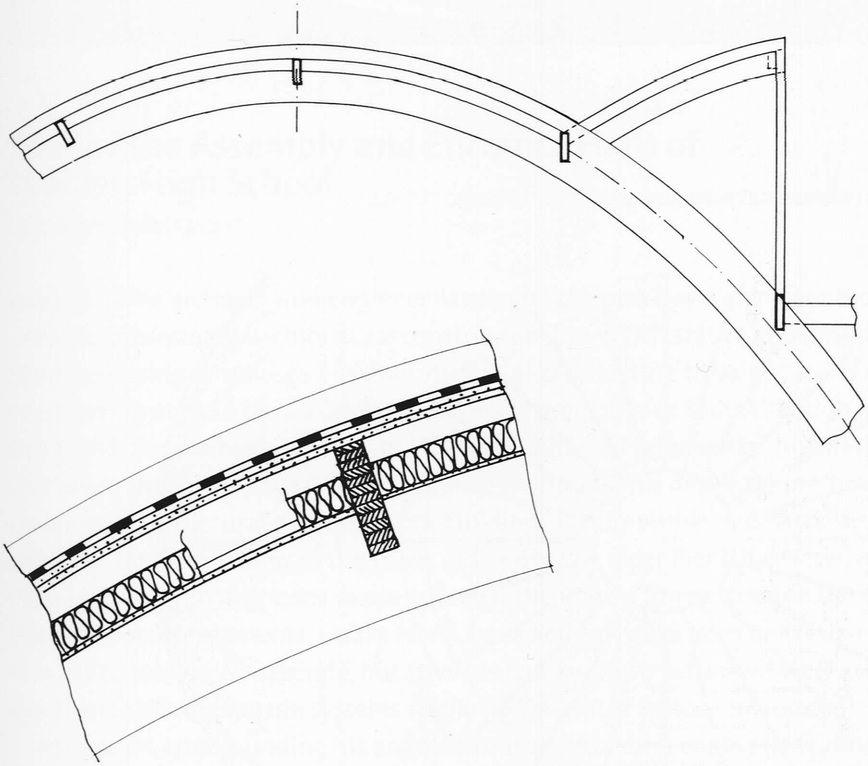
11, right | Connection between main arch and outer wall, scale 1:10. Design of outer walls from exterior to interior: vertical weatherboarding of 18 mm cedar on laths, bitumen roofing felt, 9 mm plywood, 100 mm plywood, 100 mm heat insulation in spaces of frame construction of 100 x 36 mm members, vapour barrier, 18 mm metal rails carrying 18 mm gypsum plasterboard. In these areas the main arches are covered with metal profiles for firmer fastening to wall.



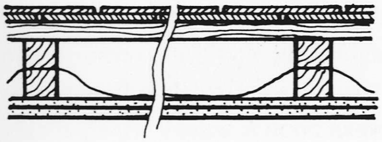
12 | Floor section, scale 1:20. Construction: 100 x 300 mm floor joists, on these 19 mm chipboards, 20 mm footfall sound insulation, 19 mm chipboard as base for floor covering. Underneath: 18 mm gypsum plasterboard on 18 mm metal rails. In space between joists two 100 mm heat insulation layers.



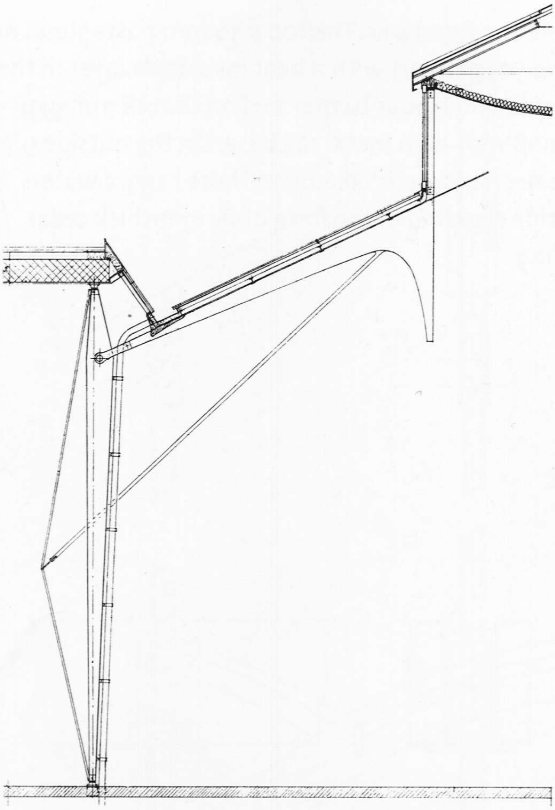
The outer walls are wood frame constructions. The 100 x 36 mm posts stand on 100 x 36 mm bottom beams some 50 cm apart with a heat insulation layer in the spaces between them. On the inside is a vapour barrier and on that 18 mm gypsum plasterboard attached to an 18-mm-high metal rail base. On the outside 9 mm plywood panels provide the necessary reinforcement. These carry a water-repellent felt paper and the outside cladding in the form of 18-mm-thick cedar planks as vertical weatherboarding.



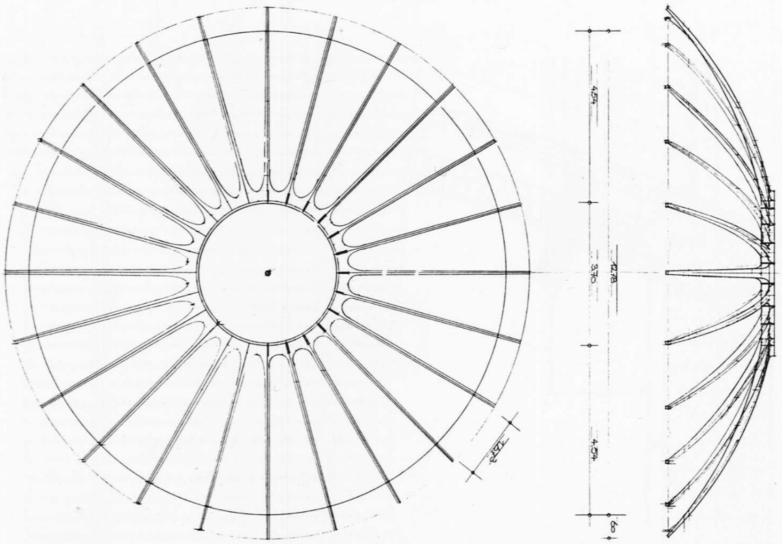
13 | Section showing waterproof roofing, scale 1:20. The 88 x 303 mm glulam beams, which span the space between the main arches, carry the curved 65 x 132 mm roof beams. Underneath, attached to these on metal rails 10 mm gypsum plasterboards, on which rests the 100-mm-thick heat insulating layer. Above this a 6 cm air space. Nailed to the roof beams, in staggered arrangement, 2 layers of 9 mm plywood. On top of these is the waterproof roofing, sand-surfaced green.



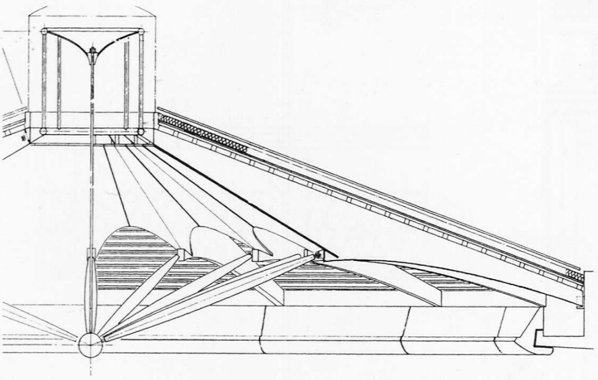
14 | Shingle roofing with shell and counter-lathing over supporting structure, scale 1:10. Waterproofing between double 38 x 38 mm counter-lathing. The supporting structure below it, not shown here, is the same as under 11, but without metal rails under gypsum plasterboard.



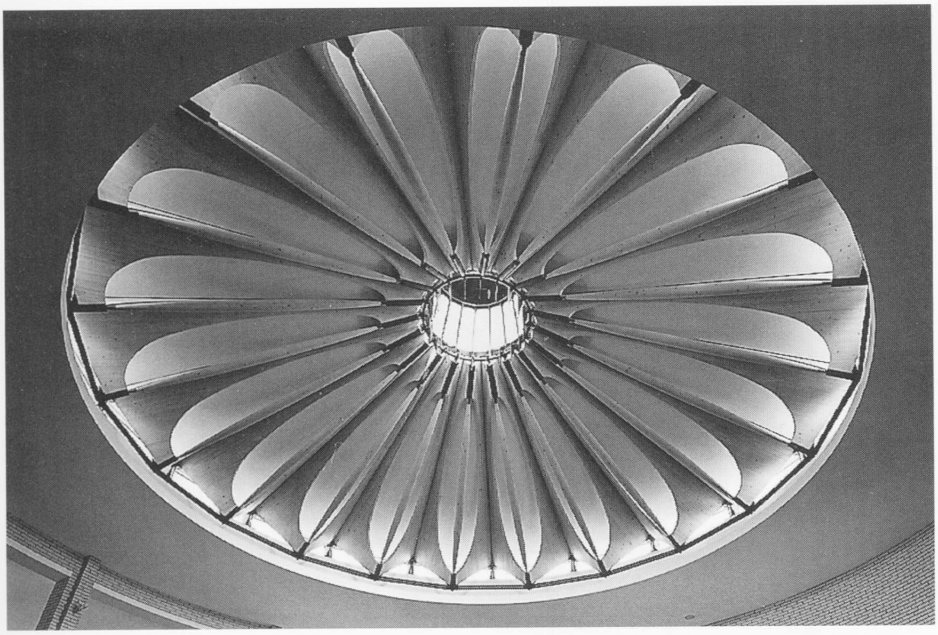
1 | Study of entrance hall, scale 1:100: “Circus Roof” with columns and rods of steel and wood. Under the glass roof translucent marble slabs.



2 | Study of entrance hall, scale 1:200: A ribbed cupola of 24 channel shell segments forms a calm radial structure.



3 | Study of entrance hall, scale 1:100: “Umbrella”. The shaped rafters are supported at the centre by compression rods that meet in a steel ball. The latter is connected under tension to the lantern, which forms the top support of the rafters.



4 | Final design of entrance hall roof.

Roof of the Assembly and Entrance Halls of Wohlen High School

Santiago Calatrava

Subject | The architect and engineer Santiago Calatrava has won recognition with his extravagant architectural constructions, in which statics and design form surprising symbioses. His dual studies of architecture in Valencia and civil engineering at the ETH in Zurich were already predictive of that. Although it dealt with the engineering subject "The Foldability of Frameworks" his thesis was written at the architectural faculty of the ETH Zurich. This desire to combine creative and structural expressions in buildings is fully visible in Calatrava's sketches. He thus follows in the shoes of the 60 year older Pier Luigi Nervi, who in his wide-span constructions made manifest the flow of forces through the use of shaped concrete elements. Unlike Nervi, however, Calatrava does not restrict himself to reinforced concrete, but tries his hand with structures of steel and wood and with composite systems involving the use of various materials.

Four years after founding his architectural and building engineering office in Zurich he was commissioned to design the roofs for the assembly and entrance halls of the High School in Wohlen, built by the architects Burkhard, Meyer and Steiger. It is interesting how Calatrava went about the task, proceeding not step by step from one single basic idea but courageously developing completely new concepts. The pleasure he derives from the realization of a particular structural idea is clearly visible. A good example of this are the preliminary studies for the round entrance hall.

In one design, which he called the "Circus Roof", the columns and bars of wood and steel were to carry a romantically capricious roof with shaped wooden ribs, translucent marble slabs and a large convex steel mirror over the central lantern. Already here the unusual three-dimensional effect is achieved by the use of clear-cut compression and tension elements. This approach was then abandoned, among other things because of the columns that rose from the floor and restricted movement in the entrance hall. Another design was based on the umbrella principle with struts and stress-bearing ribs; yet another was a flat dome carried by shaped wooden ribs springing from a central open compression ring. At last, after 15 months, came the final decision: a stellular, open, folded-plate dome in

Location
Aargauische Kantonschule,
Allmendstraße 26–26,
5610 Wohlen, Switzerland

Design and Construction of Roofs
Calatrava Valls SA,
Zurich/Paris

Design of School
U. Burkhard, A. Meyer,
M. Steiger Architekten,
Baden, Switzerland

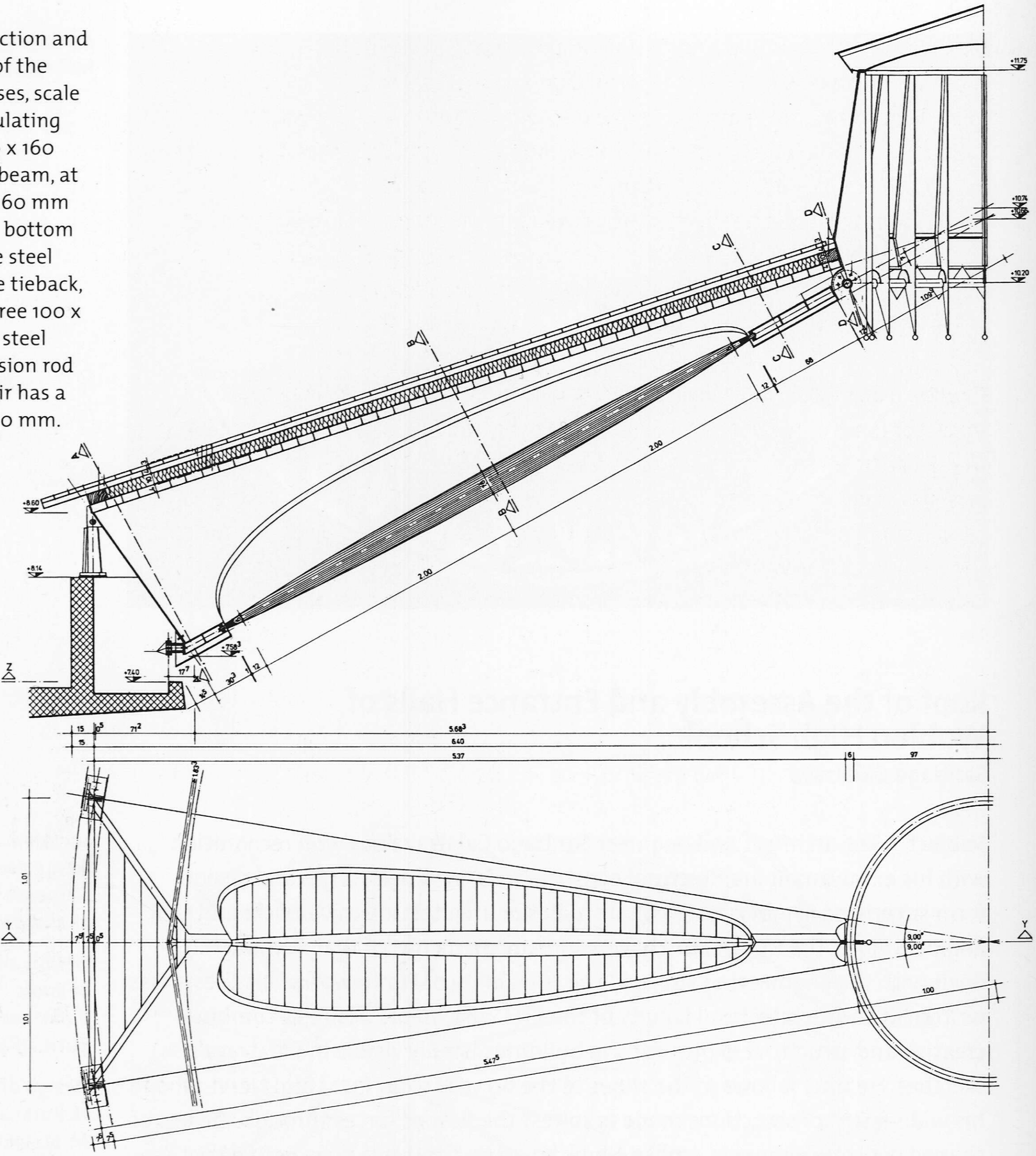
Timber Construction
Wey Elementbau AG,
Villmergen

Chief Carpenter
Hans Meier

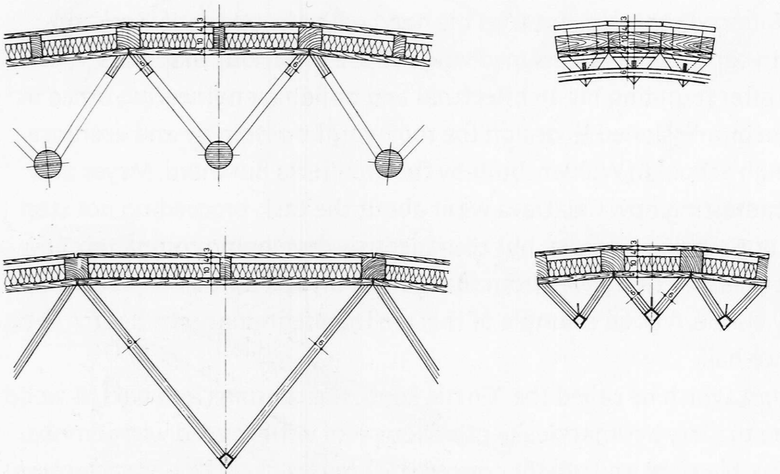
Date of Completion
1988

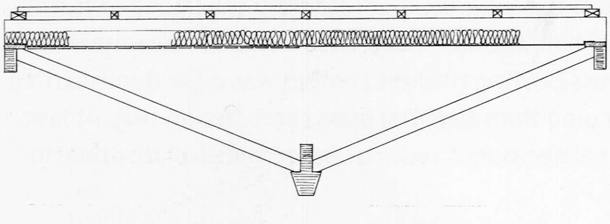
Costs
For the entrance hall cupola, for which 1000 manhours were required, the production costs, excluding planning and other incidentals, came to 200 000 Swiss Francs. For the roof of the assembly hall, including the stage roof, which was of much simpler design, the manhours needed amounted to 2500, the costs to approx. 350 000 Swiss Francs.

5 | Longitudinal section and underside of one of the entrance hall trusses, scale 1:50. At top, at insulating layer level, the 100 x 160 mm compression beam, at bottom the 100 x 160 mm edge beam. At the bottom tip of the truss the steel piece for fixing the tieback, fashioned from three 100 x 400 mm chromed steel flats. The compression rod of the laminated fir has a diameter of 60–180 mm.



6 | Various truss cross-sections, scale 1:50. Construction of roof floor: 40 x 120 mm facing boards planed on one side as truss top side, vapour barrier, 140-mm-high squared timbers, in spaces between these a 100 mm mineral wool heat insulation layer and a 40 mm air space, 22–30 mm roof boarding, standing seam roof cladding of titanium-zinc sheeting. The V-shaped undersides are of 60-mm-thick three-layer laminated wood.





7 | Cross-section of truss at ridge, scale 1:50. Floor construction: 13 mm open-joint acoustic boarding, black vapour barrier, 120 x 180 mm longitudinal beam, in between 100 mm heat insulating matting, 50 x 50 and 50 x 100 mm counter-lathing on side connections, 27 mm tongue-and-groove boarding. The bottom 200 x 330 mm arched girder is shaped for seating the strut and for greater elegance.

wood. Each of the previous ideas was in itself something out of the ordinary, both in design and execution, but the final idea is sophisticated yet simple in a very special way and at the same time of exceptional lightness and elegance.

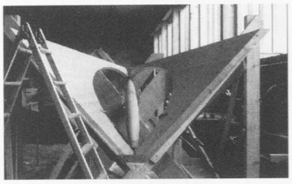
Equally original is the roof over the assembly hall, which in this particular case makes use of special struts to lift the roof from the surrounding walls, thus creating a row of windows between the two parts of the building. The supporting structure consists of triangular arched trusses with unique spatial effect, marred slightly by the simplicity of the stage opening in the end wall.

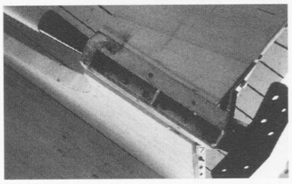
The school was completed and inaugurated in 1988.

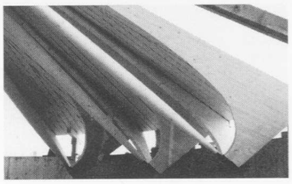
Structure Entrance Hall | The architect was faced with the task of covering a space some 12 m in diameter. The solution developed by Calatrava was a star-shaped strutted frame of triangular box-type trusses held at the centre by a compression ring 2 m in diameter of 60 mm iron tubing and supported at the circumference by the concrete ring of the floor. The triangular trusses are approx. 1.20 m high at the outer supports and approx. 30 cm high at the inner ring. They also diminish in width from 200 to 30 cm in line with the ground plan geometry. The V-shaped underneath surfaces are of 60-mm-thick three-layer glued pine. The upper surface is of 40 x 120 mm tongue-and-groove boards planed on the visible side only and serving as a deck for the roof structure. The system of supports for the circular strutted frame is divided into an upper support for the vertical loads and a 1 m lower tieback of three plates of 10 x 40 mm chromium-plated iron to absorb the horizontal forces and join the bottom ends of the V-shaped elements. Thus increased to 2.60 m, the difference in height between the two pressure points reduces the horizontal forces arising in the strutted frame. To prevent any twisting of the top tubular iron compression ring the top boarding carries a 100 x 160 mm compression beam, thus creating a lever some 200 mm long which stabilises the upper support system.

Calatrava makes this extravagant construction even more extravagant. He cuts away the underneath edge of each V-shaped wooden member, thus making it arcuate, and replaces the missing bottom edge with a compression rod of glued laminated fir. To counteract buckling these 4.20-m-long compression rods are 180 mm thick in the middle and 60 mm at each end. The lower edges of the V-trusses are replaced by welded and chromed angle bars, which, fixed to the wood surfaces by means of M6 hex-head wood screws, take up the shearing forces of the compression rods and transmit them to the bottom tiebacks. When the structure had been completed, the architect disliked the look of the joints between the boards of the roof floor and had it covered with a smooth plywood surface painted white. This, indeed, creates a much quieter effect.

Execution of the work proved particularly difficult for the timber construction firm. The V-shaped members were produced at the factory. On the site an assembly tower was erected in the middle of the room, on which the compression ring was placed. Then the V-members were linked to it by means of metal straps, which were welded to the ring. The outer support ring carries 45-cm-high steel brackets, each with a 30 cm slot for screwing up the angle steels of the V-members. The rest of the roof was then built on top of the top boarding. First, squared 140 x 160 mm timbers were screwed on to hold the V-members together and also the above-mentioned 100 x 160 mm compression beam. Then came a bottom 100 x 160 mm boundary beam with 40 x 160 mm cleats for the roof overhang and an 80 x 140 mm intermediate timber to shorten the span of the boarding over the lower area. Finally, on top of the vapour barrier and the 100 mm heat insulation came the 30 mm roof boards, roofing felt and roof skin of titanium-zinc sheeting as a standing seam roof covering. Not until the bottom tiebacks had been fitted





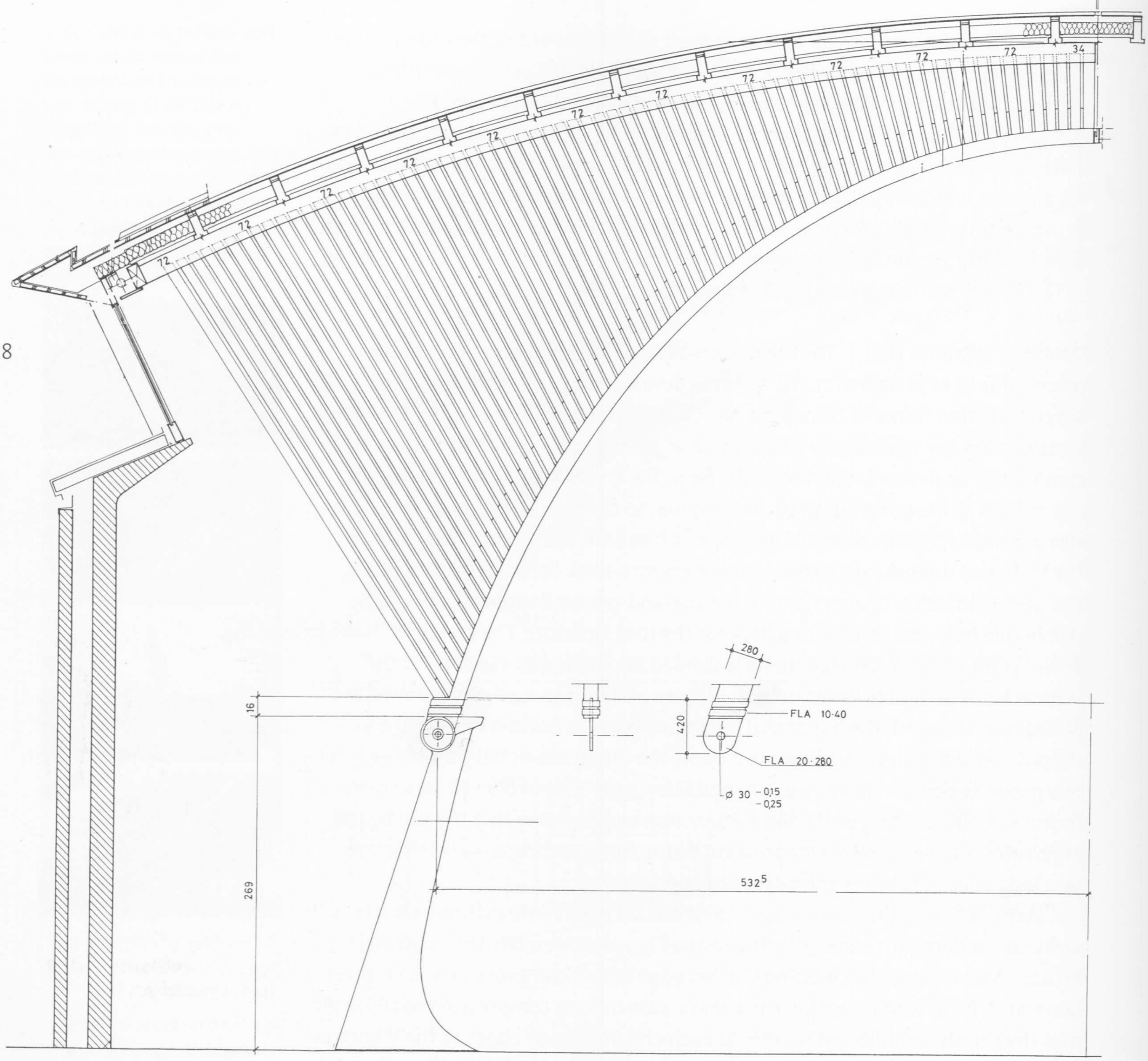


8 | Erection of entrance hall roof. V-shaped underside of truss at factory.

9 | The first truss is fitted. On right, the central compression ring with fixing rings welded in position.

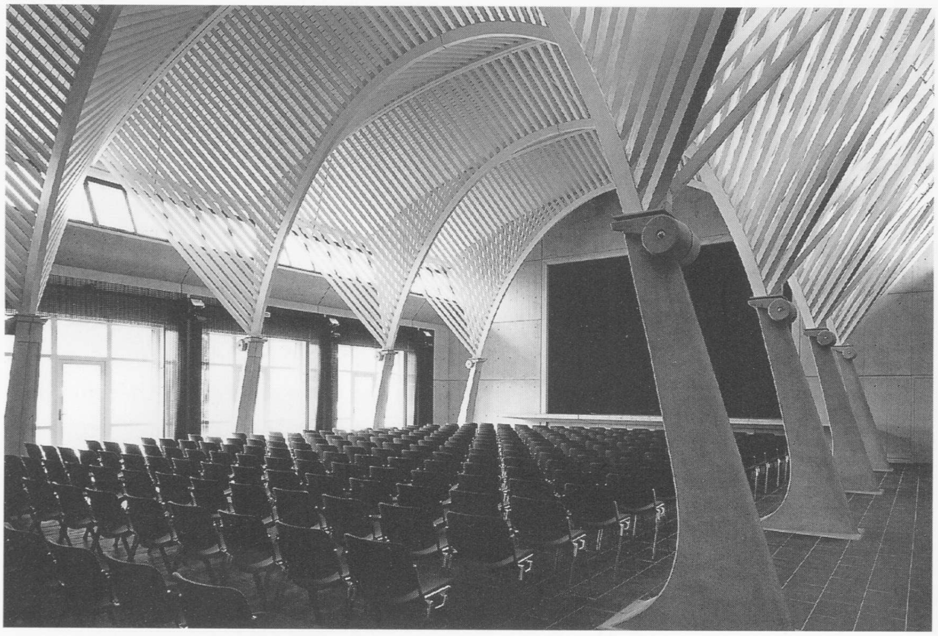
10 | The steel component between compression rod and steel flats of tieback, which are bolted to the straps.

11 | Three trusses with tiebacks in position and supports.



12 | Design drawing of assembly hall truss, scale 1:50. During execution the strut spacing was enlarged and the floor construction simplified.

13 | The assembly hall looking towards stage.



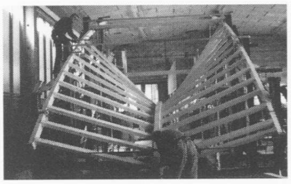
and tensioned was it possible to lower and dismantle the assembly tower. There was little horizontal displacement of the structure and the slot connections in the vertical supports proved fully adequate. This was due to the exceptionally accurate way in which the timber construction company had performed the work.

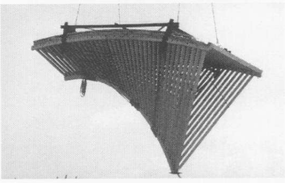
Structure Assembly Hall | The assembly hall is also covered using triangular trusses, but these arch over the hall in the usual way. The overall span is 10.60 m and the truss spacing and thus individual component width 4 m. The structure could be regarded as an elliptical three-hinge arched girder construction, which carries the intermediate floor-supporting transverse arches by way of slanting strutting. This slant gives the whole structure the necessary longitudinal rigidity. From the production point of view they are triangular trusses, since each curved beam, from the support to the apex hinge, the fan-like strutting, the transverse half-arches and the upper roof floor construction form a complete triangular component that could only be constructed at the factory with the necessary precision. The supports are shaped, 2.70-m-high concrete columns, which absorb the skew of the arches at the point of support and thus easily transmit the normal forces from arch to ground.

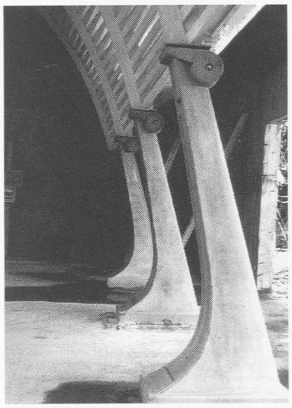
The arched beams measure 200 x 330 mm and have notches on each side serving as seatings for the struts and chamfered side surfaces at their bottom ends. The fan-like struts vary in size from 80 x 80 to 80 x 120 mm depending on their increasing length. The ten longest struts are also interconnected with steel rods to prevent buckling. The top transverse arches measure 80 x 140 mm and are held together by 4-m-long 120 x 180 mm longitudinal girders 80 cm apart. Between these is a 1.09-m-thick heat-insulating layer, on this is placed black plastic sheeting as a vapour barrier and seepage protection and 13 mm acoustic boarding with open joints. Attached to the longitudinal girders is a 50 x 50 mm counter-lathing system for the ventilation, to which the 27 mm roof boards with titanium-zinc skin are fixed. The triangular part of the truss from the point of support to the vertex hinge, together with the roof superstructure and overhang, were produced in the factory on specially designed iron-frame templates as prefabricated components. Great attention had to be paid to ensuring the neat appearance of the strutting. Their connection to the arch, for instance, had to be invisible. To achieve this the strut was first screwed to the arch through the back of it, then the strut opposite was fixed using a glued wood dowel. With the next strut the process was reversed, so that on each side of the arch there was an alternation of screwed and dowelled connections, and no connecting element was visible. Particular care was, of course, necessary to ensure a uniform arrangement of the struts, each of which had a different joint angle depending on its position in the arch. Through good preparatory work and applying a fixed-cycle work method only two days were required for the assembly of each component. For five arches, or ten components, that makes 20 days production time.

Transporting the long prefabricated arch components to the building site proved highly problematic, since they measured 4 x 5.5 x 8 m and weighed 2.5 tonnes each. With the help of the police a suitable – much longer – route was worked out to get them to the site, which, in fact, was only 3 km away. Transportation and assembly using a pneumatic crane took only a day.

After being placed in position by the crane the ten arch components were bolted together with steel plates with Compriband between the arches. To seat these on the concrete columns special steel shoes were installed.





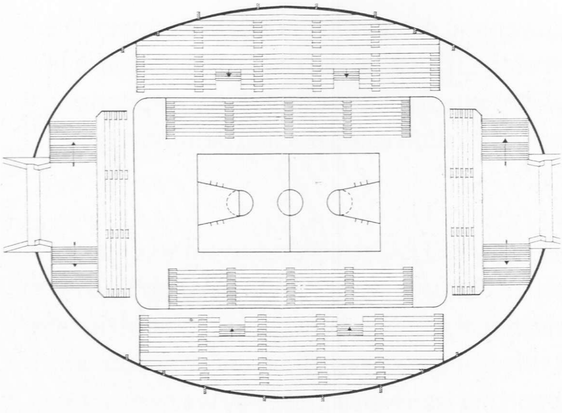


14| Erection of assembly hall roof. Fitting of struts in factory.

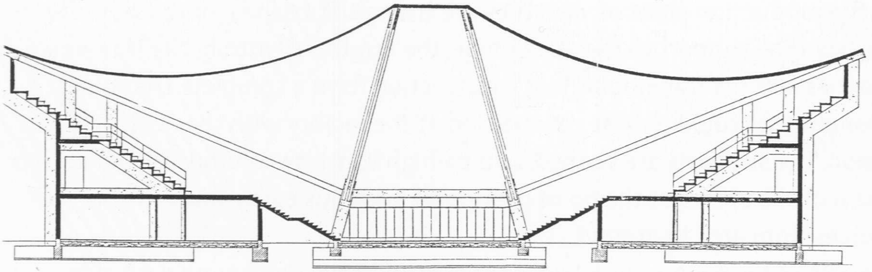
15 | An arch component is lifted into position at building site.

16 | The shaped concrete columns serve as arch supports.

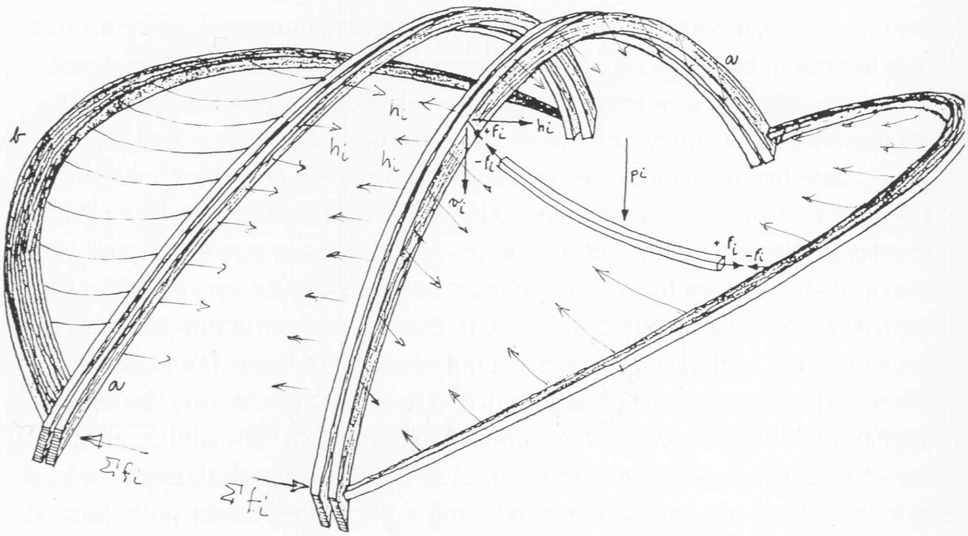
1 | Ground plan of stadium, scale 1:1000.



2 | Cross-section through stadium, scale 1:500. The tilted main arches rest on inclined concrete foundations, which duplicate as abutments for the boundary arches. These form the lateral limits of the spectator seating.

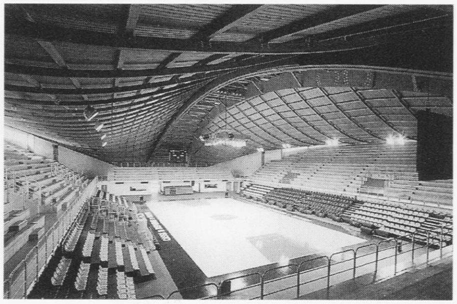


3 | Representation of structural system. The curved tie beams transmit the weight of the roof as normal tensile loads f_i. The boundary arches "b" absorb these as pressure forces, since they act almost at ground level, and collect them in the arch supports as $\sum f_i$. The main arches "a" take up the vertical fraction V_i of the tensile force fi as pressure force, which is added to $\sum V_i$ at the supports, and the horizontal fraction h_i, which is cancelled out via the coupling beams through the sameness of the two arch systems.



4 | View of the ceiling.

5 | Interior showing main beams and suspended shells.



6 | View of stadium with entrance.

“Carisport” Stadium, Cesena

Vittorio Legnani

Subject | The roofing over of sports grounds has always presented a great challenge for engineers and architects. On the one hand vast areas have to be spanned and acoustic and air conditioning requirements met. On the other, roof design must satisfy aesthetic criteria but at the same time defer to what happens on the ground below.

Dr Lignano had already designed and built several covered sports stadiums in wood when Mr. Trevisani, the President of the Cassa di Risparmio in Cesena, commissioned him with the design and construction of an indoor sports ground to seat 4200 people. In Italy one of the activities of savings banks is to help finance social or public buildings, and it was from the bank that the stadium received its name: CAsa di RIsparmia SPORT. Noteworthy in connection with this building is that the architect in charge of the planning also calculated the timber construction and then assigned its execution to the timber construction company Habitat Legno in Edolo, a firm renowned far beyond Italy’s frontiers for its glued laminated wood structures. The whole of the detail planning of the timber connections was thus in the hands of this company and not in the architect’s.

Structure | Here only the roof construction will be dealt with as an interesting solution for shells under tension between compression arches. The substructure with the spectators’ seats is of reinforced concrete and is considered merely in its function as a support for the roof.

The roof itself may be described as two identical systems, each of which consists of two arches that open out and away from each other at an angle of 83° and support between them a taut membrane. The two arch systems are limited along the longitudinal axis of the building by tension and shear connections between the “main arches”, which are inclined towards each other at a distance of 11–4.50 m. The lower “boundary arches” sweep down behind the seating, thus forming the lateral limits of the space covered. The span of the arches, that is, the longitudinal axis of the stadium is roughly 70 m. The hog, or camber, of the main arches is approx. 11.60 m, that of the boundary arches, corresponding to the spectator area, approx. 25 m. The geometry of the whole space is thus determined.

Location
Carisport, Cesena, Italy.
Follow the signposts.

Client
Cassa di Risparmio, Cesena

Architect and Structural Engineer
Dr Ing. Vittorio Legnani,
Studio Tecnici Associati,
Bologna

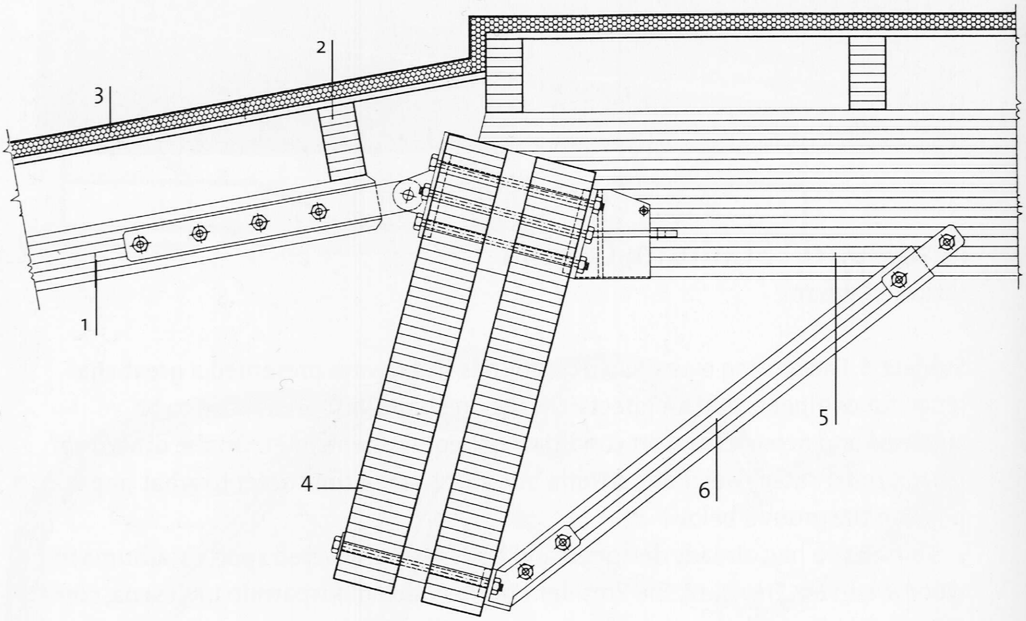
Structural Details
Angelo Micheletti

Timber Construction
Habitat Legno, Edolo

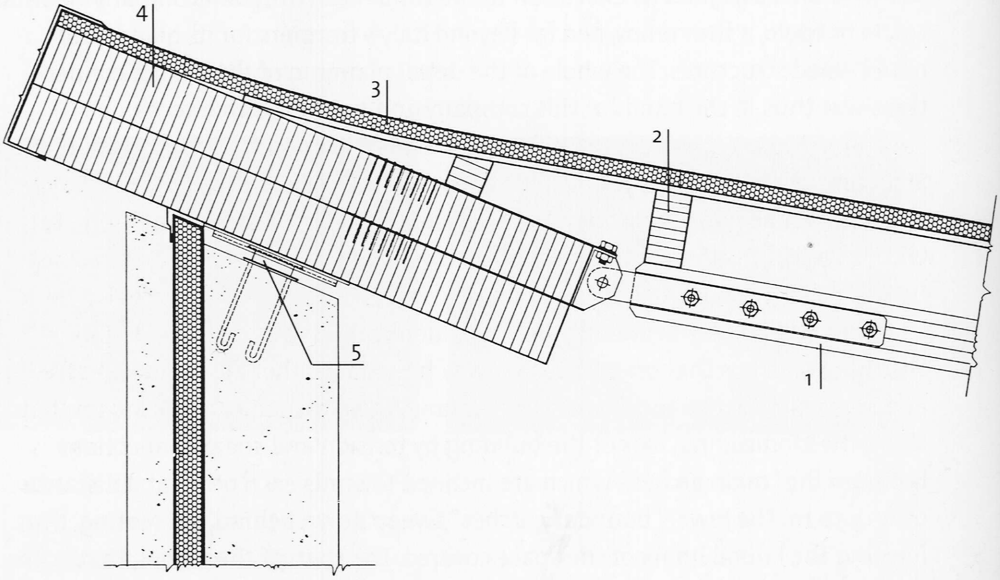
Date of Completion
1983

Costs
According to the architect the costs of the whole stadium were 4300 million Lire.

From the structural point of view the main load-bearing structure is formed by the two higher main arches in line with the building's longitudinal axis. From these the boundary arches open out wing-like, suspended by the curved tie beams of the roof. The curve of the roof and thus that of the tie beams has been so chosen that the tie beams are subjected only to tension and the boundary arches only to pressure in the direction of the arch. The vertical forces are all transmitted as pressure forces to the supports of the boundary arches and as tensile forces via the beams to the central main-arch system. Here the tensile forces from each side more or less counterbalance each other, uneven load distribution caused by wind or snow being the only factor that can influence boundary arch position. The boundary arches are thus secured against lifting or twisting – and only



7 | Section of main arch, scale 1:25. **1** Glulam roof tie beam 120 x 180 mm. **2** Glulam board-carrying members 120 x 240 mm (spacing 130 mm). **3** Roof construction: 25 mm boarding, vapour barrier, 100 mm heat insulation, two layers of waterproof sheeting. **4** Main arch comprising two 200 x 1500 mm glulam beams. **5** Boundary arch 140 x 540–210 x 800 mm. **6** Diagonal bracing 120 x 140 to 120 x 210 mm. The drawing showing the roof board-supporting members on the coupling beams dates back to an earlier planning stage. Now the roof boards are placed directly over the coupling beams and in between these on the additional timbers laid on the main arches.



8 | Section of boundary arch, scale 1:25. **1** 120 x 180 mm glulam roof tie beam. **2** 120 x 240 mm glulam roof board-supporting timbers. **3** Roof construction: 25 mm roof boarding, vapour barrier, 100 mm heat insulation, two layers of waterproof roof covering. **4** Boundary arch of two 210–1920 mm beams. **5** Sliding support of boundary arch to counteract lifting.

against such forces – by special sliding supports behind the seating areas. The main-arch supports are 4-m-high shear-wall-like abutments placed in the slant of the arches and duplicating as abutments for the boundary arches. They are designed to sustain pressure forces of some 148,000 kg each from the main arches.

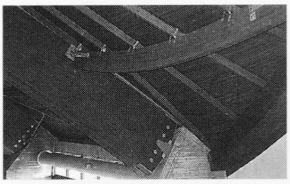
Both main arches are 200 x 1500 mm glulam twin girders held apart at a distance of 10 cm by 100 x 400 x 400 mm and 100 x 100 mm spacers. 10 m apart at the bottom and 4 m apart at the apex, the main arches are coupled by means of glulam beams with a spacing of 3.10 to 3.70 m. The cross-section of the coupling beams ranges from 140 x 540 mm to 210 x 800 mm depending on their increase in length. In the spaces thus formed diagonal ties of 30 mm bar iron are provided for extra stability. Because the coupling beams are attached to the tops of the arch girders – that is, off centre – every second beam is stayed from the lower girder edge by a 120 x 140 to 120 x 210 mm diagonal beam. For easier transportation the arches were delivered in three sections and by means of wooden butt straps jointed together to form a rigid arch.

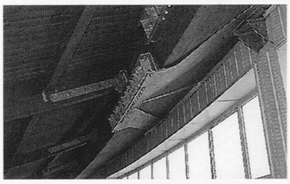
The boundary arches are also of twin glulam girder design but with a cross-section 210 x 1920 mm and no space between them. Since the connections on the roof and wall require smooth outer arch surfaces the timber fasteners of the arch sections are in the form of specially shaped flat steel plates that do not affect the cross section. The butt joints of the twin beams are staggered. The beams themselves are joined only by nailed flat iron plates, which together form the suspension element for the tie beams.

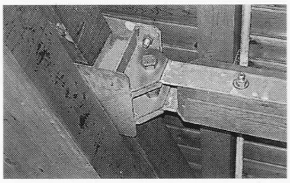
The curved 120 x 180 mm glulam tie beams are positioned where the coupling beams meet the main arches, i.e. with an average spacing of 3.50 m. By means of appropriate steel fasteners the tensile forces can thus be led away directly and, under normal conditions, free from torsion via the main arches. At a spacing of 1.30 m the tie beams carry the 120 x 240 mm glulam members that hold up the roof boarding. On this rests the vapour barrier sheeting, the 100-mm-thick heat insulation layer and the waterproofing in the form of two layers of moisture-proof sheeting. According to the architect, however, the non-ventilated roof design causes a considerable build-up of heat during the summer months.

Worth mentioning is the fact that the timbers that carry the roof boarding and are subject to bending forces display almost the same dimensions as the tie beams, which span much greater distances with no danger of buckling. The result is two spherical roof surfaces, each formed by a generously dimensioned lattice composed of similar members. As already mentioned, between the main arches in the middle of the building the timbers that carry the roof boards lie parallel to the coupling beams of the main arches, two per space and an average of 1.20 m apart. This change of direction of the roof boarding accentuates the optical effect of the central supporting timberwork and creates an interesting break between the two suspended roof surfaces.

Another point worth noting is that the steel fasteners are not concealed between the timbers but are fashioned as required by the statics of the building and by optimum manufacture. Such is the overall size of the structure and the lavish use of timber that the fasteners hardly warrant attention. They are rather a sign of artisan honesty. They may prove disturbing when near enough to catch the eye, in particular at the supports. In such cases they could shock the observer by their lack of finish but they would bring home to him the magnitude of the forces here in play.



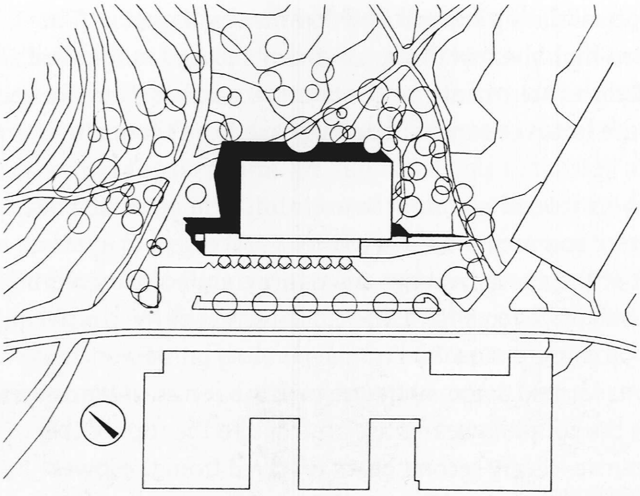




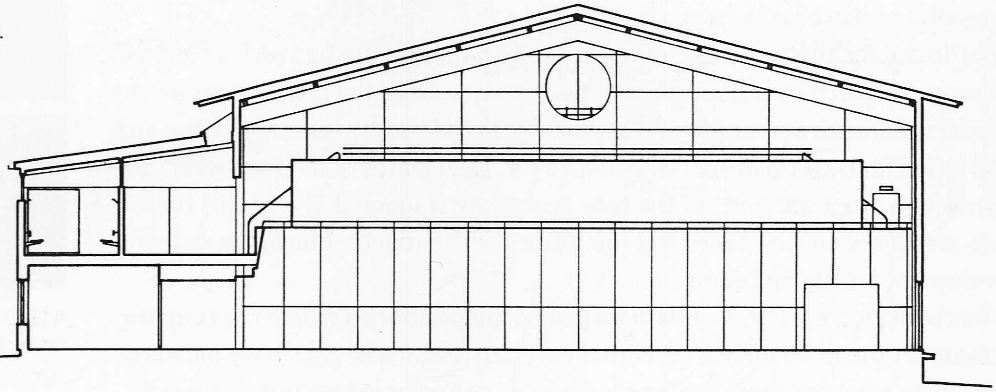
9 | Concrete support of main and boundary arch. Just visible the lowest curved tie beam, which is more amply dimensioned.

10 | Butt joint between two boundary arch sections with hot-dip galvanised steel plates. Also visible, the staggered butt joint of the upper arch section.

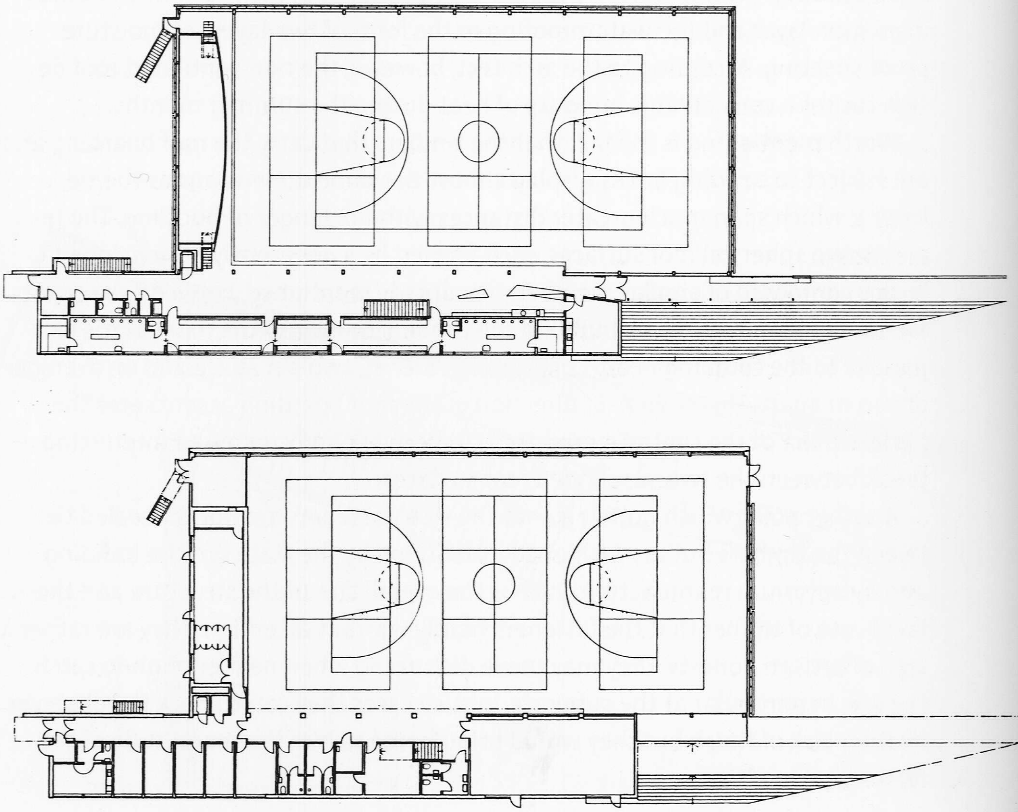
11 | Fastener of hot-dip galvanized steel between boundary arch and roof tie beam. Only tensile forces are transmitted. Any deformation occurring is sustained by the screwed joint.



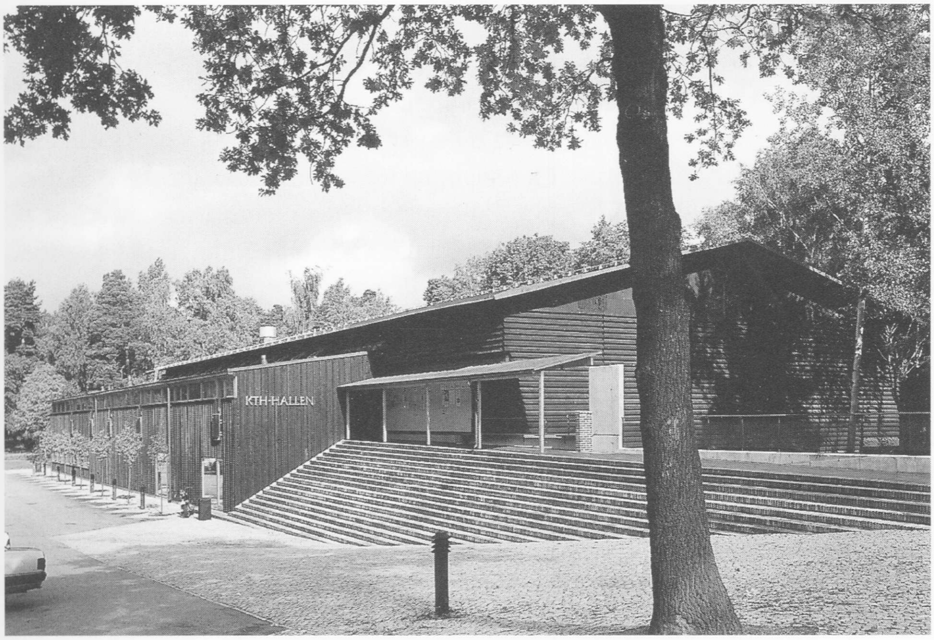
1 | Site plan, scale 1:3000.



2 | Section, scale 1:250.



3 | Plans, scale 1:750. Top: entrance level with changing and shower rooms as well as balcony and spectators' stand. Bottom: lower level with sports hall, weights room, offices, sports instructors' accommodation, medical facilities and services.



4 | The entrance: right, the sports hall; left, the ancillary block.

Royal Technical University Sports Centre, Stockholm

Johansson & Uppling

Subject | The Royal Technical University in Stockholm took an unconventional approach for its new sports centre. In 1991 the university promoted a competition to design a new sports centre among the students of the Faculty of Architecture. It was a daring experiment with various goals: better communication between the Faculties of Architecture and Structural Engineering, practical experience during the course of study and the hope of reduced planning costs. Lars Johansson and Mikael Uppling, students in their final semester, were awarded first prize and entrusted with the further development of the project. In the September following completion of their studies they founded the Company Johansson & Uppling Arkitekter AB and were appointed by the Swedish Ministry of Public Works to prepare drawings and specifications for a general contractor-type contract. In the following December Hallström & Nisses Byggnads AB were appointed as contractor and from that point onwards the architects continued preparing the construction documentation on behalf of this contractor. One year later, in December 1992, the sports centre was already complete. The sports centre was widely published which attests to the fact that this experiment, with its very young architectural team, was a success.

Design | The site was on the edge of an area of gently undulating mixed woodland with intervening lawns used by the students and university staff for relaxation, walking and jogging. This was to be the location for the new sports centre with a 42 x 22 m playing area for all types of ball games, gymnastics, other sports and competitions, together with the associated ancillary facilities. The architects created two simple structures: the sports hall itself, with a pitched roof, and a two-storey block containing the ancillary facilities, with a monopitch roof, along one side of the hall. The two structures are offset, thereby creating an internal angle at the south end which provides an obvious entrance area. A simple solution was achieved by exploiting the natural slope of the site, providing a spacious entrance to the balcony and changing rooms above and a separate entrance below to the offices, sports instructors' accommodation, medical facilities and services. The upper level offers an unrestricted view of the hall, which is linked

Location
Royal Technical University, Brinellvägen 5, Stockholm, Sweden

Client
Royal Technical University Stockholm represented by the Byggnadsstylrelsen, formerly the Swedish Government Department for Public Works.

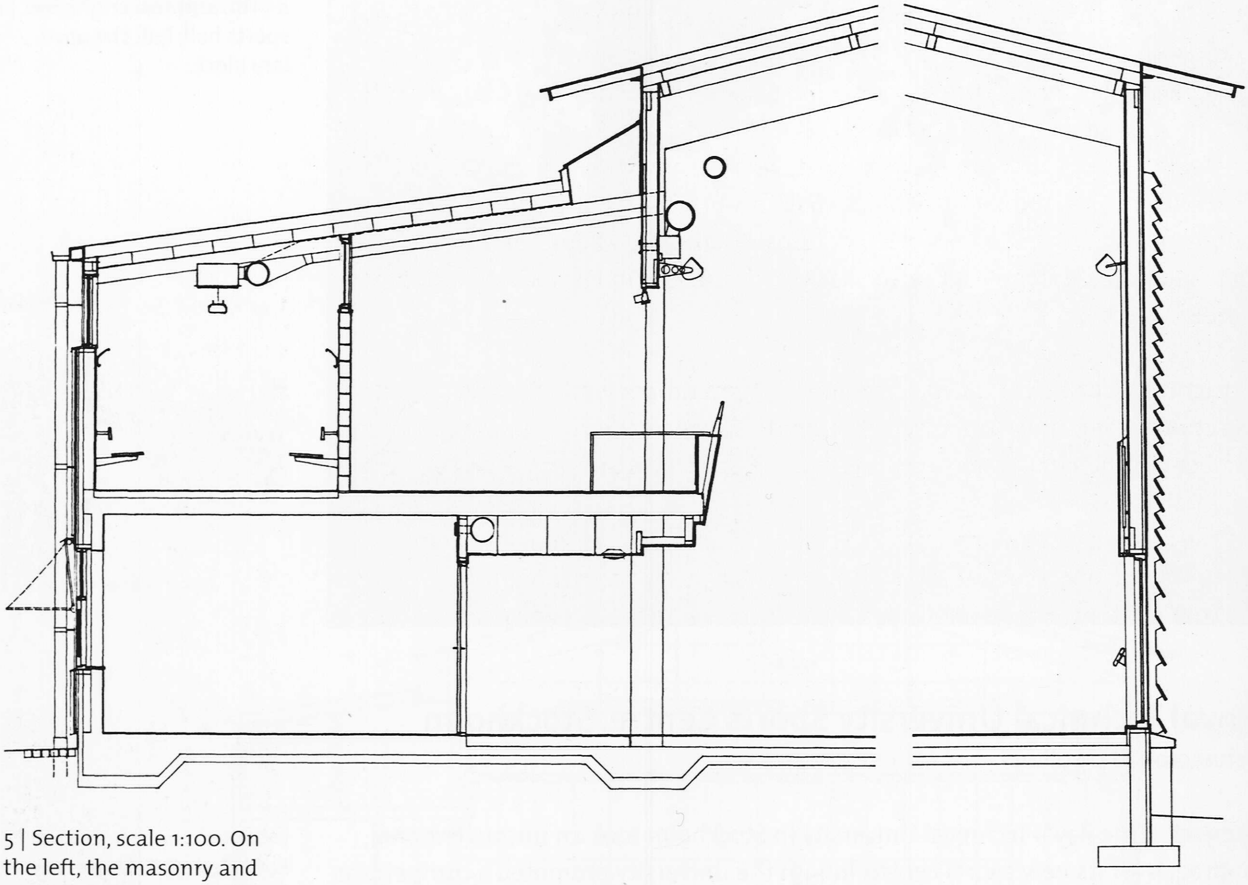
Architect
Johansson & Uppling Arkitekter AB, Stockholm
Assistant
Stefan Nyberg

Structural Engineer
Tyréns
Project Engineer
Håkoan Persson

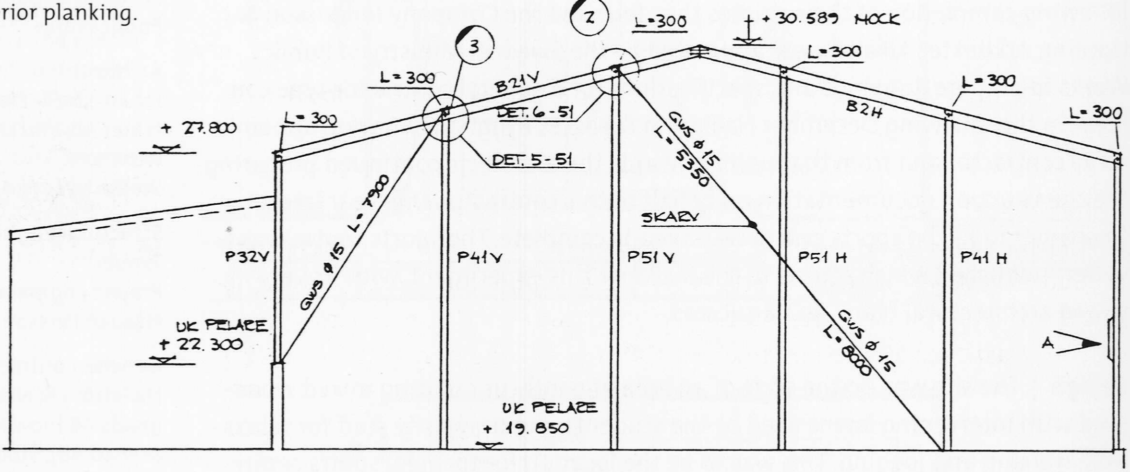
General Contractor
Hallström & Nisses Byggnads AB (now PEAB Entreprenad AB), Stockholm

Date of Completion
1992

Costs
The whole centre cost about 18 million Swedish Kronor.



5 | Section, scale 1:100. On the left, the masonry and reinforced concrete ancillary block; only the roof and the cladding are timber. On the hall side the hall columns are supported on the concrete floor slab over the lower level. On the right, the façade facing the forest with its exterior planking.

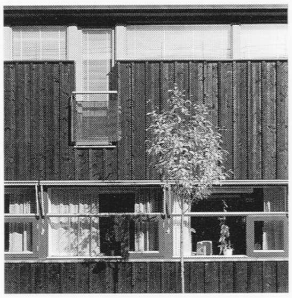


6 | South-east gable, scale 1:200. Structural drawing showing wind bracing of 15 mm diameter steel ties.

visually with the landscape outside by means of a continuous row of windows beginning without a spandrel at floor level.

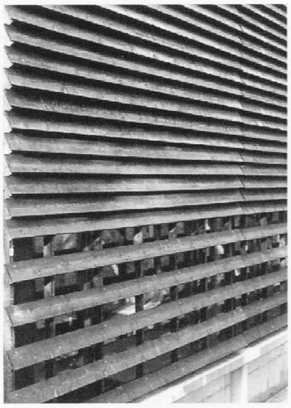
The external appearance too underlines the simple clarity of the two offset structures. The whole surface of the hall is clad with black-scumbled, horizontal pine planks, even above the row of windows. In contrast, the ancillary building is clad with vertical timber planking, also with a black scumble, which is given extra depth by way of additional vertical battens. Window and door frames are painted in bold colours, energizing the ancillary block and lending the whole building an agreeable scale.

Structure | The hall is constructed entirely from timber while the ancillary block is actually a masonry structure with reinforced concrete columns and floors, timber only being used for the cladding. Therefore, this building is not discussed in detail here.



7 | Part of the façade of the ancillary block.

The main loadbearing members for the hall consist of 225 x 165 mm glulam columns at 4.80 m centres which support the 630 x 165 mm glulam roof beams, approx. 22.50 m long. The columns stand on concrete foundations and only on the south-west side are they founded 3 m higher on the reinforced concrete floor slab of the ancillary building. The roof beams are butt-jointed in the centre at the ridge and have steel cable ties on both sides between the supports to take out the horizontal thrust of the roof beams. Therefore, the columns do not need to accommodate any additional horizontal forces from the roof construction. One nailing plate, 330 x 140 x 5 mm, is fixed to each side at the ridge joint. The gable wall frames consist of 270 x 165 mm posts (270 x 140 mm at the corners) which divide the gable end into five bays and carry the 225 x 115 mm head plate for supporting the ends of the roof purlins.



8 | The wall cladding.

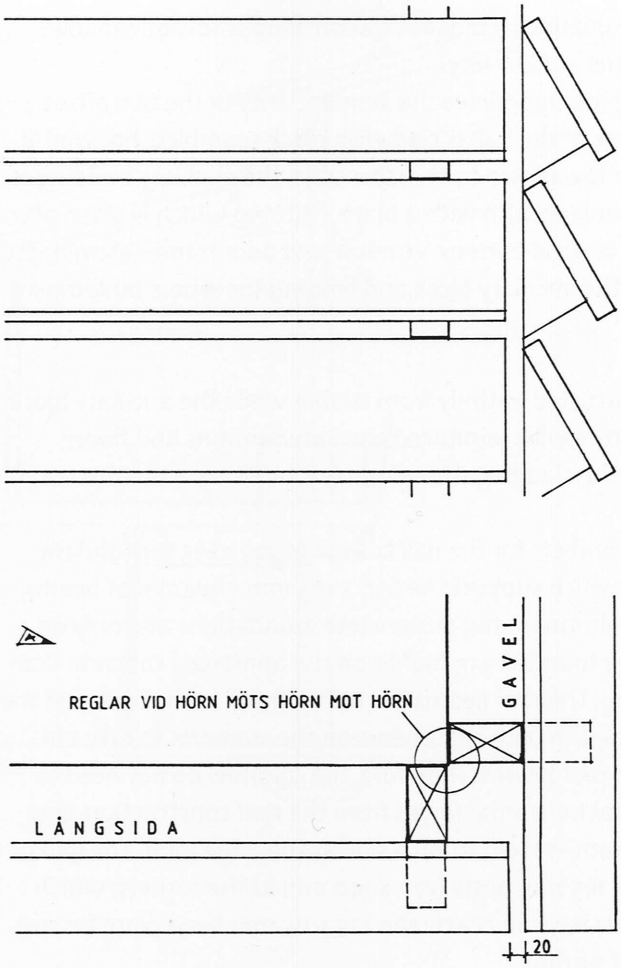
From a structural point of view, the hall columns are hinged. Therefore, bracing has to be provided in the form of 15 mm diameter steel ties placed diagonally in the end bays of the longitudinal façades. However, this is not incorporated as X-bracing but rather as ties in opposing directions in the end bays of each wall. As the tops of the bays between the columns are not closed off with a structural member, the wall elements must transfer any thrusts which occur here. The situation is similar for the gable ends except that here a head plate is provided at the top and each diagonal bracing tie crosses two bays.

9 | Interior view.

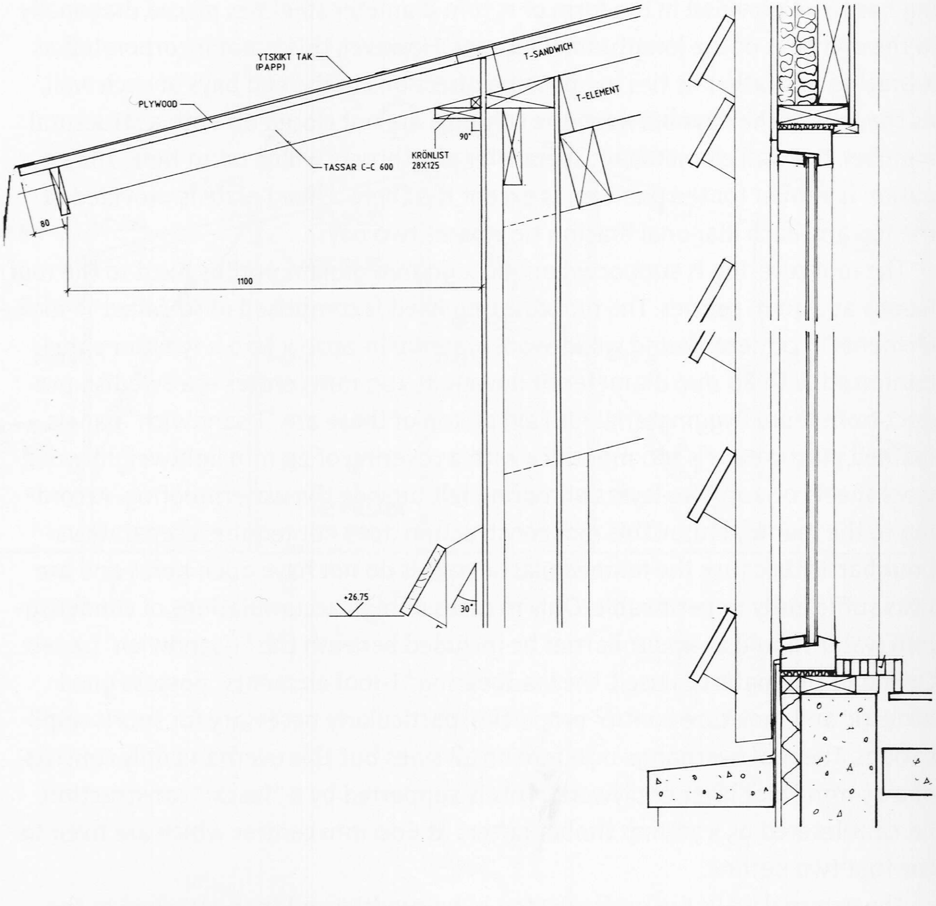
The roof covering is supported on 180 x 90 mm glulam purlins fixed to the roof beams at 2.40 m centres. The roof covering itself is comprised of so-called "T-roof elements" – cement-bound wood-wool material in 2400 x 600 x 150 mm panels reinforced with 80 mm diameter fir dowels at 300 mm centres –, a Swedish product from Tepro Byggmaterial AB. Laid on top of these are "T-sandwich" panels – foamed plastic panels 100 mm thick with a covering of 20 mm lightweight wood-wool sheets on top. Two layers of roofing felt provide the waterproofing. According to the manufacturer, this roof construction does not require a separate vapour barrier because the foamed plastic panels do not have open pores and are thus sufficiently impermeable. Only in cases of high accumulations of condensation water should a vapour barrier be included beneath the "T-sandwich" panels. Owing to the materials used, the loadbearing "T-roof elements" possess good acoustic and moisture-control properties, particularly necessary for sports applications. The roof overhangs 1100 mm on all sides but this overhang only consists of a 25-mm-thick layer of plywood. This is supported by a "Tassar" construction, i.e. cantilevered 95 x 70 mm timber rafters at 600 mm centres which are fixed to the first two purlins.

The external walls are prefabricated in bay widths and then attached to the columns. They comprise a 190 x 50 mm timber frame with a 13 mm waterproof-

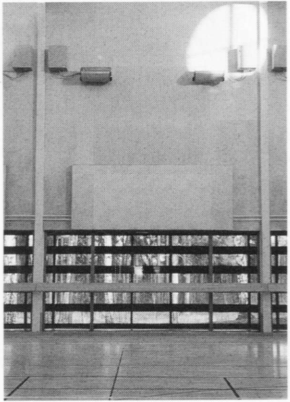
10 | Detail of cladding at corner, scale 1:10. The gable wall planks pass in front of the side wall planks.



11 | Detail of façade, scale 1:20. Roof construction: 630 x 165 mm roof beams, 180 x 90 mm purlins at 2.40 m centres, 150 mm "T-roof elements", 120 mm "T-sandwich" panels, 2 layers roofing felt. The roof overhang consists of 95 x 70 mm "Tassar" rafters and 25 mm plywood.
Wall construction: 225 x 165 mm timber columns with infill panels consisting of 190 x 50 mm timber frame, 200 x 25 mm planks on 100 x 50 mm spacer battens, 13 mm waterproof-glued plywood, 45 mm insulation between 70 x 45 mm counterbattens, 145 mm insulation between 145 x 45 mm battens, vapour barrier. To be on the safe side the contractor incorporated a 25 mm ventilation gap between the external plywood and the insulation. Interior cladding is 12 mm birch plywood.

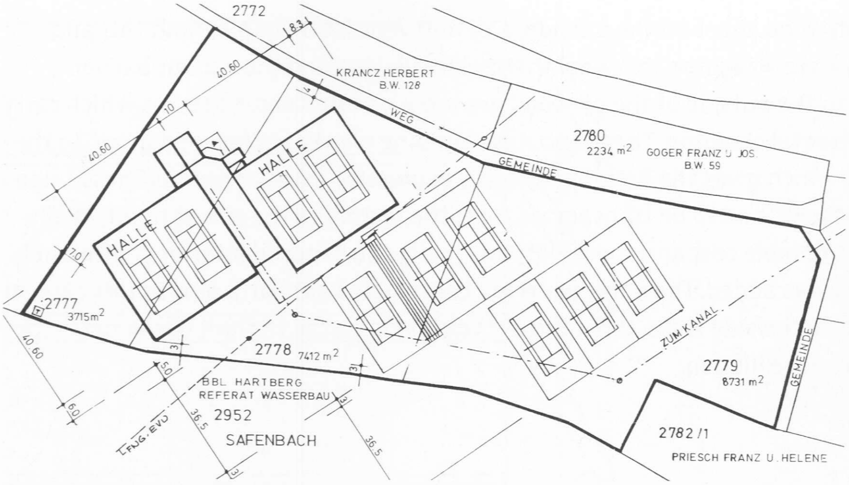


glued plywood sheet on the outside, a 25 mm ventilation gap behind this and then 45 + 140 = 185 mm rockwool thermal insulation and the vapour barrier. Affixed to the outside of the plywood are 100 x 50 mm spacer battens which carry the horizontal cladding. These 200 x 25 mm pine planks are inclined at 30° to the vertical, which gives the building a highly expressive exterior profile. These huge wall elements had to be transported from the factory to the site at night, involving considerable cost and coordination! Finally, the exposed interior 12 mm birch plywood was added. The gable walls are constructed similarly, only in this case, in contrast to the side walls, the internal cladding is placed in front of the posts so that these are hidden.

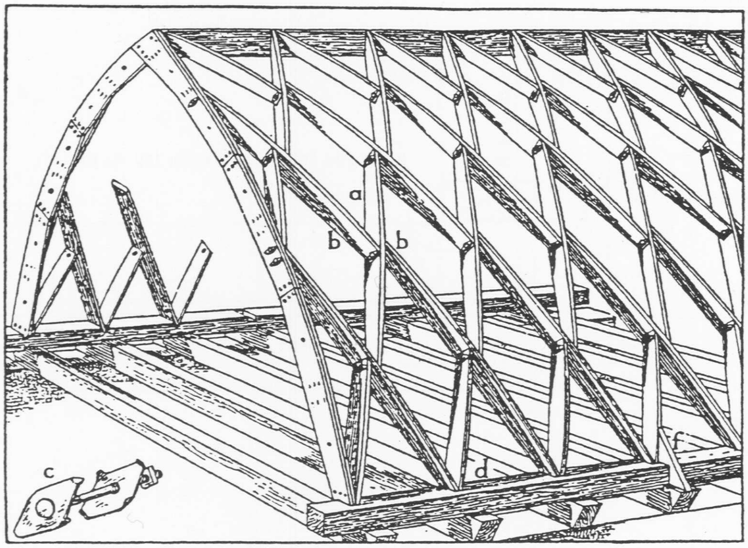


12 | Hall façade with row of windows at base.

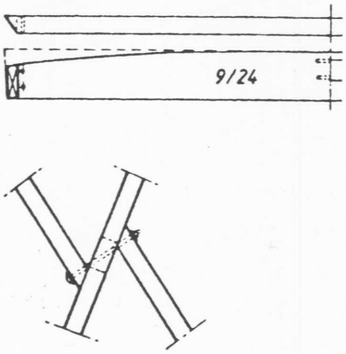
1 | Site plan, scale 1:2500.



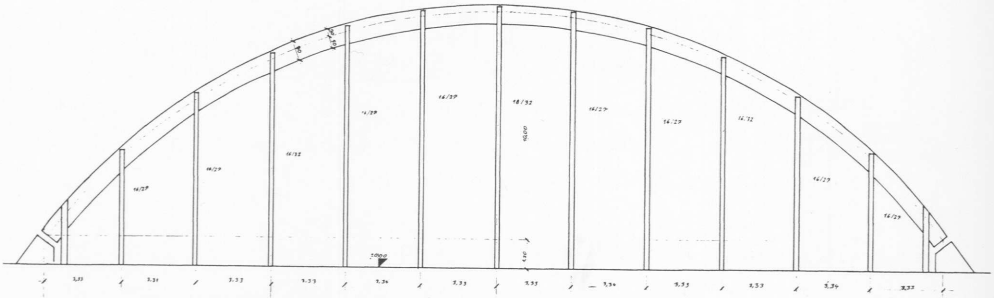
2 | The principle of the "Zollbau" roof as given in a publication from 1923: "One continuous member (a) always intersects with two identical non-continuous members (b) at every node. These are held together tightly by means of bolts (c) and specially shaped washers."

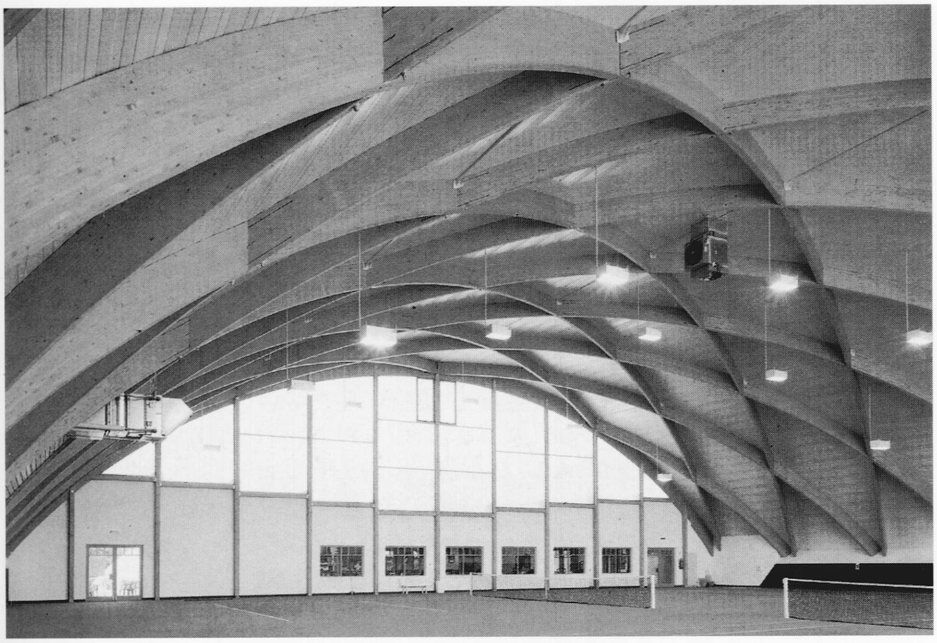


3 | The standard node of the roof system as developed by City Building Surveyor Zollinger.



4 | Gable elevation as hall cross-section, scale 1:300. The gable posts are 270 x 160 mm, in the centre 320 x 180 mm, and 320 x 160 mm at the quarter points.





5 | Interior view of the tennis hall.

Tennis Hall, Bad Waltersdorf

Plan-Kreis Heinrich & Breiner and H. Purkarthofer

Subject | When designing the tennis halls for Bad Waltersdorf's leisure facilities, the architect first had the notion of constructing the roof in the shape of a barrel vault using the "Zollinger" method, i.e. the diamond-shaped structural framework developed and patented by City Building Surveyor Zollinger, who worked in Merseburg near Leipzig in the 1920s. Its principle is a diamond pattern in which each member runs past two "diamonds" and is offset with its neighbours, thus forming a stiff, plane, loadbearing structure. All members are identical and, owing to the simple offset between members, only one fixing bolt is required at each node. Originally only intended for simple houses with a barrel vault roof, or for low-cost industrial or agricultural premises, this system is still in use today, and even for large halls – for example, the gymnasium in Berlin-Charlottenburg built by Hinrich and Inken Baller in 1987.

The principle behind "Zollbau", as it is called, is an identical pattern in the development of the arch. This pattern consists of just two elements: ribs and bolts, which is why it is so economic. Yet in our modern world with its high-tech computerized calculation and design procedures, there are other ways in which we can optimize structures. For this project, the timber engineers used the latest methods to modify the architect's design in order that costs could be reduced still further. Although the system is now based on intersecting open arches, the architect's original diamond pattern is still recognizable; only the geometry has been altered. The individual parts remained but the complete system was optimized by employing up-to-date computerized production techniques. Today, standardization through minimizing the number of individual parts is no longer the main criterion; best possible use of materials and the simplification of machine-made connections are equally important goals.

Design and Structure | The two double tennis halls are situated at the northern end of the tennis courts complex. Each hall measures 40.60 m x 40.60 m outside. The halls are arranged parallel but offset and linked by a 10-m-wide, two-storey building incorporating changing rooms, restaurant and squash courts. The really quite massive barrel vaults over the halls rest on exposed foundation plinths,

Location
Bad Waltersdorf, Austria

Client
Freizeitpark Waltersdorf
GmbH, Bad Waltersdorf

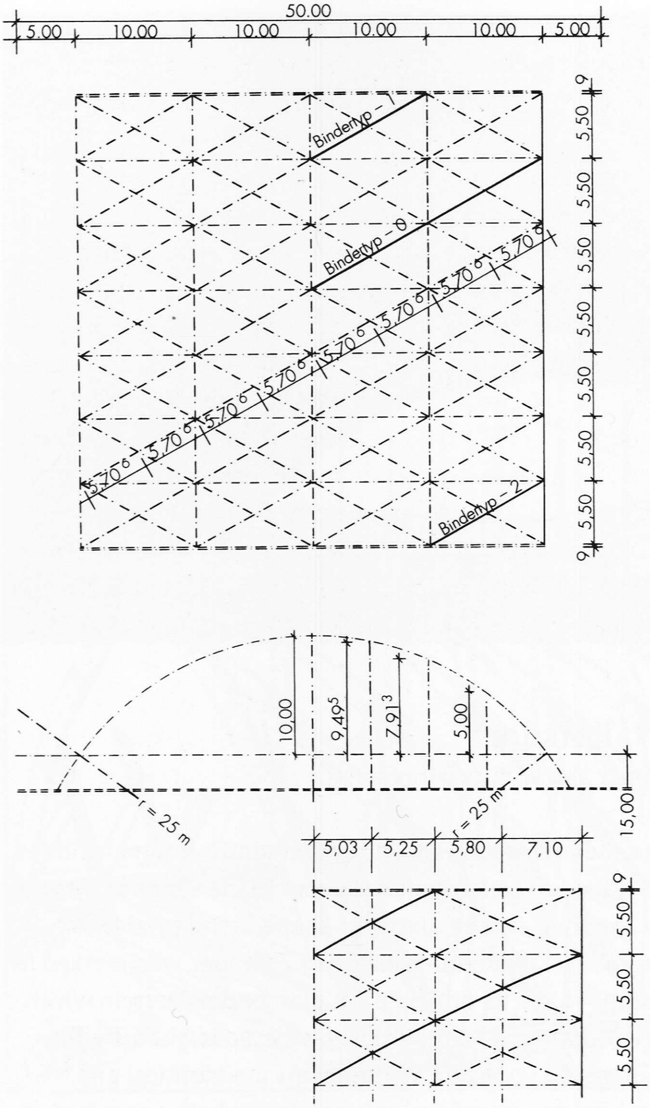
Architect
Plan-Kreis Heinrich &
Breiner Ges.m.b.H. and
Dipl.-Ing. H. Purkarthofer,
Hartberg

Structural Engineer
& Timber Construction
Hubert Kulmer Bau GmbH,
Graz

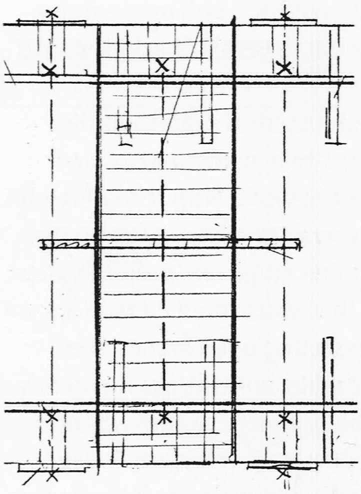
Date of Completion
1994

Costs
The cost of the timber
works for both tennis halls,
including the roofing, was
approx. 6 million Schillings.

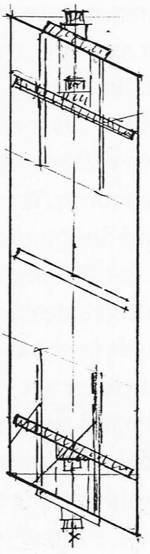
6 | Plan of arch axis; underneath, in section; bottom, development of one side showing the “diamonds”.



7 | Working drawing, section through arch intersection, scale approx. 1:10. Galvanized steel flats, rigidly connecting the incoming non-continuous ribs, pass through the continuous 600 x 160 mm rib; 1300 x 150 x 10 mm flats top and bottom, 350 x 150 x 10 mm in the centre, with bolts and steel dowels to transfer the loads. The bolts are screwed in at two levels: into the steel flat within the timber itself and then with a washer at the surface of the timber member.



8, right | Working drawing, section through joint in connecting member, scale approx. 1:10. Visible here is the angled position of the steel flats, bolts and steel dowels which needs to be taken into account.



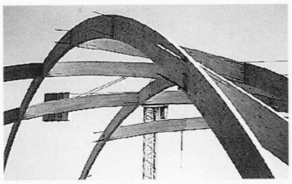
approx. 1.20 m high, placed in front of the walls which are set back into the building. This avoids height limitations within the hall, despite the low springing of the arch. Daylight enters via the gable ends and, therefore, the roof is not interrupted by openings.

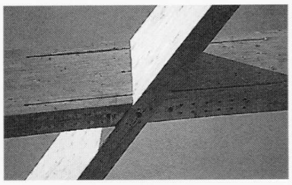
The entire construction utilizes glulam members. The basic pattern for the roof is formed by arches arranged at an angle of approx. 29° so that they intersect with each other to form the diamond-like pattern. As in cross-section the roof spans 40 m and forms an arc with a radius of 25 m and a rise of 10 m, the 600 x 160 mm arches take on an elliptical form and must span 45.65 m. The arches are straight on plan and stand vertically – not perpendicular to the plane of the arch like in "Zollbau". This leads to an actual increase in the size of the "diamonds" as they approach the supports, although they remain identical on plan – again, a deviation from "Zollbau". However, it leads to changes in cross-section over the length of the arch which ensue from the geometry and can only be sensibly solved by means of CAD. On the whole though, it follows the principle of "Zollbau" in that it is a membrane in which any load at any point causes stresses and deformations in every loadbearing member. This effect allows for savings in material even when regarding partial distributed loadings, such as snow or wind.

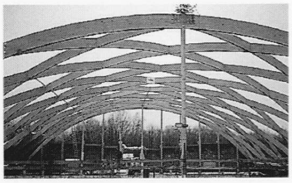
The problem of the arches intersecting in the same plane was solved by using two 1300 x 150 x 10 mm steel flats at each joint, one top, one bottom, which are fitted into slots across the non-continuous ribs and join these together by passing right through the continuous rib. In this way, the forces perpendicular to the members and the couple of forces resulting from the bending moment are accommodated. Every non-continuous rib is connected by means of one 14 mm diameter bolt and twelve 16 mm diameter steel dowels, and the continuous rib with one 14 mm diameter bolt and four 16 mm diameter steel dowels. In addition, a 350 x 150 x 10 mm flat is provided in the centre to transfer the relatively low shear force by means of bearing stresses. However, owing to the differing cross-sections of the arch members, this detail does require accurately positioned holes for the bolts and slots for the steel flats, as well as corresponding wedge-shaped washers. Nevertheless, this form of joint does make it easy to slide in the non-continuous ribs from the side during erection.

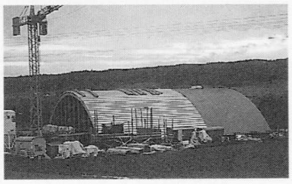
The continuous ribs are in each case rigidly jointed adjacent the ridge by means of vertical plates slotted into the members, and steel dowels. A joint at the ridge itself would have been too complicated because the arches already intersect at this point. The system of the directions of the joints was changed during fabrication, in contrast to the initial concept. Concern had been expressed regarding the, of course, unequal flexibility in the joints; it was felt that this might have an adverse effect on the overall stiffness of the structure. Therefore, the direction of the joints was varied evenly over the whole area of the "diamonds", thus cancelling out any unequal flexibility in the system. Erection was possible without the use of scaffolding. Starting at one gable arch, the continuous ribs were erected, held in place by guys and then the non-continuous ribs were erected bay by bay. The connections were assembled from elevating platforms.

The "Bramac-Domico" system was chosen for the roof construction. It consists of steel sheets top and bottom, intermediate components and a 120 mm layer of thermal insulation. This system is strong enough to cope with the largest span met with on this roof – 5.50 m – without additional support. However, this system cannot accommodate thrusts and hence cannot brace the entire building. Therefore, it was necessary to brace the diamond pattern by means of steel ties along the length of the hall at every second row of diamonds. The gable ends, as "half-diamonds", are already triangulated and are, therefore, stiff in themselves. All timber has been left untreated, thus clearly emphasizing the diamond pattern.







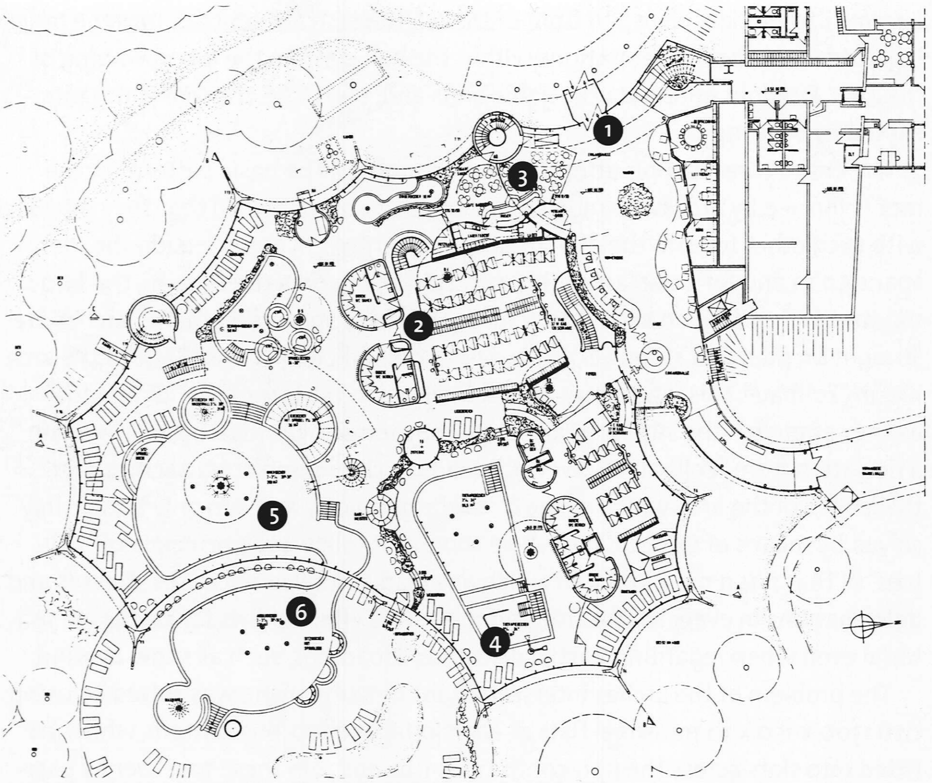


9 | Arch with projecting steel flat connectors at the intersections.

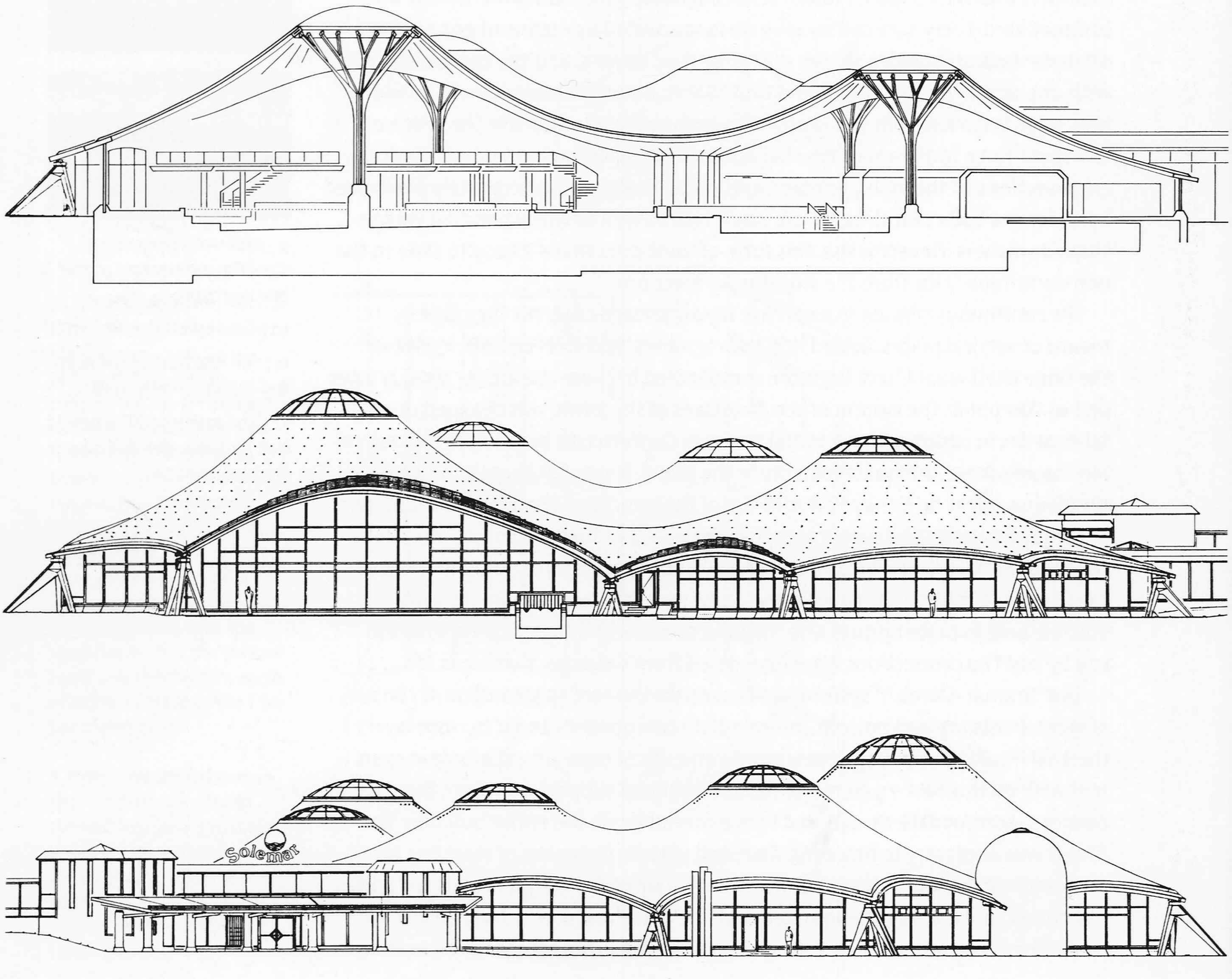
10 | A completed joint.

11 | The hall during the topping-out ceremony in 1994.

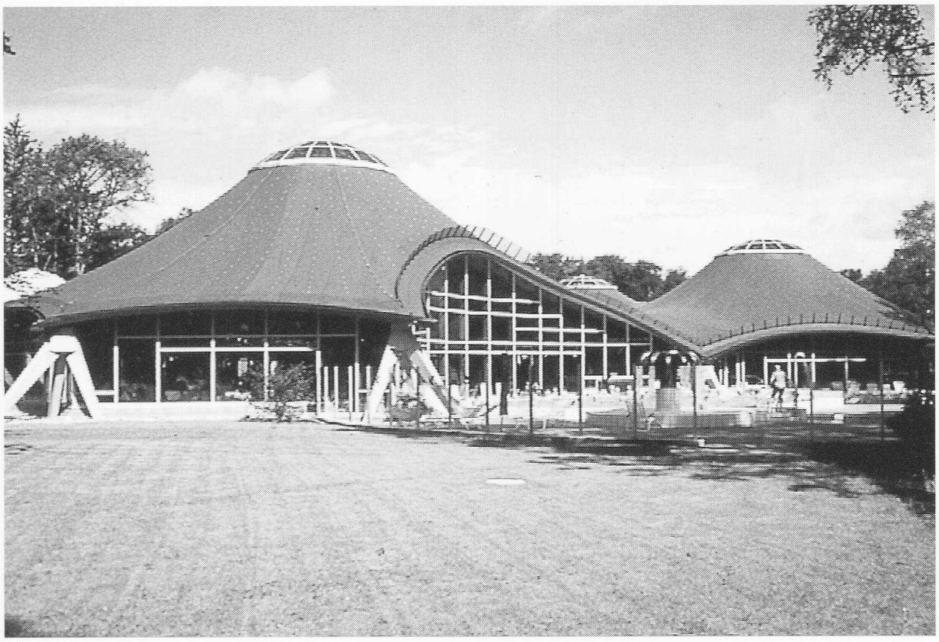
12 | The roofing to the tennis hall employs the "Bramac-Domico" system.



1 | Ground floor plan, scale 1:800. **1** Entrance hall. **2** Cubicles. **3** Café. **4** Therapy pools. **5** Swimming pool. **6** Outdoor pool.



2 | Section and elevations, scale 1:400.



3 | View from sunbathing area. The three-legged reinforced concrete roof supports are clearly visible.

"Solemar" Brine Baths, Bad Dürrheim

Geier + Geier

Subject | Over recent years public baths have undergone a dramatic change. Whereas in the first half of our century they developed from simple body-cleaning institutions to sports centres many are now changing from sports facilities pure and simple to multiform recreation centres and "adventure pools". There has been not only a proliferation of the types of bath one can enjoy – warm-water, cold-water, artificial-wave, kiddies' and whirlpool baths; such supplementary facilities as saunas, solaria, therapy rooms, cafés and resting and relaxing areas now also abound. This has given rise to new spatial concepts that accentuate individual areas without separating them one from the other – fluid spaces as it were.

An outstanding example of this are the public brine baths in Bad Dürrheim, a building erected as an extension of the town's spa facilities. Following intensive planning and a short period of construction it was opened in the autumn of 1987. The decision to use wood for the roof was an early one, for this material offers the greatest resistance to the aggressive vapours from the salt water of the baths. Apart from that with this material the architects wanted to relate the building to the wooded region around it.

Design | The whole of the ground level, including the floor and such individual units as the brine grotto, stair-towers, shower cubicles, etc. are of in-situ concrete. The whole of the multifarious panorama is covered by a vast roof with a total area of 2500 m^2. Like a net the roofshell dips and rises from one tree-like column to the next and then down to the building's arched boundaries. The saddle-like surfaces between the columns split up the interior into separate areas. The columns open up tree-like towards the top with "branches" that carry annular beams. From these the shell is suspended and above them rise cupolas of glass. The highest of the "trees" is 11.50 m, stands on an island in the large swimming-pool and carries a ring of beams 8 m in diameter. It is the centre of a space 36 m in diameter. Next to the swimming-pool stands the second highest tree 10 m high and supporting a ring 7 m across. It thus forms another separate space, 30 m across. Above the changing-cubicles and showers lower and more

Location
Solemar, Hubertstraße 8,
78073 Bad Dürrheim,
Germany

Client
Kur- und Bäder-GmbH,
Bad Dürrheim

Architect
Geier + Geier BDA DWB,
Stuttgart
Design Team
Dipl.Ing. W. Völlger, Arch.
J. Schaller, Dipl. Des. S. Kasel

Site Manager
Dipl.Ing.(FH) H.-J. Flume

Design Timber Shell Roof
Wenzel-Frese-Pötner-Haller,
Karlsruhe

Numerical Production Data
Büro für geodätische Meß- und Rechentechnik Prof. Dr K. Linkwitz, Dr H.D. Preuß, Stuttgart, with Dr L. Gründig and Dipl.Ing. J. Bahndorf

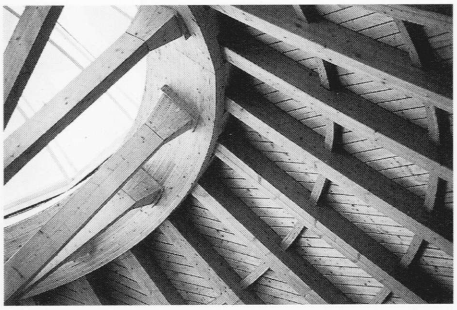
Timber Construction
Christian Burgbacher Holzwerke, Trossingen, with Chief Carpenter Martin Jörg and Georg Arno

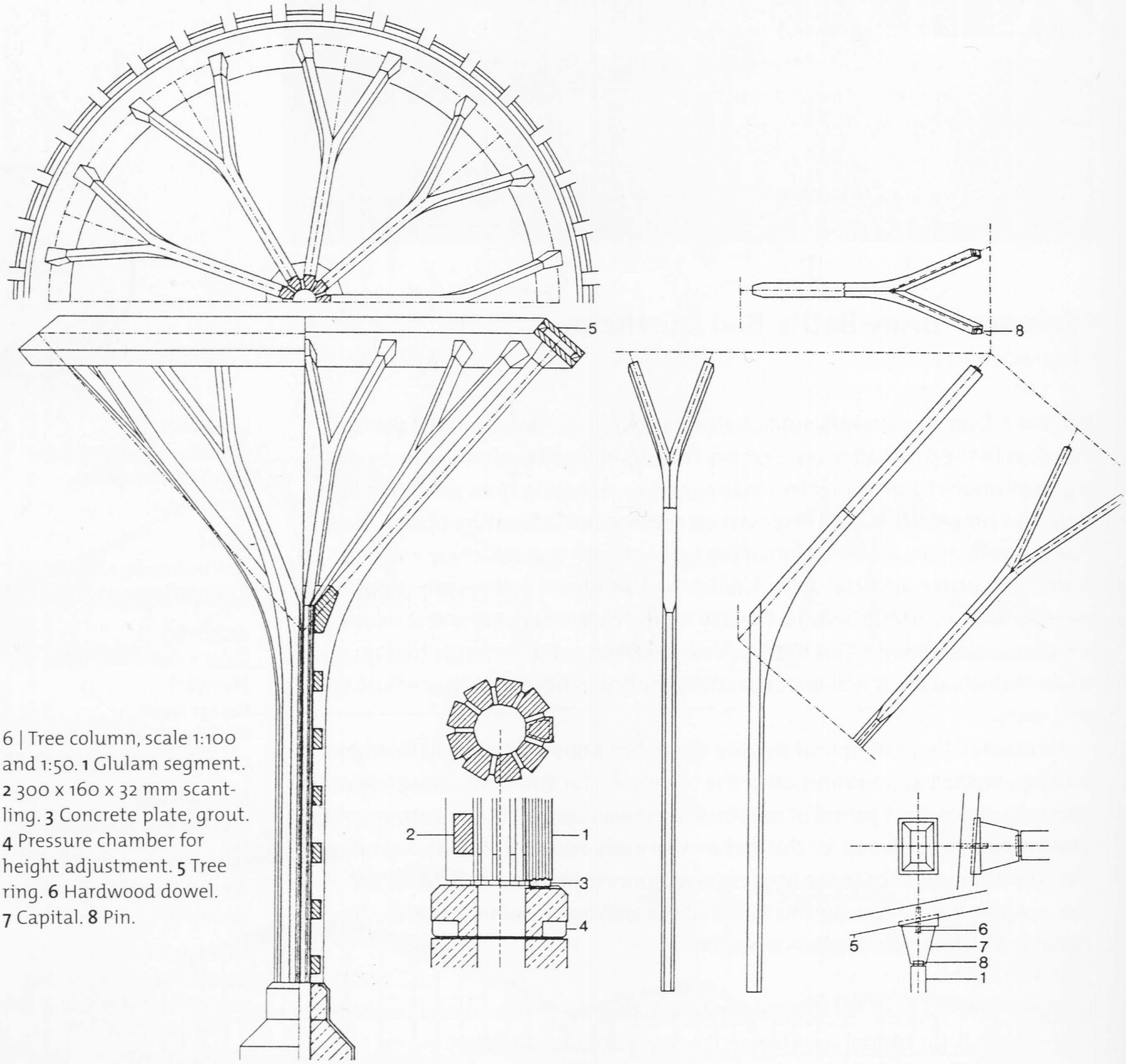
Castings
Entwicklungsinstitut für Gießerei- und Bautechnik
Dr A. P. Betschart, Stuttgart

Date of Completion
1987

4 | Roof shell under construction with meridian and annular beams that determine its spherical form.

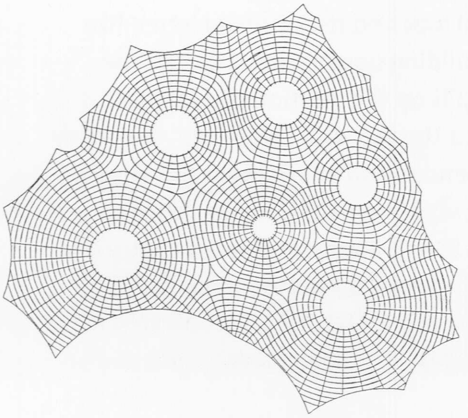
5 | Annular ring supported by “branches” of tree column and from which meridian ribs are suspended. Above it the glass dome.





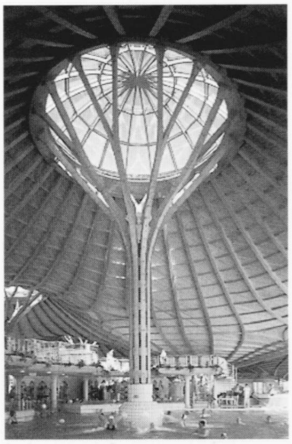
6 | Tree column, scale 1:100 and 1:50. **1** Glulam segment. **2** 300 x 160 x 32 mm scantling. **3** Concrete plate, grout. **4** Pressure chamber for height adjustment. **5** Tree ring. **6** Hardwood dowel. **7** Capital. **8** Pin.

7 | Rib structure of the roof in plan.



closely spaced trees form a hall-like room 5 to 7 m high, which opens out towards the swimming-pool. The glass façade skirts the curved boundary beams, which form the limits of the roof from one support to the next. At their lowest points these beams are carried by three-legged concrete supports. In the direction of the park the roof opens out with a wide-span arch 7.50 m above the ground.

Structure | The roof resembles a membrane stretched from five peaks to a central valley and to the open edges. The extremely complicated geometrical shape of the roof was calculated at the Institute for the Application of Geodesy in Building Construction of Stuttgart University using computer model testing. In the case of a very thin membrane the geometrical form results directly from its own internal forces, as with the film of a soap bubble. Here, in order to create a design that could be realized with a minimum of material, the relations between form and force were thus modelled in a way analagous to the calculation of rope networks.



8 | Tree column in large swimming pool with glass cupola and spherical roof shell.

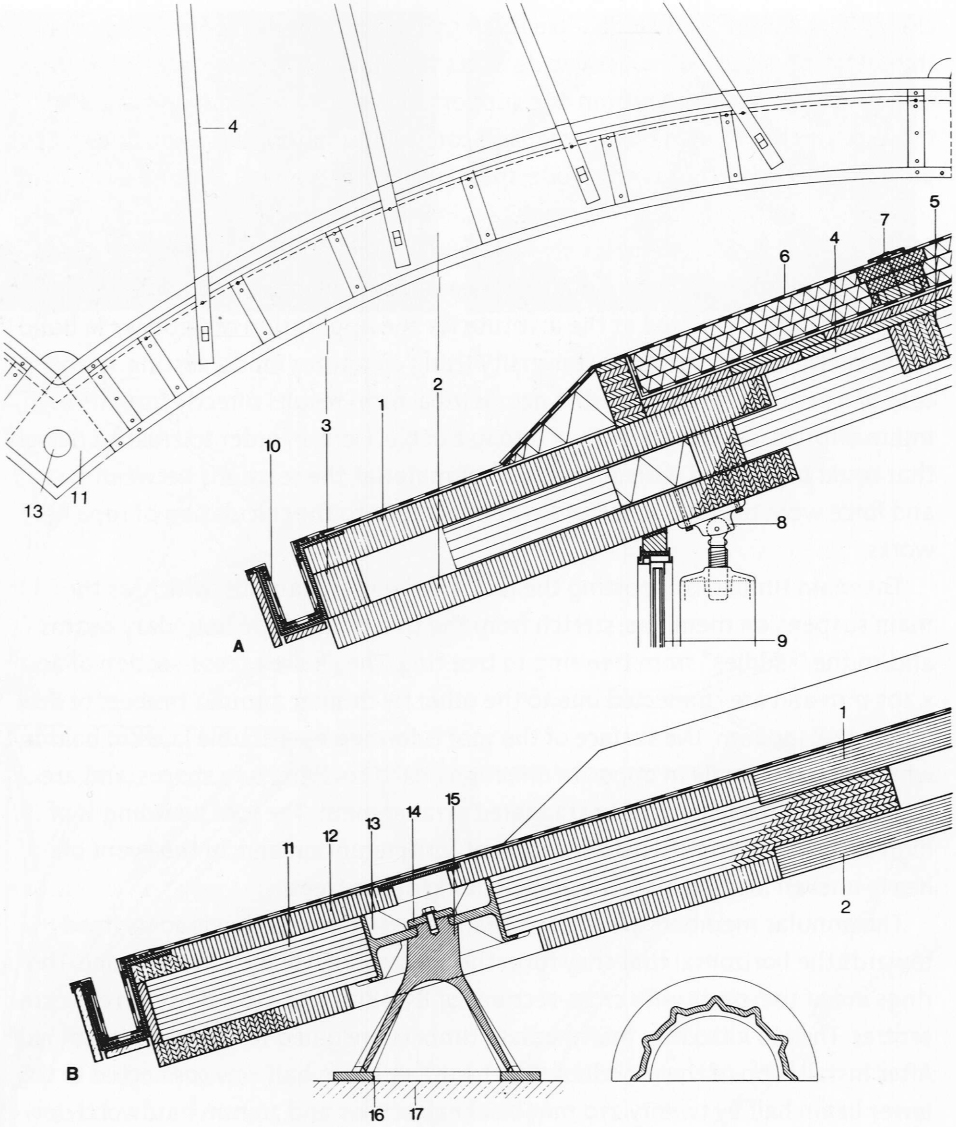
The main timbers supporting the roof are the meridian ribs, which, as the main suspension members, stretch from the tree rings to the boundary beams and, in the "saddles", from tree ring to tree ring. They have a cross-section of 200 x 205 mm and are connected one to the other by thinner annular timbers of 80 x 80 to 120 x 140 mm. The surface of the roof is formed by a double layer of boards, which run diagonally in opposite directions, each covering two spaces, and are butted to the meridian ribs in staggered arrangement. The roof boarding is of high shearing strength, ensures excellent form retention and, in the event of heavy uneven loading, prevents any bending of the trees.

The annular members are glulam beams. Their cross-section is so inclined towards the horizontal that they form the surface shell of a truncated cone. The rings are of two parts with cross-sections of 85 x 800 and 120 x 800 mm at 12 cm centres. The 120 x 120 mm intermediate timbers are glued to the lower beam half. After installation of the meridian ribs the upper beam half was connected to the lower beam half by twenty 270 mm hex head screws and 20 mm hardwood dowels. Of similar design to the annular rings, the boundary beams are 1300 mm in width. Due to the varying height and slope of the roof edge they, like the ribs, are doubly curved and twisted. Their weight is transmitted to the ground via the façade columns. The meridian ribs unload their forces in the 12 cm spaces between the tree rings and edge beams and are held in position here with hot-dip galvanized dowels of 20 mm diameter. Most of the roof load in the boundary beams is transmitted at their lowest points to the concrete supports. Here the boundary beams abut and form a massive 170-mm-high seating element of dowelled beech plywood. Let into each of these is a pot-type support of cast steel GS 52, which absorbs the bearing pressure from the roof shell and transmits it via a cast steel shoe to the reinforced concrete abutments.

The annular rings are supported by the "branches" of the trees, which are composed of several identical glued wood members running from tree ring to tree foot. Over the lower part they are bundled to form a trunk, the top part spreading like branches that carry the tree rings. The use of metal fasteners has been kept to a minimum throughout the whole of the wood structure. The metal dowels are protected from the aggressive salty air by knothole dowels, the heads of the hot-dip galvanized wood screws and nails by a coating of bitumen.

The roof is a non-ventilated roof, comprising a vapour barrier with aluminium coating, three layers of treadproof mineral wool board of 120 mm total thickness as heat insulation and a fabric-reinforced dark green pvc sheeting as roof skin. The sheeting is mechanically anchored with 3 to 4 plate anchors per square metre by means of thrust blocks of hard foam in screwed-on wood dowels.

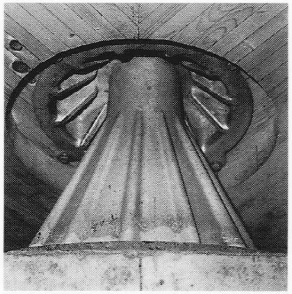
9 | Boundary beam details, scale 1:100 and 1:20. In centre: window to wall connection and façade columns; below: support with casting and plywood element.
1 Upper part of 85 x 1300 mm boundary beam, which was screwed into position after assembly of meridian ribs. **2** Lower part of 85 x 1300 mm boundary beam. **3** 120 x 120 mm intermediate timbers, which are glued to the bottom boundary beam section. **4** 205 x 200 mm glulam meridian rib. **5** 140 x 120 mm ring rib, double boarding twice 24 x 100 mm. **6** Roof construction: 1.2 mm pvc sheeting, fabric-reinforced; separating layer; treadproof mineral wool board, three times 40 mm; vapour barrier with aluminium coating. **7** Spot fixing of insulation and roof skin: plastic plate fasteners; hard foam, 200 x 200 x 40 and 150 x 150 x 80 mm; wood disk diameter 120 mm. **8** Façade column head, aluminium casting. **9** Glass façade. **10** Gutter. **11** 170-mm-thick beech plywood. **12** 60 mm glulam masking. **13** Support insert of cast steel. **14** Steel washer, diameter 130 x 20 mm. **15** Conical casting. **16** Steel ring with welded reinforcement. **17** Concrete support.



For the heads of the 108 façade columns a special aluminium construction was developed consisting of a support, ball-head bolts and an abutment. This allowed for the unproblematic and economical adaption of the columns to the varying slope of the roof. The façade columns themselves are hollow aluminium sections connected to the air-conditioning system and provided with ventilation holes to ensure a uniform temperature over the window surfaces.

Construction | Because of the large number of curved and twisted ribs and boundary arches a special works programme and production method were necessary. At intervals of some 80 cm the three coordinates and the two angles of twist of the cross-section had to be calculated for each individual rib and boundary beam. The result was up to 17-m-long glulam beams with 10 to 20, in some cases as many as 98, different cross-sections. The timber construction firm developed special steel production frames, which were appropriately assembled and adjusted on the shop floor.

Ten months were available from the beginning of production to the topping-out ceremony. The first step was the erection of the tree columns. These were each brought to the site in two sections and glued together on the spot. Then the bottom parts of the tree rings and the curved edges were fitted. At the façade columns the height and slope of the edges were exactly measured; tolerance compensation was possible at the supports. No other geodetic checks were necessary during the installation work. It sufficed to fix the meridian ribs at the top and bottom connecting points with a temporary screw and to support them with a strut. With the positioning of the annular ribs, which by their spread determined the spacing of the meridian ribs, the shape of the roof developed on its own.

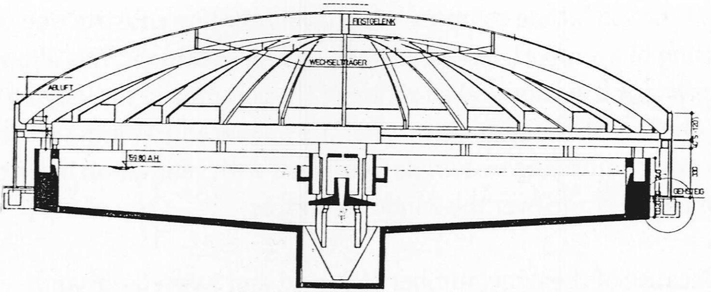


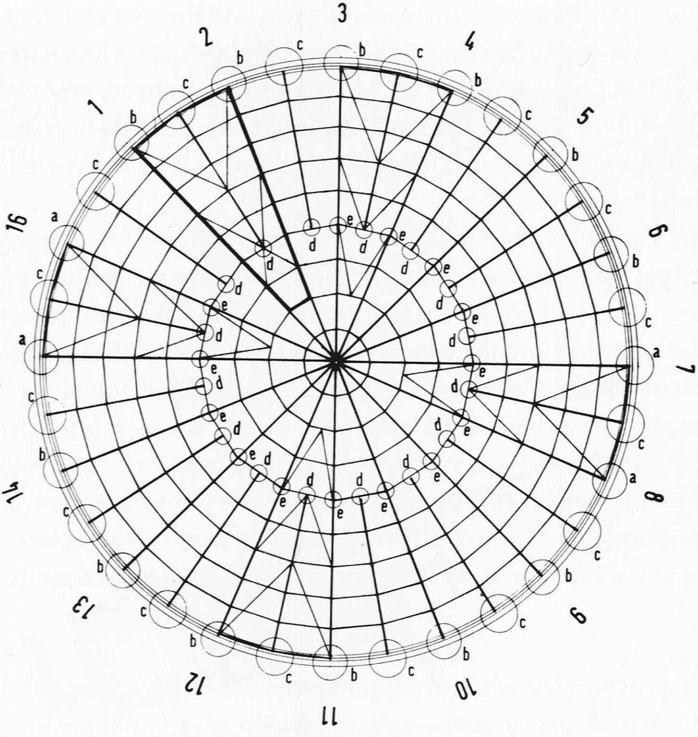
10 | Cast steel support of boundary beam.

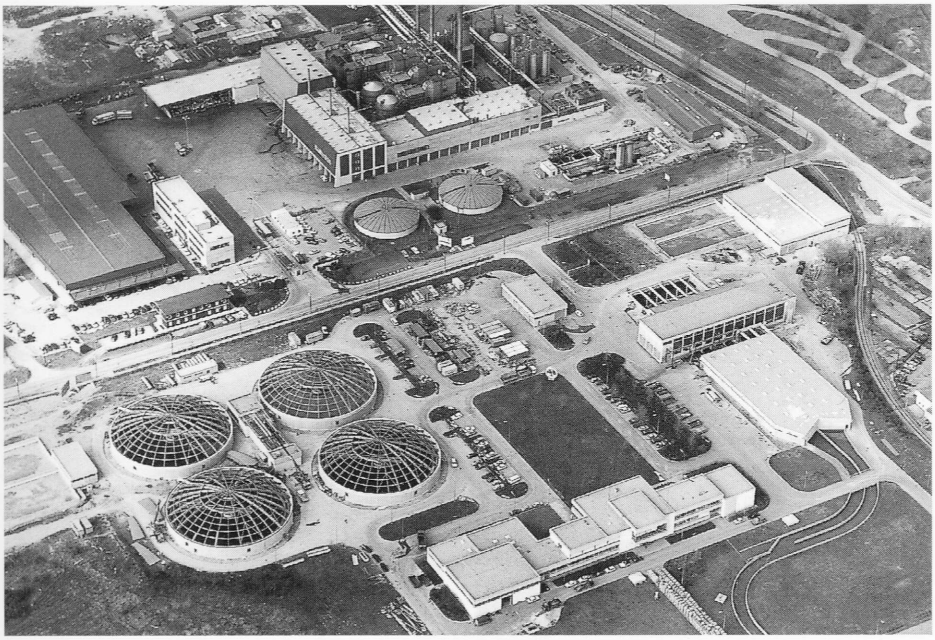
Costs | The building costs of the whole complex amounted to 20 million DM. The building costs of the wooden shell roof were in the region of 1000 DM per m^2 of ground area and thus not much higher than those of a conventional structure. The higher costs of the three-dimensionally curved glulam members were made up for by the lower amount of timber used. The planning costs were admittedly twice as high as usual, the project necessitating unusually intensive cooperation between the architects, construction engineers, geodetists and the timber construction company.

1 | Section, scale 1:500. The existing circular sedimentation tank is shown in black. At the side the separate base for the raised L-shaped reinforced concrete ring beam.

2 | Roof plan, scale 1:500.







3 | The four tank roofs under construction on site.

Roof of Main Sewage Works, Vienna

Walter Dürschmid

Subject | Timber is often used as a building material in environments where steel or concrete might be at risk due to the occurrence of aggressive vapours. This problem is frequently encountered in industrial situations. Here the emergence of laminated wood (glulam) has made the choice in favour of timber easier since this technology allows for large spans. Hence, timber is not only an extremely resistant material, but also suitable for large structures.

In Vienna the main sewage works are located relatively close to residential districts – which led to complaints from residents about strong, unpleasant odours. In 1987 the plant's operators decided to roof over the sewage facilities, to ventilate the ensuing enclosed spaces and treat the malodorous air in filters. The four sedimentation tanks, each with an outside diameter of 41.20 m, presented a particular challenge because for technical reasons, each tank had to be covered in one span. Laminated timber was chosen because of its ability to span such distances and because of its resistance to the extremely aggressive vapours given off by the sludge in conjunction with the very hot and humid atmosphere. The architect Walter Dürschmid was given the task of designing the roof and after considering a number of alternatives it was decided to opt for a single-span dome made from glulam ribs.

Design and structure | The shallow dome with a rise of 6.85 m caused a considerable horizontal thrust at the supports which had to be resisted by an outside ring beam as ties across the base of the dome were of course unacceptable. The existing edge of the tank was inadequate, so a separately founded reinforced concrete ring beam was built around the outside of the tank. It is L-shaped in section and consists of 16 individual precast units supported by concrete columns. Anchored in the internal angle of the L-section are 20 mm steel bearing plates – exactly perpendicular to the incoming rib axis – as supports for the main ribs of the dome. Interesting is the fact that these support points are located at the joints between the precast concrete units making up the ring beam; this made the detail more complicated but meant that the concrete sections were not subjected to bending stresses due to the point loads.

Location
Hauptkläranlage Wien,
Haidequerstrasse 7,
1110 Vienna 11, Austria

Client
EbS – Entsorgungsbetriebe
Simmering Ges.m.b.H.,
Vienna

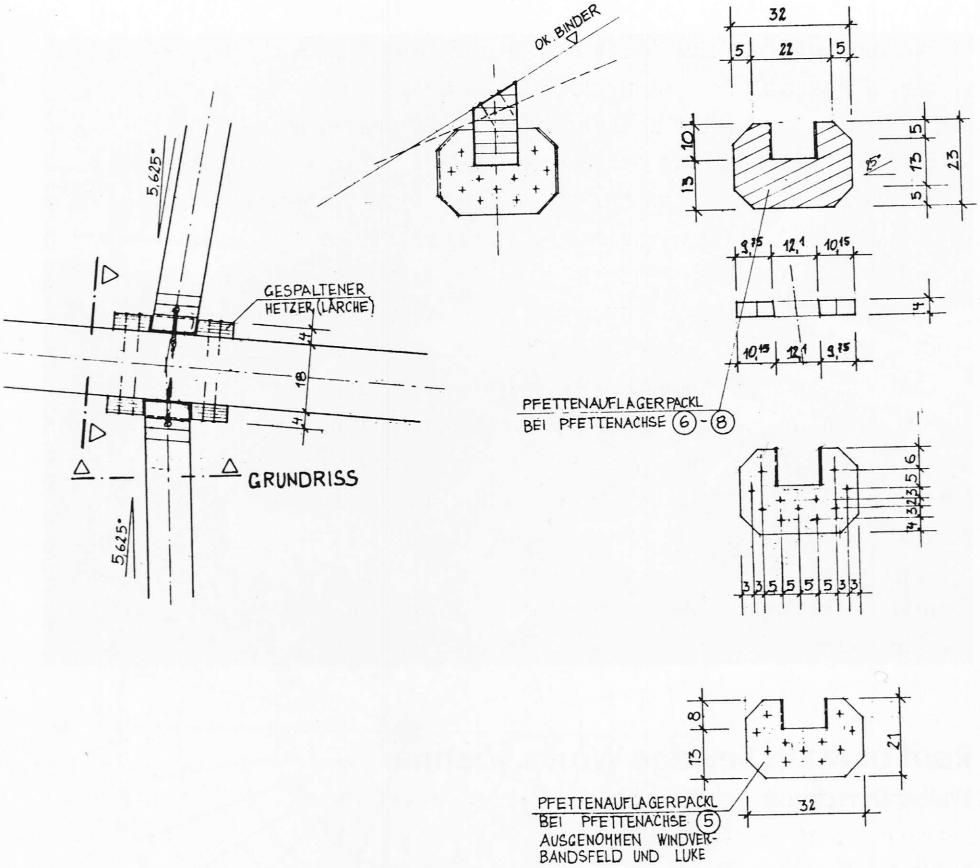
Architect
Ing. Walter Dürschmid,
Architect, Vienna
Assistant
Ing. Adamek

Structural Engineer
Ingenieurkonsulent Dipl.-Ing. Peter Kramer, Vienna

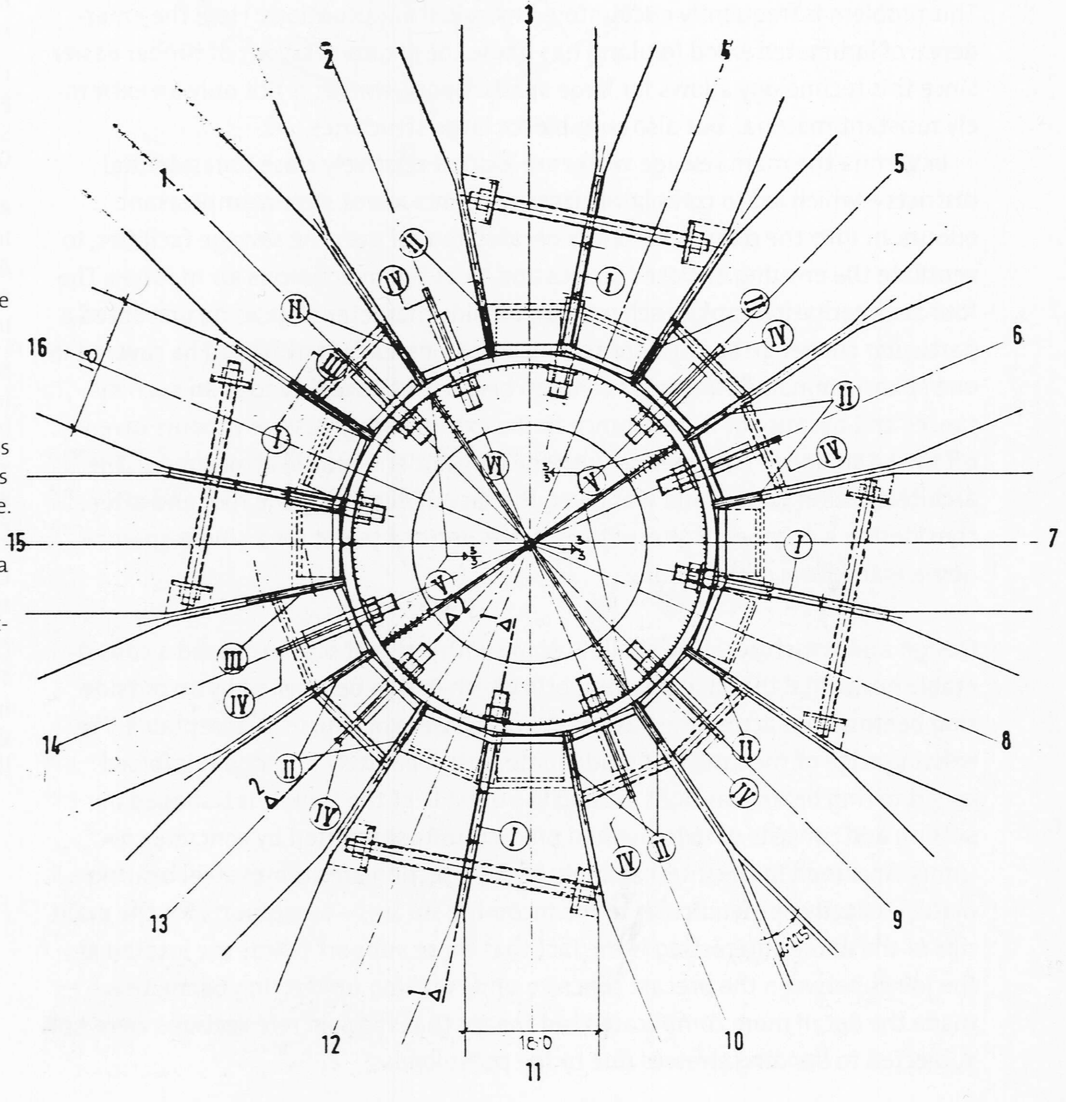
Timber Construction
Buchacher Holzleimbau
GmbH, Hermagor

Date of Completion
1988

Costs
The cost for all four domes, including all concrete works, was 48 million Schillings.



4 | Purlin connection, scale 1:20. The glulam U-shaped support bracket reduces the amount of steel in the joint. Just one M8 screw holds purlin and rib together.



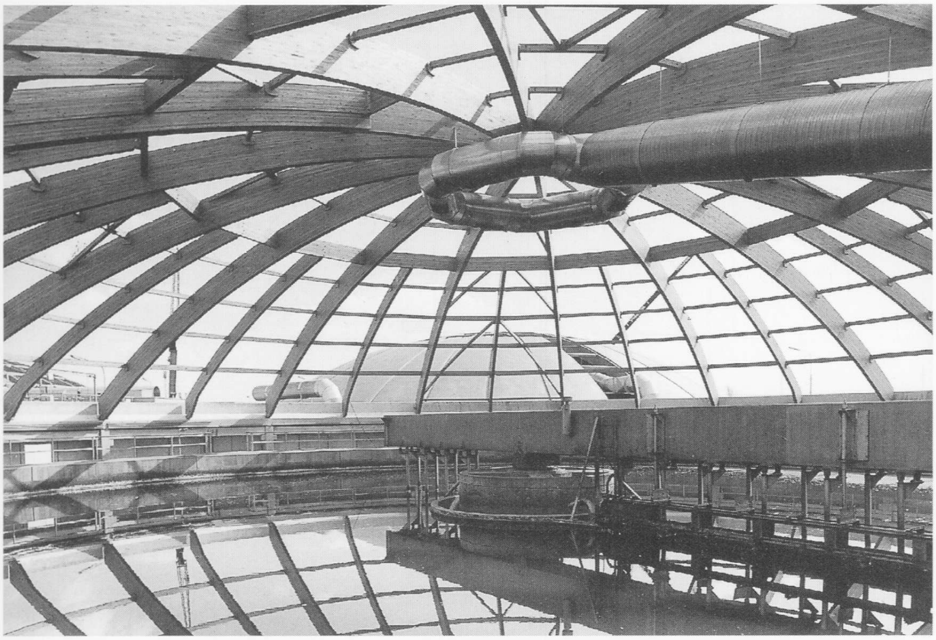
5 | Detail of crown joint, plan, scale 1:100. The steel tube, 500 mm dia., 15 mm wall thickness, 600 mm high, is stiffened internally by means of two welded rings and X-bracing made from steel flats. Flat plates are welded onto the outside for mounting and positioning the incoming ribs and wind girders. As the wind girders are erected first, only these connections have the V-shaped retainers in order to prevent slippage. Each rib is fixed using one stud which is welded onto a steel flat incorporated in the end of the rib and tightened from inside the tube of the crown hinge.

The dome itself, outside diameter 43 m and inside radius of curvature 35.76 m, is formed by 16 No. 900 x 180 mm curved main ribs, all of which are propped against a steel joint at the crown of the dome. Between each of the main ribs is a 550 x 180 mm intermediate radial beam which, however, only extends as far as a peripheral 550 x 160 mm trimmer beam stiffening the upper half of the main ribs. In addition to this trimmer beam there are further purlins between all radial beams, thus subdividing each sector of the dome into nine bays up the slope of the roof, i.e. the purlins are at approx. 2.50 m centres. Owing to their different lengths, the purlins range from 120 x 120 mm to 190 x 120 mm; they are fixed vertically so the upper edge is cut to match the respective curvature of the dome.

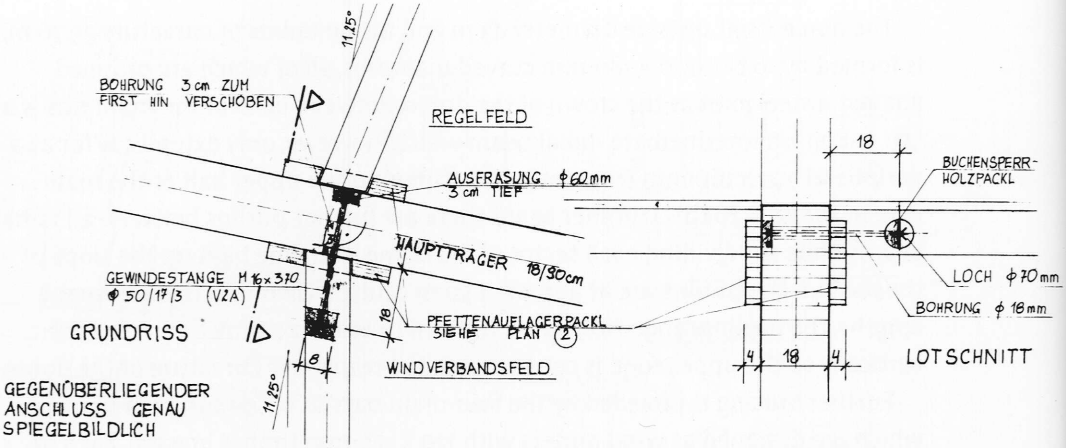
Further bracing is provided by the four main bays at 90° around the dome which are designed as wind girders with 120 x 120 mm timber bracing. Each of these four bays is a single prefabricated unit. Two opposing bays, including the joint at the crown, were erected first using four mobile cranes. Having checked the correct positioning of these, the pair of bays at right-angles to this first pair were then lifted into position. The basic framework was now stable and the remaining main ribs could be positioned. The trimmer beam and purlins were added afterwards.

Part of one of the main bays of the dome can be removed for servicing and inspecting the tank. The frame of this bay consists of 550 x 80 mm members with the same purlin arrangement as the other bays. Of course, diagonal wind bracing is also provided here by means of 120 x 120 mm members – like the wind girders. In addition, a framework to brace the lower part of this bay is formed by a curved 300 x 120 mm bottom boom in conjunction with the third purlin from the base. Four lifting eyes are provided for lifting out the element which rests on 250 x 80 mm timbers glued-nailed onto the sides of the main beams.

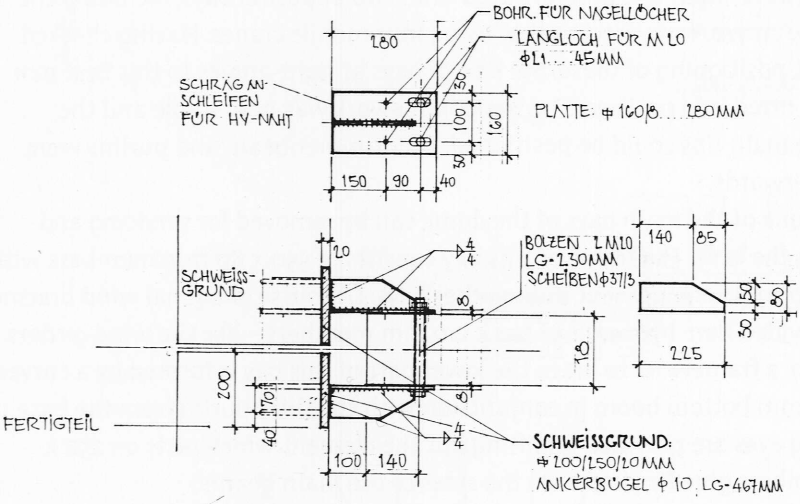
Special attention was devoted to the timber connections which, due to the dampness and the aggressive vapours, had to be realized with the minimum number of structural steel parts. However, all steel parts which are indispensable are in rustproof V2A steel, including screws and bolts. All timber members are fabricated from larch and are given a coat of protective lacquer. In order to reduce the steel in the connections to a minimum, the purlins, for example, were provided with U-shaped brackets consisting of 320 x 210 x 40 mm glulam members which were glued-nailed onto the main and auxiliary ribs. So generally, the purlins are fixed with one M8 x 160 hexagon head woodscrew per connection.



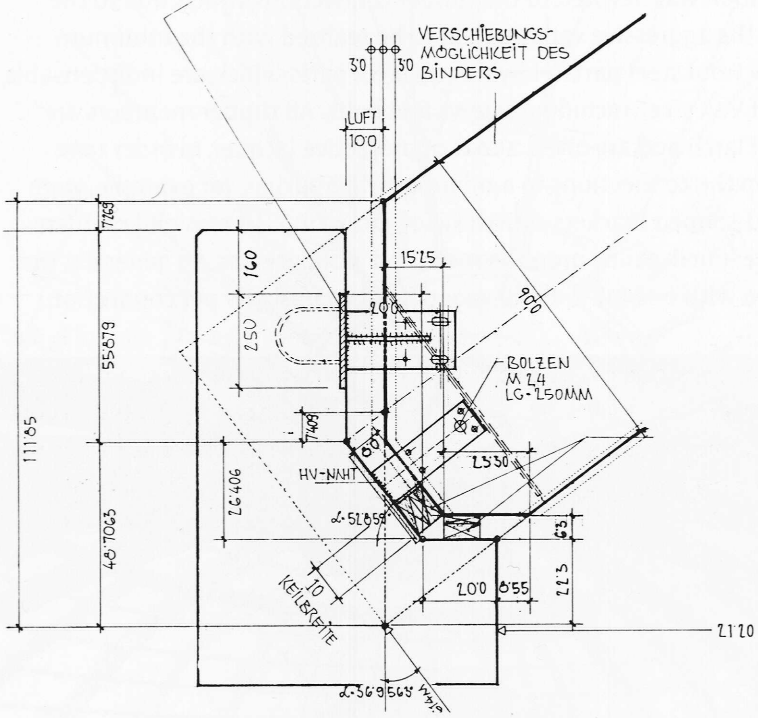
6 | The dome construction from inside. The tubular ring under the crown is the air extract duct.



7 | Purlin connection at wind girder, scale 1:20. The substantially stronger connection here is achieved by using an M16 threaded bar which is incorporated in the centre of the purlin and tightened via a 70 mm dia. hole in the side. These erection holes are left open in order to avoid forming a void in which condensation could collect.



8 | Wind girder connection, scale 1:20. The holes in the 10 mm steel flat are for M16 bolts which hold together the edge beam of the girder at the crown.



9 | Base of main rib, scale 1:20. The L-shaped concrete ring beam has a bevel in the internal angle which forms the bearing perpendicular to the incoming timber rib. After correct positioning of the rib, the lateral 12 x 100 x 310 mm lugs are welded onto the embedded steel plate. The connection to the beam is via one M24 bolt and four screws. The larch wedges assist correct positioning. The wind girder anchor is provided on the vertical leg of the reinforced concrete beam; the detail is similar to the main rib connection except that two welded stiffeners are included and the two bolts pass through elongated holes. Two threaded bars are glued into the end of the rib to prevent shear failure of the timber.

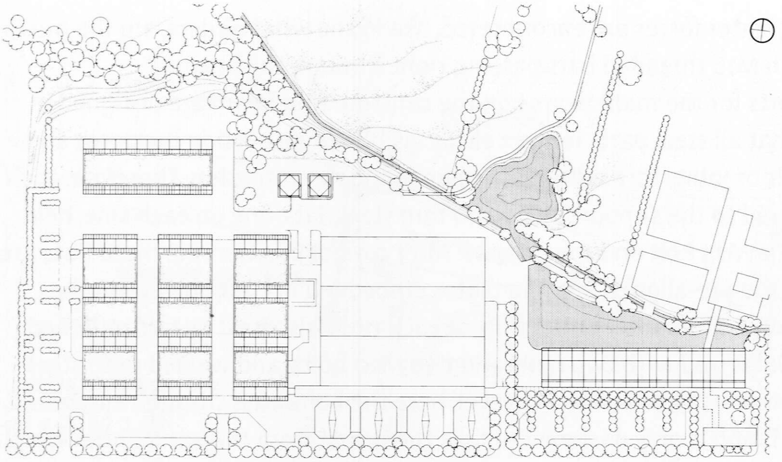
Only where greater forces are encountered, like in the wind girders, are the purlins fixed with M16 threaded bars passing right through the beams.

The supports for the main beams on the concrete ring beam are designed in such a way that all steel parts remain easily visible for inspection purposes and that any voids or joints formed remain open for good ventilation. Therefore, each main rib is fixed to the support by two 20 mm steel flats, one on each side, held in place by one M24 bolt and four screws. After correct positioning, these flats are welded onto the pre-aligned bearing plates embedded in the concrete. In the case of the wind girders, the upper part of each rib is also held by two stiffened 8 mm steel flats fixed with two nails and two M20 bolts, and welded onto steel plates anchored in the concrete. However, here the bolts pass through elongated holes as this fixing is only designed to take the thrust from the wind girder which is positioned further up the main beam and which would otherwise subject the rib to torsion because of the fixture at the base.

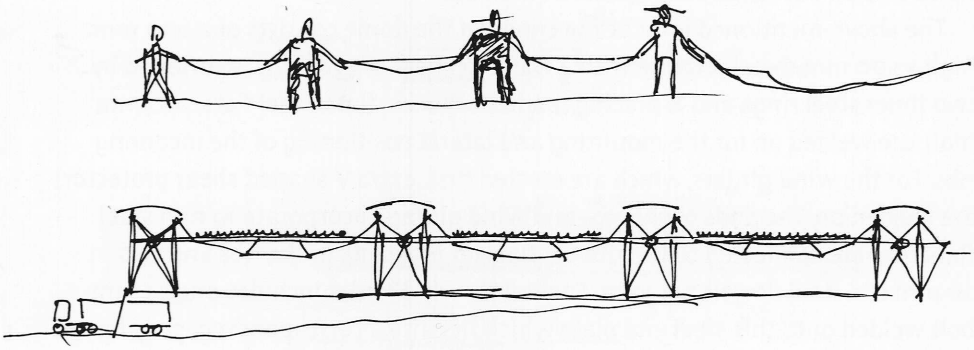
The above-mentioned joint at the crown of the dome consists of a 600 mm high x 500 mm dia. steel tube with a wall thickness of 15 mm. It is stiffened by two inner steel rings and X-bracing made from steel flats. Steel flats, 200 mm high, are welded on for the mounting and lateral positioning of the incoming ribs. For the wind girders, which are erected first, extra V-shaped shear protectors are welded on. The ends of the ribs and wind girders incorporate 10 mm steel flats that are connected to the ribs via flats let into slots in the ribs and two 20 mm dia. steel dowels per joint. Each rib or wind girder includes one 24 mm bolt welded onto this steel end plate which fits into a corresponding, pre-aligned hole in the steel tube of the crown hinge when erecting the member. The bolt is then tightened from inside the tube. The whole detail is designed in such a way that any condensation water which occurs can drain away and no hidden water traps are formed.

Large glassfibre-reinforced plastic sheets, 10 mm thick and with 100 x 100 mm strengthening ribs, form the covering to the dome. Each of these sheets covers one bay, i.e. the area bounded by two adjacent beams and purlins. The sheets are curved in both directions to match the curvature of the dome so that a smooth outer surface ensues and not a spherical polygon. They are fixed to the ribs by means of aluminium rails which hold the sheets down by means of bolts. There is a plastic extract dome at the crown, 3 m in diameter.

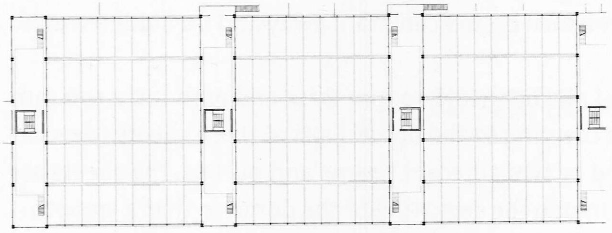
The structure has remained in unexpectedly good condition. After eight years an inspection revealed that all timber was free from defects or discolouration. All steel connections were also found to be unchanged. The occurrence of condensation water well above the level anticipated was noted but is not a cause for concern, merely leading to plans on how such large amounts of water at the supports can be drained off.



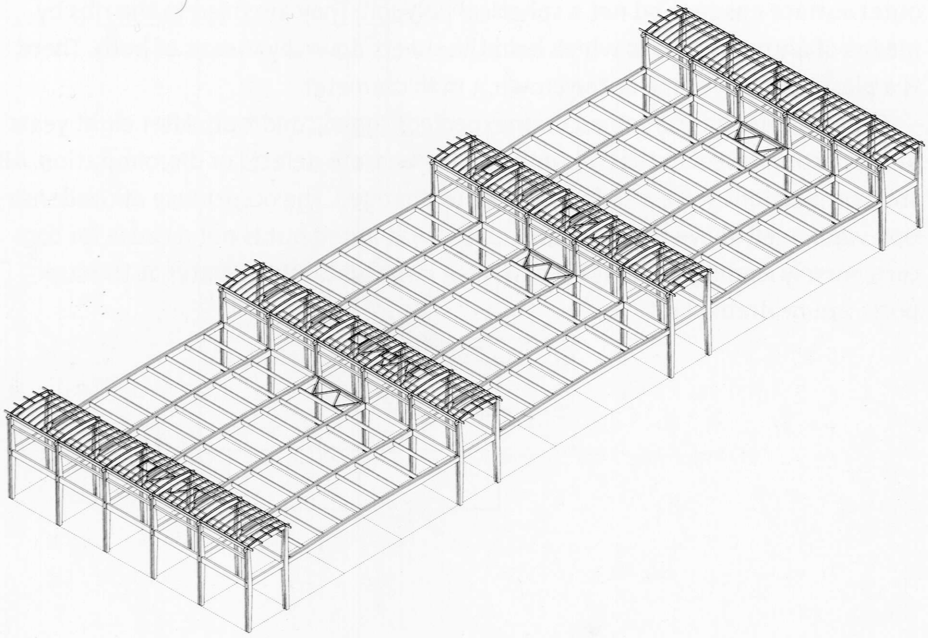
1 | Site plan of whole complex, scale 1:4000. Left, the production building by Thomas Herzog, including the planned extensions.



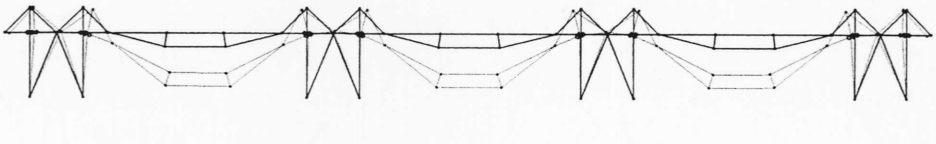
2 | Architect's sketches showing the development of the "distinguishing feature".



3 | Plan of mezzanine floor, scale 1:1000. The roofs over the production bays are supported on the intermediate 5.40-m-wide H-frame blocks. The main axes of the loadbearing H-frames run north-south and the trussed roof beams are spaced at 6.60 m centres.



4 | Isometric view of supporting structure.



5 | Diagram showing deflected shape of structure under load (deflection graphically exaggerated: vertical scale = 75 x horizontal scale).

6 | View of production building from the west.

Production Plant Wilkhahn, Bad Münder

Thomas Herzog

Subject | Industrial buildings, if they are not merely intended to house large machinery, are mostly designed to shield extensive production or storage areas from the weather. The underlying idea is to provide a horizontal covering over a working environment made up of repetitive units which can be reproduced or subdivided. Therefore, industrial buildings are often flat boxes with the administrative and communal facilities incorporated or appended at one end. As production expands so does the building – augmenting the existing form just like the extended production lines. And as restructuring of production processes is not unknown, working areas must be kept suitably neutral. This frequently results in architecturally undistinguished structures.

However, many industrial companies call for an additional factor to be taken into account in the design of their premises – an unmistakable symbolic characteristic, a "distinguishing feature" expressed in an individual and coherent architectural style. On the other hand, other companies prefer to give each expansion project a new face, planned by a different architect, as an expression of respective contemporary trends. The Wilkhahn company, a leading international manufacturer of chairs and seating, took this approach with its first building in the early sixties. The most recent projects were the production buildings designed by Frei Otto in 1987 and those described here designed by Thomas Herzog in 1992, themselves capable of further expansion. While the interesting suspended shells were the dominant features of the Frei Otto structures, the main focus in Thomas Herzog's low-energy, resource-sparing structure is the emphasis on ecological aspects, both in the design of the building and the choice of materials. In this sense timber represented an excellent choice of building material – a material which Thomas Herzog knows very well, having had many years of experience working with it.

Design | The architect's initial idea was to characterize the solidarity of the workforce, how they stand united, "guarding" the intervening production areas. The sketches of the architect reveal the further evolution of this idea. At the front of the building, four loadbearing two-legged "trestles" (H-frames) are shown spaced

Location
Wilkhahn Wilkening & Hahne GmbH, 31848 Bad Münder-Eimbeckhausen, Germany

Client
Wilkhahn Wilkening & Hahne GmbH

Architect
Prof. Thomas Herzog, Architect BDA, Munich, with Bernd Steigerwald

Planning, Tender Documentation, Site Management
Architekten Haag, von Ohlen, Rüffer und Partner, Bremen, with Dipl.-Ing. Holger Gestering

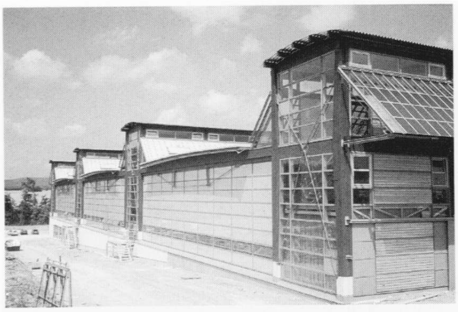
Structural Engineer
Dipl.-Ing. Sailer + Stepan, Munich

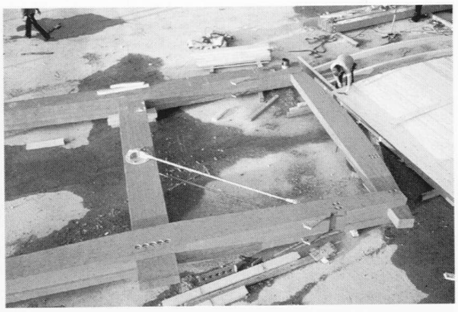
Timber Engineer
Johann Hocke GmbH & Co., Bremen

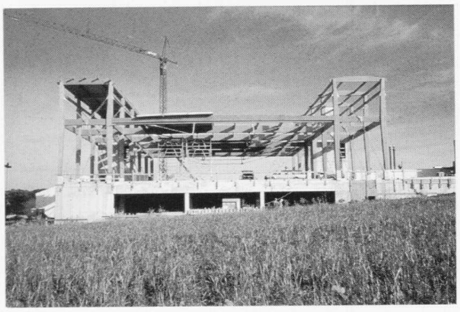
Windows, Façades
LANCO Lange Fenster- & Fassadenbau, Göttingen

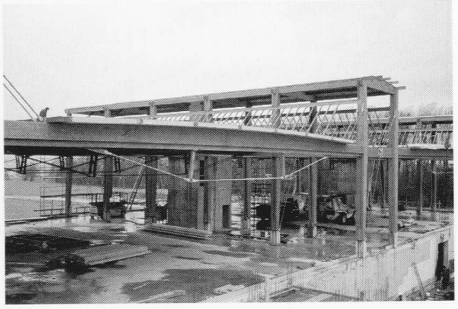
Date of Completion
1992

Costs
The total cost was 15.5 million DM including the reinforced concrete basement and the parts connecting the new and old buildings.







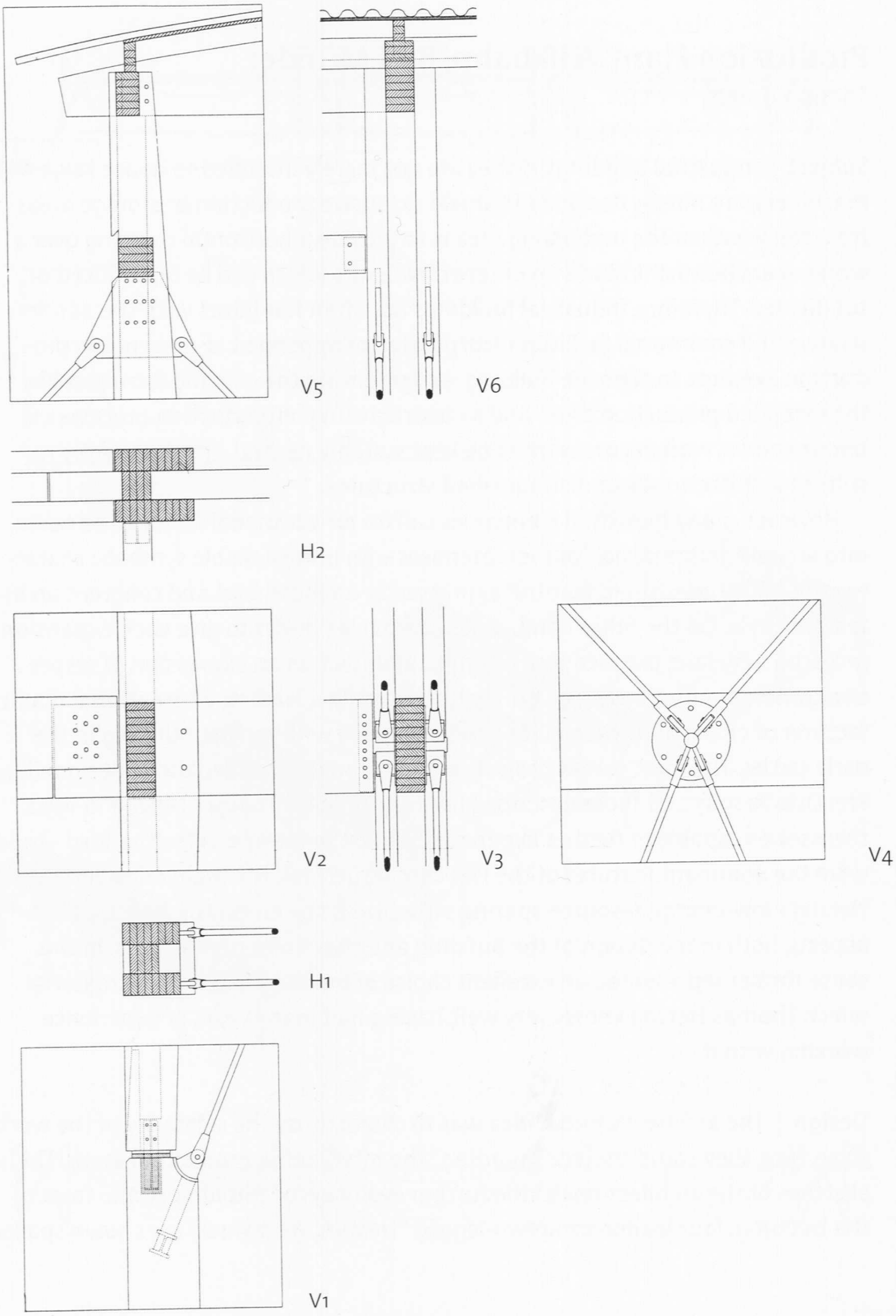


7 | The production building from the south-west. The trussed edge beam of the roof over the production bay is in front of the plane of the façade. Thus the structural system becomes apparent.

8 | Constructing the first two (northern) H-frame blocks with the production bay roof suspended between.

9 | The H-frame is assembled in a horizontal position on site. Visible here are the lateral protections of the intermediate rail, the fixings for the bracing and the curved roof beam at the top.

10 | Production bays and intermediate H-frame blocks after completion of the roof panels. Visible here are the camber of the trussed beam in the centre of the production bay and the round steel sag rods.



11 | Structural details of H-frame, scale 1:50.
V1: Base with concrete plinth. H1: Horizontal section through V1. V2: Frame at intermediate-rail level showing support for production area roof beam. H2: Horizontal section through V2. V3: Section through intermediate rail. V4: Elevation of bracing crossover on intermediate rail. V5: Frame at roof level showing hangers. V6: Section through roof beam showing upper part of frame leg in elevation.

30 m apart. These are fixed points supporting the flat roofs over the production bays. The foundation is formed by a reinforced concrete basement which projects out of the sloping hillside and allows for access and storage zones.

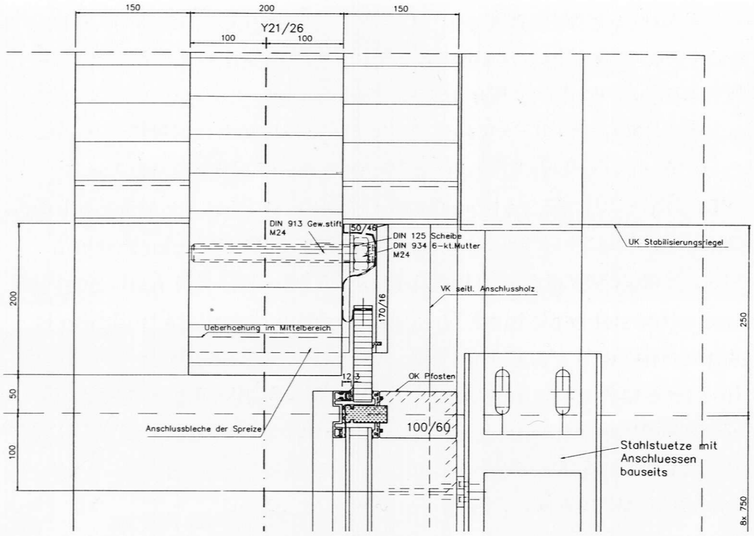
Reinforced concrete access and service cores are located within the 5.40-m-wide H-frame blocks. The three large production bays, each approx. 25 x 33 m, receive daylight through the front and rear walls as well as through the continuous areas of glazing provided between the bays and the H-frame blocks; their sloping profile helps to characterize the look of the façade. The flat roofs over the production bays are extensively planted. The depth of the complete building is 33 m, and it is designed in such a way that two further buildings, spaced 13 m apart and with the same layout, can be added at the rear. Both the production bays and the intermediate H-frame blocks are based on a 2.70 x 6.60 m grid, although for structural reasons the 5.40-m-wide H-frames (2 x 2.70 m) are offset from the grid by 150 mm with respect to the production bays.

12 | The roofs over the production bays are extensively planted. Visible here is the slight rise of the roof beams to provide drainage for the roof planting. The sloping glazing adjacent the H-frame blocks is provided with ventilation louvres.

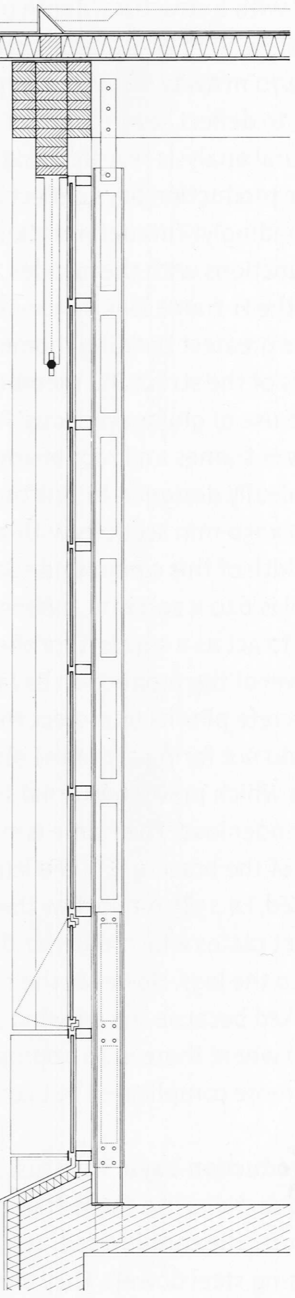
Structure | The desired building profile and the decision to employ timber had a number of consequences. The large-span roofs to the production bays were planned with glulam sections with a structural depth of 1500 mm and trussed with sag rods. The total span of 24.30 m was then shortened by suspending the start of the trussed section – 2.70 m away from the support – from the H-frame. Trussed beams, however, tend to deflect severely under load. This is also true for the H-frame bracing. A structural analysis revealed that in the most unfavourable loading case the roofs over the production bays deflect by up to 60 mm and that the H-frames deform correspondingly! This deformation had to be taken into account when detailing the junctions with the façades and roofs. It also led to the tapered strengthening of the H-frame legs by 300 mm at the level of the production bay roof, where the greatest bending moments occur.

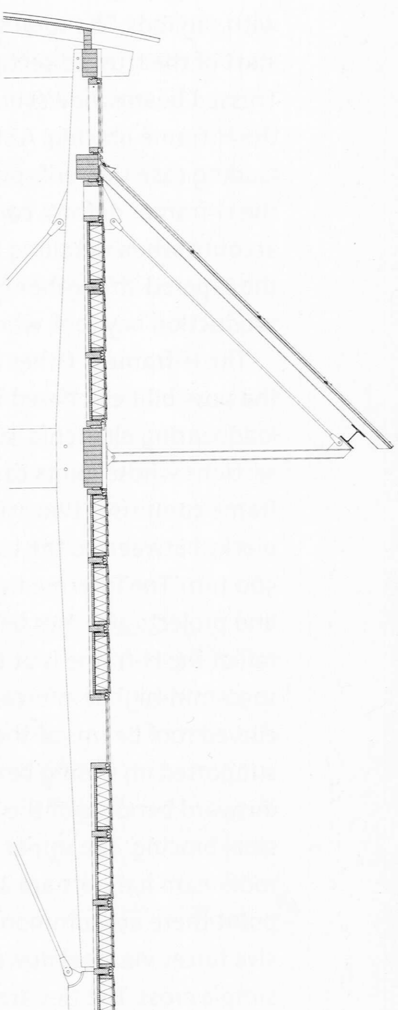
The H-frames: Other details of the structural members evolved purely out of the possibilities offered by the use of glulam sections. For example, the main loadbearing elements, such as H-frames and roof beams, are triple compound sections whose joints can be ideally designed to suit timber. Each leg of the H-frame comprises two 250–550 x 150 mm sections with 200 x 200 mm spacer blocks between so the total width of this compound section is (2 x 150) + 200 = 500 mm. The intermediate rail is 620 x 200 mm, passes between the leg sections and projects 460 mm beyond to act as a support for the roof. The intermediate rail of the H-frame is at the level of the production bay roof. The frames stand on 1050-mm-high reinforced concrete plinths to protect them against impacts. The curved roof beams at the top do not form part of the structural frame; one end is supported on sliding bearings which prevent internal stresses at the calculated outward bending of the legs under load. The frame is stabilized by 36 mm dia. steel bracing. The upper ends of the bracing join the legs at the point where the roof beam hangers are attached, i.e. 1585 mm below the top of each leg. At this point there are common gusset plates which transfer the tensile and compressive forces via steel dowels into the legs. However, the round-bar bracing is not a simple cross. The ties are cranked because the crossing point is located in the centre of the intermediate rail where there is an appropriately shaped gusset plate. Structurally somewhat more complicated but considerably more convincing aesthetically!

Trussed roof beams over production bays: The trussed roof beams over the bays are also triple compound sections like the H-frame legs. At the supports they are placed like a fork around the cantilevered "tenon" of the intermediate rail, to which they are fixed using steel dowels. They are glulam beams with a depth of 720 mm at the supports and 900 mm in the centre of the span in order



13 | Detail of junction between façade and roof beam over production bay, scale 1:10. The tight sliding joint between window façade and beam allows for the movement resulting from the beam deflection under load. The façade is supported by the lightweight steel frame behind, which is at the top propped against the roof and connected via elongated holes.

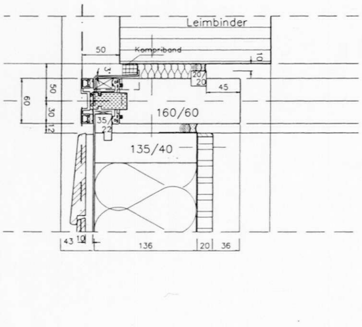




14 | Section through façade to production bay, scale 1:50. The façade is of timber-stud construction comprising 100 x 60 mm glulam members. Behind, bracing made from lightweight steel sections.

15 | Section through south elevation, scale 1:50. The panels in the timber-stud wall (consisting of 160 x 60 mm glulam members) are constructed as follows: 20 mm plywood, vapour barrier, 135 mm thermal insulation between 135 x 40 mm framing, protective sheeting, 10 mm battens, 123 x 21 mm lapped larch weatherboarding. The roof construction is not illustrated.

16 | Detail of connection between rail construction at the panel and the intermediate rail, scale 1:10.



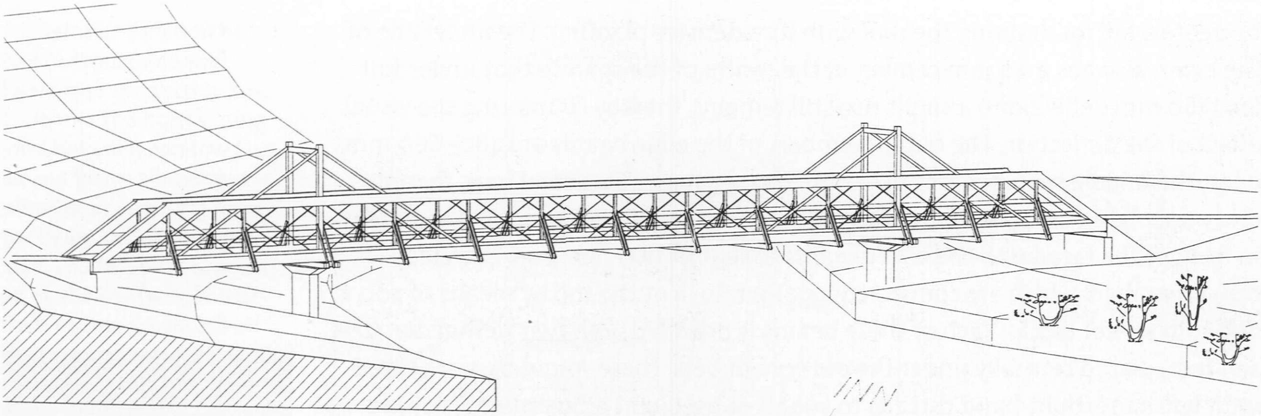
to create a fall for draining the roof with its extensive planting. The underside of the beam also has a 90 mm camber at the centre of the span so that under full load (60 mm deflection!) a slight rise still remains, thereby countering the visual effect of the deflection. The outer members of the edge beams are 480–660 mm deep, the middle member 720–900 mm. The sag rods – St52 steel bars, 52 mm dia. – are placed centrally under the whole cross-section and hence immediately in front of the façade. All the other beams consist of two 720–900-mm-deep outer members which are connected together flush at the top by means of 200 x 200 mm spacer blocks. Each of these beams is provided with two 36 mm dia. steel sag rods, placed centrally under the outer members. These round bars are fitted with left-hand/right-hand threads to enable subsequent adjustment. They are connected via cast-iron forked ends to steel gusset plates which are in turn fixed to the timber beams by means of steel dowels.

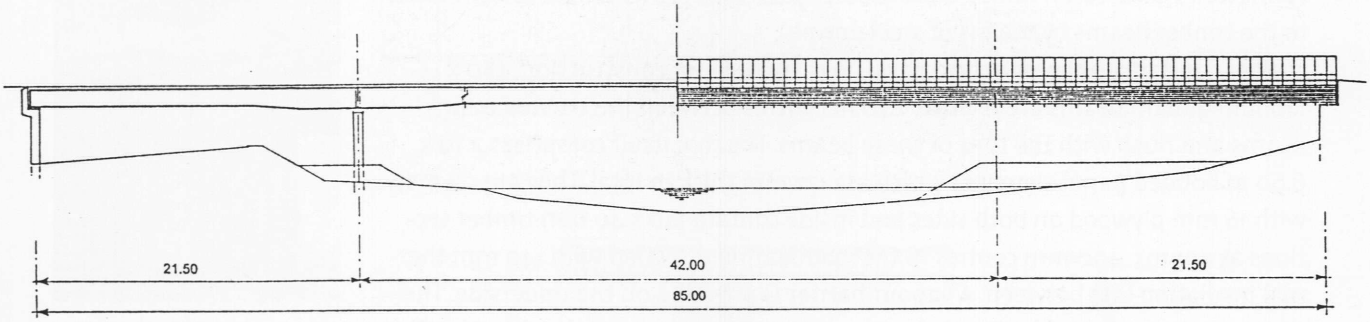
Roof construction, production bays: To carry the roof construction, 480 x 120 mm glulam beams are fixed at 2.70 m centres between the trussed main beams and flush with the tops of these beams. The roof itself comprises 2.70 x 6.60 m bonded panel elements which are 172 mm thick in total. They are covered with 16 mm plywood on both sides and inside contain 140 x 40 mm timber sections at approx. 400 mm centres in the loadbearing direction with 140 mm thermal insulation laid between. A vapour barrier is provided on the underside. The edge panels overhang the façade by 800 mm and are correspondingly wider. This construction serves as a base for the approx. 120-mm-deep substrate for the extensive roof planting. To drain the roof, a slight rise is provided in the middle such that even under loading the lowest edge is still in front of the windows in the H-frame blocks.

Roof construction, H-frame blocks: Here too, the roof consists of large-sized panels, in this case consisting of 100-mm-deep timbers in the loadbearing direction covered with 16 mm plywood. These elements span 5.40 m, are supported on the edge beams between the legs of the H-frames and are pre-shaped to a radius of 15 m. After laying, battens and counterbattens are fixed on the upper surface ready to receive the roof covering of curved, profiled steel sheeting. After attaching the roof covering, 100 mm thermal insulation is fixed to the underside with a vapour barrier beneath, fixed to the loadbearing members. Finally, thermal insulation between 40 mm battens onto which the plasterboard ceiling is fixed. Positioning the vapour barrier between the layers of insulation enables pipes and cables to be laid behind the plasterboard without damaging the vapour barrier.

The façades: The east and west elevations of the building consist of a timber-stud construction utilizing glulam members. In the production bays, welded lightweight steel sections are placed behind the posts to carry horizontal loads. Most of the long elevations comprise thermally insulated, translucent panels (U-value 1.7 W/m^{2}K). The solid panels on the north and south faces are provided with lapped larch weatherboarding externally and 20 mm coated chipboard internally (U-value 0.3 W/m^{2}K).

17 | Erecting the first roofing panel on an H-frame block. The projecting timber members are for the overhanging eaves at the gable.

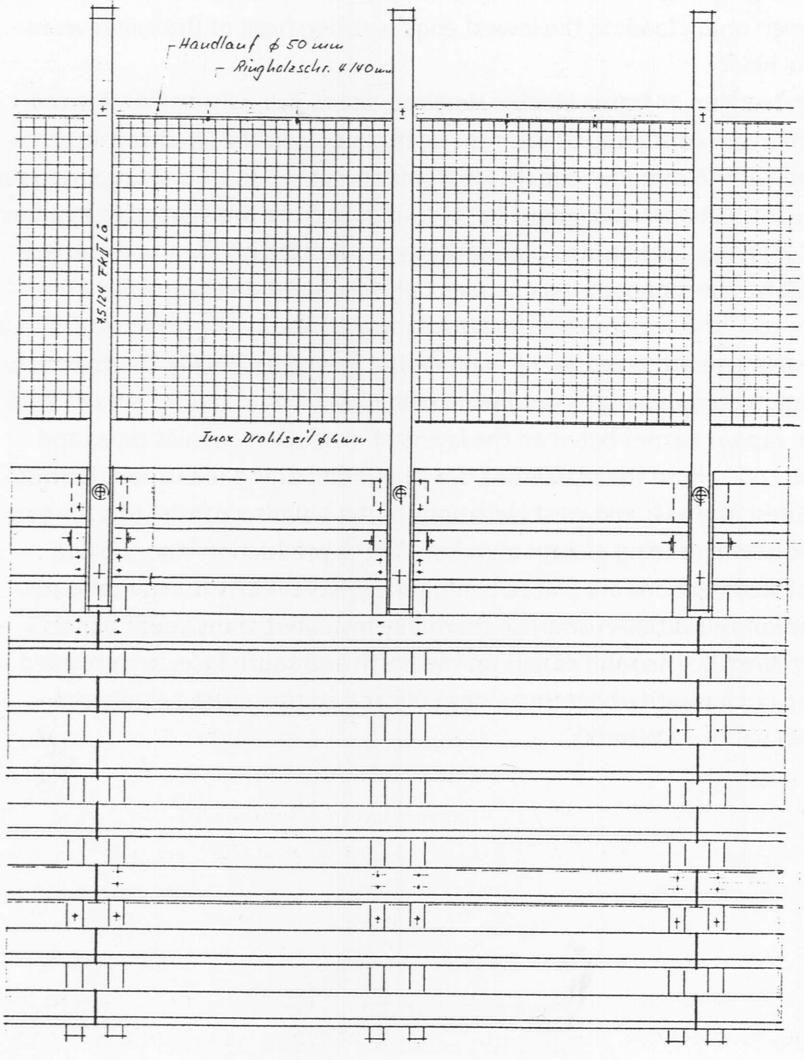


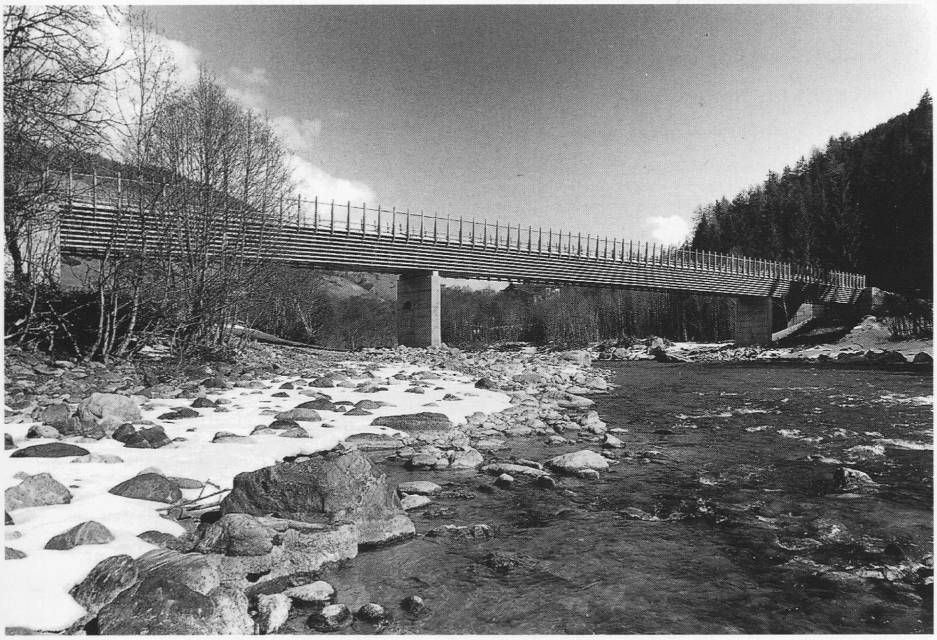


1 | The original design, which was not realized in this form, had deep, cable-stayed girders.

2 | Elevation, scale 1:500. On the right with, on the left, without the side cladding and balustrading. The cantilever joints are situated 7 m beyond the intermediate piers.

3 | Detail of side elevation, scale 1:30.





4 | View of the bridge in its surroundings.

Cross-Country Ski Bridge, Pradella

Walter Bieler, Reto Zindel

Subject | Because of its many mountain river valleys, its vast forests and its wet climate, Switzerland has a centuries-old tradition of bridge-building. This encompasses in particular timber bridges, in all shapes and sizes but always with a roof and side cladding to protect the timber. However, such covered structures were regarded as too heavy – both physically and visually – for modern bridge designs. Open, slimmer structures were called for, utilizing all the possibilities of modern technology. For instance, instead of a roof, the surfacing to the bridge deck can meet the function of providing protection for the loadbearing timber construction. Unprotected secondary members, e.g. balustrading, are regarded as expendable items and are designed to be easily replaced. This was the approach taken by Walter Bieler and his engineering team in their efforts to continue the development of modern timber bridge-building.

Design | Local power company Engadiner Kraftwerke AG wished to erect a cross-country ski bridge over the River Inn about 3 km downstream of Scuol. A design using two 8-m-deep timber girders had already been devised for this purpose, but Walter Bieler's involvement subsequently resulted in a new design in 1990. The positions of the abutments and intermediate piers were retained but instead of the girder merely a 1.70-m-deep bridge beam was proposed which, with the side planking to protect the beams, appeared to be an extraordinarily light and delicate structure, fitting in well with the surrounding landscape. This design was finally approved not only because of the 46% reduction in building costs but also because the structural concept required far fewer loadbearing members and connectors, and thus promised to be a low-maintenance design less prone to corrosion.

Structure | The bridge comprises four 200-mm-wide glulam beams placed at 1000 mm centres over the three spans of 21.50 + 42.0 + 21.50 m. The most favourable and cheapest solution was to employ the cantilever girder principle, i.e. the end spans cantilever 7 m beyond the piers and carry the 28-m-long centre section via two 20 mm dia. bolts per joint. Tensile forces are transferred to the beam ends

Location
Pradella, near Scuol, Switzerland

Client
Engadiner Kraftwerke AG, Zernez, Switzerland

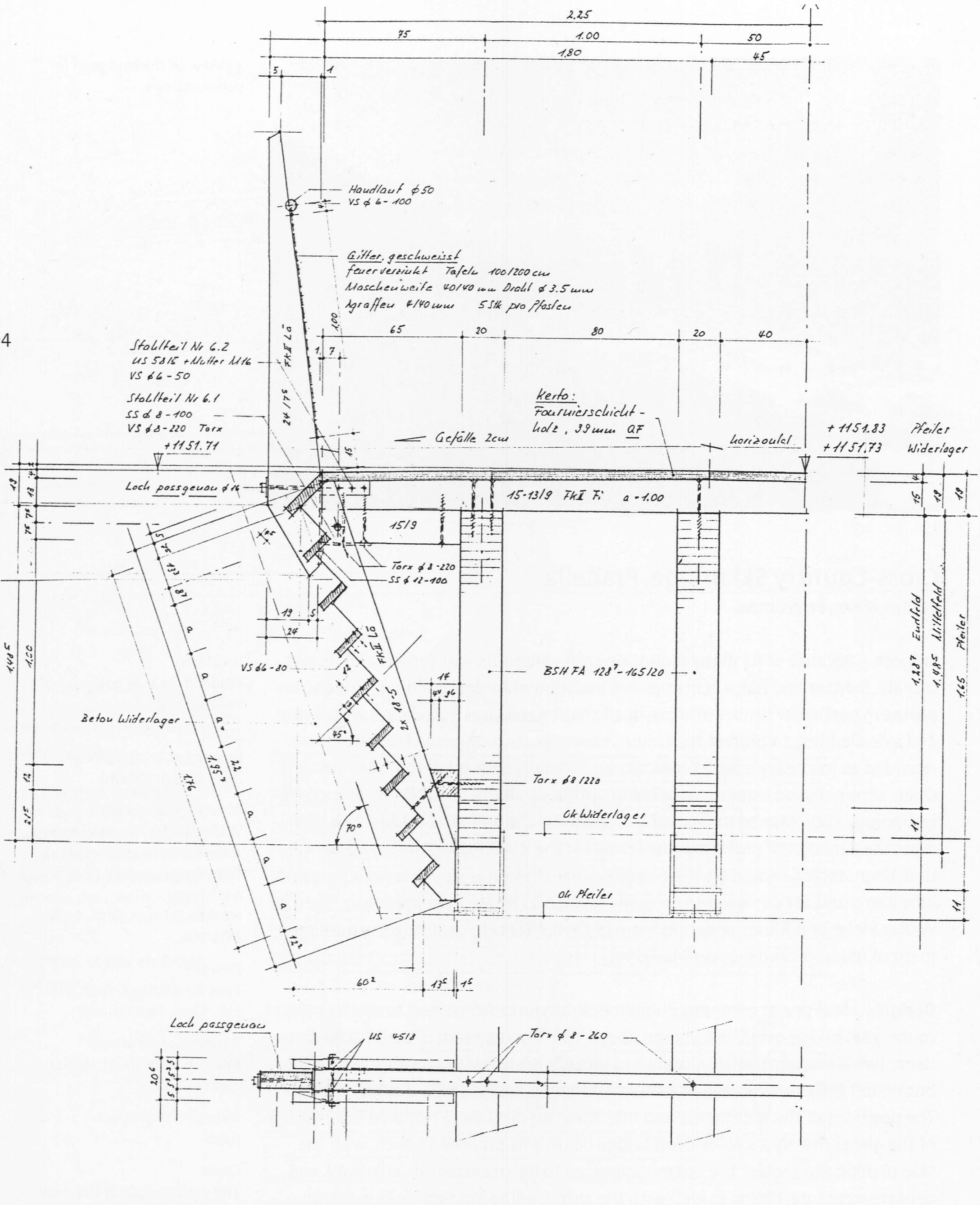
Structural Engineer
Walter Bieler Ing. SIA, Ingenieurbüro für Holzkonstruktion, Bonaduz, Switzerland
Assistant
Marcus Schmid, Dipl.-Arch. ETH/SIA.

Design
Reto Zindel, Dipl.-Arch. ETH/SIA., Chur, Switzerland

Timber Construction
Malloth + Söhne, St Moritz, Switzerland

Date of Completion
1990

Costs
The cost, including the deck surfacing but excluding the concrete works, was about 460 000 Swiss Francs.



5 | Cross section, scale 1:25. The loadbearing construction consisting of four 1287–1650 x 200 mm glulam beams, 130–150 x 90 mm transverse deck beams, 39 mm KERTO veneer laminated wood panels. Balustrading: 50–240 x 70 mm posts, to which the 50 mm dia. steel handrail and steel mesh infill are fitted.
Weather protection: 120 x 30 mm planks supported on 180 x 50 mm members cut to a sawtooth shape and fixed at an angle on the bridge construction.

by means of steel channels. Suspending joints in timber beams is advisable so that the timber is always in compression and is not subjected to shear failure. The depths of the main beams vary: 1287 mm in the end spans, 1485 mm in the centre span and 1650 mm over the supporting piers. Attached to these main beams are the transverse deck beams at 1000 mm centres: 80 mm wide and varying in depth from 150 mm in the middle to 130 mm at the edges. This produces the gentle camber required for drainage purposes.

KERTO veneer laminated wood panels, 39 mm thick, are screwed onto the deck beams. These panels not only carry the imposed loads, they also brace the bridge against wind and horizontal forces. The surface of these panels is sealed with a liquid polyurethane material on a bonding coat and then finished with AB11N asphalt as the deck surfacing and weatherproofing. The deck beams cantilever 650 mm beyond the edge beams. These cantilevers are strengthened by 150 x 90 mm sections screwed on underneath. Bolted onto the now 280-mm-deep beam ends are the posts for the balustrading: 75 mm wide x 240 mm deep at the fixings, tapering to 50 mm at the top. Also attached to both sides of the strengthened ends of the cantilevers is the framing for the protective cladding comprising horizontal planks. This framing is fixed at an angle of 70° to the outer main beams. The 120 x 30 mm planks at 220 mm centres are placed at 45° to the horizontal and hence protect the loadbearing main beams against the weather.

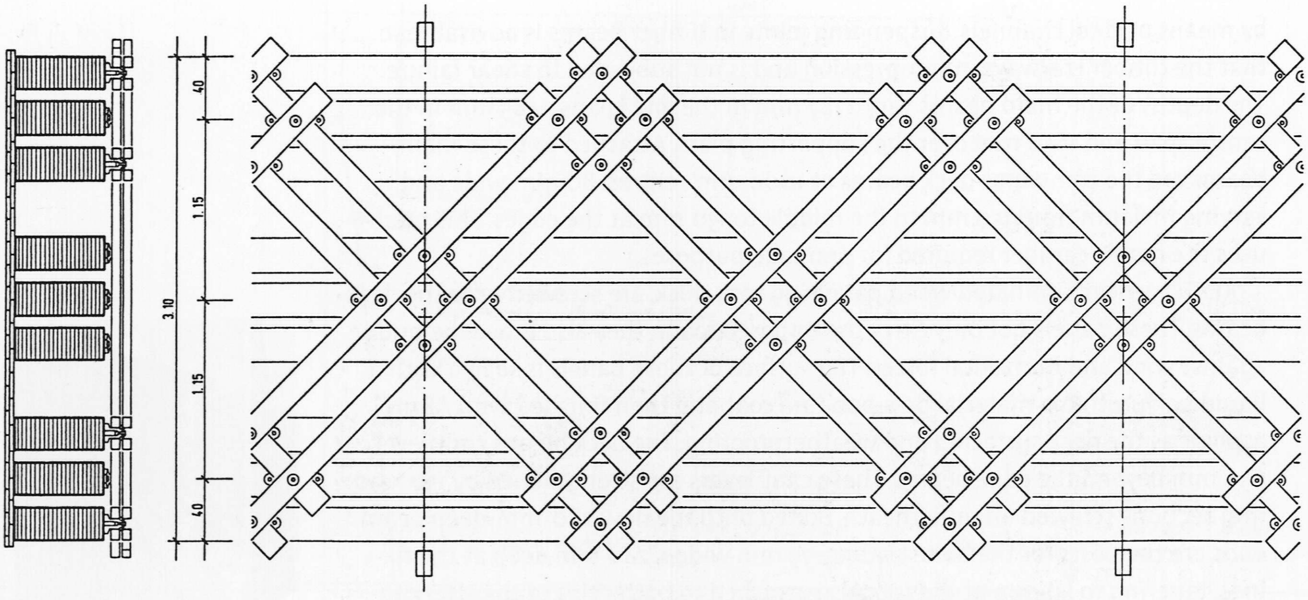
The balustrading consists of a handrail made from hot-dip galvanized tubing, 50 mm dia., and a welded, hot-dip galvanized mesh infill panel, 3.5 mm-dia. wires in a 40 x 40 mm mesh, all screwed directly to the posts. All timber members subjected to the weather, such as posts and protective cladding, are made from weather-resistant larch and easily renewable in case of rotting. Chemical preservatives were therefore not necessary.

6 | The balustrading during construction.

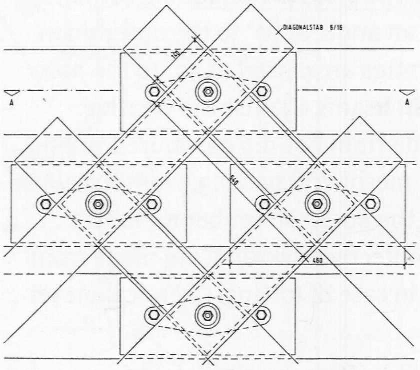
7 | Erecting the protective cladding and the posts for the balustrading from a movable platform.

Construction | The timber construction company was responsible for organizing transport, intermediate storage and the entire assembly procedure. They set up temporary erection towers under the joints in the main beams; a number of forked mountings, used to support the beam ends during erection, were temporarily fixed to the concrete piers. Two mobile cranes were used, one on each bank standing on tipped rubble embankments. It took only four days to erect the beams and lay the deck surfacing, helped by the fact that the deck beams and posts for the balustrading had been prefabricated into U-shaped elements prior to transportation.

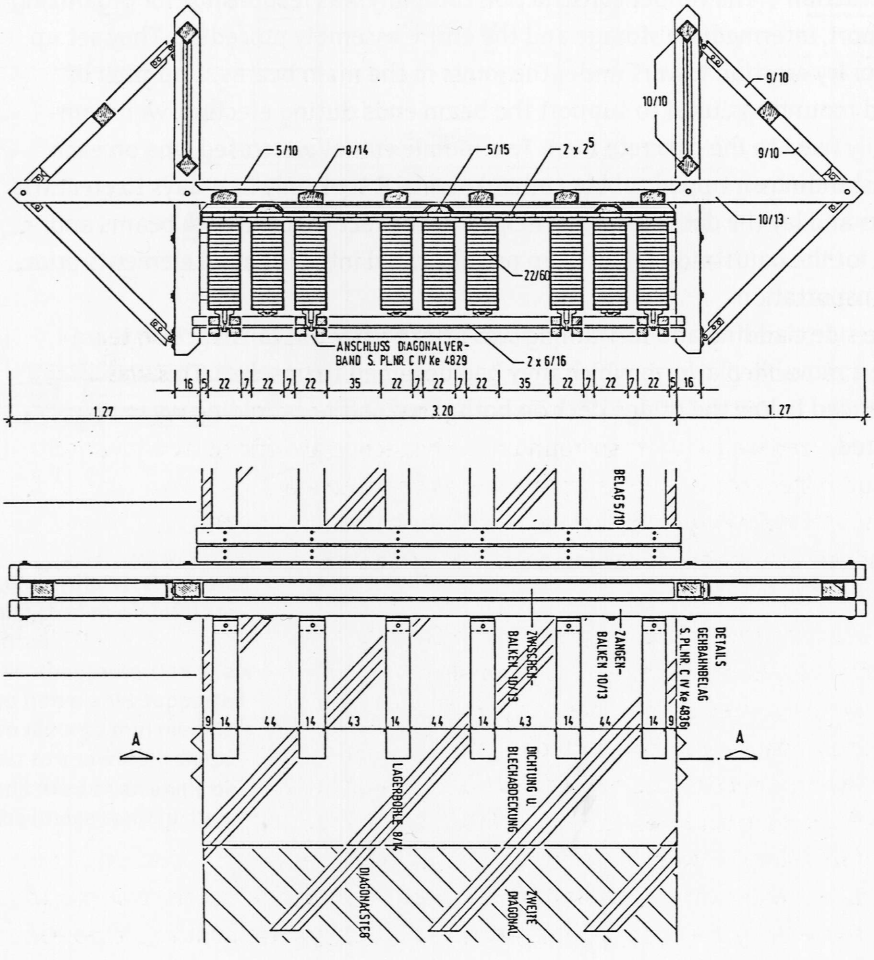
The side cladding and its framing was attached by the construction team using a movable platform which they had designed themselves. This was suspended below the bridge deck on both sides; soffit scaffolding was not required.



1 | Diagonal bracing under bridge beams, scale 1:50. The 4.60 m grid length determines the parapet post spacing.



2 | Formation of a point of intersection of the diagonal bracing, scale 1:20. The 60 x 160 mm diagonal timbers intersect at two levels. All the screw connections remain visible and accessible for inspection purposes. The nailed plates are pre-drilled and in part have perforated disks welded to them. The castings of GS 52 bolted to them transmit the intersection point loads of the bracing to the main girders.



3 | Section and plan of bridge, scale 1:50, showing the various layers.

4 | The bridge with surrounding countryside.

Bridge in the Altmühl Valley, Essing

Richard J. Dietrich

Subject | Bridges have long been a domain of civil engineers. Since structural and technical problems prevail, architects are at the most asked to help in a creative capacity. And yet bridges are structures that can dominate whole stretches of countryside and, when all's said and done, can also lay claim to being part of town or city planning and of architectural importance. The planning of such structures thus calls for a person who combines to an equal and high degree technical with artistic ability.

A good example of this is the bridge over the Main/Danube Canal near Essing in the Altmühl Valley. Here the valley of the Altmühl is of particular beauty. In gentle curves the hills dip towards the valley bottom. At the foot of a castle-crowned bluff on a narrow river bank lies the old town of Essing with its picturesque gables and towers. Here a new bridge had to be built to span the canal and its service roads, the new highway and thus the whole of the valley from one side to the other.

After considering a number of designs the client, building authorities and townsfolk decided in 1978 in favour of the novel multispan design by the architect Richard J. Dietrich. With its undulating outline and seeming weightlessness it harmonized well with its surroundings. The technical difficulties it involved were admittedly considerable. In fact, it was not until 1986, after seven years of planning and development work and with the help of engineering know-how and advanced timber construction technology, that the unusual structure was finally realized.

Based on the age-old principle of the freely suspended rope bridge, a continuous band of glulam beams runs ropeway-like from one massive bridgehead to the other over three trestle-shaped piers. With this computed curve, which results in the load being transmitted to 90% in the form of tensile forces, a slim 600 mm cross-section was possible. A row of beams subject to bending over the 75 m of the main span would have had to be six times as high. For a tensile structure of this shape wood is especially suitable, both statically and – in contrast to pure rope constructions – dynamically, for oscillations caused by the crossing of pedestrians or by the wind are absorbed by the material itself without the need

Location
Altmühltal, 93343 Essing, Germany

Client
Rhein-Main-Donau AG. Munich

Design and Construction
Dipl.-Ing. Richard J. Dietrich, Architect, Traunstein
Project Architect
Dipl.-Ing. A. Skrabl

Structural Engineer
Ingenieurbüro Prof. Dr. H. Brünninghoff and Dipl.-Ing. Rampf, Ulm

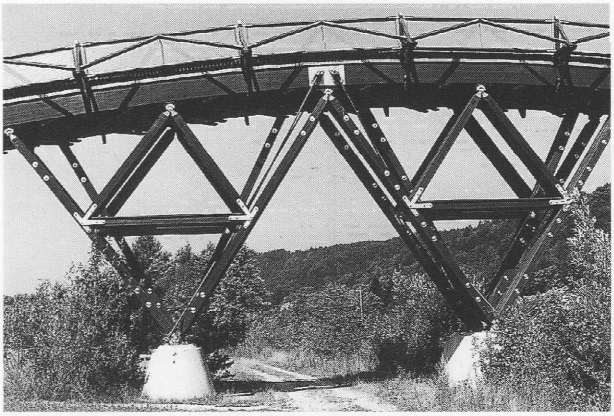
Building Dynamics
Prof. Dr. F. Grundmann, Munich

Timber Construction
Huber & Sohn GmbH & Co KG, Regensburg

Date of Completion
1986

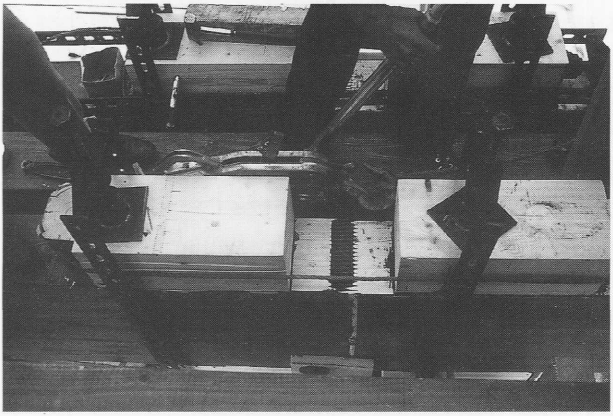
Costs
Excluding incidentals and special expenses the bridge cost 3.5 million DM to build (5000 DM per m^2 of bridgeway). The development costs for special engineering and material tests and the costs of special structure-stabilising measures were about 350 000 DM.

5 | Intermediate wood trestle supports.

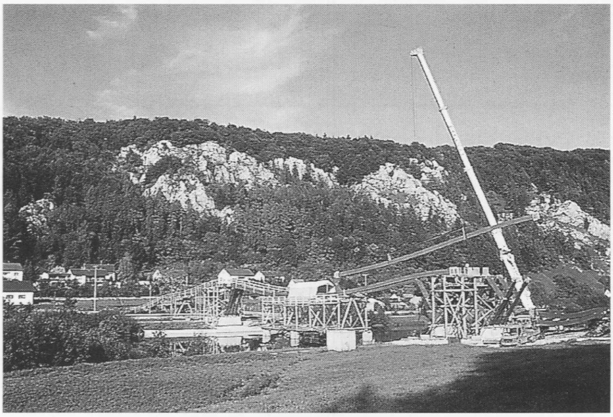


6 | Bridgehead.

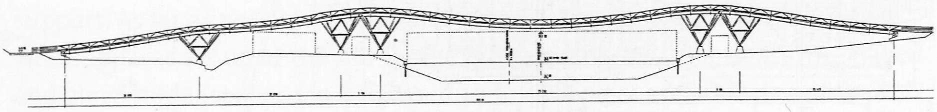
7 | In-situ butt-jointing of a main beam by finger-jointing and gluing.



8 | Lifting in a 40 m main beam.



for further stabilisation. In the case of wood there can be hardly any build-up of natural oscillation. The construction was optimized by means of wind tunnel tests. To prevent twisting of the slim girder row by lateral wind loads the system has been given a box-like cross-section and braced; on top it has a double layer of diagonal boarding, on the underneath side diagonal bracing of squared timbers.


9 | Overall view of bridge, scale 1:1500.

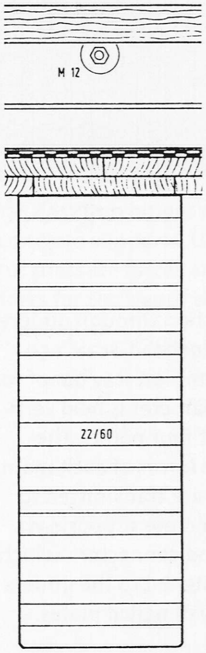
Structure | The overall length of the wooden bridge structure between the massive bridgeheads is approx. 195 m, the clear width of the footway 3.20 m. The structure is designed to carry a traffic load of 500 kg/m^2 and will thus take light cleaning vehicles and ambulances. Nine 220 x 600 mm shaped glulam beams extend from abutment to abutment in a single band over three trestle piers. The system of beams thus covers four spans of 30, 32, 73 and 35 m. The diagonal bracing on the underneath side of the glulam beam system, built using 60 x 160 mm timbers, displays a continuous lattice grid that determines the coordinates of the bridge beams. Jointing of the lattice bracing has been performed in such a way that the superimposed diagonal timbers display common points of intersection with those beneath them. Through these points of intersection runs the line of coordinates which determine the positions and dimensions of all the other parts of the structure and the bridge parapet latticework. Grid length and thus the parapet post spacing is 4.60 m.

The intermediate wooden bridge supports are in the form of trestles that open out fanlike towards the top. They are carried by concrete piers. The timbers of the trestle-type intermediate supports, hinged to the bridge beams, carry the vertical forces from each line of beams separately into the concrete supports. Horizontal wind forces are absorbed by diagonal steel ties within the supports.

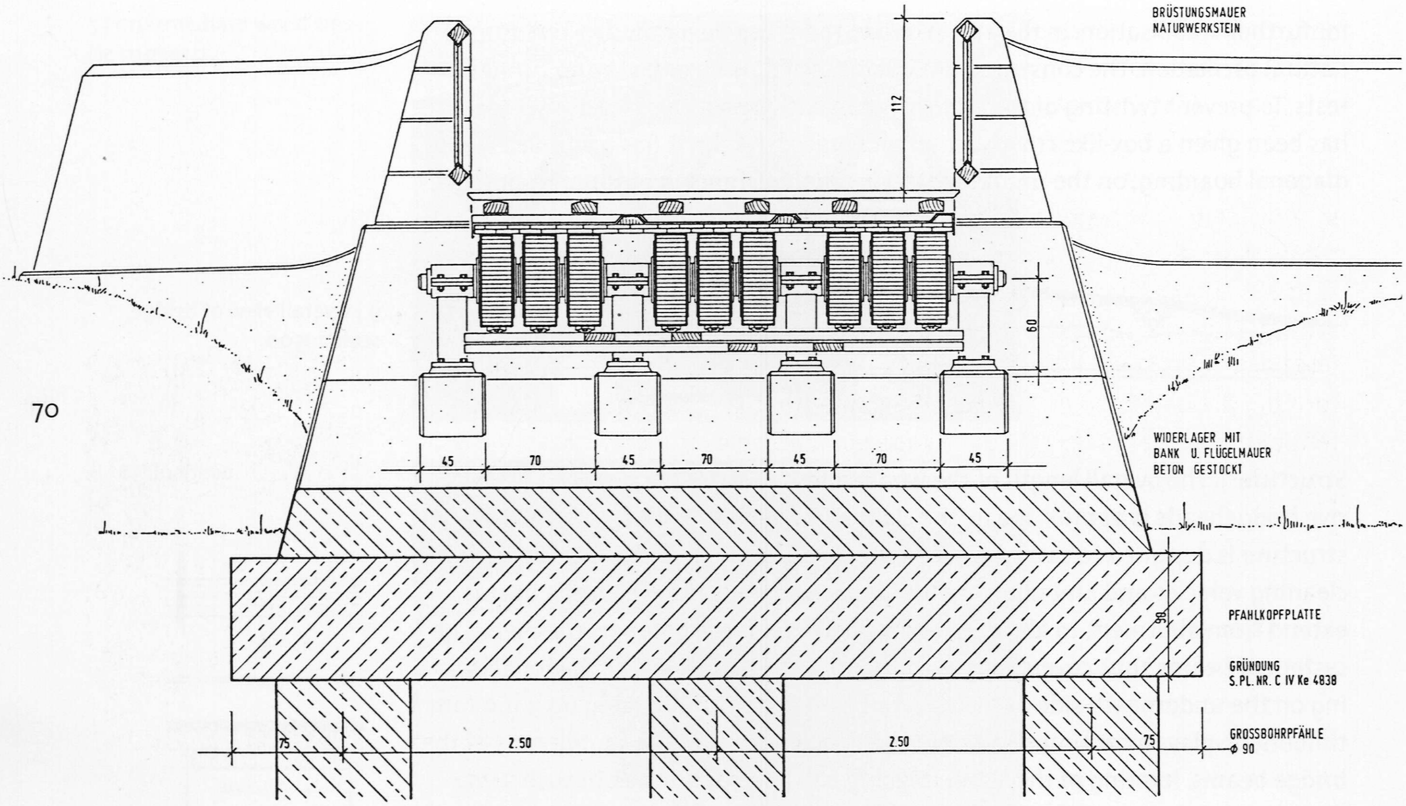
The connecting elements are in the form of cast iron hinges, which transmit the forces acting at various angles smoothly and free from strain into the bracing. The hinge pins perform merely a holding function, serving also to counteract slight lifting forces at individual points; the main pressure forces are transmitted directly by the hinge straps and cups. The hinges are the same for all the points of intersection.

At the bridgeheads the main forces of the structure are transmitted as tensile forces of a magnitude of some 4000 kN. These bridgeheads are massive reinforced concrete abutments carried by large cast-in-situ concrete piles and held secure by ground anchors. The pull of each line of beams is absorbed by the concrete abutments via steel fork-end fasteners and stretching steel anchors prestressed to 500 kN. In order to prevent inadmissible strain at the sensitive prestressed bearings caused by deformation of the bridge girder system all the forces are led into the supports by way of a common pivotal point. The vertical and lateral forces are led away via shafts on raised brackets, at the side of and between the grouped beams, to the supports. The brackets remain stable only for vertical and lateral forces; in the pretensioned direction they are more or less flexible. All the important structural parts are left visible and accessible for inspection purposes.

The parapet is a lightweight, braced timber construction. At a coordinate spacing of 4.60 m there are two beams perpendicular to the roadway that cantilever out at footway grid height. These carry the outlying diagonally strutted parapet



10 | Detail of top covering, scale 1:10. On the girders double 25 mm diagonal boarding, 50 x 150 mm canted diagonal planks, double welded bitumen sheeting, over this a titanium-zinc covering, on Neoprene intermediate layers and 80 x 140 mm timbers the footway grid with 50 x 100 mm beams of bongossi. The cantilevered 100 x 130 mm timbers for the parapet posts of larch.



11 | Section through girders at bridgehead, scale 1:50. The common stay bar of 100 mm diameter is held vertically at four points. The tensile forces of each main girder are transmitted to the concrete supports via fork-end connectors, which are fastened to the girders by way of nailed plates.

posts by means of gripper-type connectors. These components are the same throughout the whole of the bridge and were completely prefabricated at the factory. Fixed between the parapet posts are two 100 x 100 mm parapet beams, the upper one of which is braced in the middle by outlying diagonal timbers. The space between the top and bottom parapet beam is filled by a framework of angle steels holding a welded steel wire lattice. At all the intersections of the parapet framework are identical fasteners consisting of head plates with hinge sleeves and two connectors designed to adapt to any angle. Between the parapet connectors and independent of the suporting structure there is a wooden grid-type footway covering designed to take loads of up to 10 kN as required by vehicles. 50 x 100 mm bongossi planks are screwed to 80 x 140 mm supporting beams, also of bongossi, with a space in between. These grids are fixed only to the parapet connectors, so as to avoid any penetration of the bridge girder system covering. Convex bending of the bridge girder system causes downward movement of the grids; when concave movement occurs they adapt to the change. The footway grids are renewable.

Because of the high loads involved all the connections are of steel castings produced by a state-of-the-art technique. Nailed connections have also been used since high forces can be led effectively to the wood via nailed plates. Apart from that, nailed plates can be precision-fitted at the works and are not in the way during transportation. On the site, projecting castings and other connectors can also be bolted to the nailed plates.

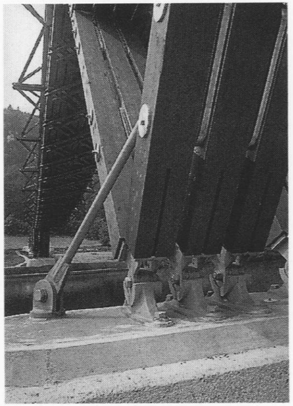
All the parts of the main structure are of Class I glued laminated fir. The double diagonal boarding on top of the bridge girders is of Class II fir, the squared timbers of the underneath diagonal bracing of solid Class I fir. To withstand weathering the bridge parapet is of larch, the footway covering of bongossi. All the steel parts are of stainless steel, the steel castings of hot-dip galvanised GS 52.

As weather protection for the bridge girder system the top diagonal boarding is covered with a double layer of welded bitumen sheeting and, on top of that, with zinc sheet. Rainwater is led away alongside the diagonal planks, except over the highroad, where it is collected in gutters and disposed of to the side of the road via waterspouts. All the parts of bongossi are protected by an air-permeable varnish applied in three layers over a primary waterproof coating.

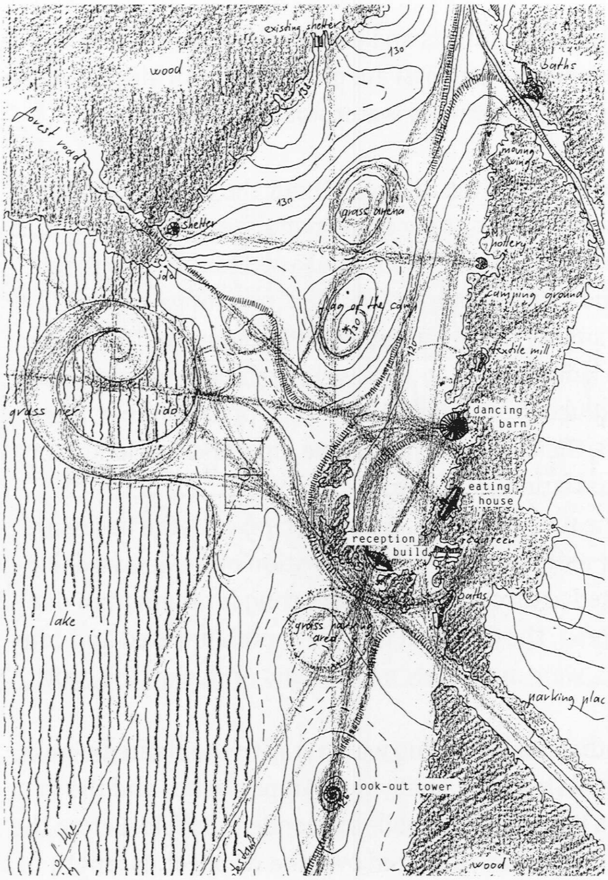
Construction | It was decided to erect the bridge without the use of scaffolding, by utilising the inherent stability of the girder band, prefabricated in sections at the works. For on-site assembly only trestles were thus used for point to point support. As far as possible the various components were prefabricated. A field workshop was set up at the site for the pre-assembly of larger units. The shaped and glued girder sections in lengths of 30 to 43 m were prefabricated at the factory and finger-jointed and glued (butt-jointed) with such precision that, after tensioning at the abutments, there were no noticeable differences in length or height between the individual strings of girders.

The next step was to fit the underneath diagonal bracing with the necessary precision using a suspended mobile scaffold. Accumulation of the unavoidable tolerances had to be prevented at all costs by compensating for them from one point of intersection to the next. The diagonal members, prefabricated and complete with their nailed plates, were accurately marked and drilled on the spot with hole cutters.

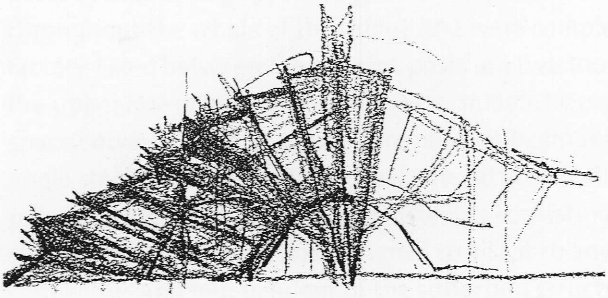
After that the top double diagonal boarding was laid with the slanted planks, the sealing layer and the metal sheeting. Finally the parapet lattice and the footway grids were fitted using a lightweight, mobile suspended scaffold. Before the bridge was opened to the public it was subjected over the whole of its length to a loading test with water-filled containers, which confirmed the structure's computed stability.



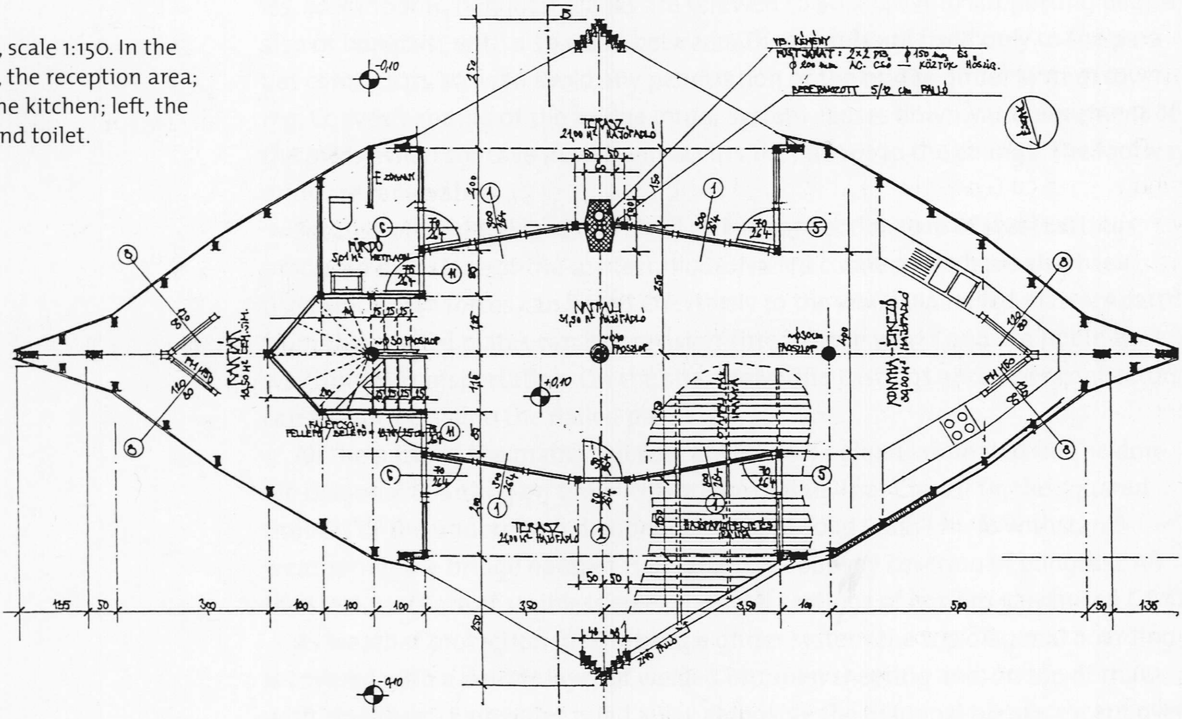
12 | Cast iron hinges on concrete supports: the cups for pressure forces and the forks for the ties of the wind bracing.



1 | Site plan. In the south, the lookout tower; in the middle, the reception building.



2 | Architect's conceptual sketch of reception building.



3 | Plan, scale 1:150. In the middle, the reception area; right, the kitchen; left, the stairs and toilet.

4 | View of reception building.

Lookout Tower and Reception Building, Nagykálló

Dezsö Ekler

Subject | Dezsö Ekler is a young advocate of "organic architecture" in Hungary. This movement is dedicated to the revitalization and self-orientation of original Hungarian architecture. The American architect Frank Lloyd Wright was a pivotal figure in the emergence of organic architecture; at the beginning of this century he postulated an autonomous architecture for the American democracy. This style was to attain its specific form through the correct use of materials, the organic embedment of a structure in its surroundings and an unmediated artistic expression. Károly Kós (1883–1977), the founder of "The Young Ones" group, defined the basis of Hungarian architecture thus: "The roots of our constructive art lie in the Middle Ages, the roots of our national art lie in folk art." He saw himself very firmly in the tradition of the English pre-Raphaelites and the Arts and Crafts movement of Ruskin and Morris. In the post-war years, particularly after the failed Hungarian uprising of 1956, the ideas of this movement were spread by Imre Makovecz in particular. Dezsö Ekler worked in Makovecz's planning cooperative MAKONA from 1987 to 1990.

The Nagykálló-Harangod cultural summer camp is intended for young people who wish to cultivate the traditions of Hungarian folk art: singing, dancing, weaving, carving, etc. Those taking part live in tents but the communal facilities are housed in permanent buildings. Each year from 1986 to 1989, the groups erected one of these communal buildings themselves under the supervision of an architect, namely Dezsö Ekler. Built under this scheme were the dance hall (1986), the dining hall and bathrooms (1987), the lookout tower (1988) and the reception building (1989). All these structures were built as a collective effort according to the architect's sketches, and only later were proper drawings prepared in order to satisfy the building inspectorate. This working together with the materials at hand led directly and rapidly from conception to finished structure.

Design and Structure Reception Building | Apart from the actual reception area itself (about 30 m^2) there was to be a small kitchen, a toilet and a small common room on the upper floor. Ekler decided on the shape of a symmetrical "fowl" which appears to crouch in the landscape with open eyes. The whole building

Location
Cultural Summer Camp near Nagykálló-Harangod, Hungary

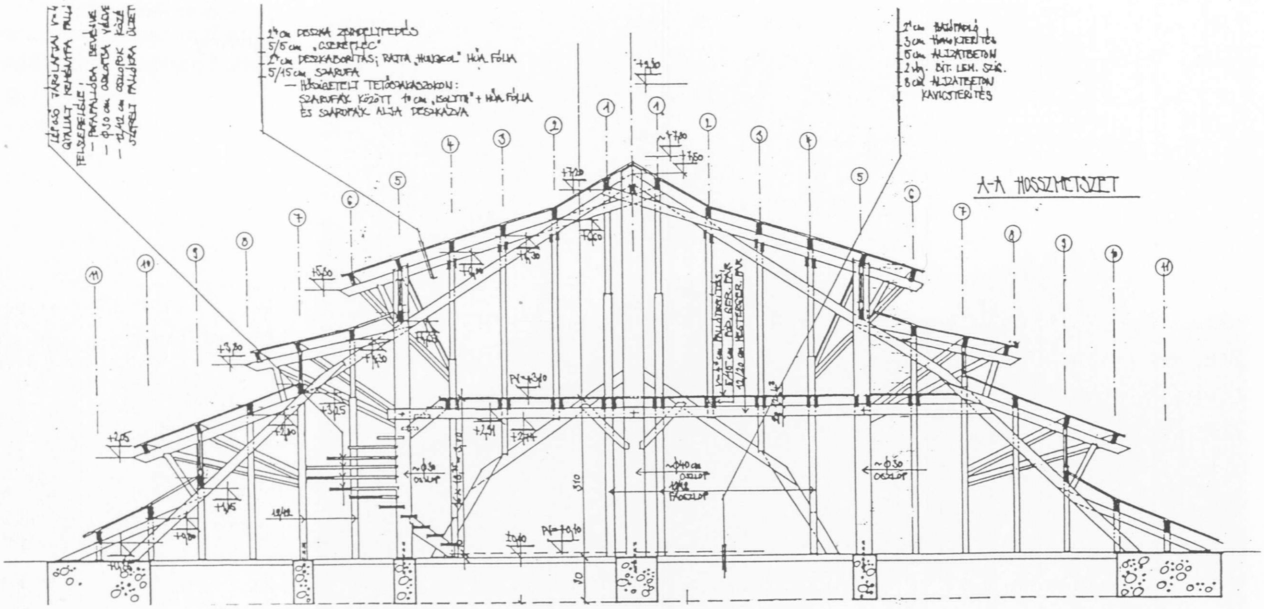
Client and Owner
Nagykálló Local Council

Architect
Dezsö Ekler Építész KFT, Budapest

Construction
Both structures were built by young people attending the camp in the summer, planned and carried out under the supervision of the architect.

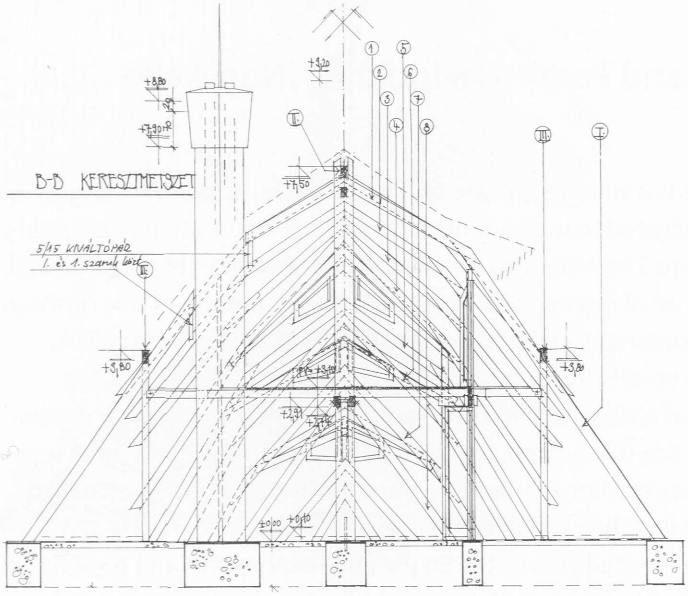
Date of Completion
1989

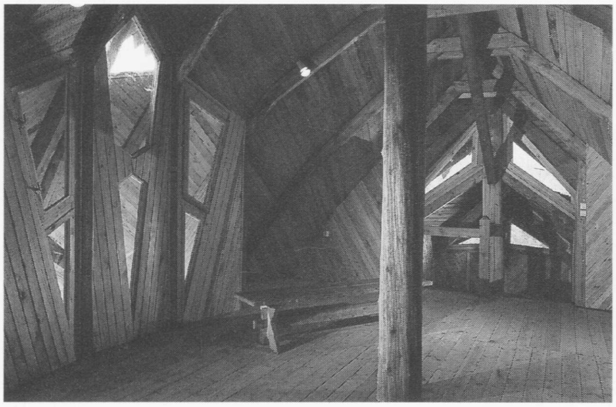
Costs
No labour costs were incurred.



5 | Longitudinal section, scale 1:150.

6 | Section, scale 1:150. Here, in the widest, central part of the building, the external walls provide intermediate supports for the ties carrying the upper floor.





7 | Common room at upper floor level showing exposed roof construction.

8 | The lookout tower seen from the reception building.

appears to be just a roof made from irregular bands of long planks which rise along the centre axis to form the various clerestory windows.

Structurally, the building consists of a loadbearing 120 x 150 mm ridge purlin which is supported by one central post 400 mm in diameter and two 300-cm-diameter posts spaced at 4.50 m from the central post. The ridge purlin is cranked over the central post and at the upper floor level with notched joints and so forms the organic, rounded shape of the building. The ridge purlin supports 75 x 150 mm rafters at 1 m centres which themselves are also cranked. Each is held in place by two 50 x 150 mm ties or by trimmers at the entrance opening or on the fireplace side. The ties support the upper floor made from 45 mm planking. In the centre of the building the ties are carried on two 120 x 200 mm beams which are fastened on both sides of the three posts, and at one end are also attached to the ridge purlin. At the other end, these centre beams are cut back to accommodate the stairs which wind around the 300 cm post at this end. As the ridge purlin is not supported by the centre beams at this end, a vertical 120 x 120 mm post is provided to carry the purlin. The roof rises locally to accommodate dormer windows; this is achieved by means of 50 x 150 mm auxiliary purlins arranged like firring pieces on the ridge purlin, and additional angled rafters. This forms the basic skeleton for the organic overall shape.

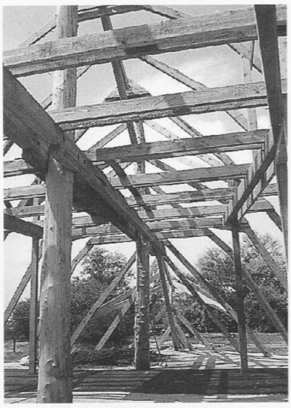
The roof surface over the rafters is constructed as follows: 25 mm timber boarding forming a flat base on which a polyethylene vapour barrier is laid, 50 x 120 mm members with 100 mm thermal insulation laid in between, then 25 x 50 mm battens and the lapped weatherboarding consisting of 25 mm planks impregnated to protect them against rot and fire.

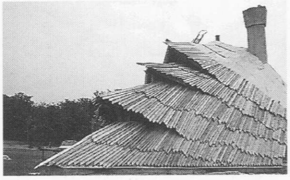
All loadbearing posts are made from robinia, which possesses greater strength. The other members – purlins, ties, boarding, battens, etc. – are made from pine.

Design and Structure Lookout Tower | The tower is actually only a double spiral of two stairs which are carried by rings of timber posts (again robinia) leaning outwards. The observation platform is at a height of about 9 m. This design, opening up towards the sky, exhibits an unconventional floral dynamic. And the high central post with its branches at the top is reminiscent of an old totem pole. Not a "hands-on" but rather a "walk-on" work of art with mythical associations!

The central "pole" has a diameter of 300–400 mm and is approx. 18 m high. It consists of two parts spliced together at a height of +7.20 to +8.80 m above the foundation to form one single member. The stairs rise in a spiral between the auxiliary posts (dia. approx. 250 mm) leaning outwards, approaching closer to the central pole as they rise, reaching the approx. 2.60-m-diameter platform at a height of about 9 m. At the bottom all posts are cast into a 1000-mm-deep concrete foundation. To prevent rotting of the posts at this problematic interface, the top surfaces of the foundation slope outwards. In addition, where they are in contact with the ground the posts are given several coats of bitumen and, where in contact with concrete (at the fixed base), they are charred and then briefly sprayed with water prior to being cast in. The ground above the foundation around the posts is also provided with an outward fall.

The two stairs rise offset by 180°, i.e. exactly opposite, and at the same pitch. This enables an extremely simple construction. Each opposing pair of posts is joined by two 140 x 200 mm ties connected together and to the central pole. These pairs of ties rise in a spiral matching the stairs, thus forming the supports for the stringers. These stringers are not conventional inclined members but instead, short 80 x 200 mm pieces placed horizontally and bolted together. The front offsets determine the pitch of the stair and the oak treads are fixed here.





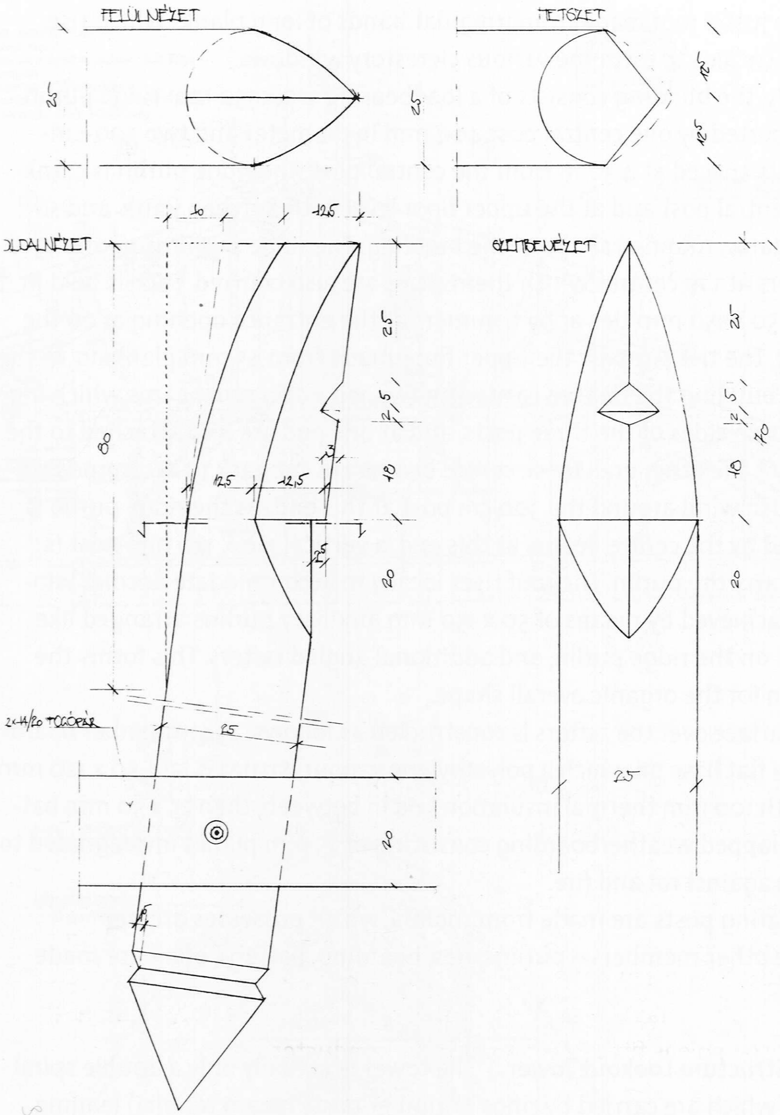
9 | The timber framework during construction: View looking along the centre axis.

10 | The double ties carrying the upper floor with main beams and loadbearing posts.

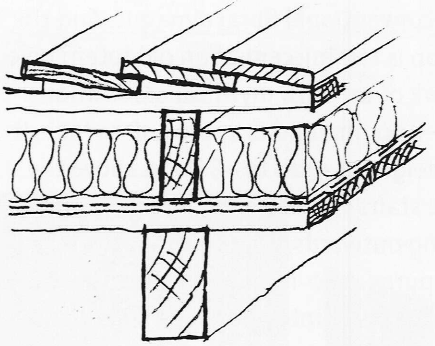
11 | The raised roof sections for the windows above the central purlin.

12 | Fixing the roof covering.

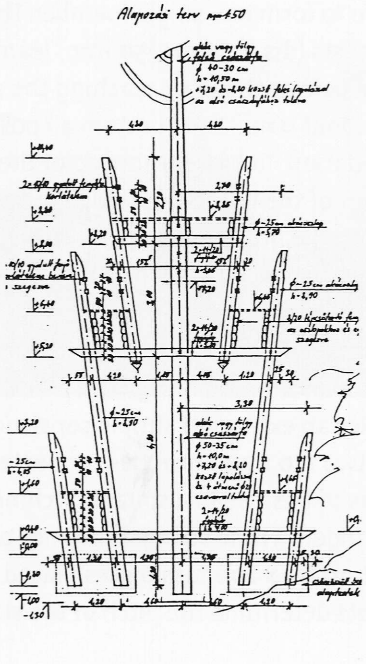
13 | End of post, lookout tower, scale ca. 1:15.

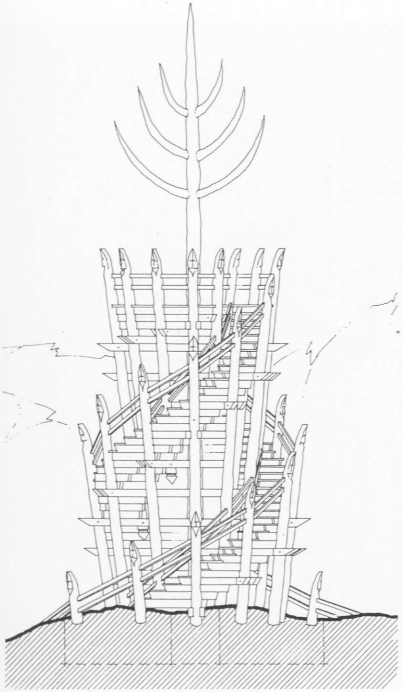


14 | Detail of roof construction, reception building, scale 1:10. From bottom to top: 75 x 150 mm rafters, 25 mm boarding, polyethylene sheeting, 50 x 120 mm members with 100 mm thermal insulation laid between, 25 x 50 mm battens, roof covering made from 25 mm lapped weatherboarding.

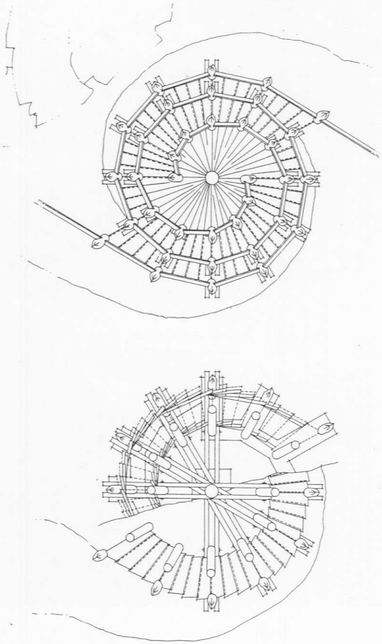


15 | Section of lookout tower.



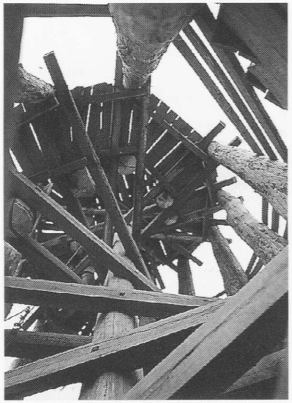


16 | Elevation of lookout tower, scale 1:200.



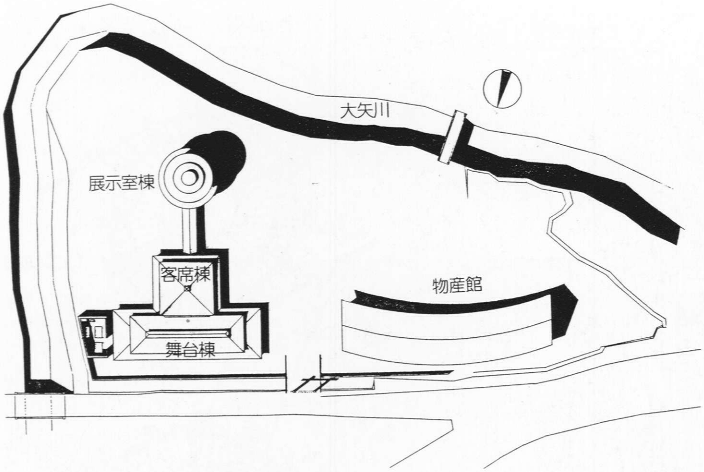
17 | Plans, scale 1:200. Bottom, the lowest level; top, the observation platform.

The detail of the fixing for the upper section of the stairs is very interesting. There is no more room at the bottom for the inner, inclined auxiliary posts carrying the inner stair stringer. So, the inner auxiliary posts begin exactly 180° offset on the existing ties at this point and are fixed by means of secondary ties correspondingly higher up the structure. A solution which is as brilliant as it is simple. The lower ends are pointed, thus allowing rainwater to drip off. The upper ends of all posts are spear-shaped to prevent water collecting. For safety reasons, the top of the central pole is fitted with a lightning conductor.

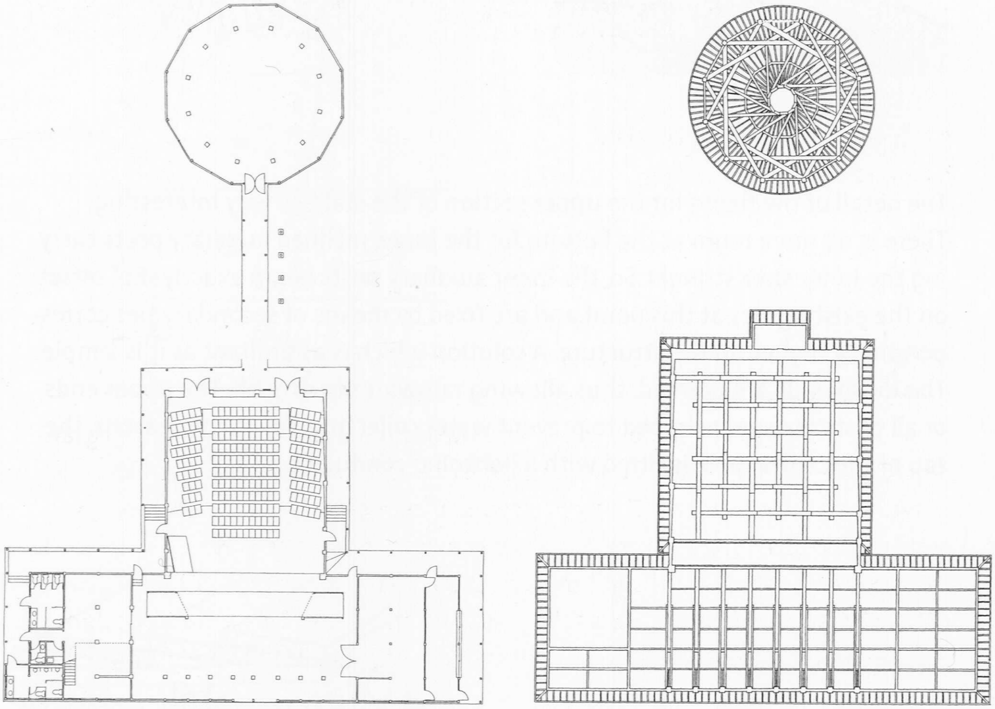


18 | Worm's-eye view of the construction.

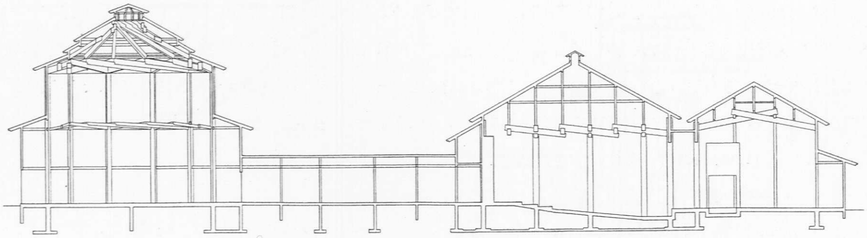
1 | Site plan, scale 1:2000.



2 | Plans, scale 1:500. Left, ground floor; right, worm's-eye view of roof.



3 | Longitudinal section through exhibition hall and theatre, scale 1:500.



4 | Overall view of puppet theatre and surroundings. In the foreground the exhibition hall, behind it the theatre with its square auditorium and rectangular block housing the stage.

Puppet Theatre, Seiwa

Kazuhiro Ishii

Subject | Kazuhiro Ishii has a special relationship with timber as a building material. According to his philosophy, timber structures – in terms of their design and appearance – should not imitate their modern steel or concrete counterparts but instead exemplify timber's own characteristics. And part of his philosophy are the "impressive dimensions". His structures – in particular the puppet theatre in Seiwa – attempt to employ timber as a building material in its very own grandeur. This is of course based on the Japanese tradition of timber buildings which, however, has been very much suppressed in recent decades by the steel and concrete of "modern" architecture. Kazuhiro Ishii admits that he was also inspired by the children's game "Waribashi" in which houses and other objects are created by using sticks and rubber bands as the "building elements". This fosters the development of a feeling for three-dimensional design, leading to a highly individual imagination.

In Japan at present, the building regulations are biased towards steel and concrete, and in fact are positively anti-timber in terms of design aspects, perhaps because of the greater stability required for taller buildings, perhaps because of the fact that wood is a combustible material. Therefore, Kazuhiro Ishii could put his ideas into practice only with a project embodying traditional Japanese culture, such as this puppet theatre. Indeed, his design for the exposed roof construction is unique and impressive.

Design | Puppet theatres have a long history in Japan and Bunraku puppet theatre has existed in its present form since the 16th century. The performers are the puppeteers, the musicians and the narrator. Each puppet requires three puppeteers! One is responsible for the head and right hand, another for the left hand and the third for the legs. Puppet drama has suffered a serious decline in audiences since the dawn of widely available cinema and television in the middle of this century. However, Seiwa on the island of Kyushu has been able to retain its puppet theatre which has risen to the status of a major cultural attraction.

The complete rebuilding of the theatre was carried out as part of a regional economic aid package. The use of timber as the main building material was a

Location
Seiwa Bunraku-kan (Seiwa Puppet Theatre), Kumamoto Province, Kamimashiki-gun, Seiwa-mura, Oaza-Taihei Haraguchi 152, Japan

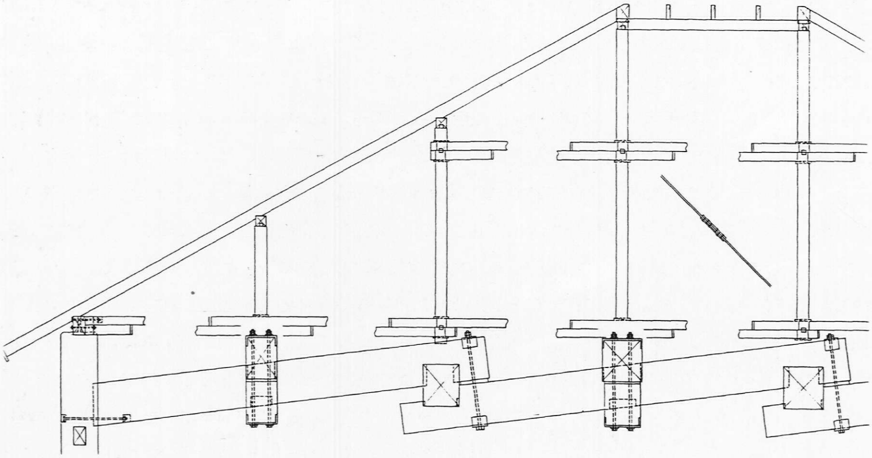
Client
Seiwa-mura (local council)

Architect
Kazuhiro Ishii Architect & Associates, Tokyo

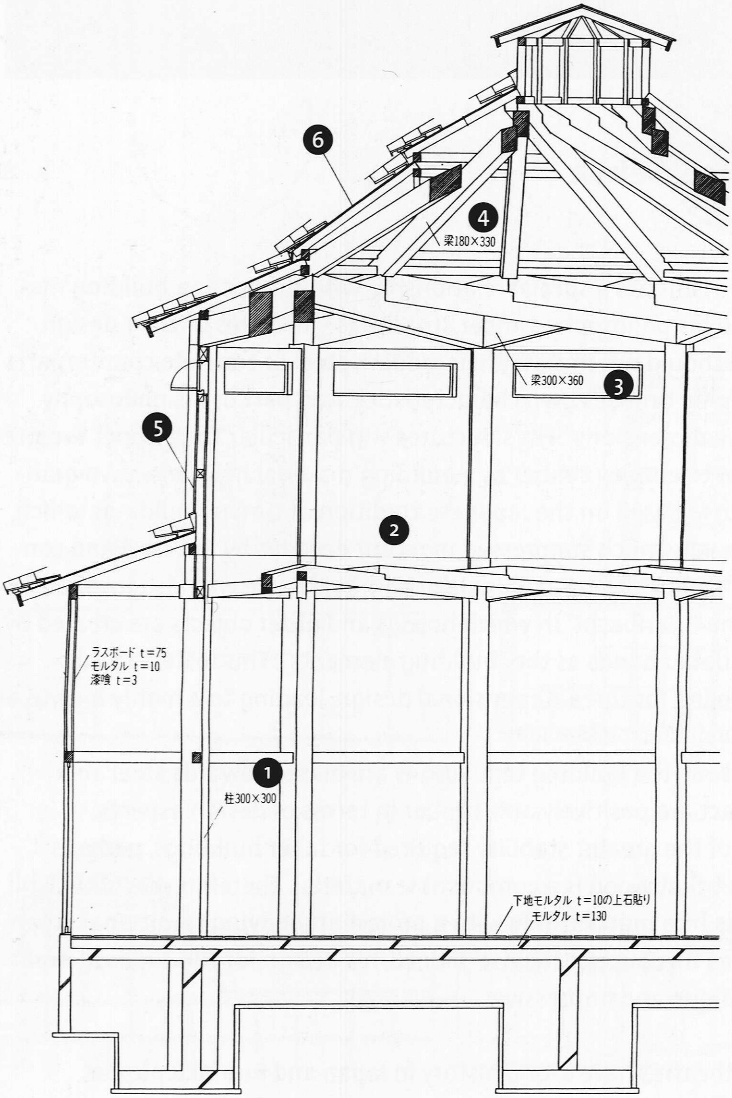
Structural Engineer
Hamauzu Kozo Sekkei-shitsu

General Contractor
Nishido Komuten

Date of Completion
1992



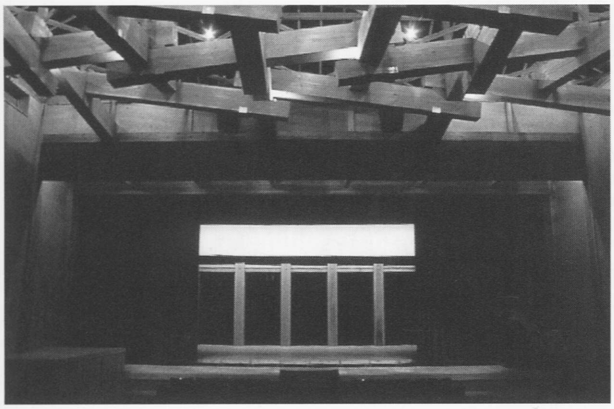
5 | Detail of roof construction, auditorium, scale 1:75. At the bottom the beams in the traditional dimensions of 390 x 420 x 3600 mm joined together by 2 No. 24 mm bolts, which form the loadbearing lattice. Above these a diagonal grid of 25 x 90 mm battens (90 mm dim. vertical). The 120 x 120 mm posts standing on these carry the 105 x 105 mm purlins right around the roof, interrupted in the central section by a further diagonal grid of 25 x 90 mm battens. The 40 x 105 mm rafters are spaced at 450 mm centres.

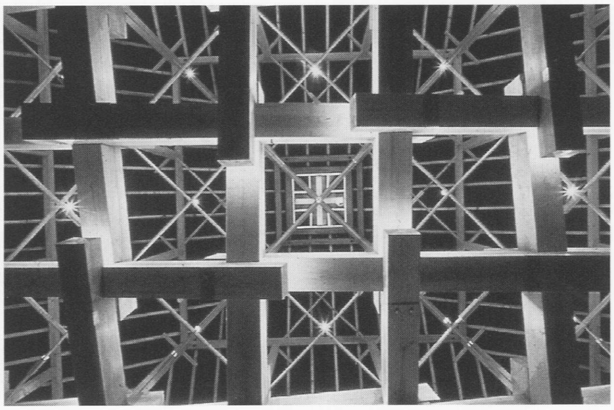


6 | Section through exhibition hall, scale 1:100. **1** Main columns, 300 x 300 mm. **2** Lower beam grid comprising 140 x 180 mm members. **3** Upper beam grid comprising 300 x 360 mm members. **4** Roof beams, 180 x 330 mm, supported on each other in the form of a spiral. **5** Wall construction: 90 x 90 mm intermediate members, 75 mm boarding inside and outside, 10 mm base coat and 3 mm finishing coat rendering on outside face. **6** Roof construction: 40 x 105 mm rafters each supported on two 90 x 90 mm purlins right around the building, 12 mm boarding with clay tiles, 50 mm rockwool thermal insulation underneath with fibreglass sheeting.

primary stipulation of the client in order to support the region's timber industry. The original intention was to offer bimonthly performances of traditional Bunraku puppet drama. However, as it turned out, the interest was so great that there are now 30 performances each month, attracting a total audience of 4,000! A success far in excess of what had been envisaged.

The project comprised the theatre itself and an exhibition hall. In his design the architect separated the structure into three distinct parts: the auditorium as a square building with a pyramid-type roof, the stage building as a rectangle at right-angles to this and with a hipped roof, and the exhibition hall as an almost pagoda-like circular building linked to the auditorium by a covered walkway. Owing to the different designs, the internal spaces each radiate a unique character. Kazuhiro Ishii's ideas are unmistakably related to those of the Buddhist monk Chogen (1121–1206) who influenced temple architecture over many centuries, as can still be seen today at the southern entrance to the Todaiji Temple in Nara and the Jodo Hall of the Jodoji Temple in the Hyogo district.





7 | The ceiling of the auditorium in the form of a load-bearing lattice of beams carrying the roof construction.

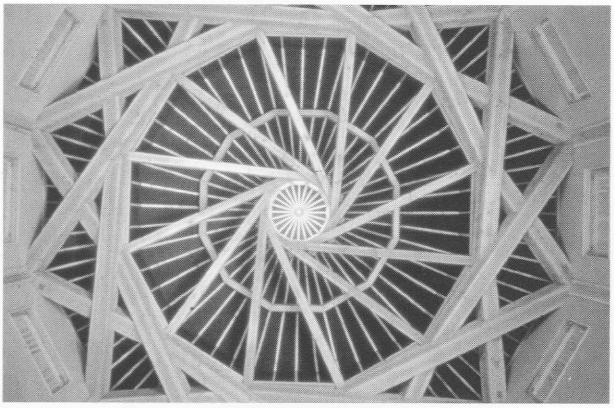
8 | Worm's-eye view of auditorium roof.

Structure Auditorium | Using the above-mentioned "Waribashi", Ishii developed a very special roof construction for the approx. 12-m-square auditorium based on the traditional dimensions for timber members, namely 390 x 420 x 3600 mm – very compact building elements. In order to be able to span the whole area without intermediate columns, he created a horizontal beam lattice made from these traditional timber blocks to support the roof structure with its much smaller-dimensioned members.

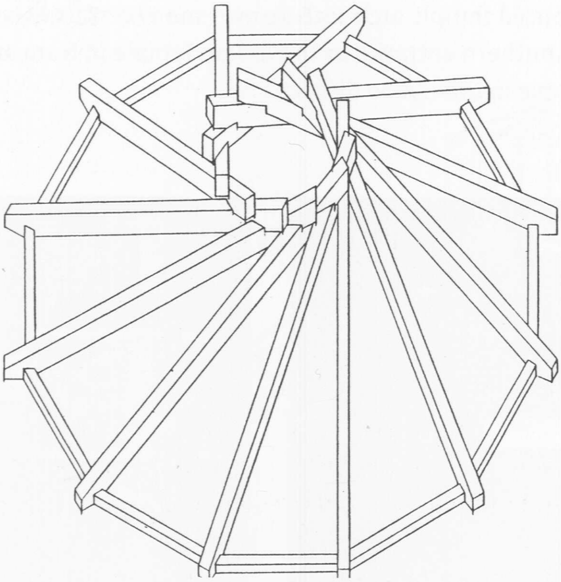
Basically, the lattice consists of cantilever beams joined to each other in a locked chain and supporting each other at right-angles. The parallel chains of beams are in each case supported in the opposite direction so the whole becomes a three-dimensional lattice system. Each joint between the beams consists of two 24 mm bolts which hold together the ends of the beams via appropriately shaped 16-mm-thick steel channels. This is a concession to modern methods but it is a suitably modest and ingeniously solved detail. Fixed to each of the high points of the lattice is a diagonal grid of 25 x 90 mm battens which cross each other at the support points. Above this is the roof truss consisting of 120 x 120 mm posts, a second lattice of 25 x 90 mm battens, the 105 x 105 mm purlins and the 40 x 105 mm rafters at approx. 450 mm centres. Incidentally, the centre posts do not run right through but instead are cut off at the level of the second diagonal lattice.

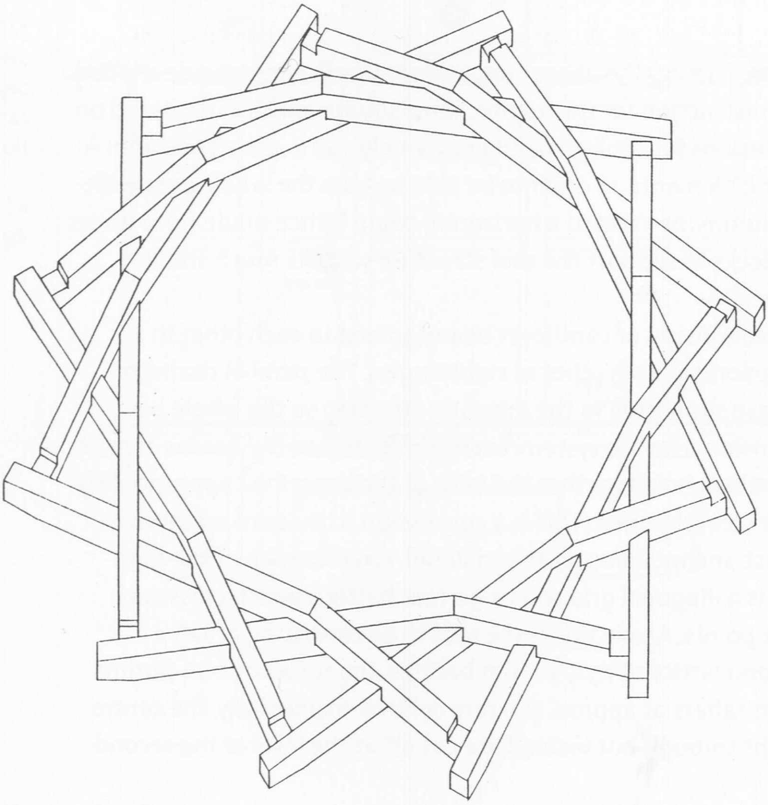
The whole roof structure weighs 15 tonnes, a joy for the timber trade but an irritation for the project's structural engineer and the local building department which had to approve it!

9 | Worm's-eye view of roof to exhibition hall.



10 | Isometric projection of upper roof construction for exhibition hall.

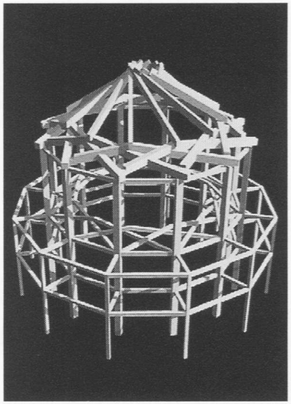




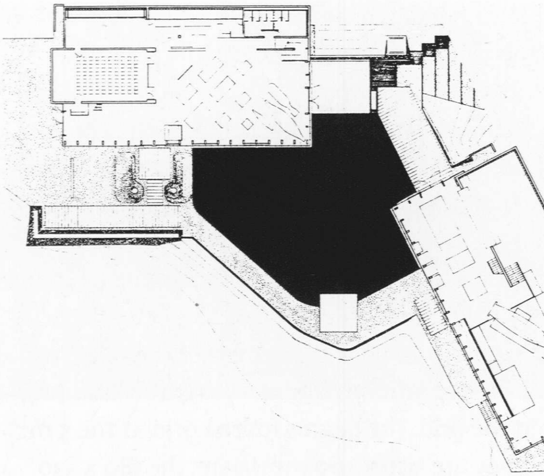
Structure Exhibition Hall | The exhibition hall is a timber-stud design without any metal connectors whatsoever. The 12 loadbearing 300 x 300 mm main columns are arranged in a circle and extend right up to the roof, a height of about 8.50 m. They are braced against each other horizontally by means of the wall cross-members and by grids of beams, one at the 5 m level and one at the eaves. A monopitch roof, supported on the main columns at the level of the first grid of beams, covers the enclosed ground floor gangway which encircles the whole building. The principle of the grid is that each beam is supported on the next one in the circle and mortised into the main columns. In each case, the beam then extends, cranked, beyond its support point on the next beam, past the next two columns and is then mortised into the next column, where it joins at the same level as the start of the next beam in the grid. The beams for the grid at the 5 m level are 140 x 180 mm; at roof level they are 300 x 360 mm. Here, the 180 x 330 mm roof beams, rising in a spiral, are supported on each of the high points of the grid. At the same height there is a 90 x 90 mm purlin right around the building which also serves as the uppermost purlin for the lowest roof surface. It is a system which looks extremely complicated but is in fact very simple structurally: each beam rests on the next one – in a circle, and with different inclinations, proportions and dimensions at the various levels. This type of construction caused the local authorities quite a headache and approval was finally granted only after they had examined a 1:30 model.

The roof construction is as follows: the conical roof surface is divided into three separate areas, each having a different pitch and each with its own rings of purlins. These 90 x 90 mm purlins carry the 40 x 105 mm rafters with the 12 mm boarding and the traditionally shaped clay tiles. Thermal insulation comprising 50 mm rockwool is fixed beneath the boarding and this is covered by fibreglass sheeting.

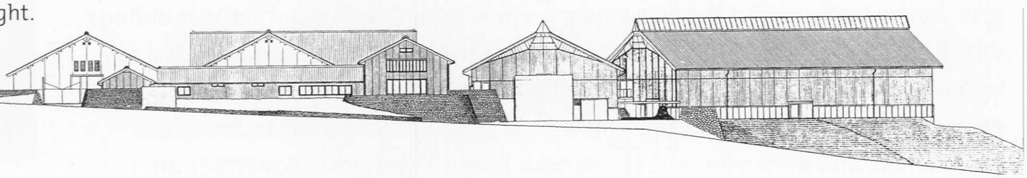
The external walls are supported by 90 x 90 mm battens mortised into the main columns. These carry the 75 mm boarding inside and outside which in turn provides a base for the 13-mm-thick rendering. Additional thermal insulation is not provided here.



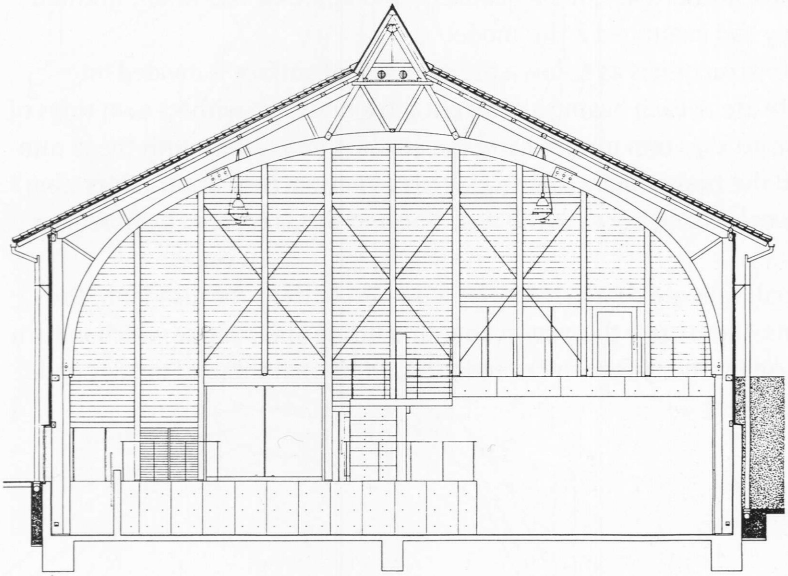
11 | The 1:30 model of the exhibition hall structure.



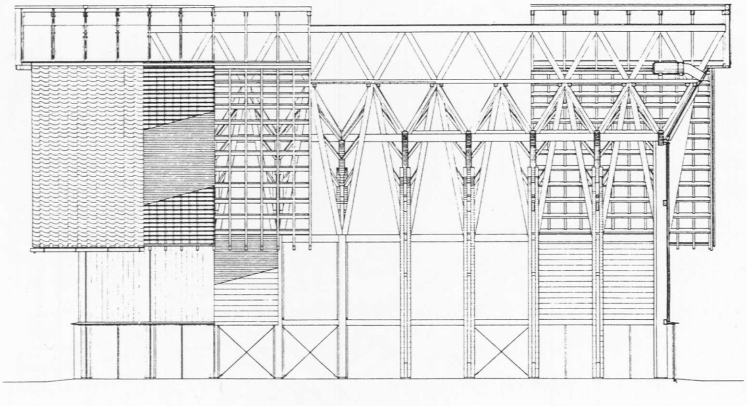
1 | Site plan of the exhibition halls, scale 1:1000.



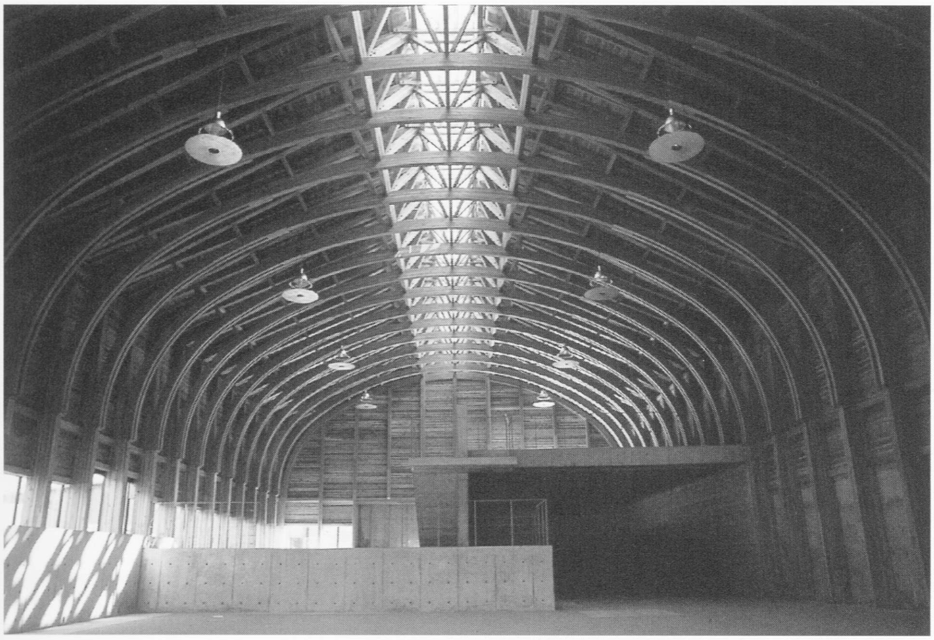
2 | Elevation of whole complex, scale 1:1000. The exhibition halls are on the right.



3 | Section through second hall, scale 1:200. Loadbearing three-centre arch, outer sections are each two 300 x 100 mm, middle section is 345 x 160 mm. Inclined 243 x 160 mm main rafters. Central A-frame with clerestory consisting of 160 x 160 mm cross-bracing.



4 | Longitudinal section, scale 1:200. Left, the various layers of the wall and roof constructions as seen from outside; right, the view from inside.



5 | The exhibition hall before the arrival of the exhibits.

Fishing Museum, Shima

Hiroshi Naito

Subject | Our modern age with its digital concept of time saps architecture's energy; for the very essence of architecture corresponds to an analogue notion of time. That is Hiroshi Naito's view. For him, the greatest handicap of modern thinking is that time is excluded as a continuum, that time is only regarded as digital – fragmented and liable to manipulation –, that the objects of the physical world are no longer permitted to age and fade away in accordance with the passage of time. Today, structures are only perceived as snapshots in their just-completed state – a momentary record without any timescale. Naito's architecture rebuffs this attitude. He attempts to include the concept of time in his designs by taking into account modern production methods, the changing demands in terms of function, and the ageing processes of the building materials.

Design | The Fishing Museum in Shima was intended to house and display about 20 000 tools used in the traditional fishing industry in the Shima region. Naito's idea was to find an "archetype" comparable to the forms of the tools exhibited; these forms grew out of the tension between the need to fulfil a function and the regularity of natural laws. The result was highly efficient and suitably durable articles. Naito says that the number of possible designs for structures planned for only a short life can be infinite. However, if they are intended to serve for longer periods, then the number of possible alternatives decreases in proportion, finally ending in just one archetype. The Fishing Museum conveys the controversial relationship between the tough coastal climate, the exhibition programme, the tight budget, the layout considerations and the design time. By analysing the individual problems and approaching them uncompromisingly, Naito was able to develop a building which comes close to the ever more simplified archetype. From the outside the exhibition halls appear very simple; from the inside they suggest to the visitor the framing of an upturned ship's hull, the shape and material creating a feeling of safety. A strip of light enters from above, through the "keel"; at the bottom, a continuous band of windows admits light and landscape. Naito is not driven by nostalgia but rather by a deep desire to find a mythical architecture with a legitimacy for our society.

Location
1731-68, Ogitsu Uramura-cho Toba-shi, Shima, MIE 517, Japan

Client
The Foundation of Tokai Suisan Kagaku Kyokni

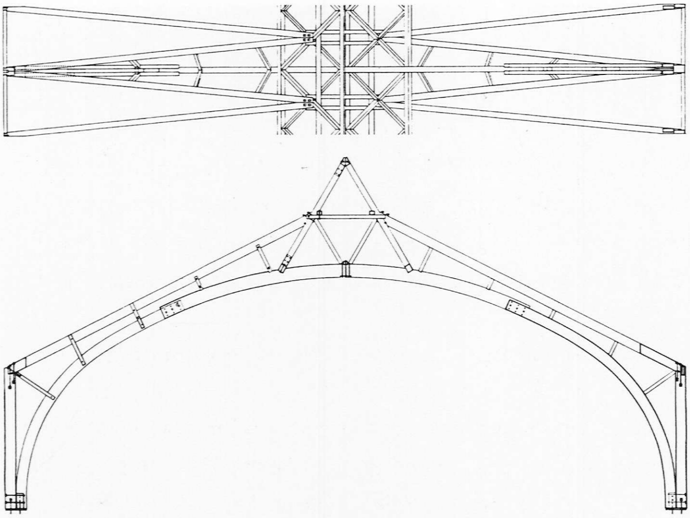
Architect
Naito Architect & Associates, Tokyo
Design Team
Hiroshi Naito, Hitoshi Watanabe, Nobuharu Kawamura

Structural Engineer
Kunio Watanabe, S.D.G. Tokyo

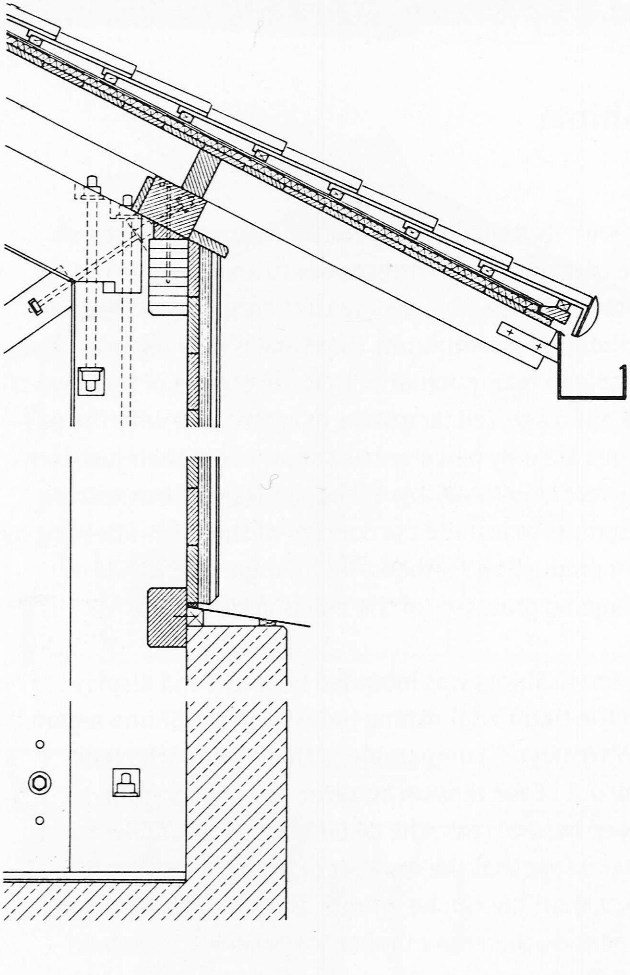
Timber Construction
Onisi Tanezo Construction Co. Ltd

Date of Completion
1992

Costs
The costs for the halls amounted to 320 million Yen.



6 | Plan and section, scale 1:200.



7 | Section through eaves, scale 1:20. Roof construction: clay tiles on tiling battens, roofing felt on 35 x 45 mm counterbattens (45 mm thermal insulation in between), 15 mm fir boarding, 60 x 120 mm secondary rafters, 120 x 150 mm cross-members, 243 x 160 mm main rafters. Wall construction: 32 mm Japanese cedar vertical boarding painted with tar, sealing layer, 32 mm horizontal fir boarding, 305 x 210 mm timber columns at 1.70 m centres.

Structure | The two exhibition halls are identical structurally. The main structural elements are the 17.5-m-span glulam three-centre arches with a spacing of 1.70 m. Each arch is divided into three parts: the two lower parts of each arch are formed by two 300 x 100 mm members and the upper section is a single 345 x 160 mm member. These three parts are rigidly bolted together at third-points. The bases of the arches are founded at upper floor level, i.e. 2.80 m or 4.20 m above the ground floor. The bases of the arches are bolted to 210 x 200 mm columns. The elegant transition piece below the wider incoming compound arch member is very striking.

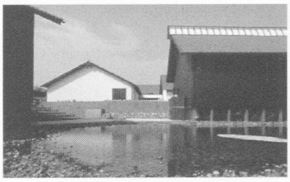
At the apex of the arch there is a continuous timber A-frame, the upper part of which contains the continuous clerestory windows. The sides are made from 160 x 160 mm members, arranged as triangular cross-bracing, which are supported on horizontal 160 x 200 mm sole plates carried on the arches. The sides are stiffened by central supports and horizontal compound members – all 90 x 105 mm. They meet the sides exactly at the points where the rafters intersect – a very interesting three-dimensional node. The horizontal compound members carry an inspection walkway. The shape of the triangular cross-bracing inevitably leads to the clerestory construction penetrating the gable ends, adding a dynamic component to these elevations.

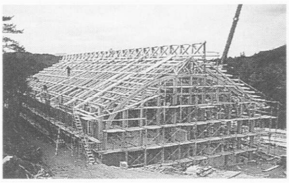
The external profile of a simple pitched roof is formed by vertical 305 x 210 mm timber posts positioned directly behind the arches and extending as far as the eaves. They are connected at the top and at the base of the arches by sturdy timber sections. The 160 x 243 mm rafters are fixed to the top of these posts by means of a notched joint. They run diagonally towards the node points of the clerestory framework, two rafters from each column. They intersect with the rafters of the next column at the clerestory framework and thus constitute an effective longitudinal bracing system for the whole building. They are propped against the arch by four inclined 105 x 130 mm members with a further prop at the eaves. The gable rafters are also fixed at an angle and so the overhanging roof helps to shape the façade further. The bolted and screwed joints of the timber members are designed in such a way that the heads of the screws or bolts are recessed for exposed connections but still accessible – a good practical and formal solution. Most of the joints higher up the roof and in the clerestory area are in the form of T-shaped steel flats which are fitted into slits and then bolted or screwed.

The external walls are extremely simply designed and do not contain any thermal insulation. Horizontal fir boarding, approx. 32 mm thick, is screwed onto the vertical timber columns, which on the gables are 210 x 375 mm members. On top of the boarding is a sealing sheet and the externally visible, vertical 32 mm Japanese cedar boarding which is then painted over with tar. This is intended to be reminiscent of old fishermen's huts, the walls of which were soaked in dark whale-oil. Indeed, the whole complex with its simple pitched roofs evokes memories of traditional fishing villages.

The rafters described above carry horizontal 120 x 150 mm members at 1.0 m centres. In turn these support 60 x 120 mm secondary rafters at 40 cm centres onto which the 15 mm roof boarding is fixed. The remainder of the roof construction comprises counterbattens under the tiling battens for the clay tiles. A 45-mm-thick layer of thermal insulation, covered with a continuous layer of roofing felt, is laid between the counterbattens. A vapour barrier is obviously not necessary here.

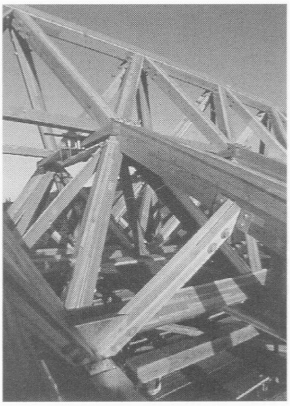
All structural members are fabricated from glulam sections.



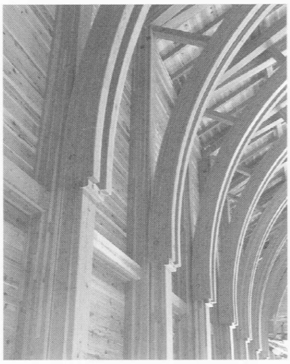


8 | View of the whole complex.

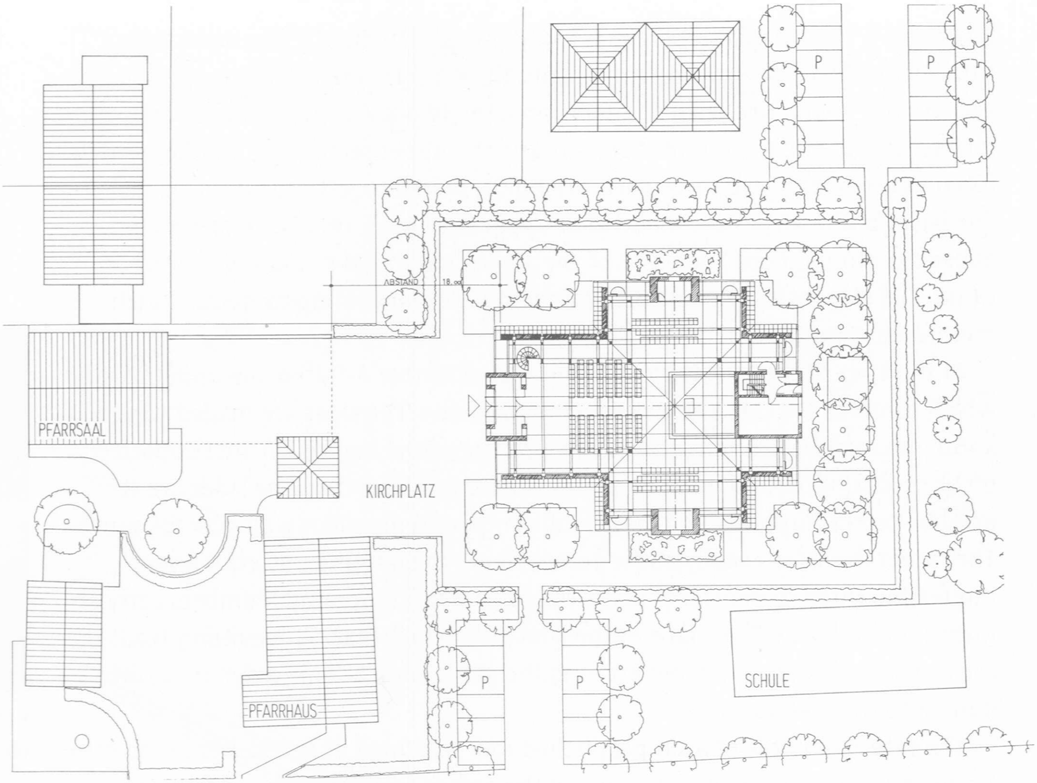
9 | The hall during construction.



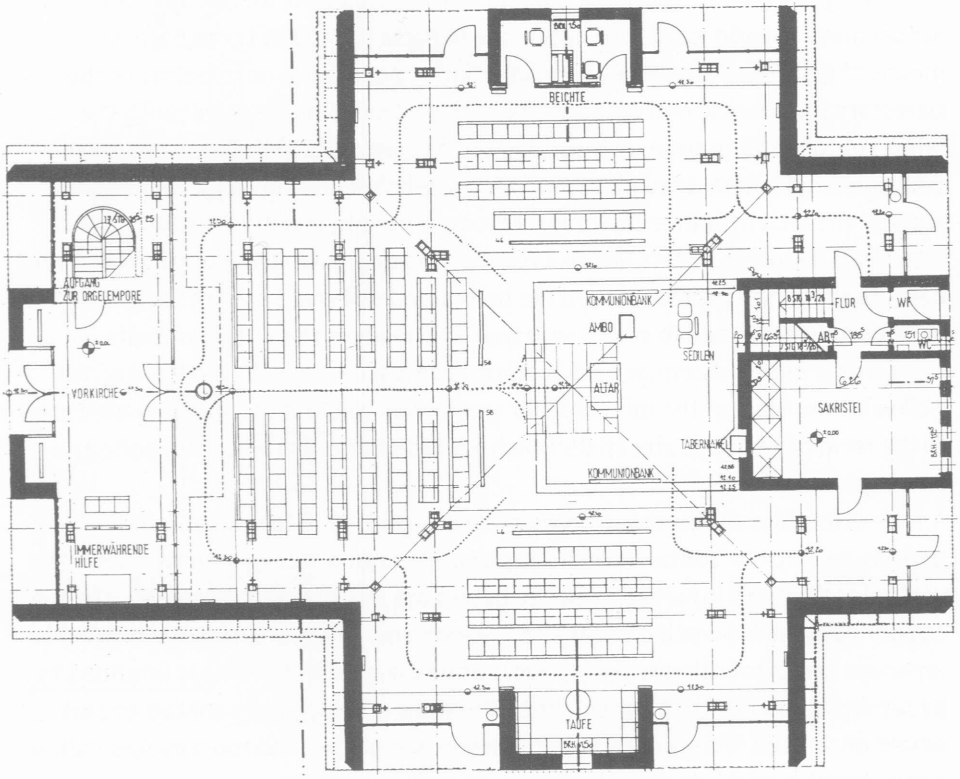
10 | The junction of the triangular cross-bracing for the clerestory sides, horizontal and inclined incoming main rafters.



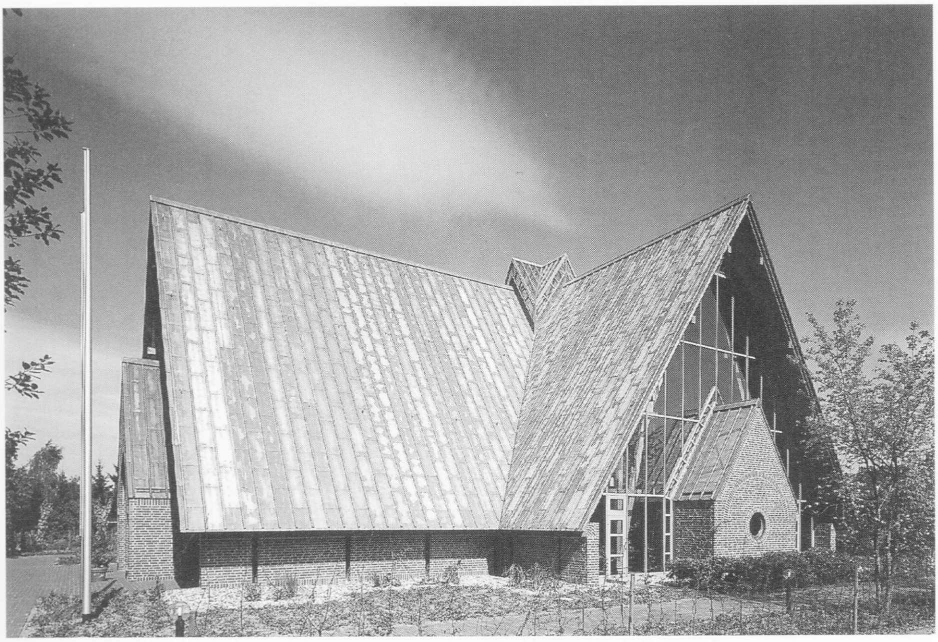
11 | Base of an arch.



1 | Site plan, scale 1:800.



2 | Floor plan, scale 1:250.



3 | View from the south.

St Joseph's Parish Church, Dormagen

Walter von Lom

Subject | Buildings which reveal their construction are trying to express their simplicity, their openness, their "honesty". And if the design is hand-crafted in traditional materials, then a sense of history and of "belonging" are also conveyed. Even today, such structures can only be built by specialists using traditional methods. On the other hand, there are buildings in which the "message" conveyed by the form itself takes precedence over the actual function of the building. In our modern age it is only the structures serving deep-rooted cultural needs which can be considered in this aspect, e.g. churches or memorials.

The parish church described here is a particularly clearly defined and imposing structure which satisfies these criteria. It generates a feeling of "belonging" while still remaining cosmopolitan, helped no doubt by the large areas of glass clearly separating the timber and masonry elements. The flat lead sheeting on the steeply-sloping vast expanse of the roof emphasizes the cross shape.

Design | The sizes and possible uses of the existing church buildings in the parish of St Joseph were no longer adequate to meet the needs and concepts of a modern community. Substantial alterations were needed in any case. Following lengthy deliberations, in which extensions to the existing 19th-century church were put forward as perhaps the cheaper alternative, the decision to erect a new structure and re-organize the existing buildings was found to be the best solution. The new church was conceived as a marshalling factor within the existing ensemble of church and parish buildings, creating a spiritual "island" and an urban identification point in the otherwise unstructured local surroundings. The old tower now forms a focal bell-tower around which the little complex of buildings is grouped. The new church was completed in 1989.

The church is a cross-shaped central room dominated by the timber roof construction, in particular by the roof trusses which appear very complex but at the same time illustrate a very simple design principle. The main supports for the roof are located 2.50 m inside the church, i.e. away from the external walls, thus suggesting lower "lateral aisles" reminiscent of the classical basilican style of church architecture.

Location
Katholische Kirchengemeinde St. Josef, An St. Josef 2,
41540 Dormagen-Delhoven,
Germany

Client
Katholische Kirchengemeinde St. Josef, Delhoven

Architect
Walter von Lom & Partner,
Dipl.-Ing. Architekten,
Cologne
Project Manager
Hubert Meuser

Site Manager
Eduard Stammel

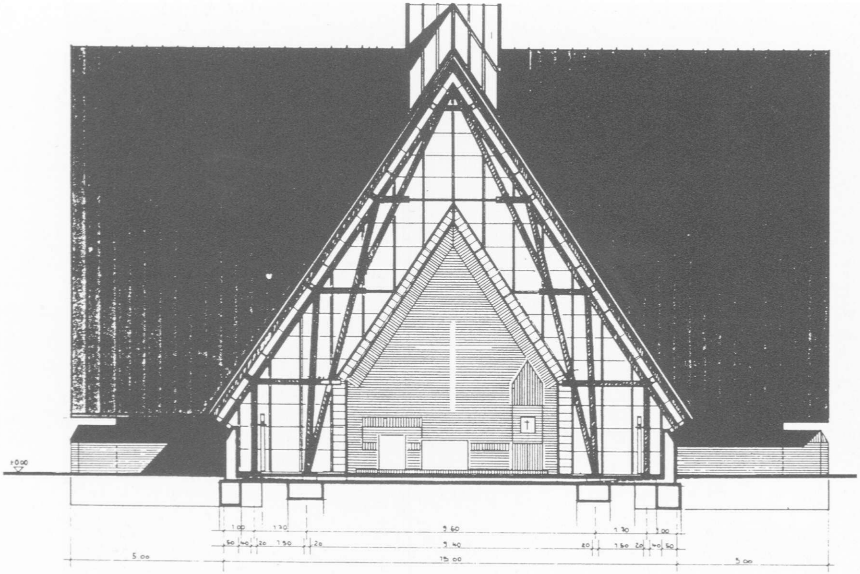
Structural Engineer
Konstruktionsgruppe für Bauwesen Tripler/Zilinski,
Cologne

Chief Carpenter
J. Happerschoss, Cologne

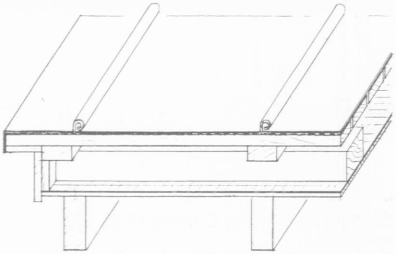
Date of Completion
1989

Costs
The total building costs for a volume of 4900 m³ were 2.5 million DM.

4 | Section through nave, scale 1:250.



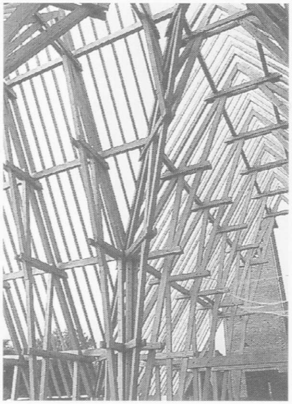
5 | Detail of verge flashing, scale 1:20.

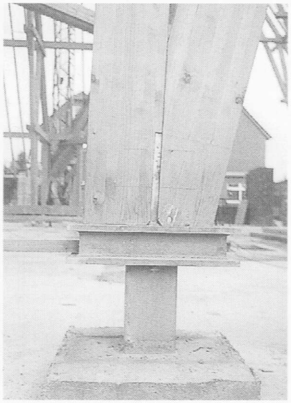


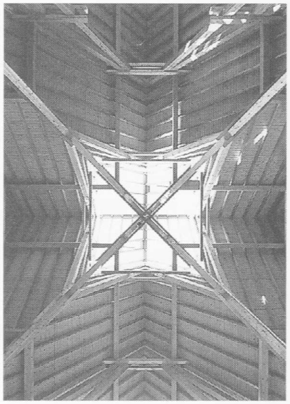
6 | View of roof during construction showing collar beam at the roof intersection.

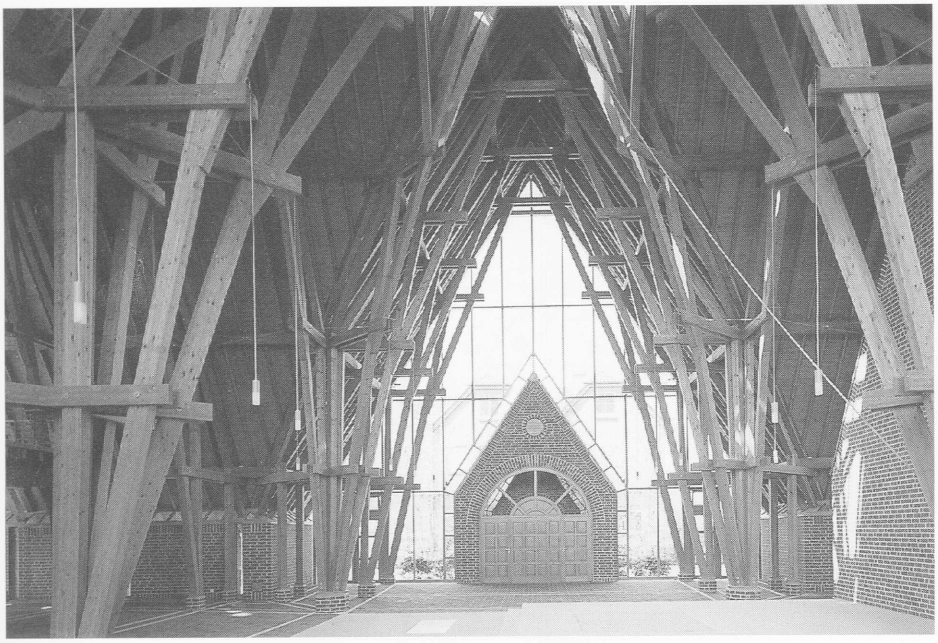
7 | The base of a standard truss during construction and before adding the masonry.

8 | Worm's-eye view of roof intersection.







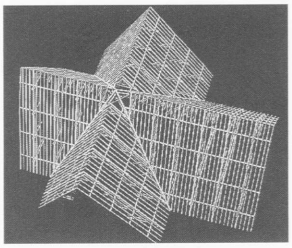


9 | View inside the church showing the truss construction at the roof intersection and the pleasantly unobtrusive lighting arrangement.

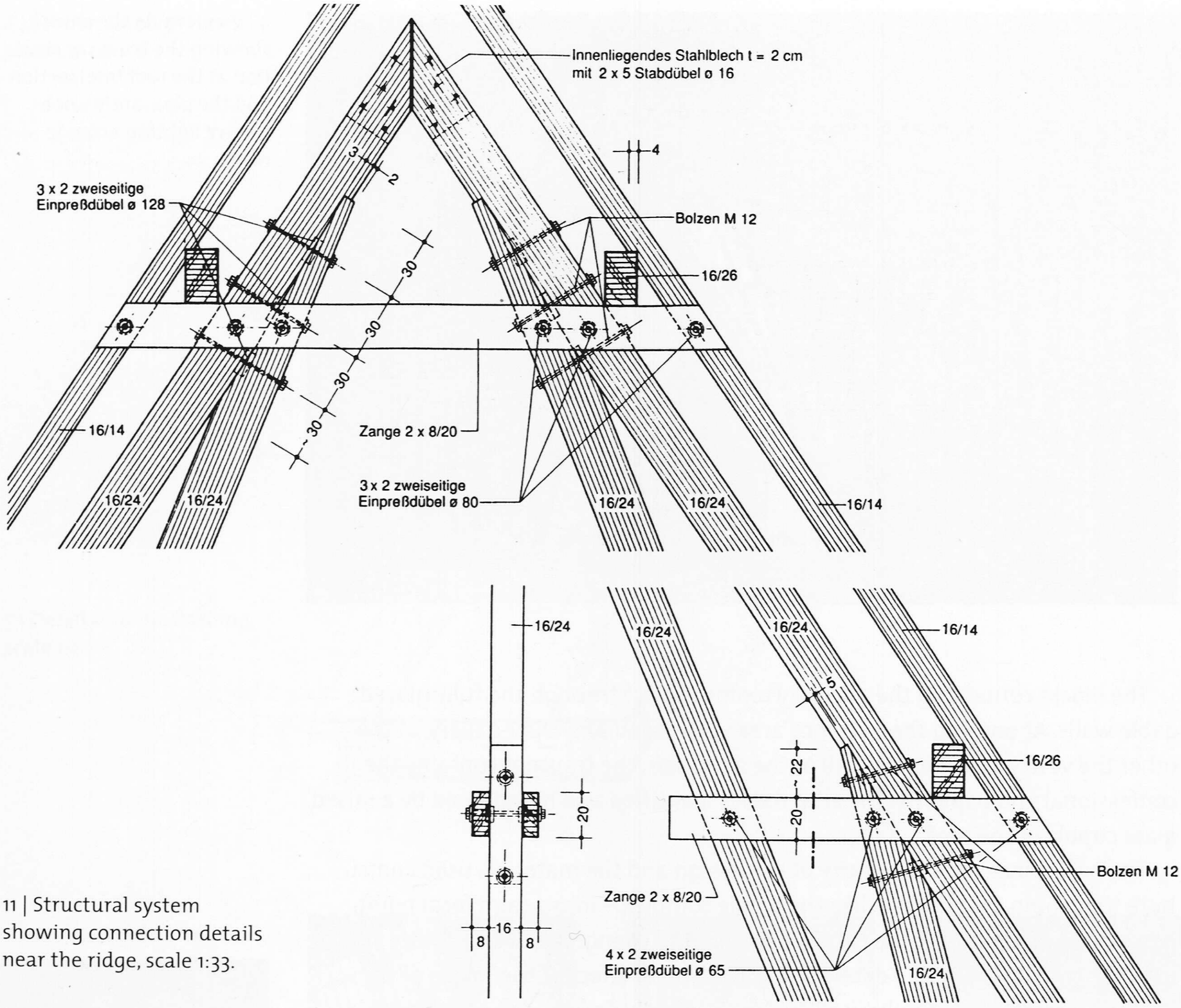
The blocks containing the ancillary rooms project through the fully glazed gable walls. At one end the entrance area with organ and choir gallery, at the other the vestry and the rear wall of the altar dais; the transept contains the confessional and baptistry. The altar dais is identified and highlighted by a raised glass cupola in the roof.

The naturalness and simplicity of the design and the materials used contribute to turning the church – like the whole complex – into a calm focal point, both inside and outside. The external spaces and changing natural lighting effects play a major role in determining the overall effect of the inside of the church, underlined and enhanced by the artistically designed areas of glazing.

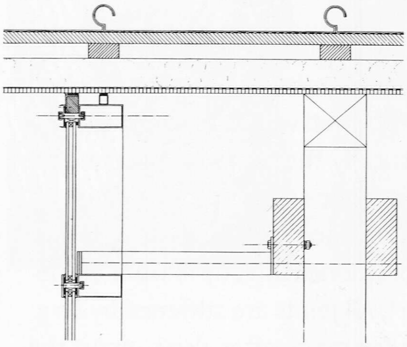
Structure | Braced roof trusses at a spacing of 3 m form the principal structural element. Struts at different angles support the main rafters at three positions. They are supported at a point 2.50 m from the external walls, i.e. within the church itself, the lowest strut rising almost vertically, the second supporting the main rafter at the two-thirds point and the upper one emerging out of this to carry the ridge. Struts and main rafter are all 160 x 240 mm. The lower section of the rafter is propped by a 160 x 200 mm post positioned directly in front of the external wall, forming a sort of jamb-wall effect. All joints are stiffened by 80 x 200 mm ties. The ties at the support points for the main rafter also support the purlins which in turn carry the secondary rafters for the roof covering itself. Purlins are 160 x 260 mm, rafters 160 x 140 mm. These rafters are spaced at 50 cm centres and carry the ventilated cold roof construction comprising 11 mm boarding and 80 mm thermal insulation. The roof loads are transmitted via the struts and posts to 300-mm-high masonry plinths supported on the foundations. Actually, the masonry itself is non-loadbearing, the loads being carried by built-in steel sections which can accommodate the horizontal thrust. The whole design is braced within the roof construction by the roof truss which resembles a timber framework. Three-dimensional stability is achieved through the intersection of the two pitched roofs in the centre of the church. All timber elements are made from glulam beams employing a resorcinol-based adhesive. Most of the timber-to-timber joints are bevelled shoulders or rebated in the traditional carpentry style.



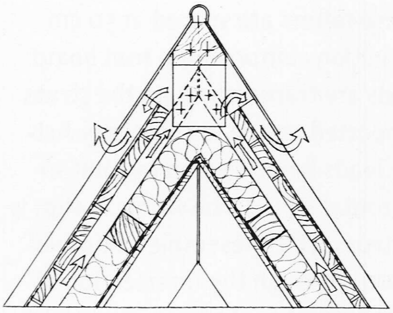
10 | Model of the roof construction.



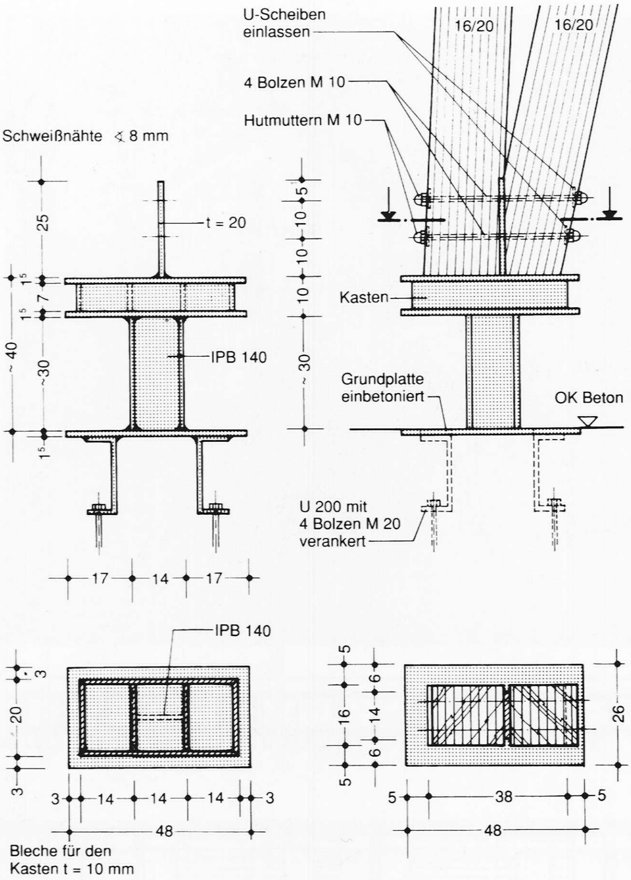
11 | Structural system showing connection details near the ridge, scale 1:33.



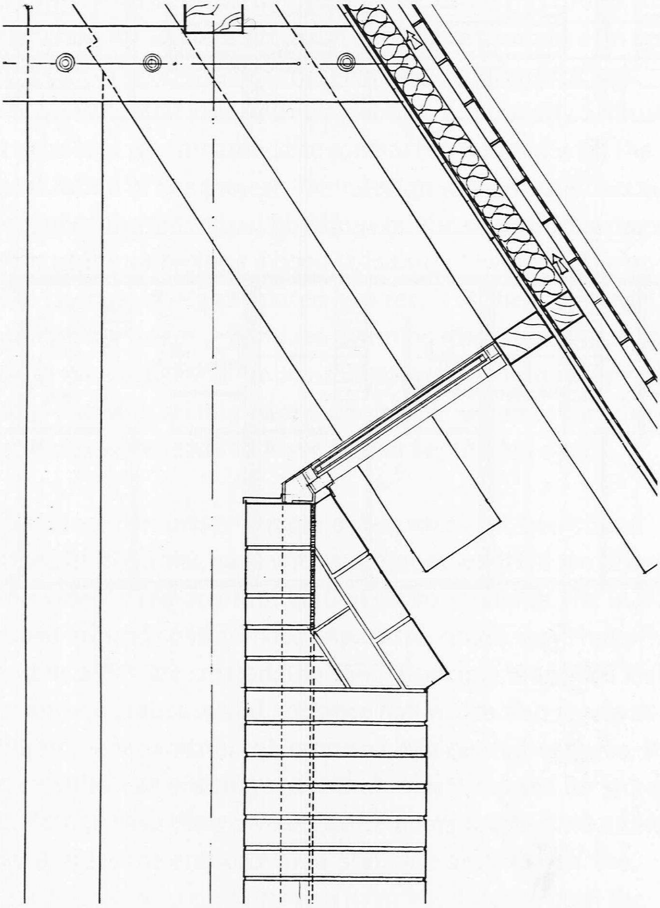
12 | Detail of connection between glass wall and roof/truss, scale 1:20. The glass wall is joined to the truss ties at 500 mm centres by means of galvanized steel sections and only sealed against the underside of the roof boarding. Therefore, the window transoms form the principal loadbearing elements in the window design.



13 | Detail of ridge, scale 1:20. The ridge capping piece permits the inclusion of a ventilation slot for the 40-mm-wide air gap of the cold roof. There is a 150 mm overlap with the roof surface.



14 | Detail of base (masonry omitted for clarity), scale 1:20.

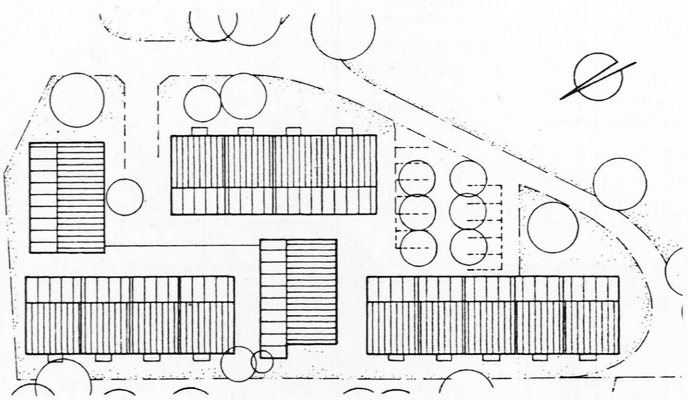


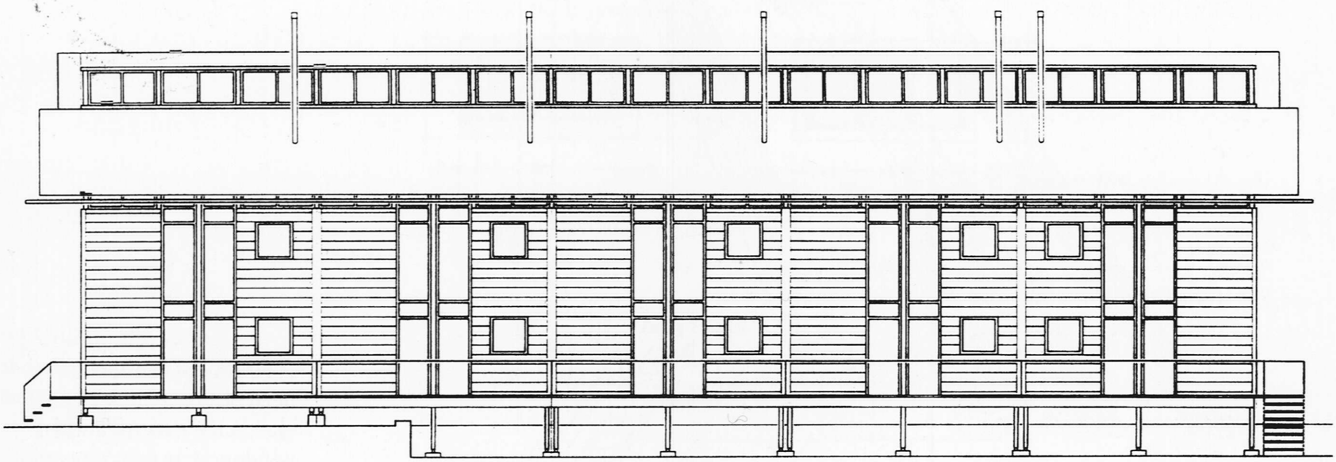
15 | Detail of connection between roof and external wall, scale 1:20. An angled window strip separates roof surface from external wall.

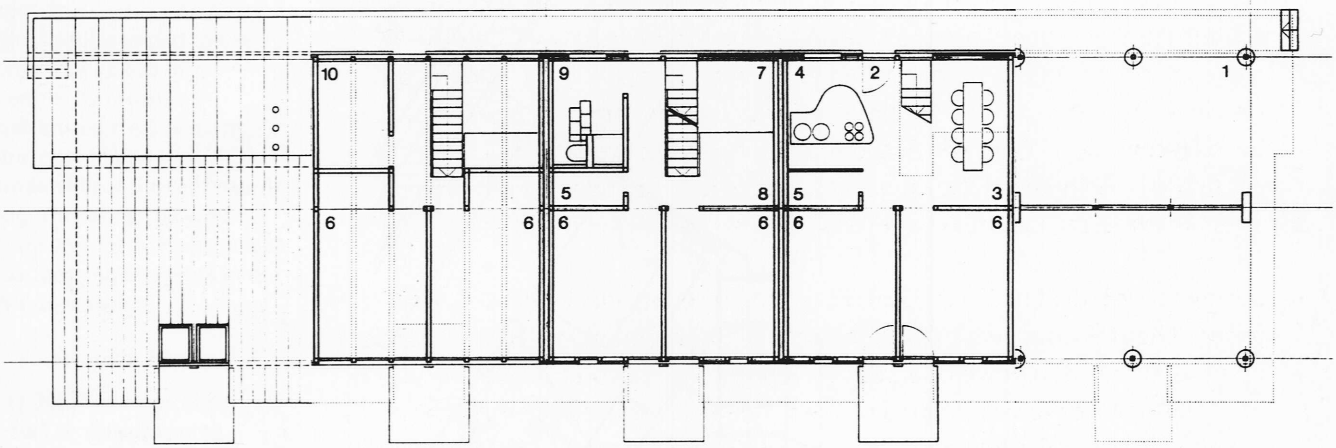
1 | Site plan, scale 1:1000.

2 | Front elevation, scale 1:200.

3 | Plan of building containing five housing units, scale 1:200. From left to right: roof plan, 2nd floor, 1st floor, ground floor, basement. The rooms: **1** Parking for cars/ bicycles. **2** Entrance. **3** Living area. **4** Kitchen. **5** Storage. **6** Bedroom. **7** Void. **8** Gallery. **9** Bathroom with shower and WC. **10** Utility room.







4 | The central section of the complex viewed from the west.

Jungerhalde Students' Accommodation, Constance

Herbert Schaudt

Subject | The provision of low-cost housing is becoming an ever more important aspect of building. One particular group of users needing special attention is students. Low incomes, relatively short periods of residence and a tendency to share accommodation are the most important requirements for this group. In 1989 the German Association for Student Affairs in Constance promoted an open competition to design a hall of residence for students. The building plot was situated on the edge of a residential area within sight of the university. Schaudt Architekten won first prize and was awarded the contract to proceed with the detailed design and realization of the project. Their design was favoured because of the skilful arrangement of the individual buildings on the site, which achieved an optimum density but at the same time a good standard of living for the occupants. Moreover, cost-savings were anticipated as a result of the proposed timber-frame construction, the use of a standard planning grid throughout and the well-conceived layout which allowed for possible conversion into independent family-sized homes. Following an intensive planning period and short construction time, the buildings were ready to move into in September 1992.

Design | The hall of residence comprises 17 more or less identical, two-storey terraced houses arranged in five units, each with a different length. Each terraced house is intended to provide shared accommodation for six students. The individual buildings are grouped around common open spaces in such a way that private, semi-private and public areas are created. The same principle is applied inside the buildings, with a common staircase and entrance hall which also serves as a communal area. Owing to the high water table caused by a nearby wet area, the buildings were raised on stilts. The ensuing space underneath is used for storage and parking. All the buildings have their own entrance doors reached via a common external walkway. Besides the entrance area, staircase and kitchen, the ground floor level of each house also contains two (11 m^2) bedrooms; both the first floor and the second floor also each contain two further bedrooms. The bathroom is located on the first floor and the utility room on the second floor. Each house is allocated a garden at the rear.

Location
Studentenwohnheim
Jungerhalde,
Am Schmerzenmösle 36,
78464 Constance, Germany

Client
Studentenwerk Konstanz

Architect
Schaudt Architekten BDA,
Constance
Project Architect
Helmut Hagmüller
Design Team: Thomas Baldauf, Gregor Mertens, Jürgen Jakob, Thorsten Gabele

Structural Engineer
Arlt, Constance

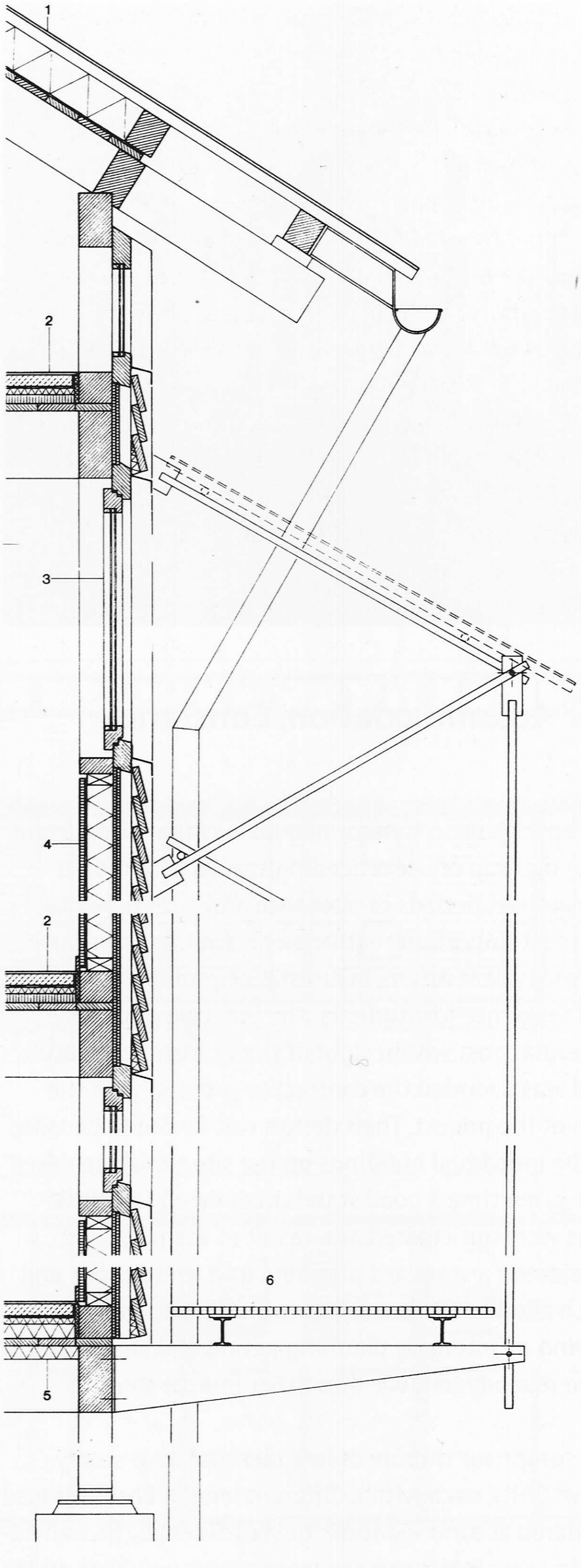
Sound and Thermal
Insulation
Prof. Dr.-Ing. Karl Gösele,
Leinfelden-Echterdingen

Timber Construction
Kaspar company, Gutach

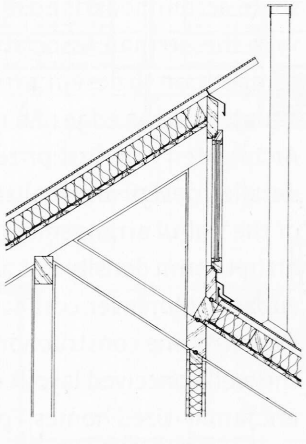
General Contractor
Wieland company, Singen

Date of Completion
1992

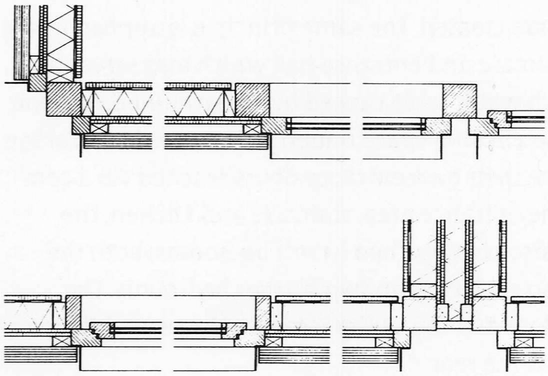
Costs
The costs of construction, excluding land and internal furnishings and fittings, was 6 718 700 DM for a total volume of approx. 8470 m^3 and a total living area of approx. 1780 m^2.



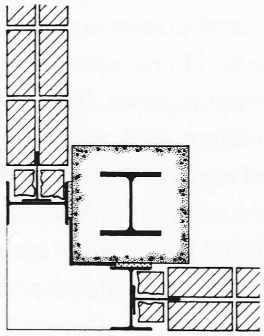
5 | Section through façade, scale 1:25. **1** Roof construction: profiled aluminium sheeting, 120 mm thermal insulation, vapour barrier, 28 mm boarding, 120 x 180 mm rafters. **2** Floor construction: rubber floor covering, 40 mm cement screed, polyethylene sheet, 25 mm impact-sound insulation boards, 30 mm chipboard (or gravel), 28 mm boarding. **3** Wood windows: fir frame with solar-control double glazing. **4** External wall construction: 120 x 120 mm columns, 12 mm plasterboard on 40 x 107 mm timber framing, vapour barrier, 100 mm thermal insulation, 2 No. 13 mm bituminous soft boards, 24 mm roughsawn fir weatherboarding on 40 x 60 mm battens. **5** Ground floor construction: as for upper floors but with additional thermal insulation and fire protection, each 40 mm thick. **6** Walkway: hot-dip galvanized steel.



6 | Section through roof showing clerestory window, scale 1:50. Internal wall construction: 19 mm V100E1 chipboard, 48 x 100 mm timber framing on all sides, special "Compriband" seal all round, 80 mm mineral fibre board, 19 mm V100E1 chipboard; total thickness 120 mm.



7 | Horizontal section through façade, scale 1:25. The external corner according to the "Mies corner" principle. The separating joints between the individual houses are filled with thermal insulation. The construction deviates from the 1 m grid at this point: the centre-to-centre spacing is 240 mm, hence the gap of 120 mm. All joints on the outside are sealed with a special "Compriband" seal.



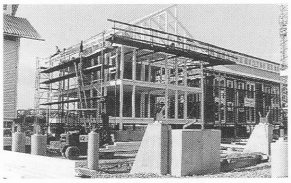
8, right | Corner detail of the Alumni Memorial Hall, IIT Chicago (1945) by Ludwig Mies van der Rohe: the "Mies corner".

Structure | Each of the terraced houses consists of a timber framework in the beam-and-column system laid out on a 1 x 1 m grid. Each house is an independent structure, totally separated from its neighbours both in terms of the centre-to-centre dimensions and the construction. The loadbearing columns of the framework are 120 x 120 mm glulam members and rise from foundation to roof in one piece. Intermediate columns, starting at ground floor level, are also 120 x 120 mm glulam members. Beams and floor joists are all in the same plane and consist of standardized solid 120 x 220 mm members. The connections between these and the connections to the columns are formed by plates with welded-on flats screwed onto the loadbearing members; the flats are then let into slots in the beams and bolted through. As the joists for the upper floors are exposed, this type of hidden joint represents a significant visual improvement. Using the 1 m grid throughout resulted in equal-length beams and identical connections which in turn allowed for extensive prefabrication and considerable simplification during production and assembly. Wind bracing is provided by steel ties with screw tensioners, arranged as X-bracing. This bracing is placed within appropriate bays in the framework and is then covered over by the wall construction.

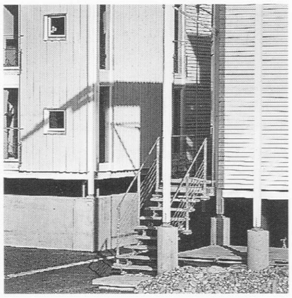
The external walls are provided with 100-mm-thick thermal insulation in the bays of the framework, covered by a vapour barrier and 12 mm plasterboard on the inside. The plasterboard is fixed flush with the inside face of the structural members, i.e. the columns remain exposed, and together with the exposed floor joists determine the internal appearance. This flush arrangement is achieved by attaching the plasterboard to 40 x 107 mm members recessed into the bays of the timber-frame construction. Covering the insulation externally are two layers of 13 mm soft boards. These are then covered by horizontal or vertical 24 mm rough-sawn fir weatherboarding on 40 x 60 mm battens. All in all, a form of construction offering a high degree of thermal insulation. The detail at the external corners is interesting, reminding the viewer of the famous “Mies corner”. However, owing to the low overall height, the exposed corner columns could be made from timber and do not require any cladding. Avoiding the use of a different material makes this corner detail almost more logical. The fir-frame windows are screwed onto the structural members from the outside and are sealed with a special “Compriband” seal let into a groove in the wood. The solar-control-glass, double-glazed windows have a special gas filling enabling them to achieve the very favourable U-value of 1.3 W/m^{2}K.

The floor construction above the joists is made up of 28 mm tongue-and-groove boarding with either a 30 mm V100G chipboard covering or, for living areas, a 30-mm-thick gravel layer to improve sound insulation. This is covered by 25 mm impact-sound insulation boards, a 0.2 mm polyethylene sheet and a 40 mm cement screed. A rubber floor covering is used throughout as a floor finish. The ground floor, open to the air underneath because the building is raised on stilts, has an additional 40 mm of thermal insulation fixed to the boarding and 40 mm fire protection cladding underneath.

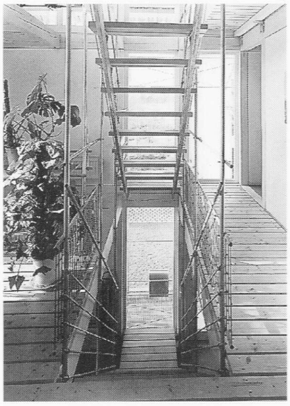
The roofs are offset monopitch roofs with a pitch of 32° and a clerestory window in between. The 120 x 180 mm rafters carry the 28 mm tongue-and-groove boarding (visible from underneath), a polyethylene vapour barrier and the 100 x 120 mm members for the profiled aluminium roof sheeting. The 120-mm-thick thermal insulation is placed between the members carrying the roof sheeting and is, therefore, ventilated from above due to the profile of the roof sheeting. The only steel elements are the stairs, stair stringers and handrails, made from hot-dip galvanized steel sections, and the external common walkways with their steel supports and open-grid flooring. The whole design is characterized by a very thorough attention to detail.



9 | This view during construction shows the structural concept. Also visible are the steel ties. On the right, an entrance façade before adding the timber cladding.



10 | External corners of two buildings showing the stilts on the foundations and exposed continuous corner columns.

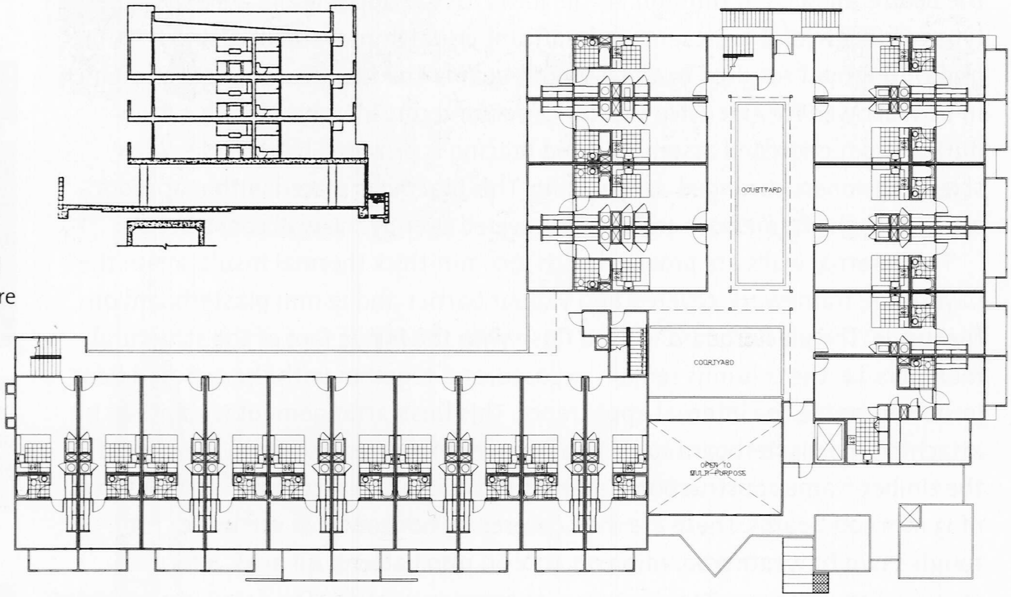


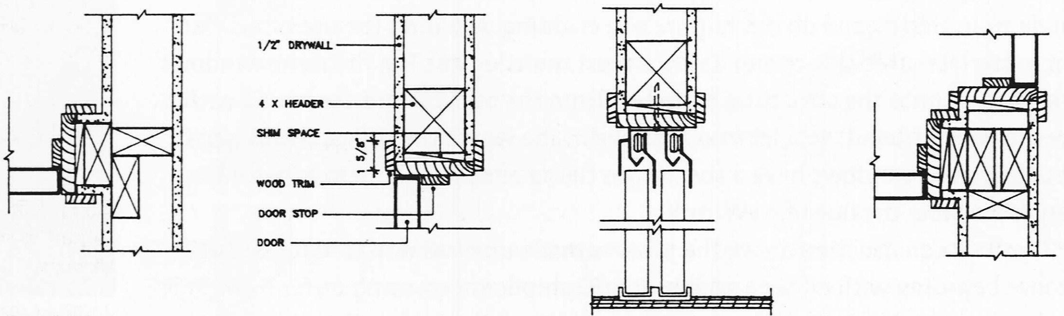
11 | Staircase at first floor level. Beechwood treads on steel stringers. The entire gallery is made from beechwood planking with open joints and no insulation or ceiling underneath. Also visible are the exposed solid timber joists which emphasize the construction.

1 | South elevation, scale 1:500. The decreasing sizes of the balcony openings to the street are clearly visible. Here on the south side the balconies on the top floor are provided with walls for shade or, in the case of the centre block, a framework for climbing plants.

2 | Cross section through residential wing, scale 1:500.

3 | Plan of standard floor layout, scale 1:500. All the apartments are connected via open walkways. The communal rooms, internal courtyards and entrance are located centrally.





4 | Standard details, which are part and parcel of working practices in the USA.

5 | View of the whole building from the south-east.

Manhattan Place Home for the Elderly, Los Angeles

John V. Mutlow

Subject | Timber-frame construction has a long tradition in the USA; 90% of all buildings, in particular residential accommodation, are built using this method. Only buildings exceeding four storeys must use non-combustible materials for the loadbearing elements, and steel or reinforced concrete structures dominate in that sector. Masonry structures are more prevalent in the eastern part of the USA, with its stronger ties to Europe. However, timber construction techniques have reached a high level of rationalization and standardization in the USA, which has led to simpler forms of construction and easier approval procedures.

Los Angeles offers a very good example of this. The city's Building Department has published calculations for the spans of beams, rafters, etc. for various loading cases as well as construction details, all of which are mandatory for developers wishing to build in the city. These strict specifications enable an architect to design a house without having to consult a structural engineer. Furthermore, the approval procedure is made considerably easier. Incidentally, since the last earthquake the provisions have been revised, in September 1995, so that they now only apply to single-storey structures.

The architect John V. Mutlow has for many years been designing housing for senior citizens on a low income. Such projects are financed by the various private and semi-official bodies involved in helping this often neglected social group. Such buildings must be as cost-effective as possible but still create a feeling of home. Mutlow's designs take maximum advantage of the standard design specifications, and the housing units are standardized to a great extent. This allows the communal rooms, internal courtyards and other special facilities to be incorporated at a favourable price – "extras" which, however, are indispensable if the occupants are to enjoy an acceptable standard of living. Small differences, e.g. in the design of the balconies, give the apartments an individual character despite the standardization.

Design | The project described here is situated in "Korea Town" and, as one might expect, is primarily occupied by Koreans. For the architects this meant that the strong family relationships of this social group had to be taken into account in

Location
Manhatten Place, 3663 9th Street, Los Angeles, USA

Client
Theodore and Soo Ng

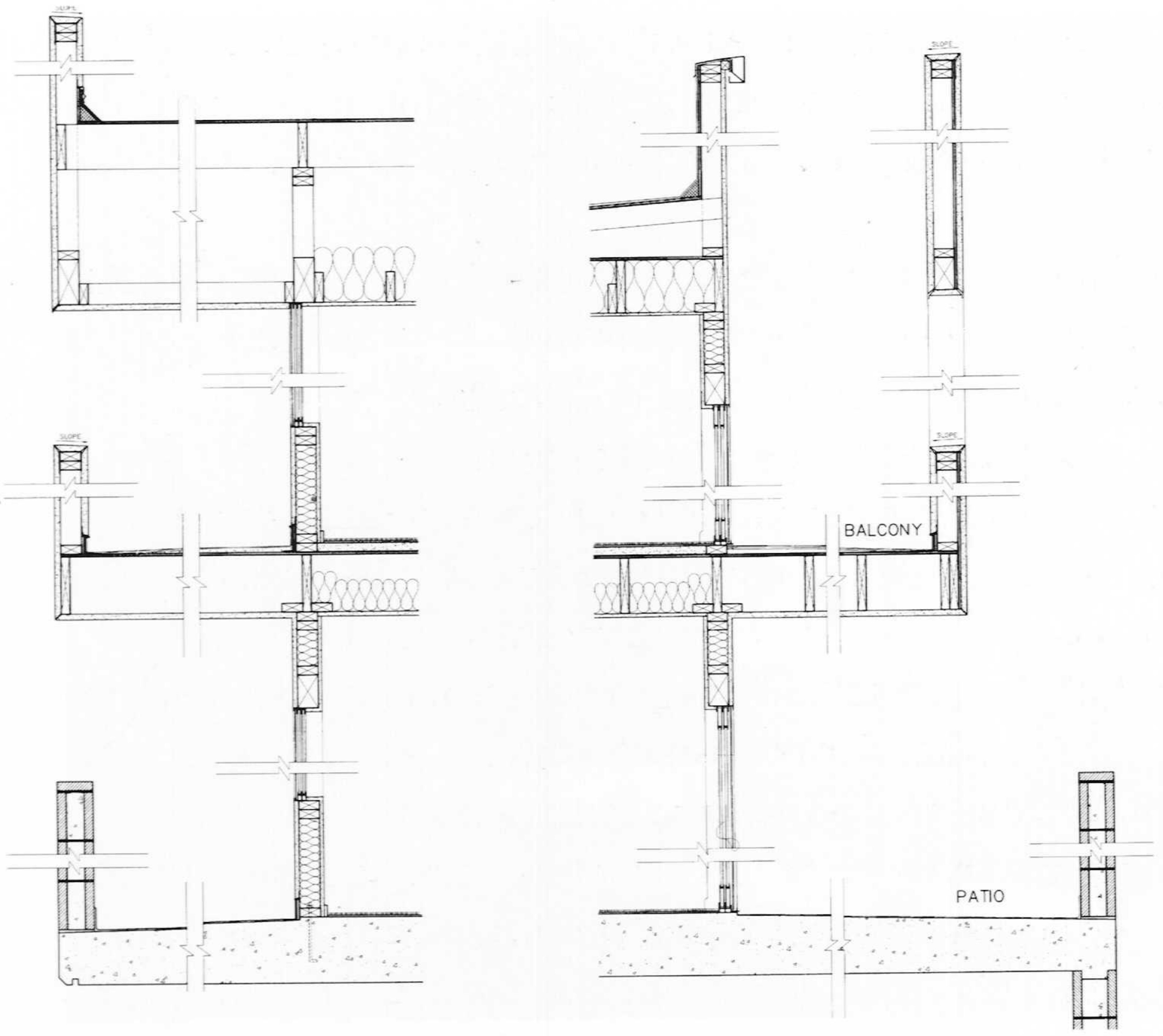
Architect
John V. Mutlow, Los Angeles
Design Team
Brian Emmerson, John Neel, Don Dimster

Structural Engineer
Jitu Mehta & Associates, Los Angeles

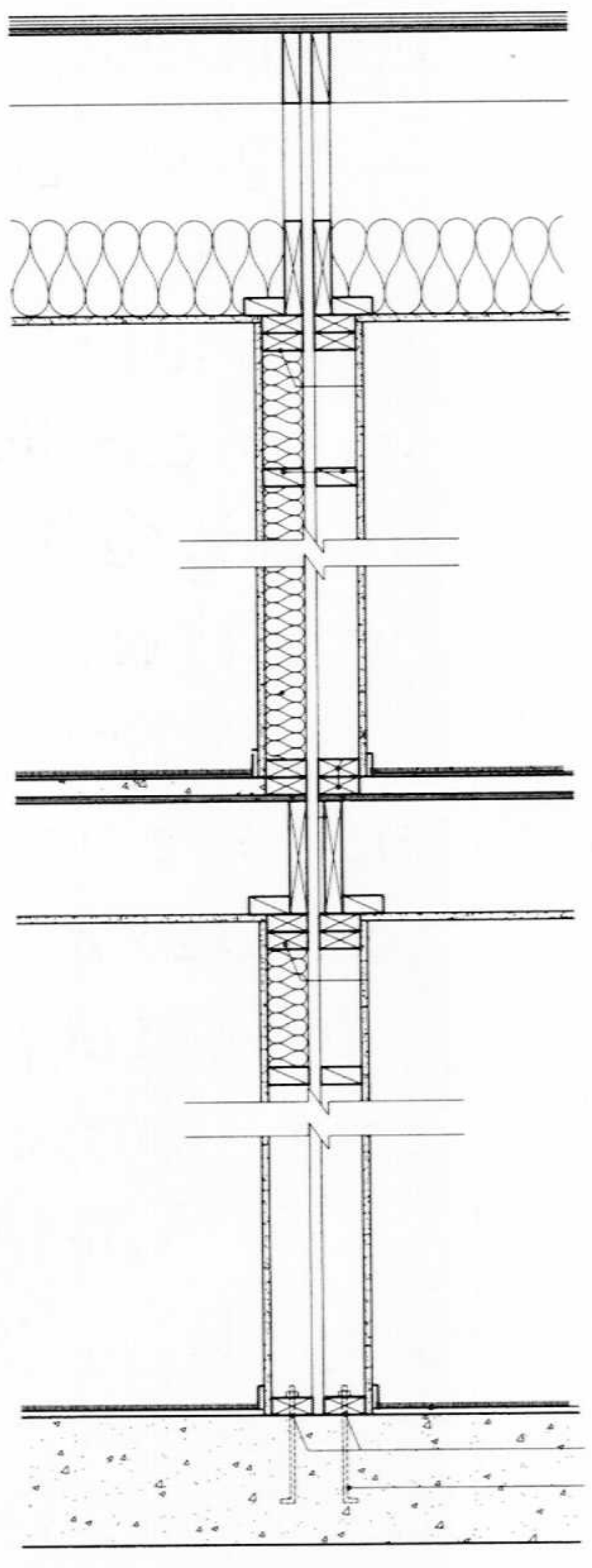
General Contractor
Alpha Construction, Los Angeles

Date of Completion
1993

Costs
The total building, including the garages, was built at a cost of 2.75 million US Dollars. This was financed by the "California Housing Finance Agency" and the "Los Angeles Community Development Department".



6 | Section of external walls, scale 1:40. Left, walkway side; right, balcony side. Roof construction: 4 layers of roofing felt, 16 mm plywood, 2 x 10 inch joists at 40 cm centres, 16 mm plasterboard suspended ceiling on 2 x 6 inch joists, 250 mm thermal insulation on plasterboard. Intermediate floor construction: foam-backed carpeting, 50 mm lightweight screed, 16 mm plywood, 2 x 12 inch floor joists at 40 cm centres, 16 mm plasterboard ceiling underneath. External wall construction: 3-coat external rendering on wire mesh, 100 mm thermal insulation between 2 x 4 inch timber studs at 40 cm centres, 16 mm plasterboard internally.



7, right | Section of wall between apartments, scale 1:40. Construction: 16 mm plasterboard, 100 mm thermal insulation between 2 x 4 inch timber studs at 40 cm centres, two 2 x 4 inch standard members top and bottom, 2 x 4 inch timber sole plate (on reinforced concrete slab), 30 mm gap between loadbearing walls, other side similar except no insulation.

the design. The old southern Californian style of a house built around an internal courtyard presented itself as a good solution; this courtyard would form the focal point for visits from relatives and for playing with the children and grandchildren.

The site is at the corner of two streets, the east and south façades facing the road. A 5 x 3 m floodwater culvert crosses the site, thus preventing the provision of a basement garage. Therefore, the ground floor merely contains the entrance and the garages, all in reinforced concrete. The apartments themselves are located above this in three storeys. Entrance, communal rooms and connecting courtyards are concentrated in the corner of the building where the two residential wings meet. All 60 apartments are accessible via open walkways and although only small – each is only 50 m^2 – all apartments receive daylight and ventilation from both sides.

The apartments are arranged thus: entrance, living area, dining area, kitchen, bathroom, bedroom, with a row of built-in cupboards opposite the kitchen and bathroom, as is so common in the USA. All the apartments have balconies with different designs facing the street; each group of six apartments is combined to form a three-storey "cluster" which enlivens the façades and helps to disguise the fact that all the apartment layouts are identical. The building, completed in 1993, was well received by its new occupants. In fact, the common feeling expressed itself in the unanimous decision to convert the multipurpose room near the entrance into a chapel.

Structure | This is a structural timber-frame building which is characterized by the closely spaced, standardized timber beam-and-column construction. In general with buildings of one or two storeys height all structural members measure 2 x 4 inch (approx. 50/100 mm). With three storeys, however, larger sections (3 x 4 or 2 x 6 inch) must be used for the construction of the lower storey, as was the case with this building. Its layout is marked out on the concrete foundation, or rather the reinforced concrete slab over the garages, using standard 2 x 6 inch timber sole plates (approx. 50 x 150 mm) anchored to the concrete with steel bolts. The walls for the first floor are then built on these using 3 x 4 and 2 x 6 inch studs spaced at 40 cm, covered both sides with 16 mm plasterboard. The framework for the storey is completed with a head plate comprising two horizontal

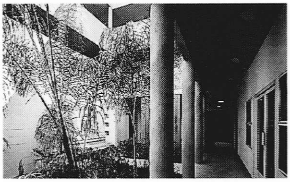
2 x 4 or 2 x 6 inch members. The cavity is filled with insulation batts, and stiffening intermediate studs are incorporated if required. Fixed to the head plate is the ceiling construction consisting of 2 x 12 inch (50 x 300 mm) joists at 40 cm centres.

Owing to these very thin joists, 2 x 12 inch stiffening timbers must be provided at each end; likewise every 2.40 m (max.) within the span. An 18 mm plywood covering to the joists provides a stiff plate effect. This acts both as a backing for the floor construction and as a support for the walls of the next storey. The second and third storeys are constructed identically except that here 2 x 4 inch members are used. Apart from that, the lower supporting members are doubled, i.e. two 2 x 4 inch, owing to the thickness of the floor construction.

Instead of plasterboard the external walls have a layer of plywood to which the bituminous felt is nailed. The outer skin consists of a three-coat external rendering on a wire mesh. Remarkably, no internal vapour barrier is necessary for the external walls; in this climate the warmth comes mainly from the outside so that the thermal insulation is not subjected to any long-term and, hence, damaging water vapour from the inside. The walls separating the individual apartments are doubled with a 3 cm gap and only have plasterboard on the sides facing the rooms – a form of construction which is sufficient for sound insulation purposes in this case.

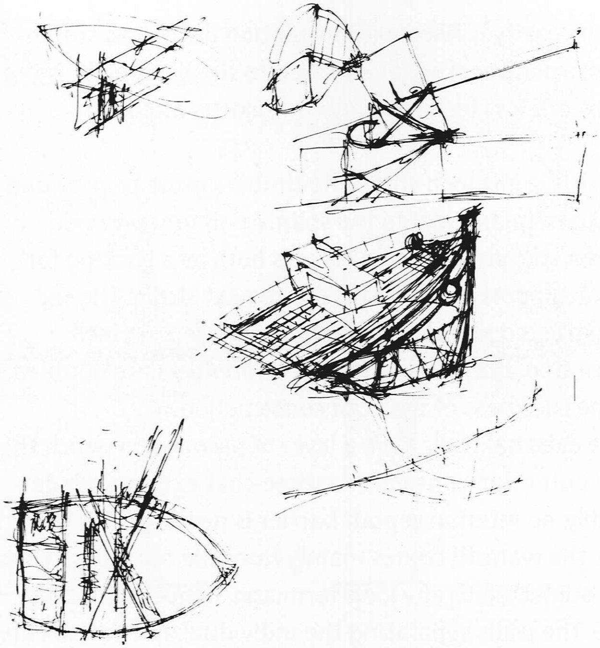
The flat roof is laid to a fall of about 1 in 25 and terminates on all sides behind the projecting parapets of the external walls. The loadbearing 2 x 10 inch joists follow the fall of the roof and are covered in 16 mm plywood and four layers of roofing felt. The plasterboard ceiling below the roof is attached to horizontal joists suspended from the roof joists. The 250-mm-thick thermal insulation is laid directly on the ceiling and there is no vapour barrier. The air space above the insulation is ventilated via grilles incorporated in the external walls with covers to protect against rain penetration. Exposed downpipes on the external walls are used for draining the roof. Spouts are laid through the parapets and over each an overflow pipe in case the spout should become blocked and also to enlarge the flow cross-section for the case of heavy rainfall.

The details of this structure more or less correspond to the Californian standard for timber-frame construction. It is interesting to see how the idea of Venturi's "decorated shed" has been realized effortlessly here and how post-modern forms have arisen naturally out of the possibilities created by the timber-frame concept. This is especially evident in the projecting balconies. Perhaps post-modern architecture had its real roots in the timber designs of California and was then later transferred to other countries, somehow adapted for other materials and only in a formalistic sense.

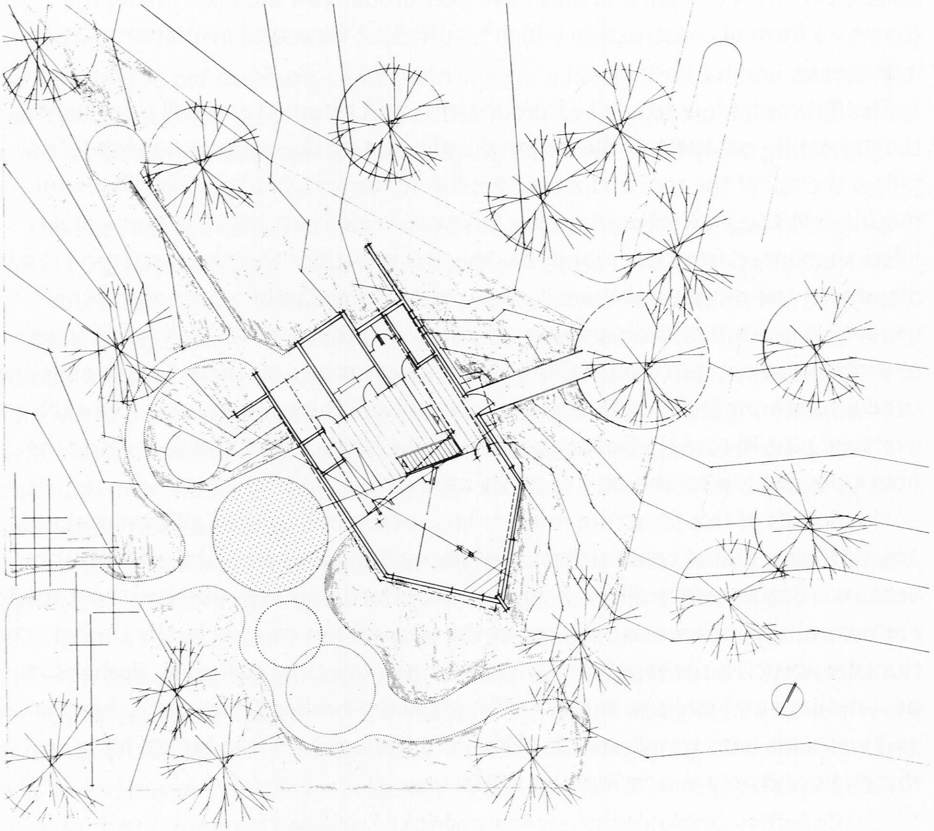


8 | Internal courtyard, on the right the communal room, above, the connecting walkways.

1 | Preliminary sketches by the architect.



2 | Site plan with entrance level (top storey), scale 1:500. In the bow recreation and common room, in the middle the entrance hall with staircase to bottom storey, on slope side head teacher's room and toilets.



3 | The "bow" of the kindergarten ship.

4 | The "Ship" seen from the west and showing the different surfaces.

"Luginsland" Kindergarten, Stuttgart

Günter Behnisch

Subject | This new kindergarten was built on the edge of a residential area of single and multifamily houses in Untertürkheim, Stuttgart. The plot is on a long slope facing south-west with a five-metre difference in level. A difficult task which, after a number of unsatisfactory inquiries by the Municipal Construction Department, was assigned to the architects Behnisch & Partner. Günter Behnisch describes the reflections that resulted in the unusual design:

"Certainly there are many ways of tackling such a problem. One would be to put up a building similar to the houses nearby: single or two-storey cubes with gable roofs. In the morning the children would simply go from the houses they live in to a house in which to play. A practical solution but one offering little difference between the children's world and that of the grown-ups. On the other hand, one could erect a building which, for a start, didn't exist in the world the children had hitherto lived in, something that couldn't have come from the world of grown-ups ... that doesn't pay off. A huge elephant you could live in or a ship, or something that looked like, or reminded you of, an elephant or a ship; a thing that didn't belong there, that no one expected to see in the middle of vineyards; something that might have slipped in from a world of make-believe: a ship that would belong to the children's world and form part of it; a ship that would sail away with you to some wonderful place; something you would fondly remember or that would evoke questions like 'What on earth is that ship doing in the middle of those vineyards?' or 'What's that prince doing on the star, the gnome in the shadowy corner, the nymph in that cool, clear water?' ... Things not found in our everyday world."

Originally the idea was to erect a reinforced concrete structure and face it with wood, it being assumed that with this material the unusual shape – the sloping and hanging walls – could best be realised. From the tenders received this was then seen to be too costly. However, the Municipal Construction Department was ready to put out another invitation to tender, specifying the shape of the building but not the material to be used. It was then found that with a timber skeleton construction and plank and beam walls the building could be comfortably financed. Within the short period of three months a completely new working plan had to be drawn up. The model based on it was then made available to the contractor as a guide.

Wood being a rather singular material requiring special jointing techniques, there was at first some hesitancy about using it for constructing the shape of a

Location
Kindergarten Luginsland, Lotharstraße 24, 70327 Stuttgart-Untertürkheim, Germany. Dates for public visits are arranged every six months by the team of kindergarten teachers. For information phone 0711-337544.

Client
Stuttgart Town Council, Technisches Referat, Hochbauamt

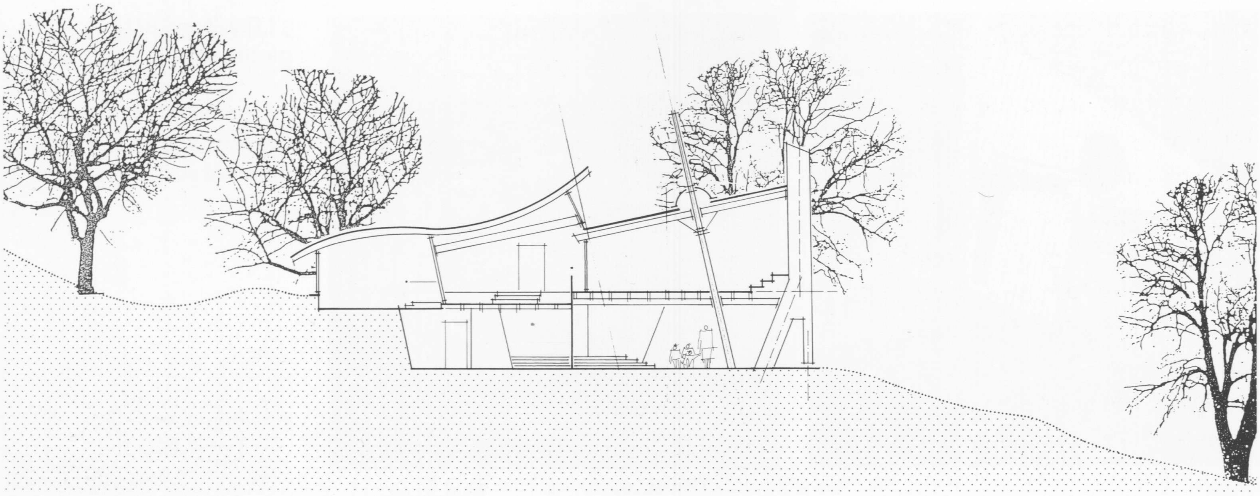
Architect
Behnisch & Partner, Freie Architekten BDA, Stuttgart
Project Architect
Sibylle Käppel-Klieber

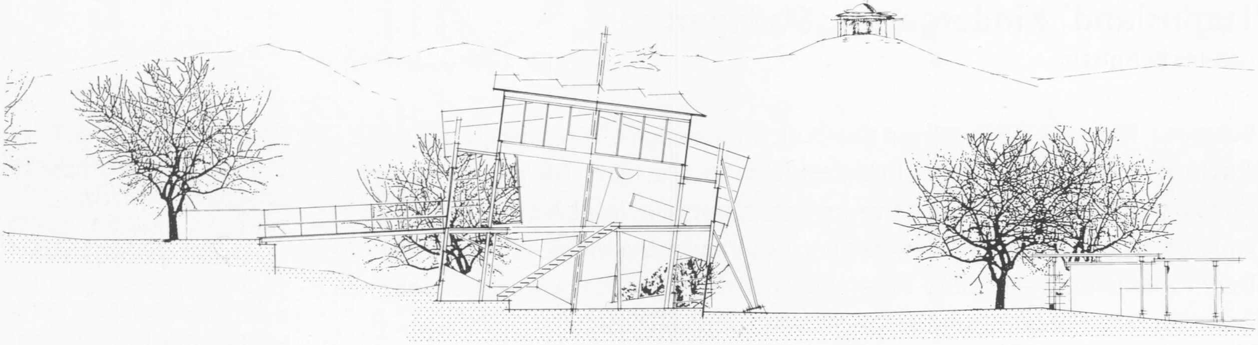
Timber Construction and General Contractor
Huber & Sohn, Bachmehring

Structural Engineer
Brünninghoff + Rampf, Ulm

Date of Completion
1990

Costs
At a net ground plan area of 317 m^2 and a gross cubage of 1 350 m^3 the building costs were approx. 1.7 million DM. The total costs amounted to approx. 2.7 million DM.





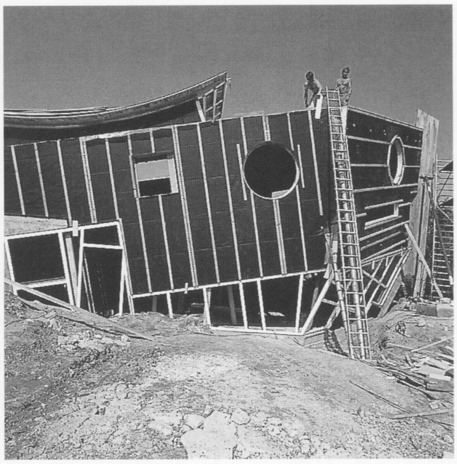
5 | Longitudinal and cross-section, scale 1:300.

6 | View of entrance hall with curved "cabin roof".

7 | Entrance hall during the construction stage. Same view as illustration 6.

8 | Lower recreation and common room with "mast" and double central joist.

9 | The "Ship" during the construction phase before the weather boarding or corrugated aluminium was fitted.



ship, which in concrete and steel could have been erected without any visible supporting structure, as flat surfaces and lines. But, as Behnisch said, "We got used to the idea and today we feel that the charm, the distinctive feature of this building, is that we have here something that was originally not intended to be of wood and has now been realised in that material." The observer has, however, the impression that wood is the most congenial material for this particular form and that the design could not have been solved in a better way. In 1991 the building won a number of prizes, including the Hugo Häring Prize awarded by the State of Baden-Württemberg.

Design | The "Kindergarten ship" emerges, so to speak, bow foremost, from the hillside. The external geometry is at an angle both length- and crosswise and is "disrupted" by the horizontal levels. This results in rooms of unusual shape. Two groups of infants are accommodated on two different levels with a recreation and common room each, the sanitary facilities, and adjoining rooms, the head teacher's room, and a large and small hall. Access to the building is via a "landing-stage" at the upper level. The outdoor and play areas can be reached directly from both levels.

10 | The „cabin roof" during the construction stage.

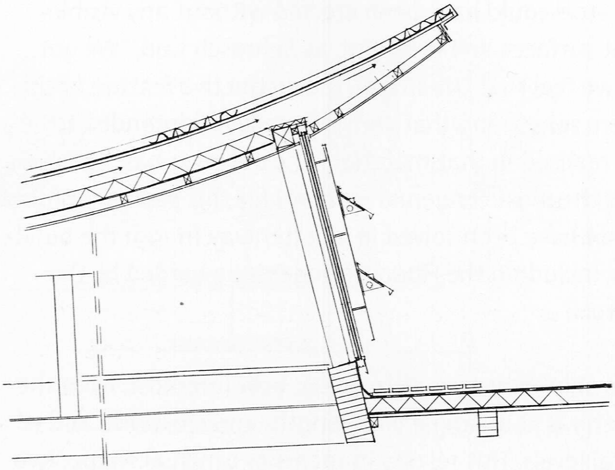
11 | Connection between „mast" and joist during construction.

Structure | The roof loads of the "Cabin roof" are taken up by the glulam beams which, curved to the shape of the roof, span the length of the cabin. The roof skin is of corrugated aluminium sheeting on 24 mm wood boarding and an underneath layer. The roof is insulated with a 100 mm mineral wool layer in the spaces between the 140 x 240 mm longitudinal members. The result is a ventilated roof with a 140 mm air space above the heat insulation. The underneath facing is of red fir-veneered plywood, attached to the glulam beams by means of 40 x 60 mm wood laths. This plywood sheeting serves as bracing for the sloping roof girders.

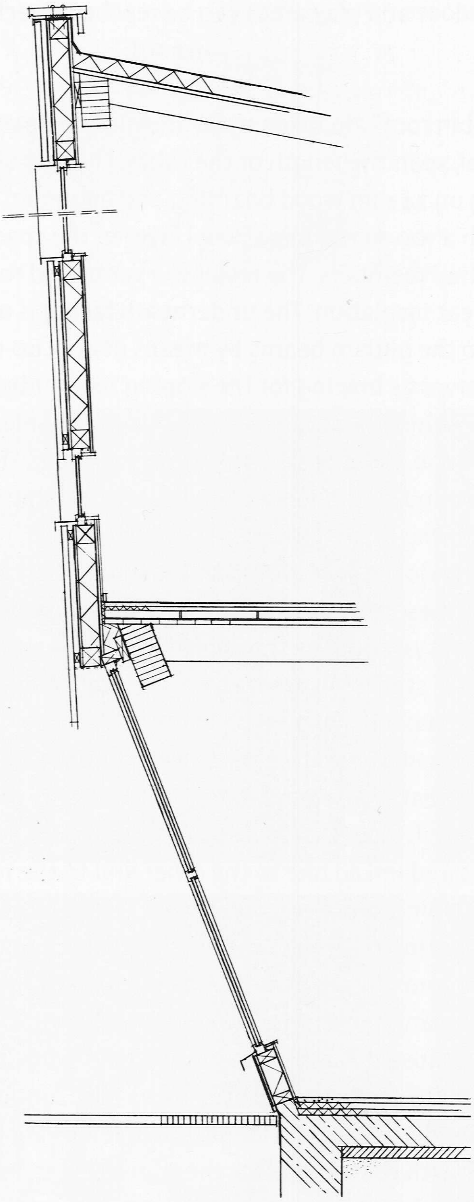
The "Upper Deck": The upper deck, which slopes towards the back and side, consists of a system of 120 x 160 mm solid wood beams of 800 mm spacing. The two-span beams are supported at one end by timbers running along the ship's side and at the other by an 180 x 300 mm glulam girder in the centre of the building. The longitudinal forces of the sloped roof are led into the members that run along the ship's side. At the stern these forces are transmitted to the floor, here of reinforced concrete, via bracing systems. The transverse forces are absorbed by stiffening walls and by a steel stanchion acting from outside against the ship's side at its theoretical buckling point. The roof above the system of beams visible from underneath consists of 22 mm tongue-and-groove boarding, the vapour barrier, 100 mm Roofmate heat insulating board and two layers of bonded sealing foil, a non-ventilated roof, that is, with wooden gratings for walking on, resting on Neoprene supports and linked one to the other and to the roof parapet to facilitate walking on the sloping surface.

The "Tweendeck": The floor construction resembles in the main that of the upper deck. The timbers are 140 x 240 mm glulam beams at 80 cm intervals. The centre bearer is of double cross-section and measures twice 140 x 400 mm. Although the floor is not at an angle, because it is supported by inclined parts, e.g. the bow, mast, external and intermediate columns, it exerts forces both longitudinally and transversely, like the upper deck does. The longitudinal forces are led via the joists to the massive stern. As with the upper deck the transverse forces are taken up by the reinforcing walls and a steel stanchion. To ensure effective sound insulation the floor has been provided with 50-mm-thick slabs – laid dry – underneath the 250 mm mineral wool footfall insulation boards. In the spaces between the slabs the pipes of the underfloor heating system are embedded in perlite loose fill. The floor covering consists of strip flooring laid on finger-jointed

12 | Cross-section of "cabin roof" and "upper deck" with row of sky-lights, scale 1:50. Design of "cabin roof": 15 mm maritime pine-veneered plywood panels, 60 mm lathing, vapour barrier, 140 x 240 mm joists with binders, 100-mm-thick mineral wool insulation layer and 140 mm air space, 24 mm squared timber boarding, insulating foil, 55 mm corrugated aluminium.
Design of "upper deck": 120 x 160 mm solid wood beams, 12 mm tongue-and-groove boarding, vapour barrier, 100 mm ROOFMATE heat insulation, welded insulation sheeting, wooden lattice on Neoprene supports. In front of strip windows sunshades of edged titanium/zinc sheeting.



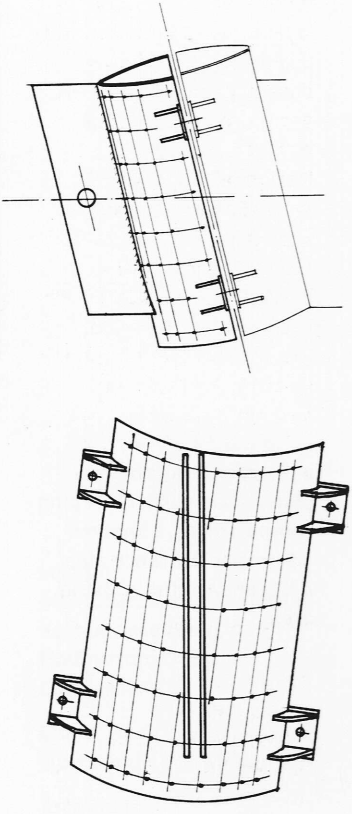
13 | Cross-section of façade, scale 1:50. Design of wall component with weather-boarding: 15 mm maritime pine-veneered plywood panels, varnished, vapour barrier, 120 mm hydrophobic mineral wool sheeting, 15 mm squared timber boarding, bitumen felt, 40 x 60 mm lathing, on top of this rough-sawn weather-boarding or 40 mm corrugated aluminium. In the final construction the wall panels at the bend at "tweendeck" height were not joined one in front of the other, as shown in the drawing, but evenly one above the other, which resulted in better connections and sealing.
Design of "tweendeck": 140 x 240 mm glulam beams, 28 mm tongue-and-groove boarding, 10 mm perlite loose fill, 50 mm slabs, 25 mm footstep sound insulation boards, 25 mm chipboards, finger-jointed and glued together, covered with linoleum over wool felt or 22 mm strip flooring throughout landing area.



and glued chipboard or linoleum on wool felt. The sound insulation has proved fully adequate.

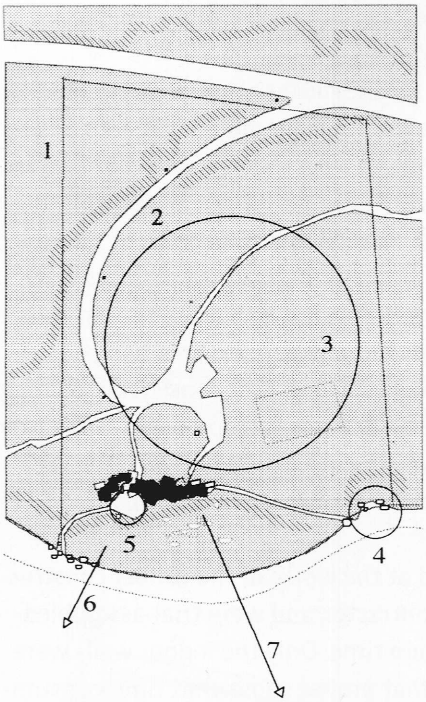
The "Ship's sides": The outer walls consist for the most part of prefabricated storey-high wood-frame components of 40 x 120 mm squared boards with a 120-mm-thick insulating layer of hydrophobic mineral wool sheet (Rockwool RFP). On the inner side the components are covered with a vapour barrier and 15 mm maritime pine-veneered plywood boards and coated with DD varnish or scumble. During transport to the site and installation the interior plywood surfaces were protected by hardboard. On the outside they are covered with a vapour-permeable membrane and 15-mm-thick planks. After the wall components had been fitted the ventilated outer covering was fixed in position. This consists partly of 40 mm corrugated aluminium sheeting on 40 x 60 mm spaced boards and partly of rough weatherboarding over spaced boards. The insulation between the wall components and between these and the window frames is of Compriband or plastic foam. Visible joints are silicon-filled.

All the structural parts were prefabricated at the works of the timber construction company, which also acted as general contractor, and were trial-assembled in the factory, thus speeding up actual erection time. Only the indoor walls were produced on the spot, a mode of procedure that proved somewhat time-consuming.



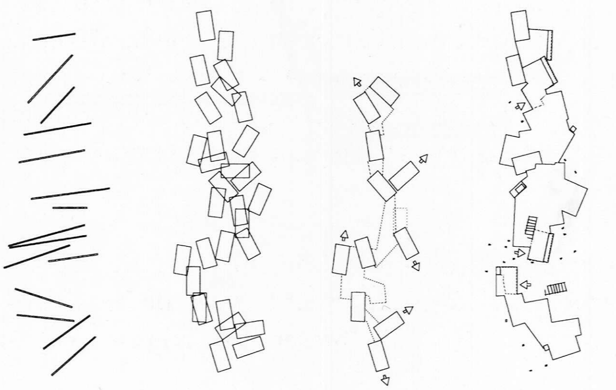
14 | Detail of connection between "mast" and central joist. On the mast two shells of 8 mm steel plate form a sleeve, which is nailed to the mast with 56 nails. Welded to this are two 8 mm flat bars, which are bolted to the flat 15 mm connecting plate of the central joist.

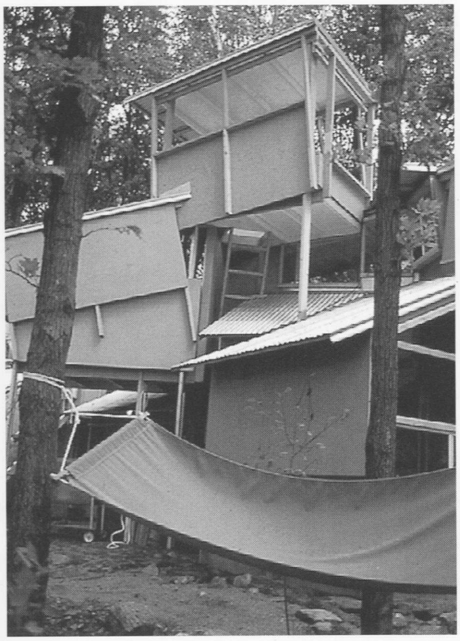
1 | Site plan, scale 1:2000. **1** Lakeside plot covered in forest. **2** Entrance drive. **3** Flat area with tall trees. **4** Mooring jetty. **5** Patio. **6** View across bay. **7** View of lake.

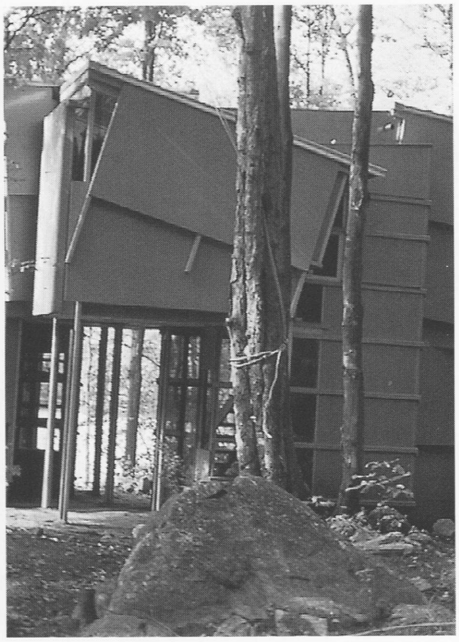


2 | North elevation and plans, scale 1:250. **1** Sleeping compartment. **2** Shower. **3** Screened entrance area. **4** Kitchen/dining. **5** Living area.

3 | Concept diagram. From left to right: position of sole plates; arrangement of the 32 floor panels; the upper floor showing the views; the ground floor with entrances indicated.







4 | The lookout tower seen from the lake side.

5 | Access passage between the entrance areas protected by insect screens, looking towards the lake. Left the living area, right the guests' bedroom.

McMullen Summer-House, Haliburton

Carmen and Elin Corneil

Subject | "Organic architecture" strives for natural designs and for unity between buildings and their surroundings, in accordance with the teachings of Frank Lloyd Wright. Time and time again, this claim has spurred architects on in the search for new definitions. Yet one will scarcely find a more rigorous and dedicated approach to this style than the McMullen summer-house situated amid the forests of northern Ontario on the northern bank of Kashagawigamog Lake.

Even its evolution was a process of organic growth. The whole approach was influenced by the fact that funds were very limited but not – according to the architects – the love of adventure! Friends and the whole family were involved in the planning and building work. This also gave rise to the "organic" functional design. Thirty-two standard plywood sheets (8 x 4 feet) from a do-it-yourself store served as the modules for the floor layout; these were used to set out the building on the site – completely without any fixed grid system – around the trees, exploiting the views and taking into account the planned functions of the accommodation. The architects compare the layout to falling leaves forming a pattern on the ground. And hence the design was to mirror the process of organic growth as well.

Tree tunks, firmly rooted in the ground, support parts of the building above. Roofs overlap like leaves. Structural elements are simply piled on top of each other and yet clearly define their own position in each case. In nature, rocks represent fixed points. In a similar fashion, the plywood sheets are the "rocks" of this house, their positions determining the final shape of the building. Of course, the building of such a structure was made easier by the fact that it is an unheated summer-house, merely a retreat from the urban daily grind and the demands of everyday life. The amateur construction team built the house over three successive summers.

Design | The building is sited across the slope which drops down to the lake and is accessed from the north through the forest. There are two entrances, one leading to the central living area and the other to the kitchen. The living area with its

Location
McMullen Summer-House,
Kashagawigamog Lake,
Haliburton, Ontario,
Canada

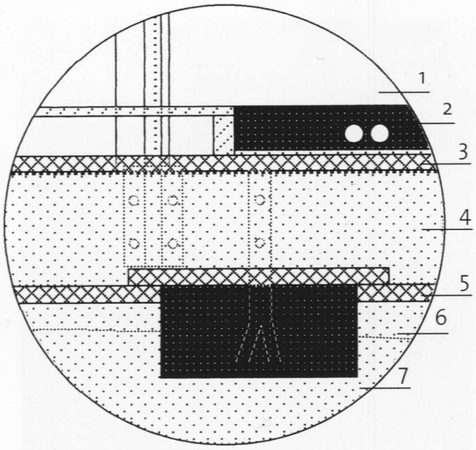
Client
David and Chris McMullen

Architect
Carmen and Elin Corneil,
Toronto and Trontheim

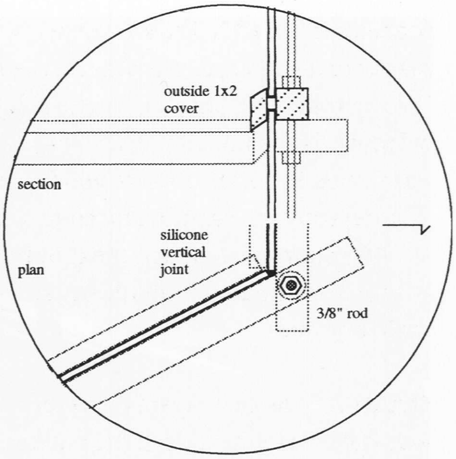
The Construction Team
Odd Øverdahl, Janne Corneil
Assistants
Espen Hagen, Natalka Lubiv, Rolf Siefert, August Schmidt, Gavin Leeb, Rick McKenzie, Rob Cadeau, Louis Franceschetti, Robert Phillip, Marit Corneil, Jennifer McMullen

Date of Completion
1990

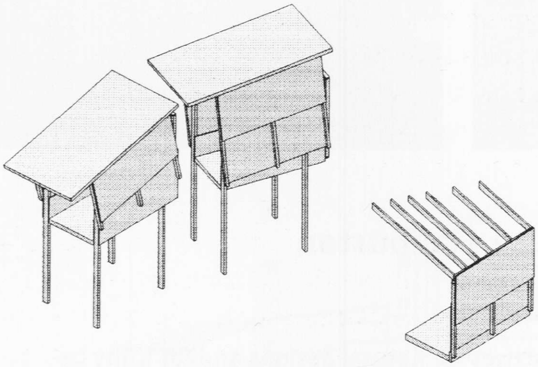
6 | Foundation construction: **1** Retaining pole and timber column. **2** Floor panel and concrete screed with services. **3** Ventilated insulation layer with damp-proof membrane underneath. **4** Compacted sand between two 50 x 250 mm sole plates. **5** Foamed-glass insulation, 40 mm. **6** Concrete raft foundation. **7** Undisturbed ground.



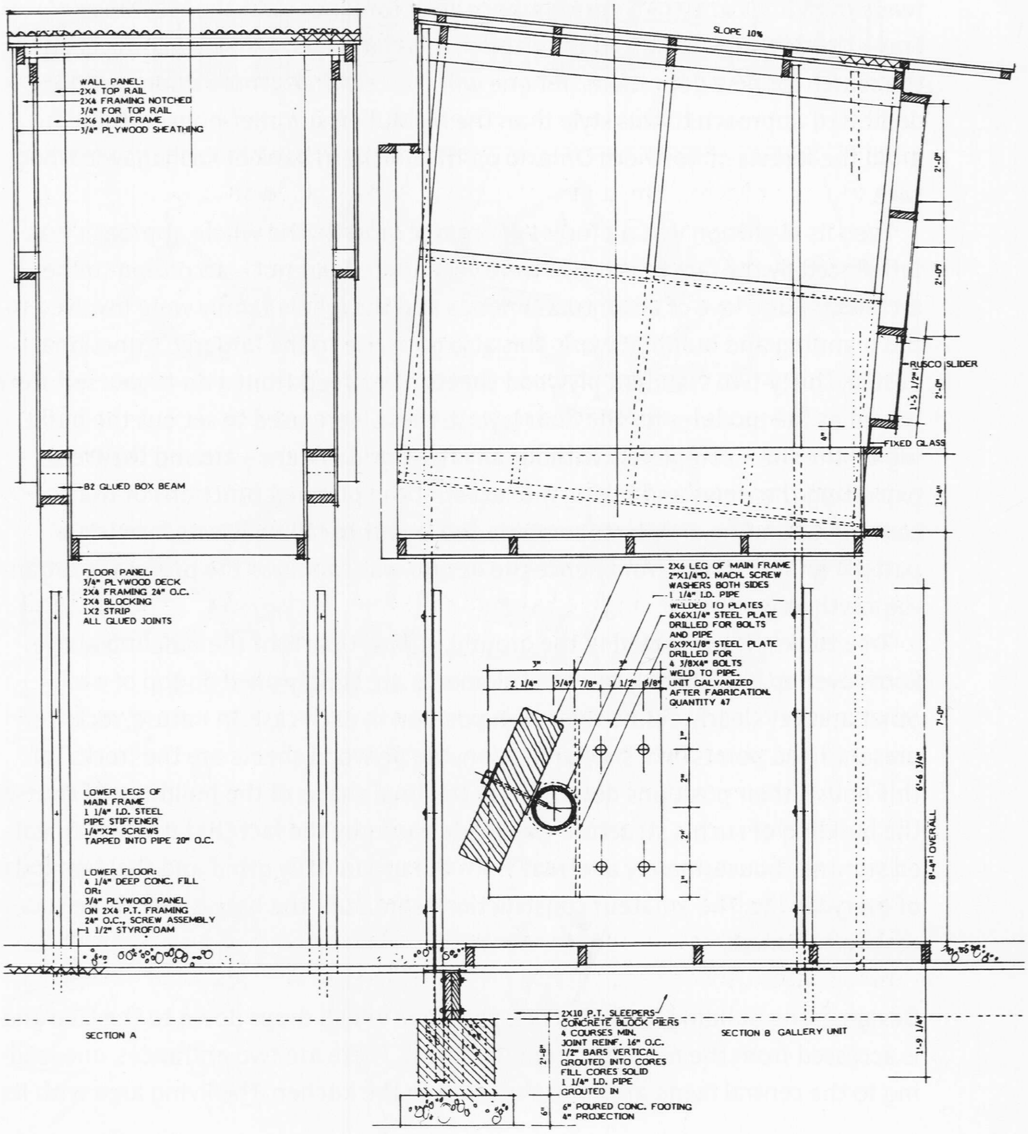
7 | Detail of glazing. A 9.5 mm steel bar supports 50 x 50 mm horizontal battens for the panes of glass which are held in place by means of bevelled 25 x 50 mm beading on the outside. The vertical butt joints are sealed with silicone.



8 | Isometric view of two-storey prefabricated elements. On the right, a single-storey extension with monopitch rafters.



9 | Section through two-storey element, scale approx. 1:40. Shown here are the 150 x 50 mm columns with the 32 mm diameter retaining poles and the 2440 x 1220 mm standard floor panel of the upper floor. The inclined roof element is placed over the main framework. The detail shows the welded anchor plates of the retaining poles as well as the screwed joint with the timber columns.



fireplace is linked to the kitchen via a dining area and to the bedrooms above by means of a staircase. This staircase leads to a landing with the bathroom, containing toilet and shower, on one side, and from where passages and bridges lead off towards the individual sleeping compartments. These compartments are positioned to suit the views, which were considered from the outset. Back on the landing you can reach the lookout above by way of a ship's ladder, or descend another staircase to reach the ground-level patio in front of the living area. There is a separate bedroom for guests at the western end of the house adjacent the main entrance.

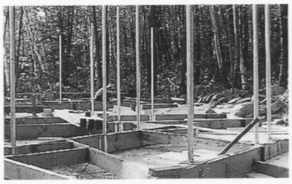
Structure | As there were a number of trees close to the house and as the subsoil was full of large boulders, the builders decided in favour of a raft foundation. The site was first levelled by introducing a layer of sand on which the building was set out. The trenches for the footings were excavated down to the level of the existing subsoil and then the whole area of the building was covered with 38 mm foamed-glass insulation. The layout was then set out again on this insulation and the main sole plates (two 250 x 50 mm members, impregnated), including the foundation anchors, carefully positioned. The trenches for the footings were then filled with concrete up to the level of the top of the insulation.

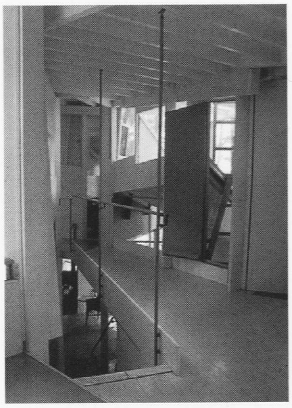
Next, the retaining poles for the building's columns were bolted onto the sides of the main sole plates and screwed on from above. The 3 mm fixing plates had been welded onto the 32 mm diameter retaining poles prior to galvanizing. Finally, the sole plates were braced with cross-members and the bays filled to the top with sand; a damp-proof membrane was then laid across the whole construction. More foamed-glass insulation was laid on top of this but here in strips with ventilation gaps between. The prepainted floor panels were then laid in their predetermined layout between the retaining poles. These panels are the basic modules and consist of 2440 x 1220 x 19 mm standard plywood sheets (8 x 4 feet) with 100 x 50 mm framing and transverse members glued on at 600 mm centres.

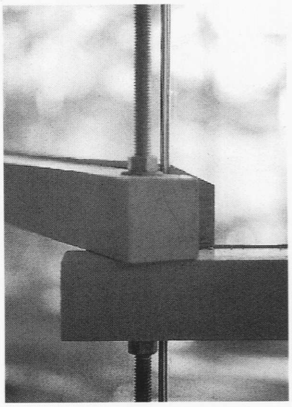
The structural system of the house resembles the American "balloon frame" system, i.e. the framework columns continue past the floors and support these. In this building, with its highly eccentric layout, the columns for the single-storey sections are located according to the positions of the ground-floor panels, whereas those for the two-storey sections are aligned with the upper-floor panels. The floor panels are always supported by four 150 x 50 mm columns which are fixed with four screws to the pre-installed retaining poles. The roof construction is noteworthy: elements comprising the roof surface itself and the side walls joined to it at right-angles, are placed over the main frame construction at an angle to suit the roof pitch – with the construction left exposed externally! The walls consist of 100 x 50 mm framing clad externally with 19 mm plywood. The roof itself is formed by a loadbearing panel, 100 x 50 mm battens fitted to this with 40 mm thermal insulation laid between, and, finally, profiled steel sheeting. The loadbearing roof panel is a 19 mm plywood sheet with 100 x 50 mm timber stiffeners glued-nailed to the underside at 600 mm centres.

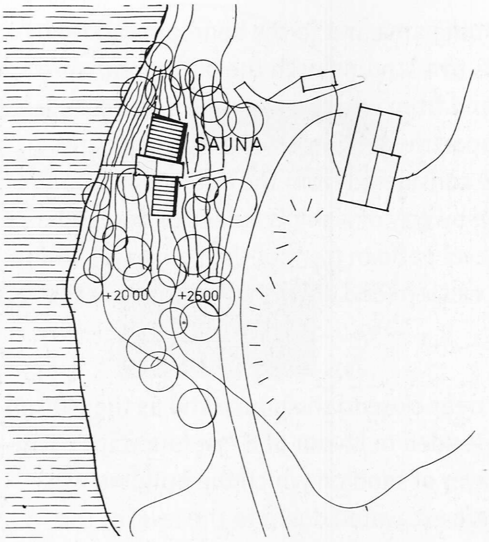
The two-storey frameworks were assembled on site on the ground before being lifted into position and fixed to the retaining poles. All transitions and gussets which ensue as a result of the geometry are filled in, glazed or provided with insect screens on site. Windows are timber-framed, single-glazed.

After the electrics and plumbing were installed in the ground floor, the intervening spaces between the floor panels were filled with a concrete screed.

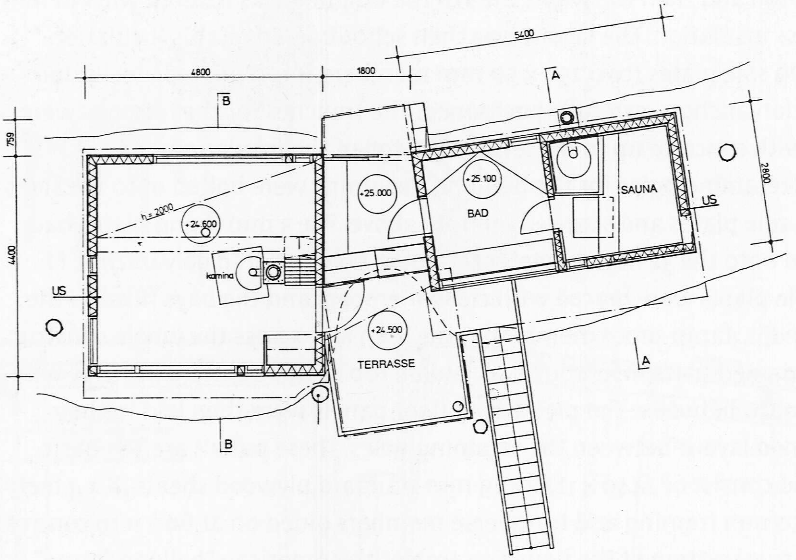

10 | The foundation during construction. Visible are the compound sole plates with their stiffening members and bolted retaining poles. The bays have not yet been filled with sand.


11 | A view of the upper floor showing the stairs ascending from the living area, the bridge to the western sleeping compartments and the ship's ladder leading to the lookout tower.

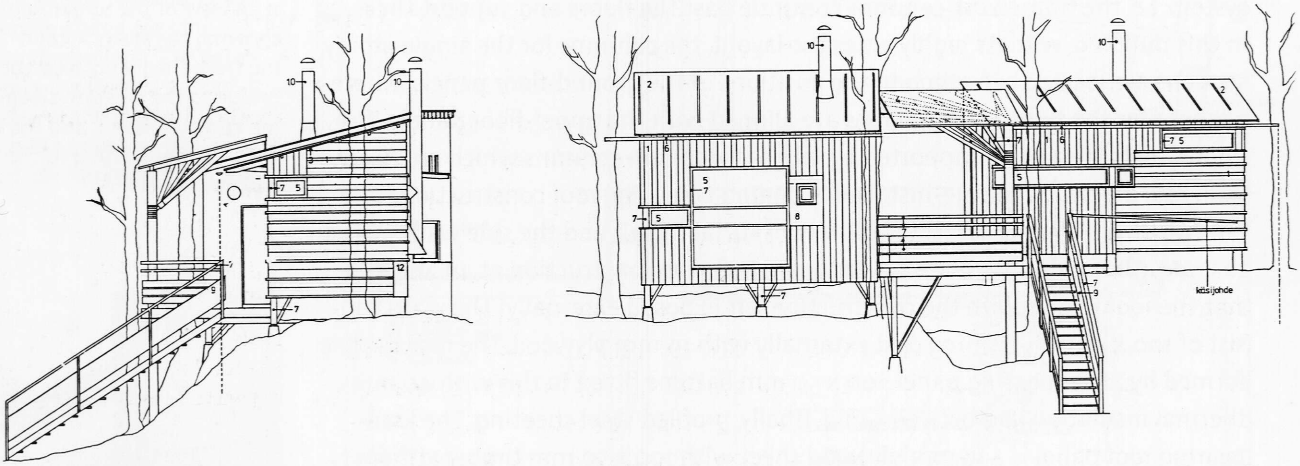

12 | Glazed corner detail.



1 | Site plan, scale 1:1000.



2 | Plan, scale 1:150. On the left, the sitting room, on the right, the sauna with changing/shower room, between them the patio.



3 | South and west elevations, scale 1:150. The effect of the different claddings is clearly visible.

4 | View from north-west towards sitting room and patio.

Rausti Sauna, Pornainen

Brunow & Maunula

Subject | For decades Finland was a nation hemmed in by the Eastern and Western Blocks, until this power balance subsided. As a mediator and official/unofficial point of contact between both sides it enjoyed great attention. This fostered a flourishing economy which also led to notable investment in the construction sector; many buildings for government, administrative and sports purposes bear witness to this. They were all built in an age dominated by steel and concrete; the indigenous material timber remained totally neglected – like in most other countries. As the "Cold War" ended, so did Finland's economic prosperity. The financial consequences of the great building boom are proving to be enormous, the economy is stagnating. With the general rebirth of interest in timber as a building material, Finland too – which in Alvar Aalto has an architect of international renown – is beginning to re-establish traditional forms of timber construction. Unfortunately, funds and hence opportunities for major experiments are considerably limited. Therefore, it is the young architects who are trying to find a new vocabulary of home-grown architecture by way of smaller projects.

Finland is well known for its many lakes, its vast forests – and its saunas! More than one-third of Finnish households possess a summer-house somewhere in a forest by a lake and with a sauna. A special culture of relaxation and seclusion has evolved over a long period of time, a culture which matches the natural circumstances and exploits them to the full. The Finnish sauna is a product of this environment. Typical features are the wood-burning stove, which ensures the dry heat amid the cold arctic climate, the wooden surfaces in the sauna – for wood is the only material one can touch at such temperatures (approx. 90°) – and a lake nearby for intensive cooling. The necessary changing room, indoor and outdoor areas for sitting or relaxing as well as cooking and sleeping facilities round off the Finnish sauna. In this way, a few days or weeks can be spent relaxing and "recharging the batteries".

Design | The house belonging to the client's family is situated on the steep east bank of the Niinijärvi Lake about 50 km from Helsinki. The sauna was to be built halfway up this bank. The architect conceived the sauna as a resting point on the

Location
Villa Rausti, Niinijärvi,
07170 Pornainen, Finland

Client
Mr. and Mrs. Uki Rausti

Architect
Brunow & Maunula Architects, Helsinki
Design Team
Juhani Maunula, Vesa Pekka Erikkilä, Anna Brunow

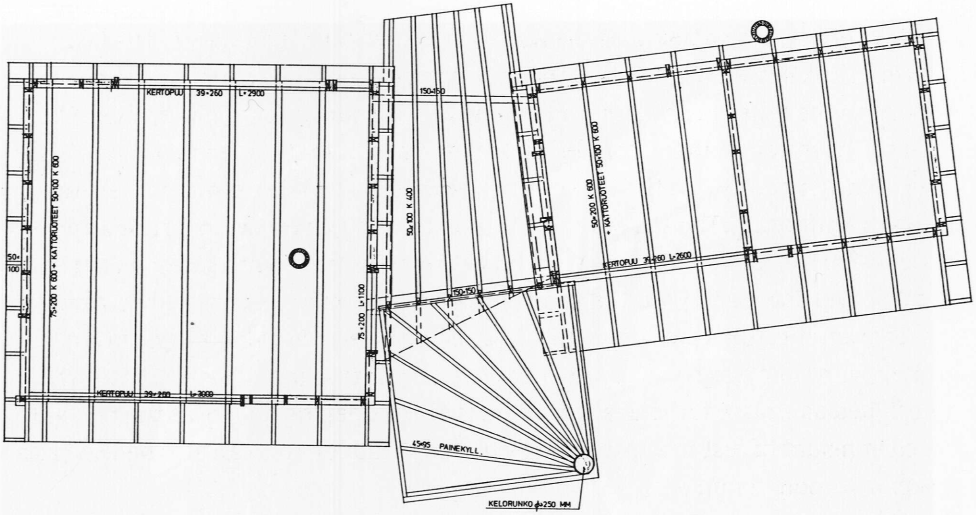
Structural Engineer
Pentinmikko & Tikkala Oy, Helsinki

Timber Construction
H. Myllynen, Sipoo

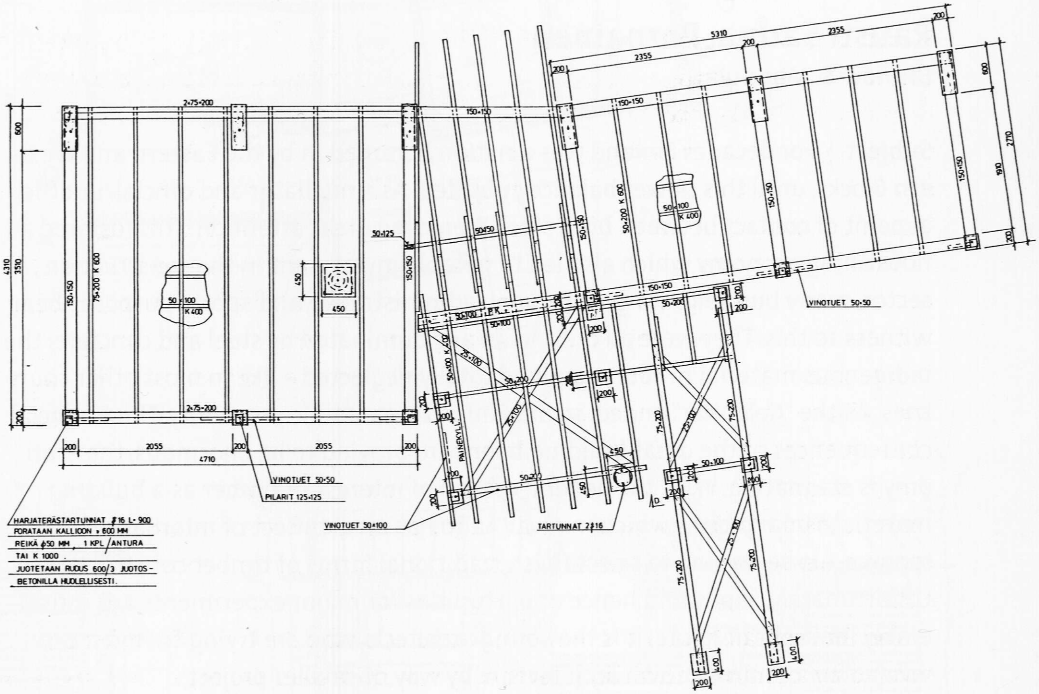
Date of Completion
1991

Costs
The total cost of the building was 245 000 Markka.

5 | Structural drawing of roof beam layout, scale 1:100.



6 | Structural drawing of floor beam layout, scale 1:100.



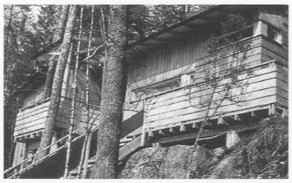
stairs between the house and the water. A small patio with a view of the lake forms a link between the sitting room on one side and the changing and shower room on the other side which leads to the actual sauna room. So the whole Finnish sauna ritual is catered for. The stove in the sauna room is fired with wood in the traditional way and the upper bench is wide enough to permit bathers to lie down comfortably. The shower room has no running water; water for pouring over the bathers is provided in wooden buckets. The patio with screened bench for cooling down and with the stairs enabling bathers to descend to the lake, has a transparent sunshade at the front supported by wooden struts. The sitting room with fireplace, seating, small cupboard and large panorama window, is designed as a place for relaxation. There is also a sleeping gallery at the rear with a clear height of just 1.20 m, reached via a ship's ladder. This can also be used as a separate room for guests.

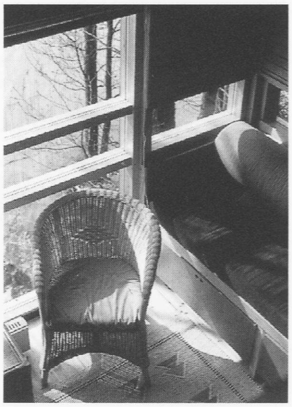
The stairs were re-routed during construction. In order to ease the climb, a return was incorporated and the pathway laid around the outside of the sauna. That somewhat diluted the original idea of the simple resting point halfway down to the lake but, on the other hand, gave the internal functions more coherence and avoided their being split in two by the pathway.

Structure | Owing to the steep slope of the ground, the building was conceived as a wooden box placed directly on separate pad footings at the rear (i.e. against the slope) while the front was propped up on 125 x 125 mm timber stilts, again on separate pad footings. At the rear a continuous strip footing would have been disadvantageous because water draining down the slope would have become trapped behind it; hence pad footings were used here as well. Resting on these footings and parallel to the slope are the 150 x 150 mm main beams which carry the floor joists at 600 mm centres, notched onto the main beams. These joists are 200 x 75 mm in the sitting room and 200 x 50 mm in the sauna itself, due to the different spans. The external walls are in timber-frame construction consisting of vertical 125 x 50 mm studs at 600 mm centres standing on a similarly sized sole plate. At the top they are connected to 260 x 39 mm glulam beams, positioned on the inside face, which carry the 200 x 75 mm or 200 x 50 mm rafters at 600 mm centres; the pitch of the roof is about 15°. The glulam beams are made very narrow in order to allow the thermal insulation to continue past virtually unimpeded.

The roof contains 100 + 100 = 200 mm insulation laid between the rafters, covered by a continuous airtight layer of 13 mm chipboard. On top of this, secondary rafters, 100 x 50 mm, guarantee a 100-mm-deep ventilation gap below the tongue-and-groove boarding, and support the overhanging eaves. Bituminous felt provides the waterproofing for the roof. Fixed below the main rafters are 50 x 50 mm battens at 400 mm centres with a further 50 mm of insulation between them, the vapour barrier underneath this and finally the ceiling, made from 70 x 15 mm fir planks left exposed. In the sauna room itself, 22 mm counterbattens fixed between the vapour barrier and the ceiling construction create an additional ventilation gap.

The external walls contain 125-mm-thick thermal insulation in the bays, covered internally by a vapour barrier and the 70 x 15 mm fir planks which form the wall finish. In the walls to the sauna room, an additional ventilation gap is provided similar to that in the roof. On the outside there is a continuous layer of 30 mm chipboard with 22 mm vertical counterbattens to provide an external ventilation gap, followed by the horizontal 100 x 22 mm sections which carry the wall finish comprising 25 mm impregnated fir planks in random widths. For aesthetic reasons, some sections of the external walls are clad horizontally instead. At the

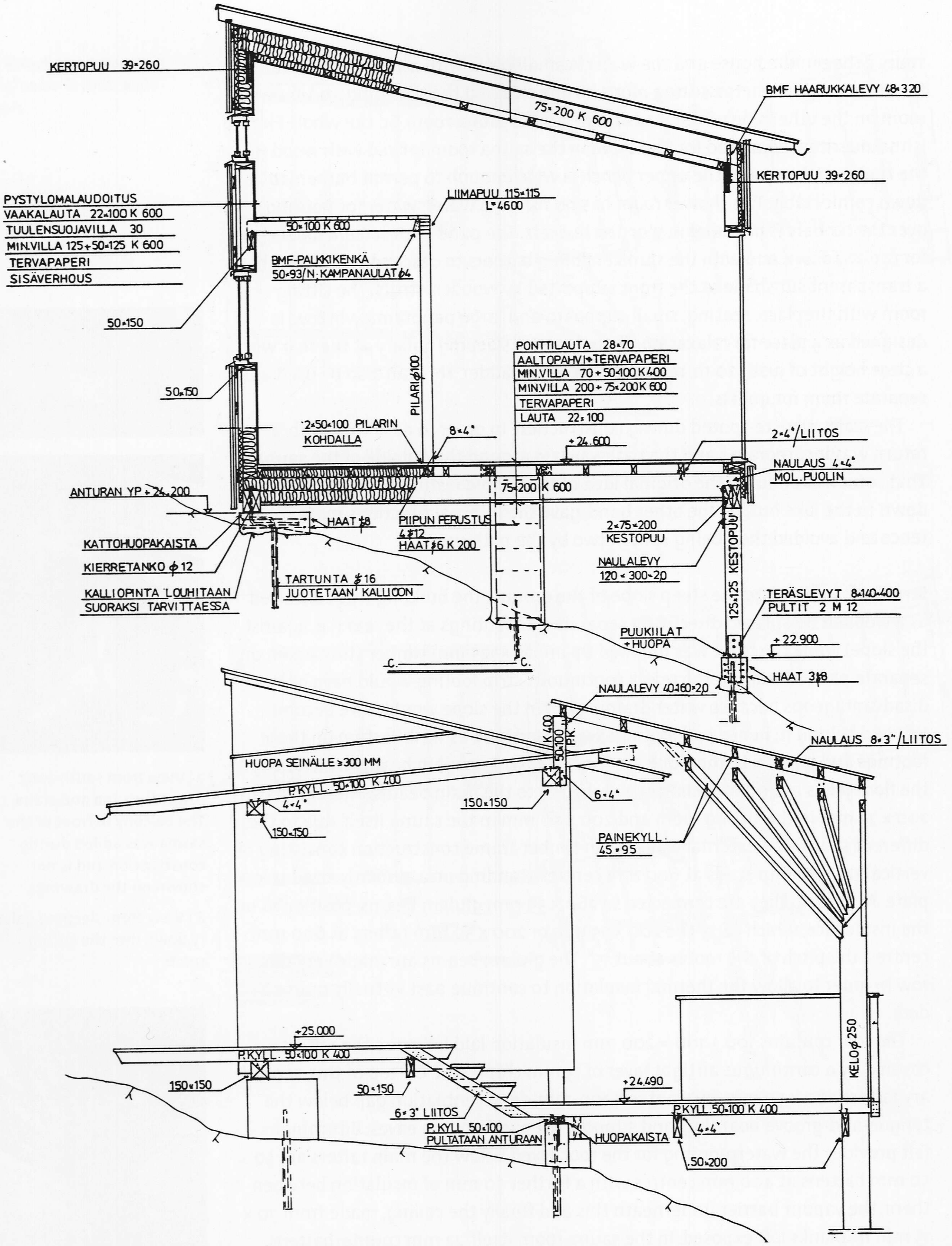




7 | View from south-west towards sauna and stairs. The balcony in front of the sauna was added during construction and is not shown on the drawings.

8 | View from sleeping gallery down into the sitting room.

9 | The umbrella canopy.



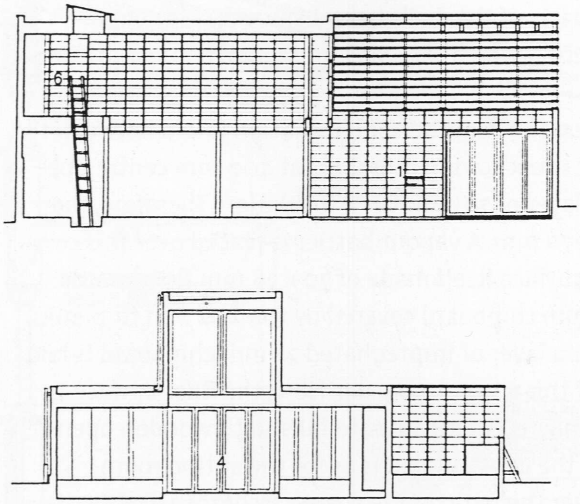
10 | Section through sitting room and patio, scale 1:50. Floor construction, sitting room (from top to bottom): 70 x 28 mm floorboards, vapour barrier, 70 mm insulation between 100 x 50 mm sections at 400 mm centres, 200 mm insulation between 200 x 75 mm joists at 600 mm centres, 13 mm chipboard, 22 mm timber cladding.
Wall construction (from inside to outside): 15 mm timber cladding, vapour barrier, 125 mm insulation between 125 x 50 mm studs at 600 mm centres, 30 mm chipboard, 22 mm ventilation gap, 100 x 22 mm planks, 25 mm exterior cladding. Roof construction (from top to bottom): 2 layers bituminous felt, tongue-and-groove boarding, 100 x 50 mm secondary rafters at 600 mm centres, 13 mm chipboard, 200 mm insulation between 200 x 75 main rafters at 600 mm centres, 50 mm insulation between 50 x 50 mm sections at 400 mm centres, vapour barrier, 15 mm exposed ceiling.
Floor construction, patio: 25 mm floorboards, 100 x 50 mm sections at 400 mm centres, 200 x 50 mm or 250 x 50 mm transverse beams (150 x 150 mm at the rear). Umbrella canopy: circular pine column, 250 mm diameter, 95 x 45 mm inclined struts mortised and glued into column, 95 x 45 mm canopy supports connected to the struts, ribbed plastic decking.

rear of the building, the lower parts of the walls have a smooth cladding of waterproof-glued plywood sheeting which serves as protection against drifting snow.

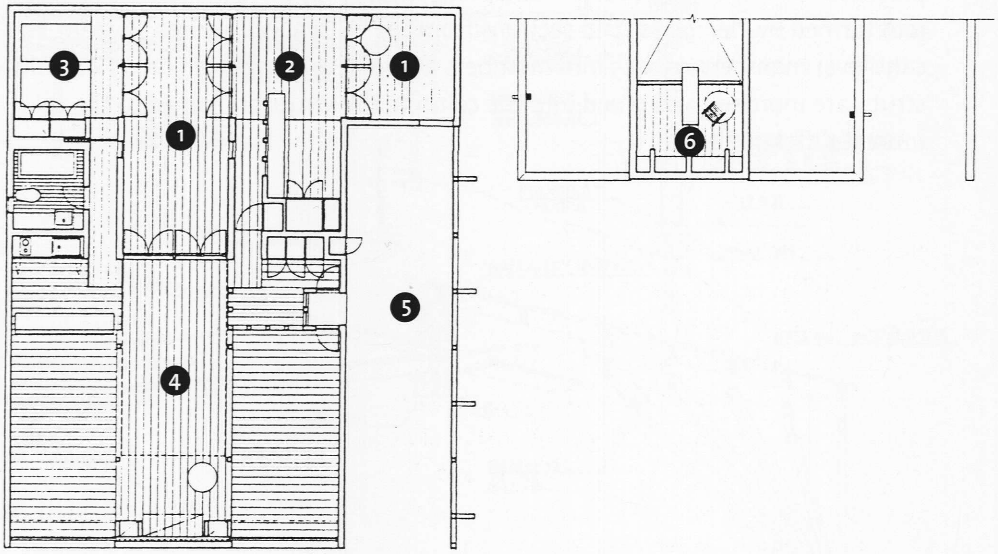
In the sitting room 100 + 100 = 200 mm thermal insulation is laid between the floor joists. These joists support 100 x 50 mm members at 400 mm centres, between which there is a further layer of 70-mm-thick insulation. Therefore, the total thickness of insulation is 270 mm. A vapour barrier is placed over this construction followed by the floor surface itself made of 70 x 28 mm floorboards. Below the joists is a layer of 13 mm chipboard covered by 100 x 22 mm fir planks. In the sauna and shower rooms, a layer of impregnated 22 mm chipboard is laid on the floor joists and on top of this a vapour barrier. Here, the floor surface is formed by a 40–60-mm-thick concrete screed laid to falls, with wooden open-grid flooring on top. The rest of the construction is as for the sitting room.

The umbrella-type canopy over the patio is a real eye-catcher. A 250 mm diameter timber column, which also supports one corner of the timber patio, is provided with struts at the top in a fan formation, clipped to which is the square roof formed by Plexiglass strip sections from the "ICOPAL-Valovoima" system. The cantilever members, 95 x 45 mm members at roof level supported on 95 x 45 mm struts, are mortised and glued into the column. The struts are joined to the column at different levels.

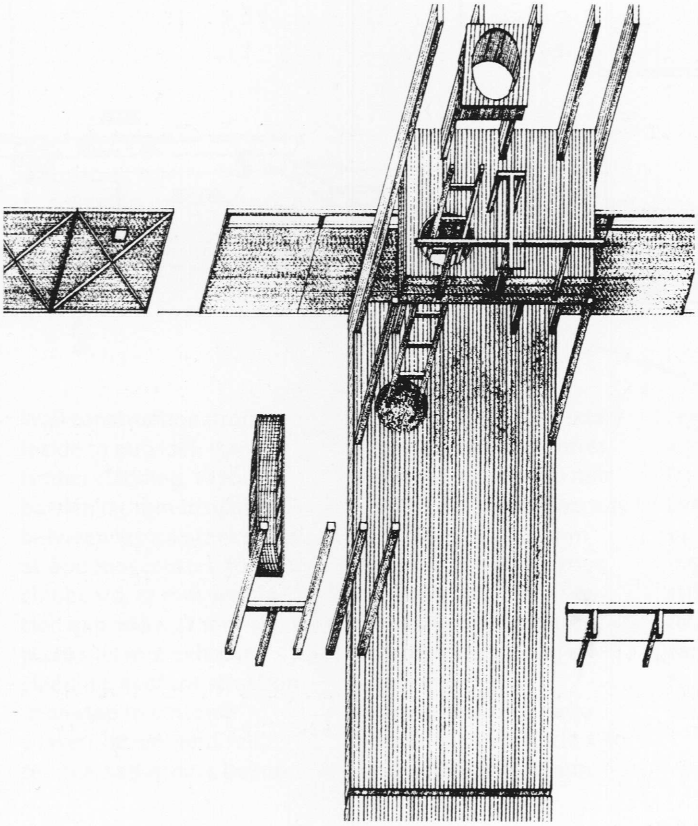
1 | Sections, scale 1:200.

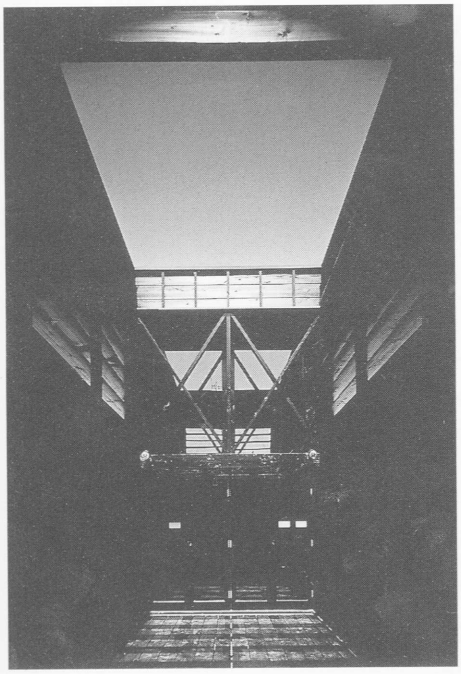


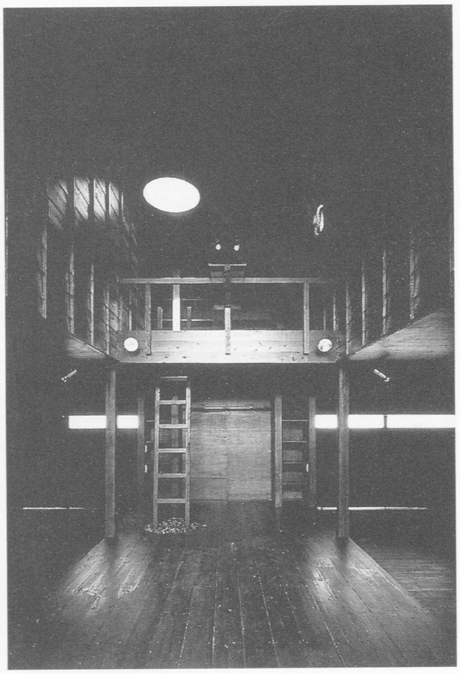
2 | Floor plans, scale 1:200.
1 Internal courtyards.
2 Study. **3** Bedroom.
4 Living room. **5** External carport. **6** Library gallery.



3 | Isometric projection of space-generating elements.







4 | Entrance to external carport.

5 | Living room looking towards the library gallery.

Weekend House, Osaka

Hiroshi Nakao

Subject | The architect Hiroshi Nakao, only 35 years old, has also made a name for himself as an artist through various exhibitions in Japan and elsewhere. Professor Masao Furuyama from the Technical Institute in Kyoto describes him as not belonging to any architectural or artistic school, his architecture representing an antithesis to conventional visual refinement and his work resisting all explanation. He refers to him as an architectural archaeologist who digs deep, discovers his works like archaeological treasures and then reveals them to the world. So, like stone-age artifacts, his works are uncannily corporeal, yet inexplicable. According to Furuyama, Nakao's architecture is like coal – originally wood but now highly compressed and mutated into jet-black stone.

His "Dark Box and Birdcage" (Nakao's title for the weekend house), built in 1991, is a petrified black object like a mineral, like a crystal. Of course, this interpretation is very sympathetic to the pure geometrical styling of classical Japanese architecture. Perhaps this approach even evolved from this almost abstract type of architecture. In any case, the weekend house is an extraordinarily simple and clearly defined structure which, with its sparse furnishings, exudes a Zen-Buddhist composure. Simple means have been employed here to create a room layout which is up-to-date but also timeless.

Design | Hiroshi Nakao has accommodated the simple layout in a basilica-like structure based on a 3 x 3 m grid. The tall "nave" contains the living room and the equally high internal courtyard, linked with each other via a large glazed wall. The upper section of the courtyard walls above the "lateral aisles" is broken up by horizontal slats. Like in a clerestory, the light penetrates into the courtyard through these slats and also from above via the open roof. At the rear of the living room there is a small gallery (approx. 6 m^2) which can only be reached by a ladder. The ladder is located in an imaginary vertical "shaft" identified by three circular openings: a rooflight at the top, the access opening at gallery level and a recess in the living room floor which is filled with black pebbles. These define the position of the ladder and crunch when ascending or descending – a sensory effect desired by the architect.

Location
Prefecture Osaka, Japan (further details withheld at the request of the client).

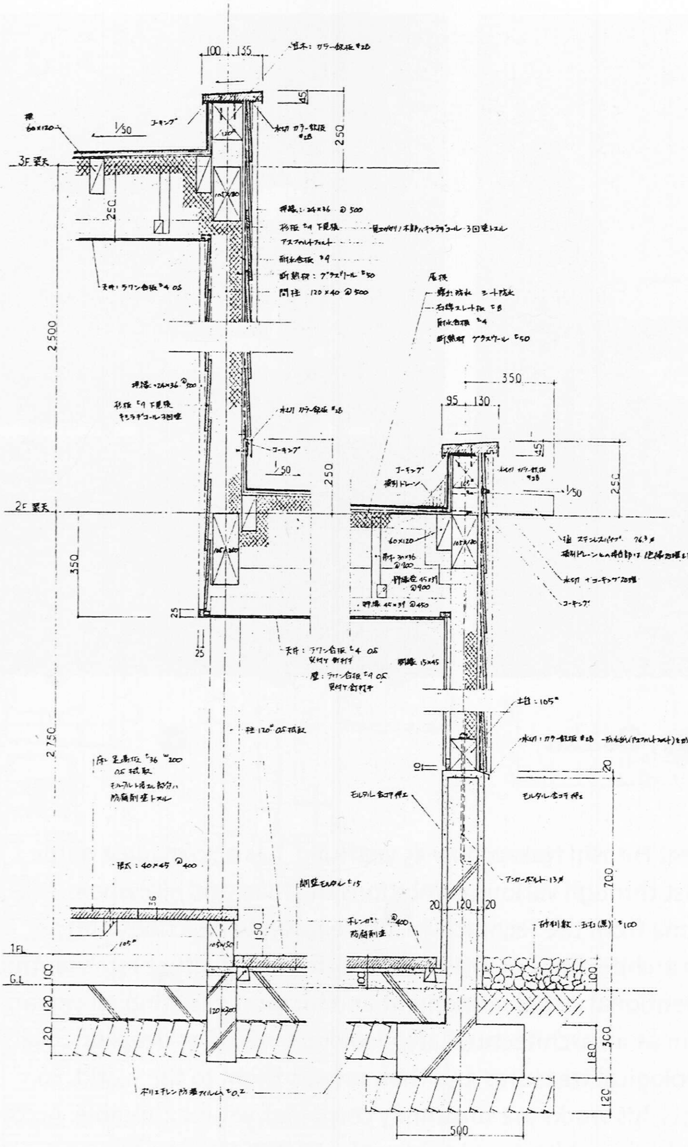
Architect
Nakao Serizawa Architects, Tokyo
Design Team
Hiroshi Nakao, Masahiko Inoue, Hiroko Serizawa

Structural Engineer
Mase Building Agency

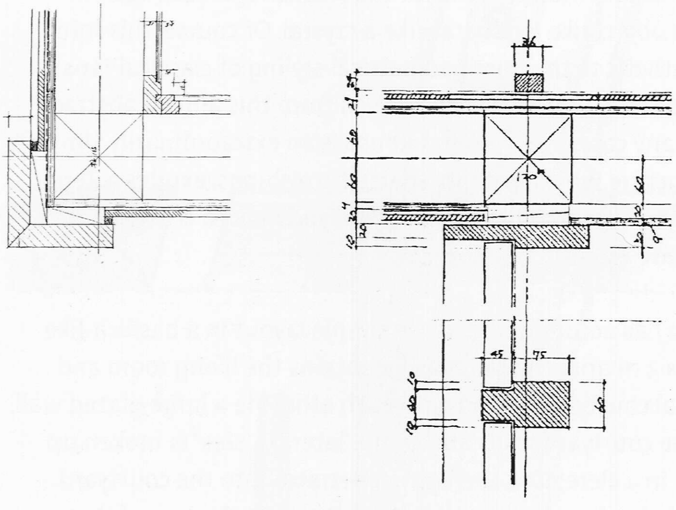
General Contractor
Tomi Komuten

Date of Completion
1991

Costs
The project cost 25 million Yen.

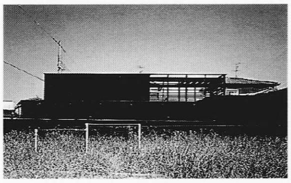


6 | Section, scale 1:25.
Roof construction from top to bottom: roofing felt, 8 mm asbestos-cement sheeting, 4 mm plywood, 60 x 120 mm members laid to match roof fall on 105 x 180 mm roof joists, 50 mm thermal insulation between 60 x 120 mm members, suspended timber lattice comprising 38 x 45 mm battens, 4 mm plywood ceiling.
External wall contruction from outside to inside: horizontal 240-mm-wide tongue-and-groove planks, waterproof sheathing paper, 9 mm chipboard, 40 x 120 mm studding at 500 mm centres, 50 mm thermal insulation in the bays; in living areas, tongue-and-groove planks as on the outside, otherwise 4 mm plywood on 15 x 45 mm battens.
Floor: surface of 36 x 200 mm planks on 40 x 45 mm battens, mortar levelling course, concrete ground floor slab, polyethylene sheeting.



7 | Horizontal section through exterior wall, scale 1:10. Left, an exterior corner; right, joint with patio door between study and internal courtyard.

The living room extends on both sides into the lower lateral aisles where the floor too is 150 mm lower. This leads to an unusual dual usage: on the side facing the road the aisles are provided with sliding doors so that they may be used as garages if required. The aisles extend alongside the internal courtyard, providing – on a 450 mm plinth – kitchen facilities, bathroom and a small bedroom on one side as well as entrance hall and study on the other. Both the bedroom and the study open across their full width onto the middle courtyard. Furthermore, the study also opens across its full width on the other side onto another small, enclosed and lower courtyard situated at the end of the carport and access area. Hence the result is highly differentiated spaces with different lighting effects. However, the underlying harmony of the black-painted, strict geometric wooden surfaces prevails; floors, walls and ceilings which in no way conceal their identity.



8 | Exterior view of the "Dark Box and Birdcage".

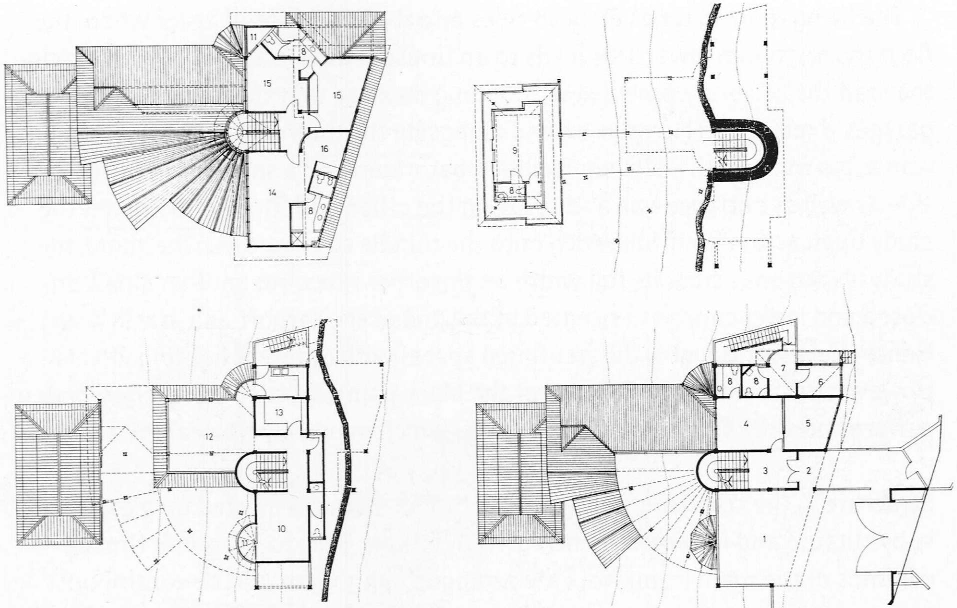
Structure | The structure, exclusively of timber-frame, is erected on a concrete substructure and reinforced concrete foundations. The 120 x 120 mm timber columns of the main framework are arranged in a 3 x 3 m grid on continuous 105 x 105 mm or 105 x 150 mm sole plates supported on the concrete strip footings. Only at the road end is the final bay shortened to 2.3 m. In the middle rows of columns, between "nave" and "lateral aisles", the columns are connected together by 105 x 240 mm beams at the level of the aisle roofs and by 105 x 180 mm beams at the level of the nave roof. Fixed to these are the loadbearing 105 x 180 mm roof joists which are positioned at half the bay width, i.e. at 1.50 m centres. The lower outer walls of the aisles are of identical construction and form the exterior supports for the roof joists. The roof joists in turn carry 60 x 120 mm secondary members at 400 mm centres which support the actual roof construction and are positioned at different levels to accommodate the 1 in 20 roof fall.

The external walls incorporate 120 x 40 mm studs at 500 mm centres between the main columns. Attached to the inside of these are 240-mm-wide tongue-and-groove planks which are butted together at the main columns and which are provided with vertical 34 x 36 mm cover strips at all studs and main columns. This surface made up of horizontal planks and vertical battens at 500 mm centres prevails over the entire building. Only in some ground-floor areas is the interior cladding in the form of smooth plywood panels. On the outside face, 9 mm chipboard, to brace the whole construction, is screwed to the intermediate studs and main columns. This is followed by a waterproof sheathing paper and tongue-and-groove planks like the inside. The 50-mm-thick thermal insulation is placed between the vertical studs.

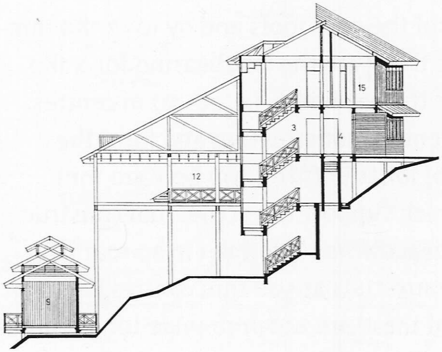
The 60 x 120 mm members supporting the roof construction are covered by one layer of 4 mm plywood and one layer of 8 mm asbestos-cement sheeting followed by the actual roofing felt. The thermal insulation – again 50 mm thick – is nailed onto the underside of the plywood. The roof beams support a suspended ceiling consisting of 4 mm plywood on a grid of 38 x 45 mm battens suspended on 30 x 36 mm hangers.

The floor is made from 36 x 200 mm planks which are fixed to 40 x 45 mm battens at 400 mm centres. These are supported by 105 x 105 mm members or, in the areas where the floor is lower, embedded as fixing strips in a mortar levelling course which covers the entire concrete ground floor slab. Polyethylene sheeting is laid on the compacted ground under the concrete to protect against rising moisture.

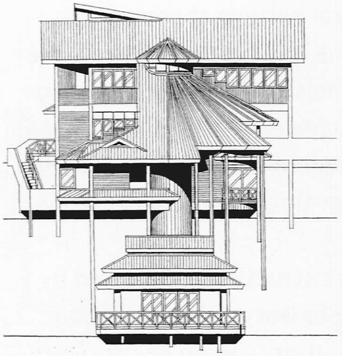
All wooden surfaces, including cover strips as well as window and door frames, are painted black. This ensures the lighting effects which the architect wished to achieve – the contrast between jet-black and glistening brightness.



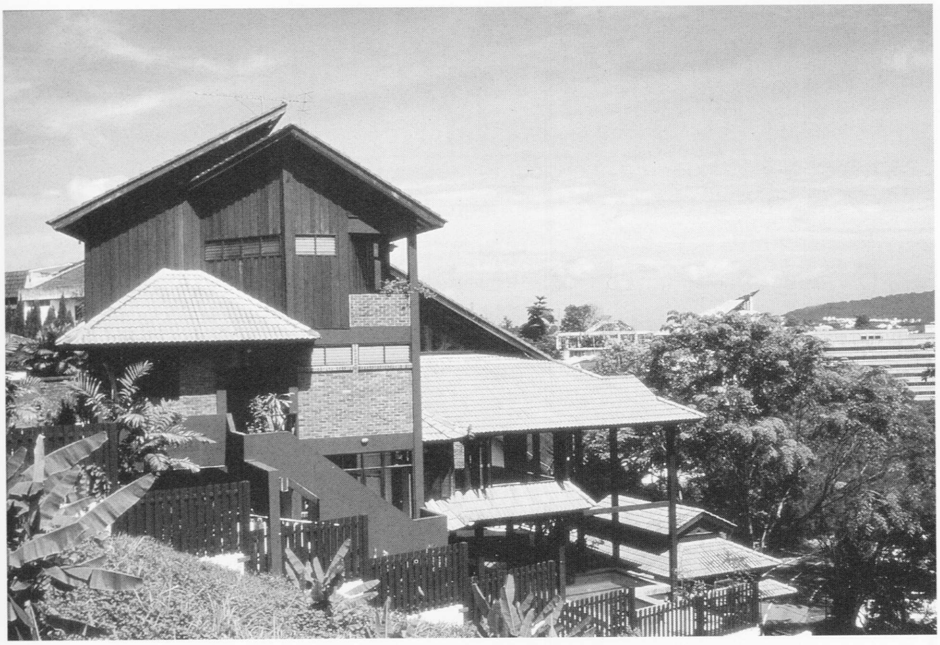
1 | Plans, scale 1:500. Left, upper floor, ground floor; right, lower floor, patio and guest-house. **1** Garage. **2** Entrance. **3** Main stairs. **4** Family room. **5** Study. **6** Staff. **7** Utility room. **8** Bathroom. **9** Guest room. **10** Dining room. **11** Balcony. **12** Living room. **13** Kitchen. **14** Master bedroom. **15** Bedroom. **16** Dressing room.



2 | Section, scale 1:500. Left, the separate guest-house.



3 | West elevation, scale 1:500.



4 | View from south.

Tang House, Kuala Lumpur

Jimmy Lim

Subject | Throughout the whole of South-East Asia, on the Pacific rim, from Indonesia to Burma, from Thailand to the Philippines, there is a uniform, traditional style of architecture with only slight regional variations. Its character is mainly determined by the hot and humid tropical climate with its frequent heavy rainfall, and it is based on the same underlying principles due to the very active intercultural exchange within this region. They are timber-framed structures with steeply sloping roofs, walls with large openings for good ventilation and stilts to raise them clear of the ground, as protection against snakes and other animals. This basic form is also reflected in the many modern buildings in the region, enriched with contemporary styles and updated with modern building materials and construction methods.

One of the best-known exponents of this school which unites the traditional and the modern, is the Malaysian architect Jimmy Lim. He first came into contact with Western styles of architecture while studying in Australia. Those architects that explored the borders between East and West had the greatest influence on him, such as the American Frank Lloyd Wright.

Lim's buildings are characterized by wide overhanging eaves, open wall constructions and interesting sequences of rooms which unfold to their occupants as they pace through them. This contrasts with the concept of fixed "optimum" or "photographic" viewpoints as they are typical of traditional Western aesthetics. Lim practises "T'ai Chi", as he calls it, when planning his structures. This includes the idea of using your opponent's strength to your own advantage. He describes the procedure thus: to re-interpret problems positively and exploit obvious difficulties so that, on the whole, an improved design is the result. For example, if only unskilled craftsmen are at his disposal, then he employs basic, simple timber joints and builds up the whole design on this strategy. The use of recycled building materials also influences his work. In this sense, his inclusion of tradition is both justified and consequential.

Design | Tang House stands on a modest 752 m² plot of land in Damansara, a prosperous suburb of Kuala Lumpur. From the road the ground falls away steeply towards the west with a view of the valley in which the residential town of Da-

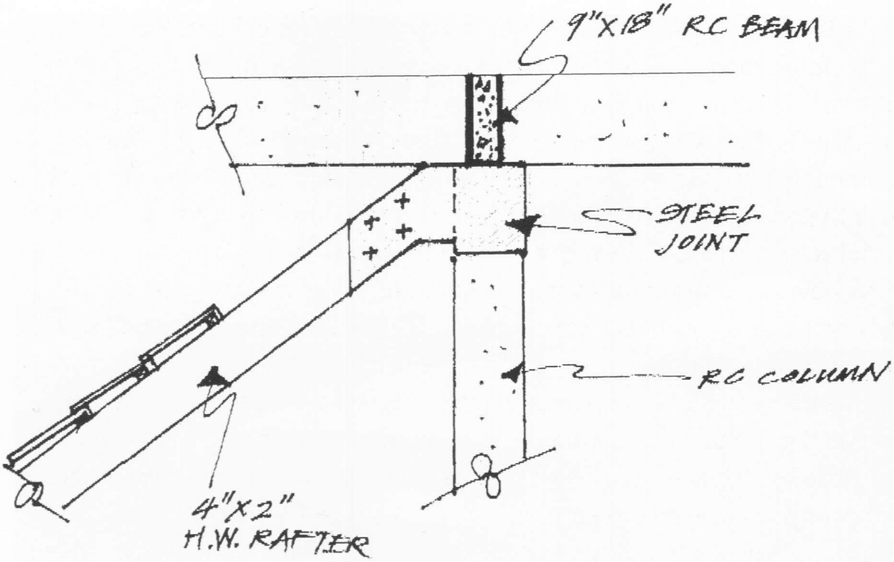
Location
1 Lorong Buluh Perindu 5,
Jalan Damansara,
Kuala Lumpur, Malaysia

Client
Mr. Tang Woh Heng

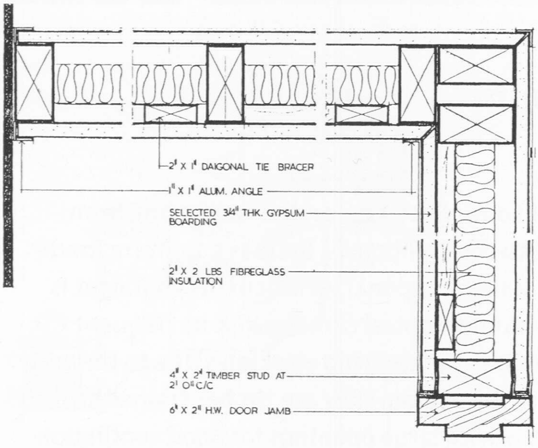
Architect
Jimmy Lim, CSL Associates,
Kuala Lumpur

Structural Engineer
H. P. Lee & Rakan, Kuala Lumpur
Project Engineer
Yap Yee Oon

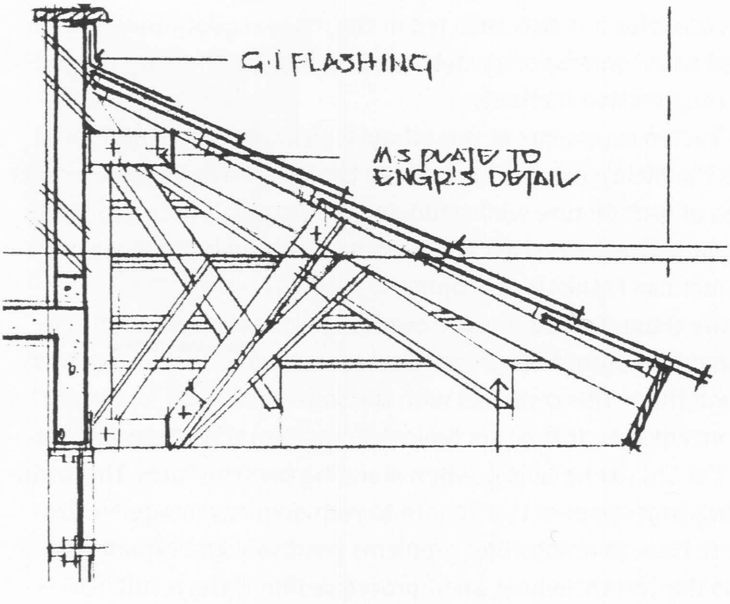
Date of Completion
1988



5 | Central support for rafters of canopy roof, not to scale. Steel mounting plates for each rafter are welded to a steel collar fitted to the top of the circular reinforced concrete column.



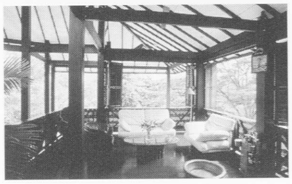
6 | Section through internal wall, scale 1:10. The timber frame consists of 100 x 50 mm studs at 600 mm centres. The bays are cross-braced with 50 x 25 mm battens and provided with 50 mm glass-fibre insulation. Both sides are clad with 19 mm plasterboard.



7 | Detail of circular roof over balcony, scale 1:25, showing the umbrella-type diagonal struts supporting the rafters.

mansara is expanding. The architect responded to this difficult location by designing a four-storey structure which is very compact compared with others in this district. Besides a study and library, the entrance level also includes a large garage. The floor above contains bedrooms and bathrooms while the floor below accommodates the kitchen, dining room and open living room. Below that is a patio with pond and the stairs to the separate guest-house lower down the slope. A central staircase links all levels; with its rounded, projecting landings, it represents an obvious central axis for the whole house. It also marks the centre of the canopy-type open roof construction which, in a grand gesture, opens out in front of the house, providing shade and creating covered areas.

Upon entering, guests experience a gradual process of opening out, lending the house the character of a refuge, luxurious and screened off from the outside world. Little by little the initial enclosing walls and heavy materials like concrete and masonry give way to timber frameworks with wooden panels and finally to the spacious timber ribs of the great canopy roof over the open living room. The intermediate landings of the staircase play a special role in the whole experience; the changing views exploring the surroundings: the open roof construction above, the patio with pond below and the lush landscape beyond.



8 | View from below with staircase tower. Left, the balcony to the living room; right, the circular roof over the balcony to the dining room. The polygonal arrangement of the purlins to the umbrella-type roof, and their supports in the form of columns and struts, are clearly visible.

9 | The living room with view to the west.

Structure | Owing to the steeply sloping ground those parts of the building directly on the slope had to be constructed in reinforced concrete. If direct contact with the ground was not possible, then concrete plinths with masonry infills were provided. The 180 x 50 mm joists of the timber floors rest on nibs on concrete beams. Reinforced concrete floors are only used for the garage and rooms where water is used.

The walls of the upper floor are all in classical timber-frame construction: 100 x 50 mm studs at 600 mm centres with 50 mm glass-fibre insulation in the bays, 50 x 25 mm battens as diagonal bracing and clad both sides with 19 mm plasterboard. All roofs are made entirely from chengal, a local species of hardwood. The large, open, canopy-type roof, spanning in a protective gesture majestically over the living room, is of particular interest.

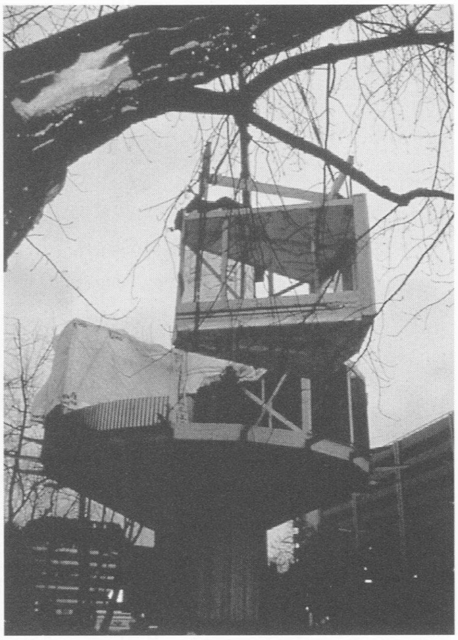
For this roof, 100 x 50 mm rafters fan out from the centre of the staircase tower like the ribs of an umbrella, forming the basic framework visible from below. At the top the rafters are connected via steel plates to a steel collar which is mounted on top of the central reinforced concrete circular column in the staircase. The rafters are supported along their length by 200 x 50 mm purlins at a spacing of max. 3 m, each of which carries three or six rafter bays. These purlins form a polygon around the stairs and are supported on 230 x 230 mm columns at the corners of the polygon. The only means of lateral support to these columns is afforded by 230 x 75 mm horizontal beams between them at ground-floor level, some of which are arranged radially. Purlins and intermediate beams are mortised into the columns in the traditional way. The uppermost purlin (here 100 x 100 mm) is supported by diagonal 100 x 75 mm struts propped against the staircase landing. These diagonal struts, which help to emphasize the umbrella nature, are used again as the only means of support for the smaller circular roof. Above the living room, the canopy-type roof changes to a straight hipped roof with 100 x 50 mm rafters at 460 mm centres, but not without leaving an open triangular clerestory light facing north.

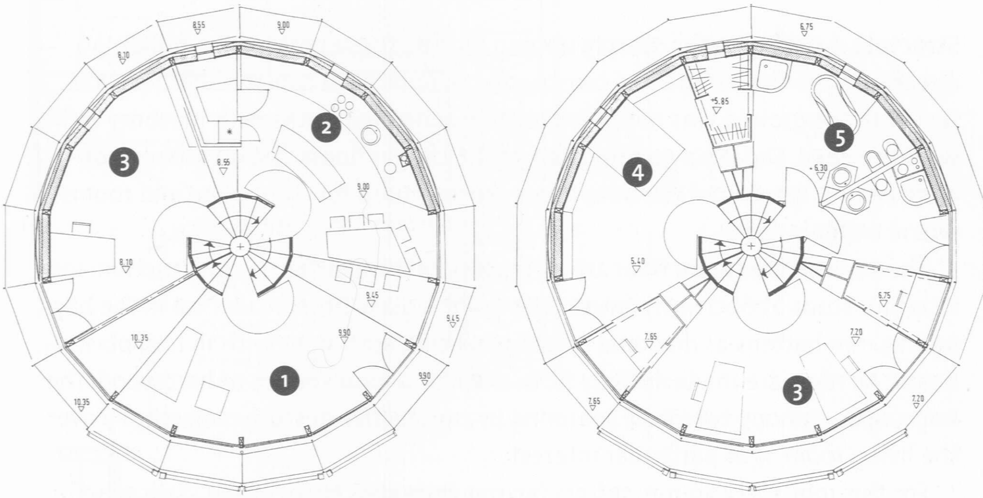
10 | View from patio level through the timber framework of the open roof towards the guest-house and the balcony to the living room, whose open timber balustrading is clad with a strip of roofing.

Profiled clay roofing tiles on 50 x 25 mm battens form the roof covering. Underneath is a sisal mat with an aluminium coating to both sides and between the rafters 50 mm glass-fibre insulation on a chicken wire mesh. White-painted chipboard completes the roof construction. Both serve to insulate the house against the heat.

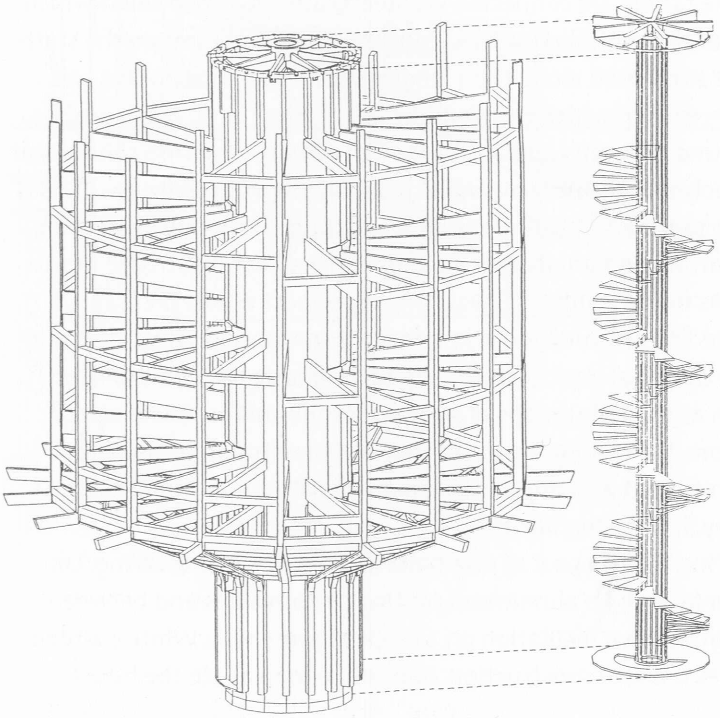
1 | Overall view of solar-energy house.

2 | The storeys for the SWISSBAU '95 solar-energy house were fabricated and erected in sectors resembling "pieces of cake".

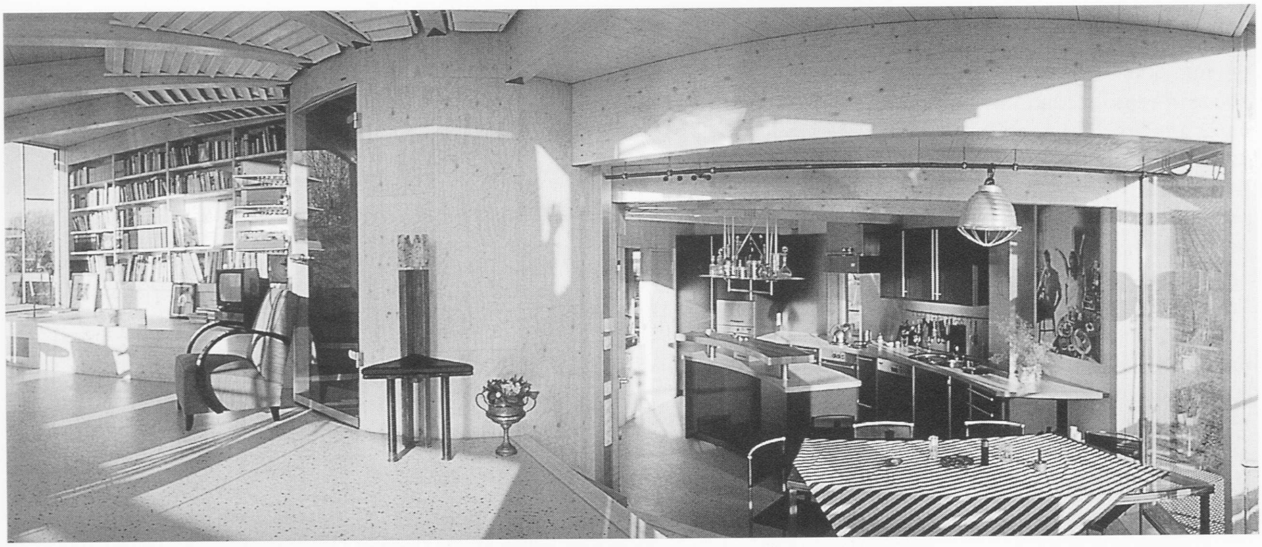




3 | Floor plans, scale 1:200. **1** Living room. **2** Kitchen with dining area. **3** Study. **4** Bedroom. **5** Bathroom.



4 | Isometric projection of timber framework.



5 | Room with panorama view.

“Heliotrop” Solar-Energy House, Freiburg

Rolf Disch

Subject | Architects who are actively involved in low-energy and environmentally compatible designs readily make use of timber because it is a replenishable and recyclable material. The architect Rolf Disch from Freiburg is very active in this field. Over a period of ten years he developed a prototype for a solar-energy house which, if the design is fully applied, not only requires no outside energy supplies but indeed can feed electricity back into the public network! A so-called “negative-energy house”. He has attempted to reduce building costs by employing series production techniques and standardization. This is essential because the engineering input for maximum energy savings on this scale is very cost-intensive. The Freiburg solar-energy house described here has approx. 200 m^2 of usable floor space. The architect built it for his own use as house, office and demonstration project. Interesting in the “Heliotrop” design is the practical use of timber to meet extreme functional demands, in this case due to the need for the whole house to rotate.

Design | Working with the idea of optimum passive-energy utilization, the architect created a house which on one side has large window areas consisting of solar-control glass which allow the passage of sunlight, and also permit the occupants to enjoy the view, and on the other side, walls with a high degree of thermal insulation and no openings. He then refined the age-old principle of aligning a house in the north-south direction by incorporating an electronic control on the window side which turns the building to follow the sun or, on hot summer days, turns the building away from the sun. This led to the concept of the “treehouse” which stands on a “trunk” and then widens out above for the accommodation spaces. This design achieves a far better utilization of solar energy than conventional, fixed houses.

The central “trunk” contains a spiral staircase. The bottom 3 m above the massive foundation stands alone and contains the entrance. The actual house itself starts above this and is 11 m in diameter, i.e. the rooms are 4 m wide arranged around the central staircase tower. However, the floors are not just flat discs. The, in total, 18 bays around the staircase are divided into groups of five bays at diffe-

Location
Ziegelweg 28, 79100 Freiburg/Breisgau, Germany

Client and Architect
Rolf Disch, Freiburg/Breisgau

Structural Engineer
Lignaplan/Blumer AG, Waldstatt, Switzerland, and Prof. E. Gehri, ETH Zurich

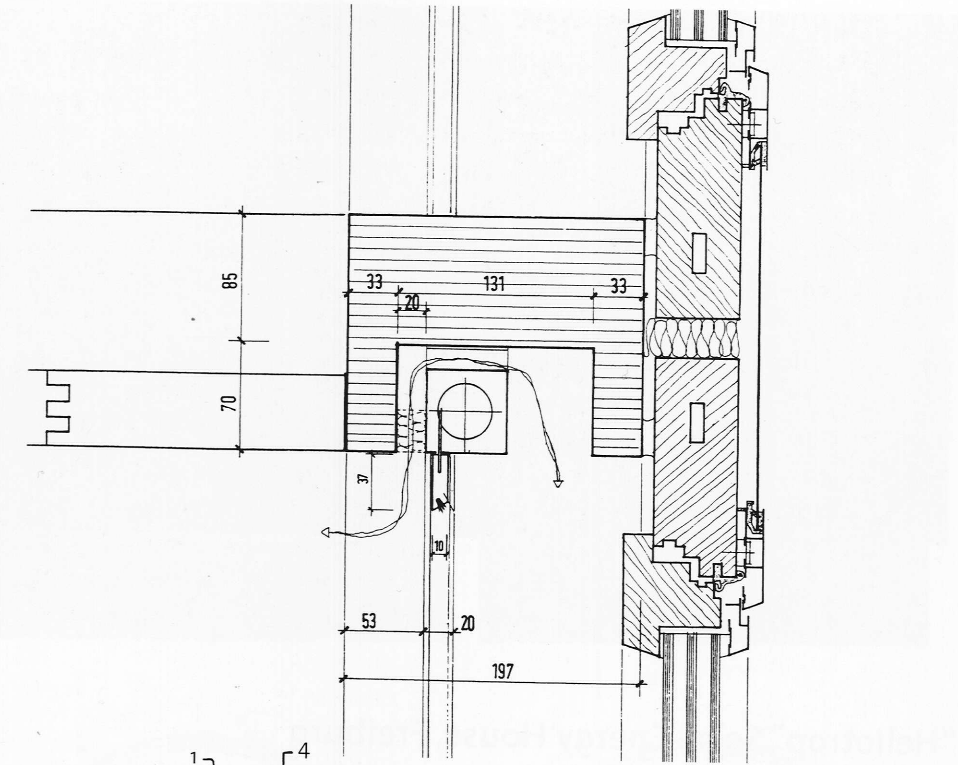
Project Engineer
A. Wirth

Controlling Engineer
Jürgen Ehlbeck, Karlsruhe

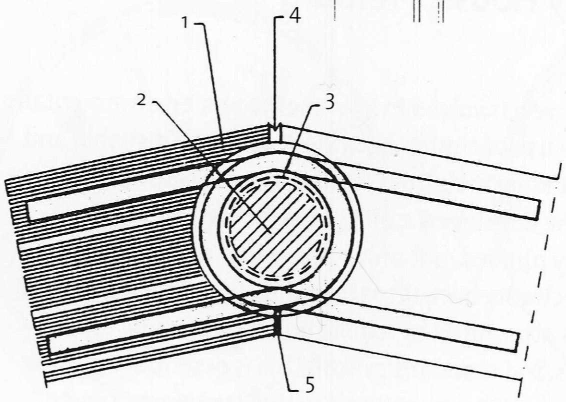
Timber Construction
Prefabrication
Blumer AG, Waldstatt
Assembly
Unmüßig & Co. KG, Freiburg

KERTO Wood Panels
Interpan Engineered Wood Products GmbH, Finnforest, Düsseldorf

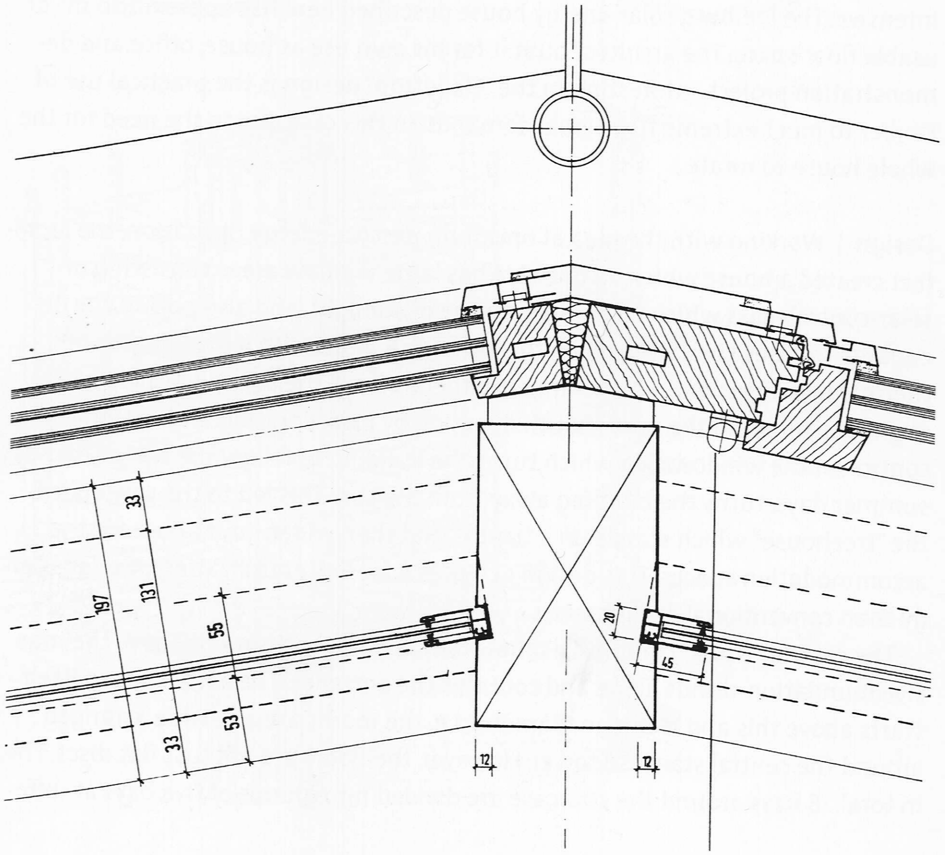
Date of Completion
1994



6 | Vertical section through façade, scale 1:5. The 70 x 130 mm notch in the 155 x 200 mm beam accommodates a roller blind. The beam only serves to fix the façade and window elements. The floors are supported on the radial 120 x 240 mm beams which are fixed directly to the columns. The windows are fixed on the outside: wood frames covered with aluminium sections, solar-control glass, triple-glazed with a U-value of 0.4 W/m²K (filled with xenon gas).



7 | Connection in the joint between the KERTO-Q boards: **1** KERTO-Q board. **2** Swiss threaded and ribbed bars, 55 mm. **3** Threaded bar, 46 mm. **4** Joint for poured epoxy resin. **5** Tar sealing tape.



8 | Horizontal section through façade, scale 1:5. The enclosing windows and external walls are always fixed in front of the load-bearing beam-and-column construction (with 120 x 200 mm columns). The peripheral balconies in front of the façade are made from galvanized steel sections and are self-supporting.

rent levels. These levels are arranged like a giant spiral around the central tower, rising in steps of 900 mm. (There is one bay between each group of five which creates a sort of step, i.e. 2 x 450 mm, between the levels.) The cleverly arranged partitions lead to interesting room layouts. A "solar sail" is mounted on the roof. This can be rotated independently and is fitted with a photovoltaic unit which can deliver several times more electricity than the house needs. The massive foundation contains a basement with approx. 120 m^2 of usable space reached via a separate entrance.

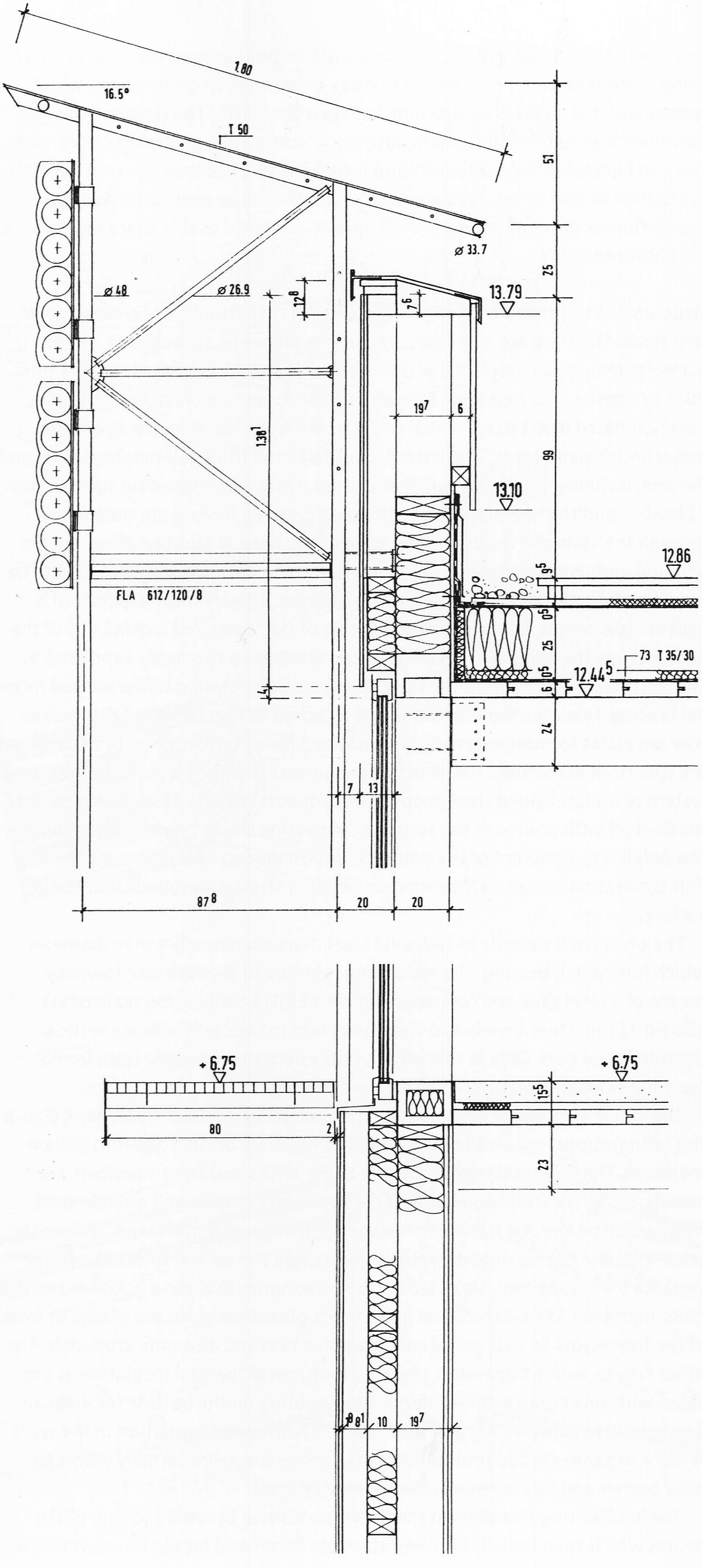
Structure | The principal loadbearing element is the "trunk", the central tower containing the staircase. It is fabricated in one piece like a giant tube, 3 m in diameter and 14.50 m high. It has 18 sides, each of which is formed by a 110-mm-thick by approx. 500-mm-wide Finnish KERTO-Q board – a crossply-bonded veneer laminated wood panel which enables the "trunk" to meet the F90-B fire protection requirements. The vertical loads from the three full-height storeys and the roof, including the "solar sail" installation (170 tonnes including superimposed loads!), and the horizontal loads amounting to 12.5 tonnes, are transferred through the staircase tower into the pivot at the base. In addition there are the bending moments due to wind and a non-symmetrical superimposed load to be considered. The total bending moment of approx. 1850 kNm corresponds to a load of "400 people, all standing on one side of the tower and looking out of the windows", as the engineer checking the calculations so succinctly expressed it. The staircase located within the tower prevents the inclusion of the normal internal bracing. However, the floors and roof attached to the outside of this hollow core are plates forming external, spiral-shaped frames which prevent the walls of the core from deforming. The structural engineers designed a special connecting system of integral glued steel hoops with peripheral longitudinal steel elements finished off with poured epoxy resin for connecting the segments of the tower. The detail is reminiscent of the poured joints on precast concrete components. This connection can also accommodate bending stresses perpendicular to the surface.

The pivot itself consists of two solid steel rings, each nearly 3 m in diameter, which form a ball bearing. The inside ring is bolted to the staircase tower by means of a steel shoe, the connection to the KERTO boards being realized via 480 No. 14 mm steel dowels and the connection to the cast joints via vertical threaded steel bars. Only in this way can the enormous forces be transferred from the wooden tower into the steel ball bearing.

The external envelope of the building is formed by a timber framework (F30-B fire rating) supported on a triangular frame made up of 120 x 240 mm glulam members. The substantial axial stresses in the struts and cross-members are transferred by means of steel dowels (BSB system) to inside and outside steel rings which on the one hand balance the opposing horizontal forces and, on the other, transfer the residual differential forces into the central tower. The framework for the façade consists of 120 x 220 mm columns and 160 x 200 mm profiled cross-members. The solar-control glass, triple-glazed windows are placed in front of the framework so that good sealing against rain and draughts is possible. The other façade, with no openings and a high degree of thermal insulation, is provided with silver-grey, profiled aluminium cladding on the outside (with an air gap behind to allow for natural ventilation). The thermal insulation in the walls is 180 + 100 mm, i.e. 280 mm thick in total, and is covered internally with a vapour barrier and two layers of 12.5 mm plasterboard.

The loadbearing members in the floors are formed by 120 x 240 mm glulam beams which span radially between staircase tower and façade framework; the

9 | Section through façade, scale 1:20.
Wall construction: 120 x 200 mm loadbearing columns with 180 mm thermal insulation in between, vapour barrier and 2 layers of 12.5 mm plasterboard on inside; 100 mm thermal insulation batts between 100 x 60 mm battens on outside behind silver-grey, profiled aluminium cladding.
Floor construction: loadbearing 120 x 240 mm glulam beams, 50 mm tongue-and-groove boarding, 100 mm floating screed including footfall sound insulation. The horizontal façade beams are fixed at the level of the boarding and screed. Roof construction: 120 x 240 mm glulam beams, 60 mm tongue-and-groove boarding, vapour barrier, T35/38 mm footfall sound insulation mat, 21 mm Styrodur 3000S, waterproofing layer, 20 mm protective mat and loosely laid wooden open-grid flooring.

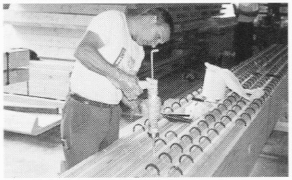


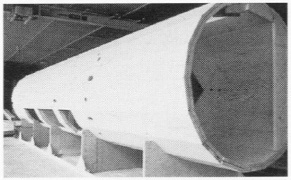
undersides remain exposed. These beams carry a 50-mm-thick tongue-and-groove boarding with a floating screed and footfall sound insulation totalling approx. 100 mm, and a PVC or carpet floor covering. The rooftop patio has a vapour barrier on top of the boarding, 250 mm thermal insulation, plant root-resistant waterproofing, 20-mm-thick protective matting and loosely laid wooden open-grid flooring.

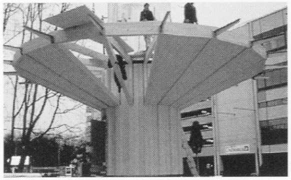
Construction | Very accurate work was required in the fabrication of the 15 tonne staircase tower. The segments were fabricated by the Blumer company on the CNC-controlled "Lignamatic", including the rebates and holes, to a dimensional tolerance of 0.2 mm. These pieces were joined in jigs after glueing in the hoops. To carry the vertical loads, the lower section of the 18 sides of the core were strengthened with additional vertical timbers. Once on site, the complete, finished tower, including staircase, was lifted into position on the prepared steel rings of the pivot mechanism by means of a mobile crane.

The entire façade of the "Heliotrop" solar-energy house was assembled on site using beam-and-column construction. The system has in the meantime undergone further developments. Now the storeys are fabricated in sectors like "pieces of cake"; these are then lifted into position with a crane. This leads to a significantly shorter assembly time of about 14 days. The solar-energy house exhibited at SWISSBAU '95 in Basle was in fact built according to this method. It was dismantled after the exhibition and rebuilt in Nuremberg.

Costs | The total cost of the "Heliotrop" house, excluding foundation, waste disposal facilities such as composting system and biological waste-water treatment, as well as seasonal hot water storage, was approx. 1.8 million DM. However, the "Heliotrop" house is assembled from "modules" which permit the construction of smaller and simpler houses. For example, the smallest unit – without pivot mechanism but with panorama glazing (U-value 0.4 W/m^{2}K) and 120 m^2 of living space – costs about 700 000 DM. This price includes all ancillary costs.





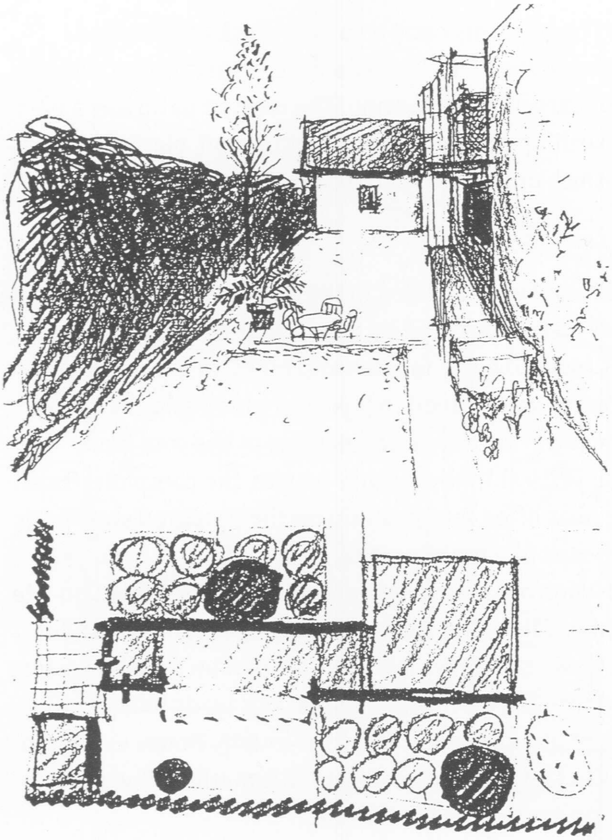


10 | The steel connecting hoops are glued into the KERTO-Q boards in the factory.

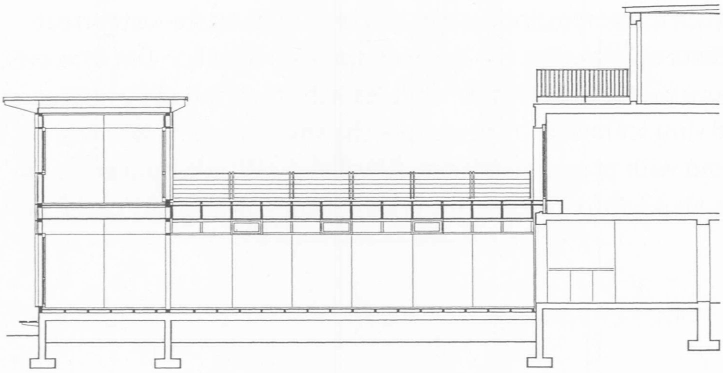
11 | The completed "trunk": 3 m in diameter and 14.50 m long, with door openings.

12 | The supporting construction for the façade and floors is attached to the "trunk" on site.

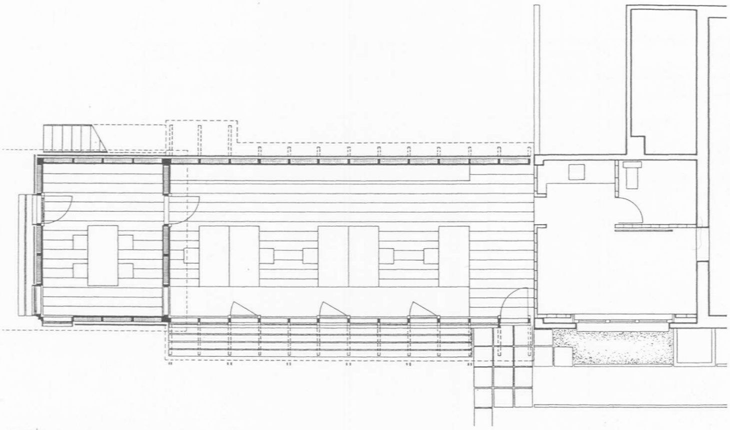
1 | Architects' sketches of layout concept: building and garden.



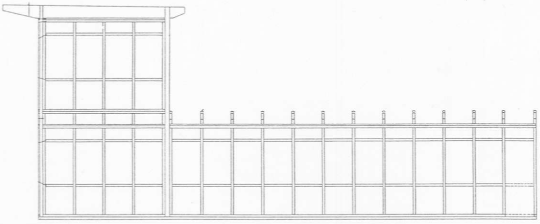
2 | Longitudinal section, scale 1:200. The timber construction is supported on a concrete substructure and rests neatly against the existing masonry building.



3 | Plan, scale 1:200. Meeting room and office with projecting balcony.



4 | Longitudinal section through timber frame, scale 1:200. The regular column grid is clearly visible.



5 | South-east elevation of extension. Above, the private rooftop patio, below, the office, on the left, the pavilion, right, the old house.

Extension to Architectural Office, Lausanne

Maria + Bernhard Zurbuchen-Henz

Subject | Extensions to buildings can be approached and designed in different ways. They can either match the style and material of the existing building, merely only altering its size, or they can intentionally deviate in terms of style and material, thereby expressing something new and leaving the nature and size of the original structure untouched. Here, the second approach was chosen and implemented in a convincing fashion.

Design | The house belonging to the architects Maria and Bernhard Zurbuchen-Henz is located on the edge of the city of Lausanne, in a district with a mixture of different building styles consisting of housing blocks and small detached houses with garden sheds. This theme was taken up by the architects as they started planning their office extension in 1989; the project was completed in 1991. The new lightweight wooden pavilion represents a functional but informal extension to the original detached home. The simple design is a skilful answer to the existing circumstances, such as the narrow plot, the lush vegetation and the heterogeneous surroundings. Owing to the distances to the boundaries which had to be maintained, the new structure had to be built in the middle of the plot. Therefore, the garden was subdivided into different sections: front garden, back garden and patio. The front garden is used exclusively by the office, the rear part is private and the patio serves as a direct external extension of the house. The banal detached house dating from the 1930s and converted as long ago as 1964, is clearly improved by the addition of this extension.

The architects chose timber as their building material because, due to its unpretentiousness, it best satisfied the nature and scale of the project. In addition to that, the extension had to be completed quickly and on a low budget. The result was a formally modest but very skilfully designed structure.

Structure | The building not only exhibits wood both inside and outside – it is also conceived as a timber-framed structure. The two-storey pavilion in the garden, with meeting room downstairs and private accommodation upstairs, is placed at the end of the single-storey office wing. The complete extension rests

Location
Maria and Bernhard Zurbuchen-Henz, Ch. de Maillefer 19, 1018 Lausanne, Switzerland

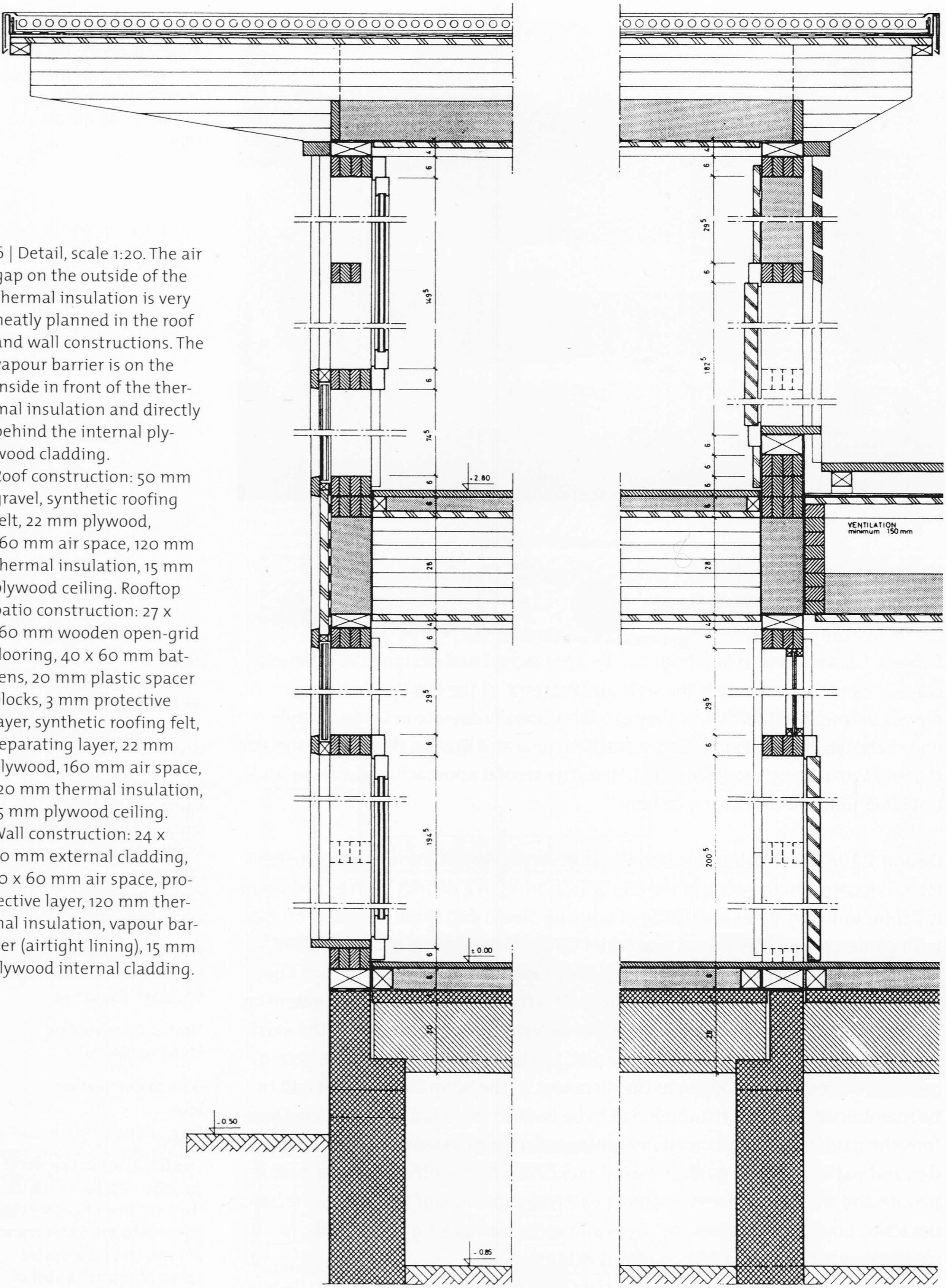
Client and Architect
Maria and Bernhard Zurbuchen-Henz, Architectes FAS/SIA, Lausanne
Project Architect
Claire Bertusi

Structural Engineer
Jean-Pierre Marmier, Ing. EPUL/SIA, Lausanne

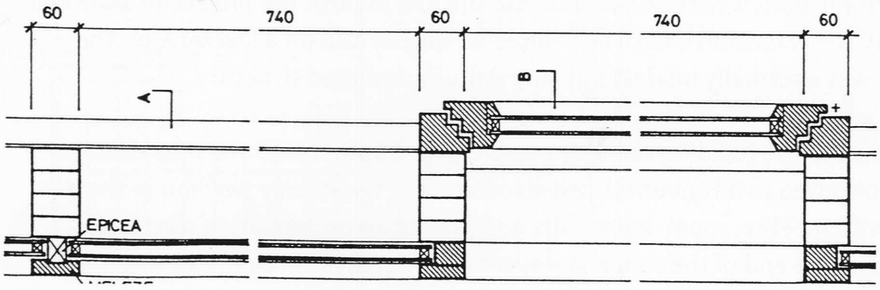
Timber Construction
Mullener SA, Pully

Date of Completion
1991

Costs
The total cost of the works was 180 000 Swiss Francs. For a volume of 325 m^3 that equates to 376 Swiss Francs per m^3, and for a usable space of 109 m^2, a cost of 1 121 Swiss Francs per m^2.

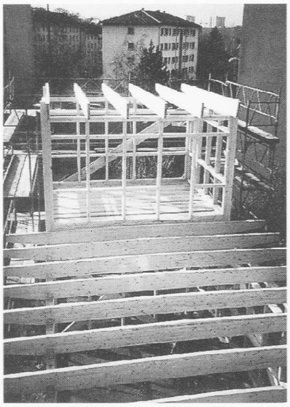


6 | Detail, scale 1:20. The air gap on the outside of the thermal insulation is very neatly planned in the roof and wall constructions. The vapour barrier is on the inside in front of the thermal insulation and directly behind the internal plywood cladding.
Roof construction: 50 mm gravel, synthetic roofing felt, 22 mm plywood, 160 mm air space, 120 mm thermal insulation, 15 mm plywood ceiling. Rooftop patio construction: 27 x 160 mm wooden open-grid flooring, 40 x 60 mm battens, 20 mm plastic spacer blocks, 3 mm protective layer, synthetic roofing felt, separating layer, 22 mm plywood, 160 mm air space, 120 mm thermal insulation, 15 mm plywood ceiling.
Wall construction: 24 x 80 mm external cladding, 30 x 60 mm air space, protective layer, 120 mm thermal insulation, vapour barrier (airtight lining), 15 mm plywood internal cladding.



7 | Detail of window, scale 1:10. The window frames for the opening lights are screwed directly behind the structural members and include a silicone seal. The fixed lights lie in the plane of the air space and are attached to the timber members from the outside.

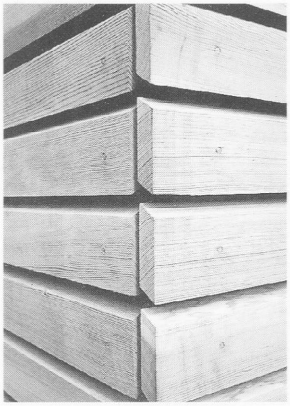
8 | The two-storey pavilion from the west. The stairs lead from the rooftop patio down to the private part of the garden.



9 | The pavilion during construction. The necessary bracing is attached on the outside so that the plywood providing the permanent stiffening can be screwed on later from inside the framing.

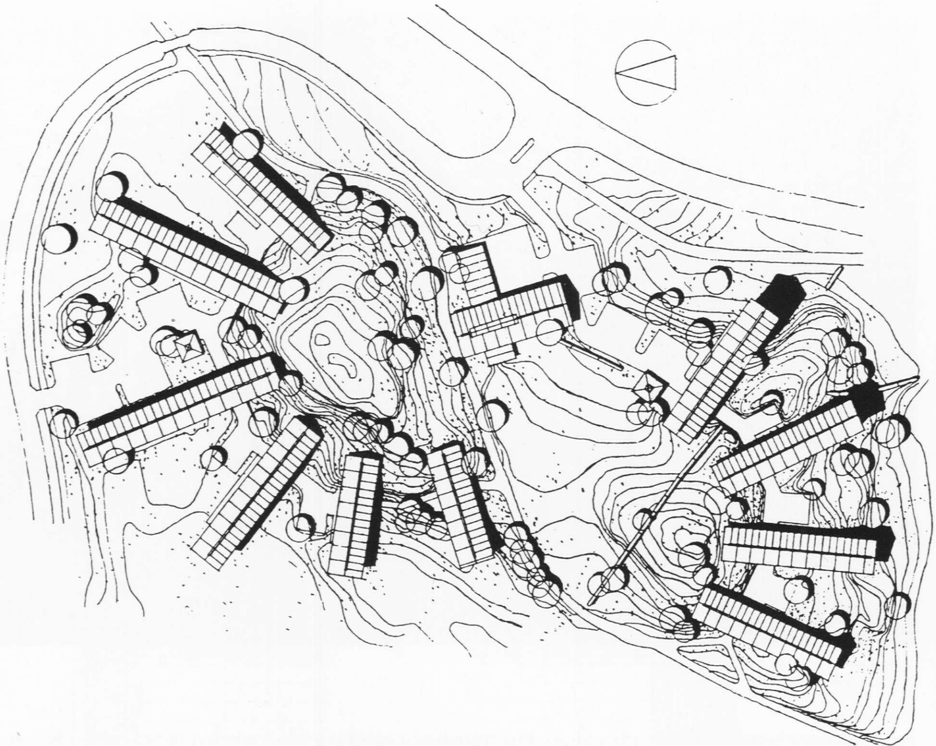
on a concrete plinth which raises the timber construction about 400 mm above ground level and hence protects it from splashes of water. The timber frame consists of 60 x 120 mm studs at 80 cm centres and of 280 x 60 mm floor and roof beams. All the structural timbers, such as columns, header/footer joists and beams, are glulam members. Stability is achieved by way of the 15-mm-thick plywood panels which remain exposed internally.

The thermal insulation is placed in the bays between the beams and consists of 120-mm-thick rockwool batts. The roof of the pavilion, a cold roof like the office wing, has a 150 mm ventilation space between thermal insulation and roof covering. The roof covering itself is made up of 22 mm plywood covered with a synthetic roofing felt. The roof of the pavilion includes a 50-mm-thick layer of gravel on top of the felt for protection. In the case of the patio, battens on spacer pieces are used to support the wooden open-grid flooring above the roofing felt. The external walls have open-joint boarding ventilated from behind consisting of 24 x 80 mm douglas fir planks. None of the timber has been treated in any way; it retains its natural colour and will change with time accordingly. The only metal to be seen externally is in the form of the hot-dip galvanized steel posts for the balustrading around the patio. When asked "Why metal here?" the architects replied: "We wanted to have a clearly defined volume made of timber, all other elements are only implied and form only apparent spatial boundaries."

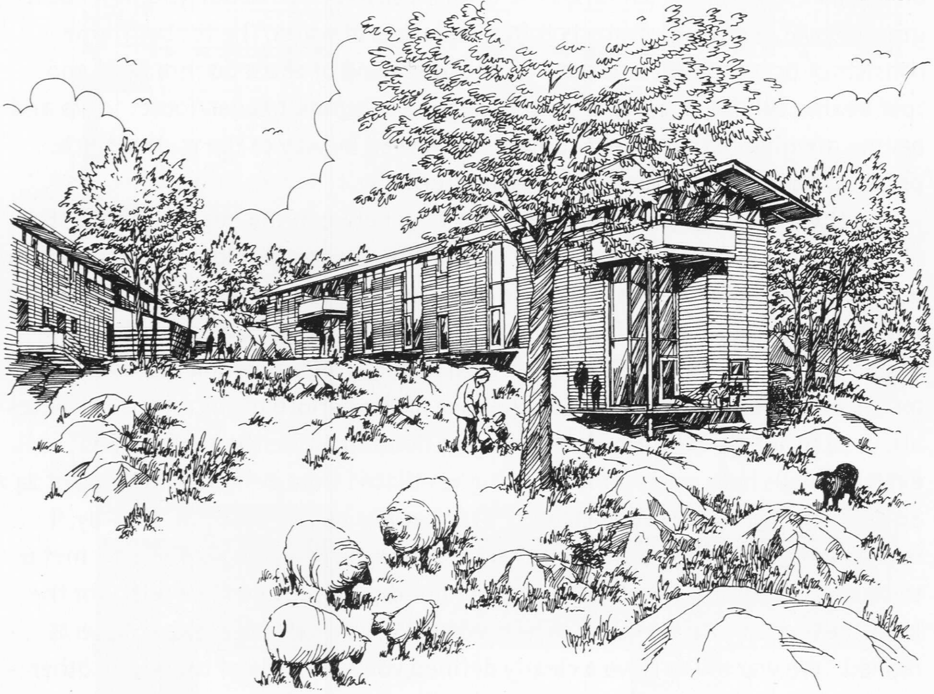


10 | Simple external corner detail for the boarding. Visible here are the open joints and the shaping to deflect the rain. The horizontal external corners of the planks are at the same height, conveying the impression of continuous strips.

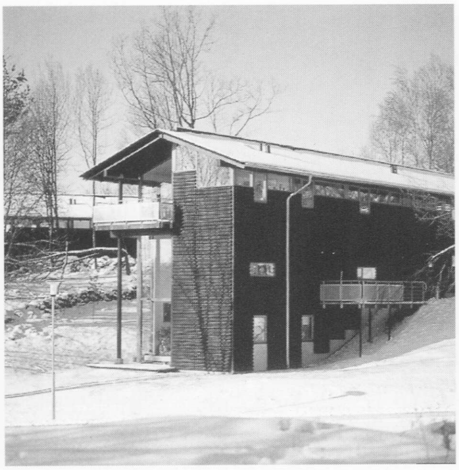
1 | Site plan, scale 1:2000. The fan-shaped layout of the housing blocks pointing downhill from the knolls opens up towards the surrounding landscape.



2 | Architect's perspective drawing.



3 | Floor plans, scale 1:500. Top, upper level; bottom left, entrance level; right, basement level in three-storey end house.



4 | View of the valley-facing gable of one of the blocks.

5 | The living room in a three-storey end house. The narrow window strip below the roof is interrupted at certain points by deeper windows.

“Nielsen” Housing Estate, Borås

Tegnestuen Vandkunsten

Subject | Borås is a small Swedish town about 50 km east of Göteborg. In 1990 the town’s Urban Planning Director Hasse Johansson initiated a competition for a “Nordic Building Exhibition”. Houses designed by Danish, Finnish, Norwegian and Swedish architects were to be erected by 1994 in the garden town of Hestra on the northern edge of Borås. The aim of the competition was to instil new momentum into the good but formally rigid style of Swedish housing design. The prizewinners should incorporate their ideas for and their experiences with social housing in their own countries and build examples of this among the trees, fields and rocks of the site chosen for the competition. The architectural team of Tegnestuen Vandkunsten from Copenhagen in Denmark was chosen, a group which had already attracted attention with a number of interesting housing projects. At first, the Swedish contractual system, which separates the planning side (architect) from the construction side (contractor), conflicted with the Danish system, in which drawing up tenders and on-site supervision are part of the architect’s remit. However, the possible difficulties were eliminated through a personal agreement. Jens Thomas Arnfred, the responsible project architect and co-founder of Vandkunsten, was very familiar with the Swedish planning and building system as a result of his teaching experience at the Chalmers University in Göteborg. Furthermore, the boss of the building contractor Fristad Bygg visited the architect’s offices in Copenhagen in order to find out about the Danish system of building. In the end, this led to optimum cooperation; the architect was able to take part in the decision-making concerning constructional details while work was proceeding on site. This is normally impossible with the contractor system but in this case it proved its worth in every sense.

Design | It was an attractive elevated rural site with two knolls. The architect placed ten slim, extended rows of houses fanning out around the two knolls, thus achieving optimum landscaping across the whole site. At the same time, the topography of the site was emphasized by the buildings being laid out in the same direction as the slope of the ground. The buildings are up to three storeys high, growing out of the slope under the horizontal line of the eaves.

The individual buildings comprise three to five terraced houses differing in height. The road around the site passes through an opening in each of the buildings. This is situated between the uppermost single-storey house and the other houses, and extends up to the underside of the roof.

Location
“Nielsen” Housing Estate, Hestra Parkstad Symfonigatan, Borås, Sweden

Client
AB Bostäder, Borås

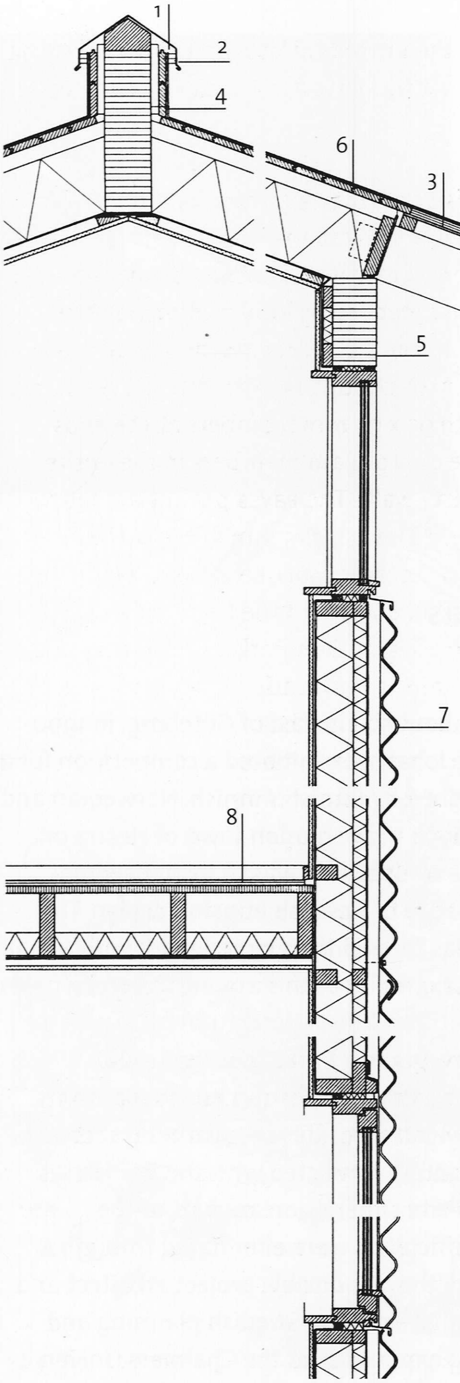
Architect
Tegnestuen Vandkunsten, Copenhagen, Denmark

Structural Engineer
STIBA, Sven-Olof Augustsson

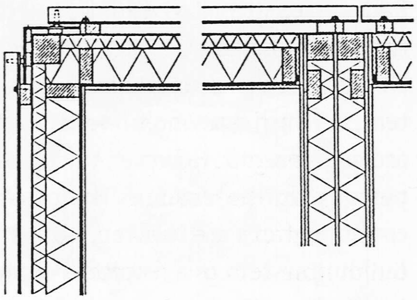
General Contractor
Fristad Bygg, Fristad, Sweden

Date of Completion
1994

Costs
The cost for a total living space of 3596 m^2 was 45 million Swedisch Kronor, including all ancillary construction costs. This equates to a price/m^2 of 12 500 Skr.



6 | Vertical section, scale 1:25. **1** Metal capping. **2** Spacer piece and protection against drifting snow. **3** Fibre-reinforced cement board, 6 mm. **4** Glulam ridge purlin, 140 x 495 mm. **5** Glulam eaves beam, 140 x 270 mm. **6** Roof construction: 2 layers roofing felt, 23 mm boarding, 45 mm air gap, 220 mm thermal insulation between rafters (45 x 220 mm + 45 x 45 mm), vapour barrier, 28 x 70 mm battens, 13 mm plasterboard. **7** Wall construction: profiled fibre-reinforced cement cladding, 38 x 70 mm pressure-impregnated battens, airtight sheeting, 120 + 45 mm thermal insulation between 45 x 120 mm timber members and 45 x 45 mm battens, vapour barrier, 13 mm plasterboard. **8** Floor construction: Beechwood flooring, one layer 500 g bituminous felt, 22 mm chipboard, 70 mm insulation between 45 x 195 joists, sheeting, 22 x 70 mm battens, 13 mm plasterboard.



7| Horizontal section through wall, scale 1:25, showing the loadbearing 95 x 95 mm members and the 45 x 120 mm members in the thermally insulated infill panels and the connection to a loadbearing wall.

During the planning, special attention was paid to creating diverse types of rooms. Likewise, providing a view of the attractive rural surroundings was also taken into account. Following this principle, the two- and three-storey terraced houses each have a two-storey void linking the kitchen below with the living room above. This created an exciting interior and interesting natural lighting effects.

Large overhanging eaves and the continuous narrow row of windows just below emphasize the slim nature of the buildings. The light-colour natural wood window frames contrast very effectively with the black, profiled fibre-reinforced cement wall cladding. The carefully detailed design illustrates the philosophy of the architects: to use simple and cheap building materials as far as possible but to demand the best craftsmanship and best materials at those places where people come into contact with the structure. This is a philosophy also adopted by Ralph Erskine. Therefore, the simple but stable construction with its industrial-type cladding allowed funds to be redirected into providing generous interior layouts and creating differences between the individual houses. This enabled the budget to be kept within the mandatory cost framework for social housing in Sweden.

Structure | It is a timber stud system consisting of 95 x 95 mm members which are continuous from concrete foundation to roof, i.e. a maximum of three full-height storeys. In the meantime, in Sweden as in other countries, timber houses having more than just two storeys are also approved by local authorities. The buildings are braced by the transverse party walls between the houses as well as by the other structural internal walls, all of which consist of 13 mm plasterboard on both sides of 45 x 95 mm members with 95 x 95 mm members at the ends. The ridge purlins and eaves beams are the only glulam members in the entire construction and are supported on the party walls. The eaves purlins are 140 x 270 mm and the ridge purlins 140 x 495 mm. The 45 x 195 mm joists of the intermediate floors are also supported on the transverse walls, i.e. parallel with the longitudinal sides of the building. Although the width of the building is only 6 m, to span the joists in this direction is not unusual in Denmark and Sweden. This technique allows the external walls to remain as non-loadbearing, uninterrupted, independent infill panels inserted between the loadbearing timber columns.

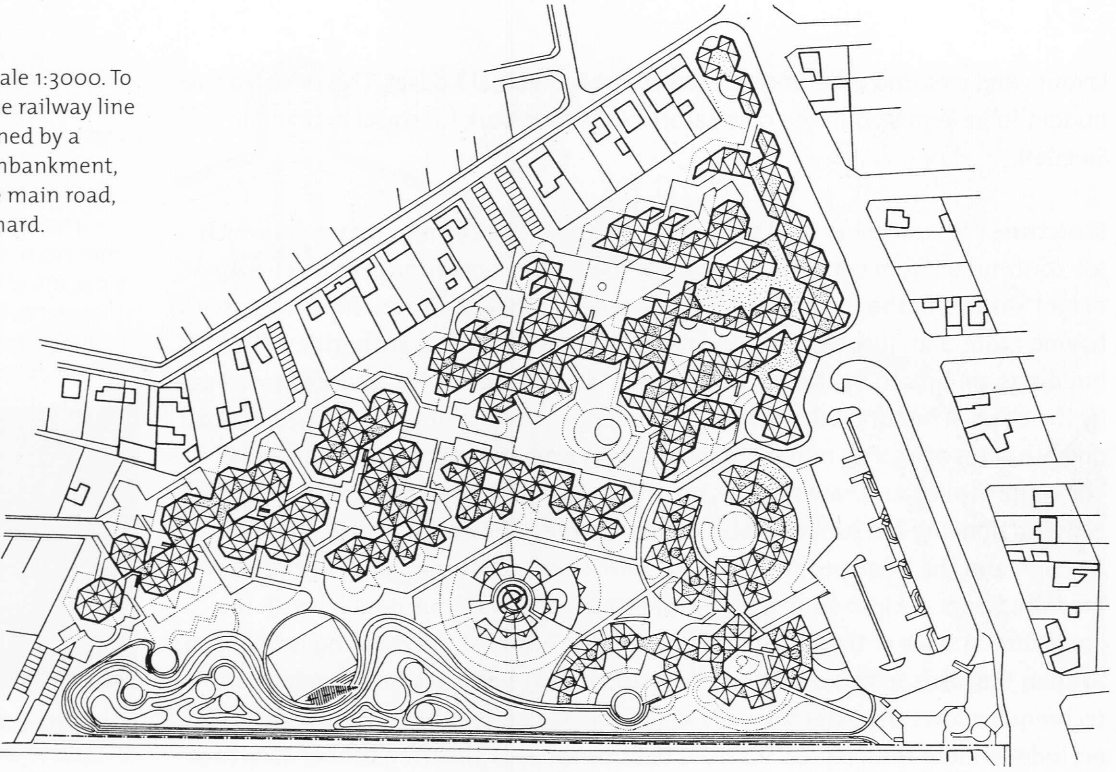
The external walls comprise 120 x 45 mm members with 120-mm-thick thermal insulation in the bays, 45 x 45 mm battens fixed in front transversely with 45 mm thermal insulation in between. This eliminates any through-joints in the insulation which has a total thickness of 120 + 45 = 165 mm. On the inside there is the vapour barrier and 13 mm plasterboard. The external insulation is covered by an airtight lining underneath the external cladding which consists of black, profiled fibre-reinforced cement sheeting fixed horizontally on pressure-impregnated 38 x 70 mm battens.

The ridge purlins and eaves beams carry 45 x 220 mm timber rafters at 800 mm centres. Between the rafters is a 220-mm-thick thermal insulation with the vapour barrier underneath. The ceiling is 13 mm plasterboard on 28 x 70 mm battens. A 45 mm air gap is formed above the insulation by means of 45 x 45 mm battens which are nailed along the top of the rafters. Fixed to these is the 23 mm tongue-and-groove boarding and the whole roof is covered with two layers of roofing felt. The rafters extend 1.20 m beyond the eaves beam; here, the 45 x 45 mm battens are fixed across the rafters. The roof construction consists of a 6 mm fibre-reinforced cement board, the 23 mm tongue-and-groove boarding, the roofing felt and the gutter along the edge. At the gable ends the overhang is formed by the projecting ridge purlin and eaves beams. Interesting and effective is the detail at the ridge where the ridge purlin projects above the line of the roof and the air gap above the insulation is ventilated at the sides of the purlin.

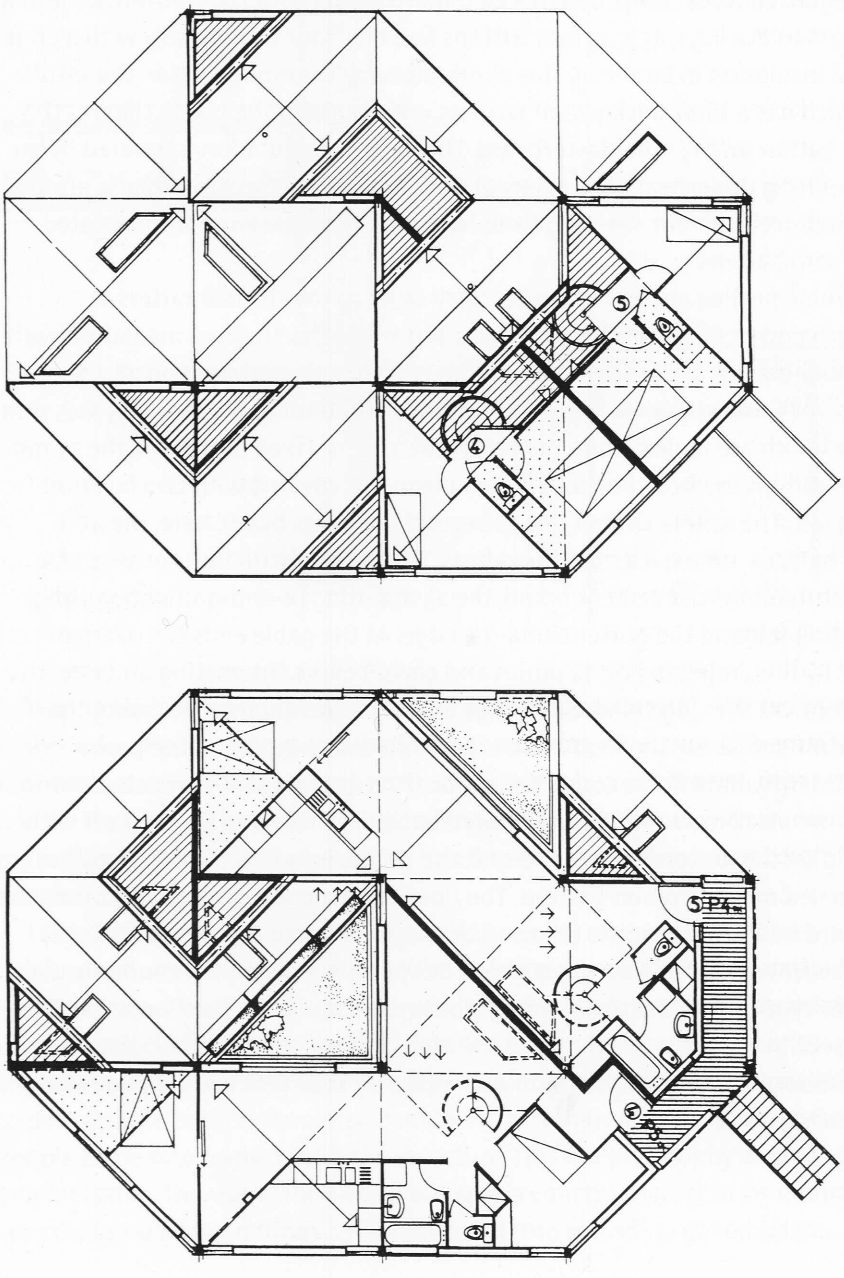
The intermediate floors comprise loadbearing 45 x 195 mm joists at 400 mm centres. Insulation, 70 mm thick, is placed between these and finished off with sheeting on the underside. Like the roof, the ceiling is 13 mm plasterboard but here carried on 22 x 70 mm battens. The floor construction consists of 22 mm chipboard nailed to the joists followed by a layer of 500 g bituminous felt to which beechwood strip flooring is glued. Despite the low impact-sound insulation, this type of construction is acceptable in Sweden when the floor is between rooms within the same occupancy.

All timber elements are joined to each other by means of nailing plates or metal fixings.

8 | Elevation showing horizontal profiled fibre-reinforced cement cladding and untreated wood windows. The supporting structure for the elevated entrance walkway is made from hot-dip galvanized steel.



1 | Site plan, scale 1:3000. To the south is the railway line which is screened by a landscaped embankment, to the east the main road, Rue Pierre Sémard.



2 | Plans of the prototype, scale 1:200. This initial demonstration building is located on the western edge of the estate. It consists of eight 4.90 x 4.90 m modules and four triangular half-modules placed across the corners. The 1st and 2nd floors illustrated here show the interesting apartment and room layouts as determined by the geometry. The arrows indicate the direction of the respective ascending ceiling.

3 | View of the development from the screening embankment.

"Pierre Sémard" Residential Development, Le Blanc-Mesnil

Iwona Buczkowska

Subject | Residential developments, especially when they are built using standardized components to keep costs down, can easily turn out drab and monotonous. Nevertheless, it is the task of the planners to make such developments lively and interesting. Using standard terrace house designs, however, urban developments rely mostly on the nature of the sites available and very little on the houses themselves. New forms, aimed at achieving greater integration and the formation of clusters, have evolved from the hitherto conventional developments with detached and terraced houses. This trend was helped, perhaps even instigated, by the relaxing of rigid building regulations, in particular by the introduction of mixed vehicular/pedestrian traffic areas. In the forefront here were planners in the Netherlands who as early as the late seventies permitted so-called "Wohnerften", i.e. streets in which pedestrians and vehicles share equal priority. Standardized buildings could thus be grouped into a development with a coherent but varied form. The Dutch provided some early and astounding examples of this type of settlement (Alkmaar, Zoetermeer).

Local authority requirements regarding fire protection have also become somewhat better differentiated, thereby allowing the approval of concentrated timber-frame developments provided that certain conditions are satisfied. This change in attitude has led to developments like the one described here – 225 housing units on the north-eastern outskirts of Paris; an interesting housing estate formed from an agglomeration of identical buildings – and all built entirely from timber.

Design | The architect Iwona Buczkowska was given the task of creating a densely-settled housing estate. The site was adjacent a railway line near a station in an existing residential area consisting of detached houses. Despite the density of the development it should reflect and augment the scale and intimacy of the surroundings. The aim of the architect was to redefine the traditional urban vocabulary of streets, squares, passages, etc. in a modern way, to create an organic diversity of angular passageways, internal courtyards, semi-private and private zones. The fluid relationship between the buildings and their surrounding or

Location
Rue Pierre Sémard,
93150 Le Blanc-Mesnil,
France. The estate is situated adjacent "Le Blanc-Mesnil" railway station on the Paris-Roissy Airport route.

Client
Sodédat 93 (Société départementale d'aménagement du territoire de la Seine Saint-Denis) appointed by Le Blanc-Mesnil council.

Architect
Iwona Buczkowska,
Ivry-sur-Seine

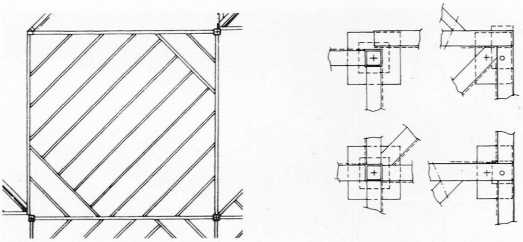
Structural Engineer
Ing. Truong (prototype); the contractors were responsible for subsequent phases.

Timber Construction
CMBP (prototype), Houot (1st phase), Quellec (2nd phase)

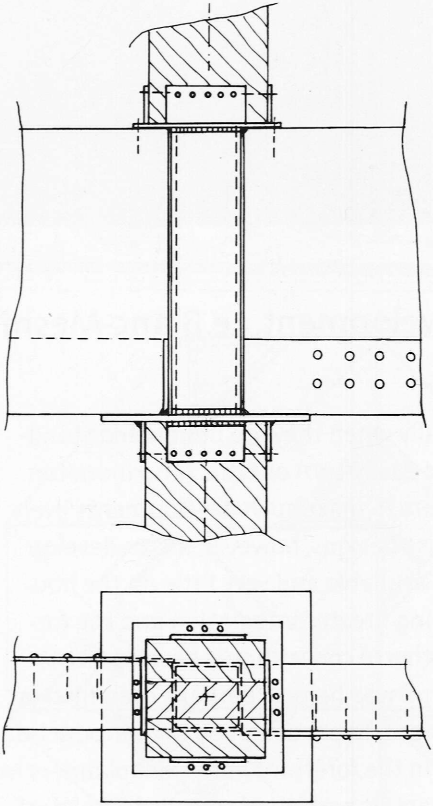
Date of Completion
1992

Costs
The average cost was 5000 French Francs per m² of usable floor space.

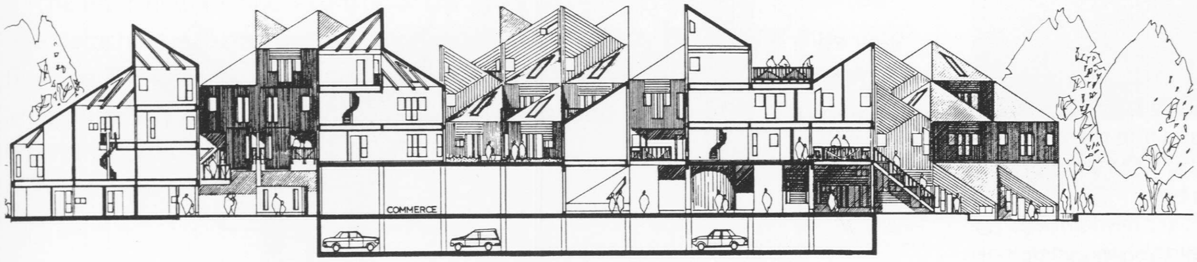
4 | Plan of typical floor construction, scale 1:200. The uniform loadings on the main beams in both directions are achieved by the diagonal arrangement of the floor joists. The various column/beam connections at the intersections of the grid lines are drawn at a scale of 1:50.



5 | Joint between main beam and column, scale 1:10. In the prototype and the 1st phase the columns are connected between floors by a 90 x 90 x 390-mm-long hollow section to which the incoming beams are attached. Welded onto this hollow section top and bottom are square end plates with connecting lugs containing nailing holes for fixing the beams and columns.



enclosing spaces should create a lively experience and be an ever-present aid to orientation. A simple basic module arranged in a variety of combinations would create this vivacity but, at the same time, instil a sense of coherence. The architect decided on a basic unit measuring 4.90 x 4.90 m. Up to a height of three storeys these units would have a double monopitch roof with the common low point on the diagonals. The outcome of this design is that, externally, dynamic roof peaks ensue which determine the enduring appearance of the development. The project was carried out in several phases. A prototype consisting of five housing units was built in 1986 to illustrate the possible combinations, overall appearance and technical details. The first phase comprising 88 housing units was completed in 1988, and the second phase followed in 1992 with a further 132 units and 700 m^2 of floor space for commercial purposes. The final phase of 50 units, a kindergarten and other communal facilities has not yet been built.

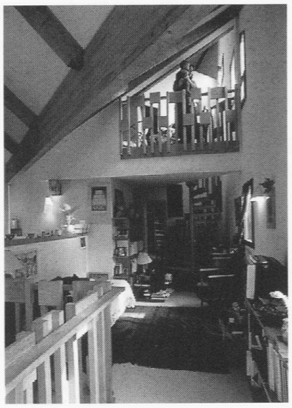


6 | Section, scale 1:600. Basement garages and commercial premises are constructed in reinforced concrete.

Structure | The entire estate is built using timber-frame construction. Reinforced concrete is only used for the basement garages and commercial premises, which form the foundations for the timber-frame housing above.

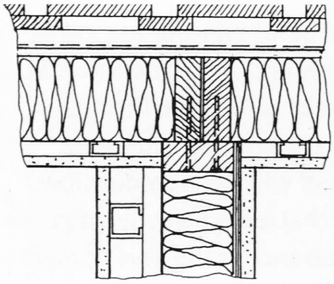
The whole scheme is based on the constant 4.90 x 4.90 m grid. Positioned on the grid intersections in the prototype and the first phase are loadbearing 160 x 160 mm glulam main columns, each just one storey high. In the second phase the columns are 140 x 140 mm and are continuous over the full height of the building. The main floor beams – on the grid lines, i.e. 4.90 m long – are 380 x 100 mm glulam members fixed to the main columns. These main beams carry the actual 250 x 50 mm floor joists arranged at approx. 600 mm centres and at an angle of 45° to the main beams. This means that all main beams in both directions are equally loaded. Apart from that, this diagonal arrangement matches the geometry of the entire development, which is comprised of the squares formed by the grid itself and by halving these squares diagonally.

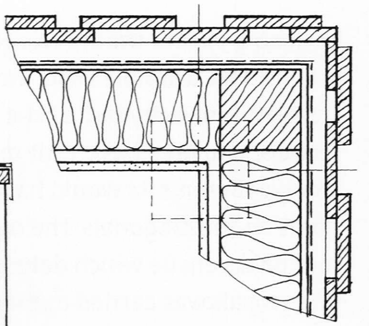
The roof surfaces give the whole settlement its very own identity; the roofs rise in monopitch form from the diagonals and so sharp peaks ensue at the corners of the squares. The roof pitch is the result of the geometric relationship of the ridge being exactly one storey above the eaves. The roof support beam – a 380 x 95 mm glulam member – is positioned on the diagonal unless there is an internal wall underneath; in this case the support is formed by two 496 x 44 mm beams, one on each side. The 150 x 70 mm rafters at 1.36 m centres rise from these roof support beams to carry the 120-mm-thick sandwich-construction roof deck. These sandwich elements are 450 mm wide and consist of chipboard outer layers with a 100 mm thermal insulation filling. The waterproofing is provided by roofing felt with a bonded white gravel topping.

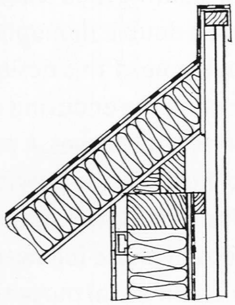


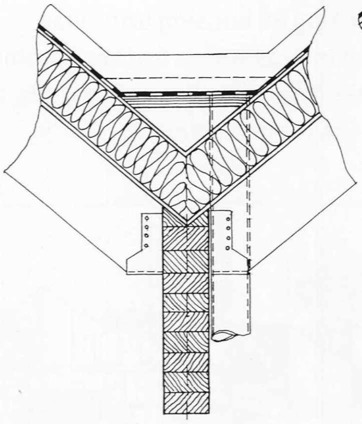
7 | View of an apartment storey showing exposed diagonal roof beam and ceiling rising on both sides.

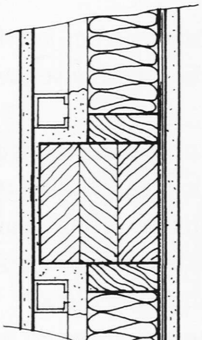
In the façades the main columns are replaced by the façade construction which, for structural reasons, is offset outwards from the grid. The timber-frame façades are made up of 115 x 115 mm columns on the grid lines and intermediate 115 x 38 mm vertical studs at a spacing of 600 mm which are connected to con-

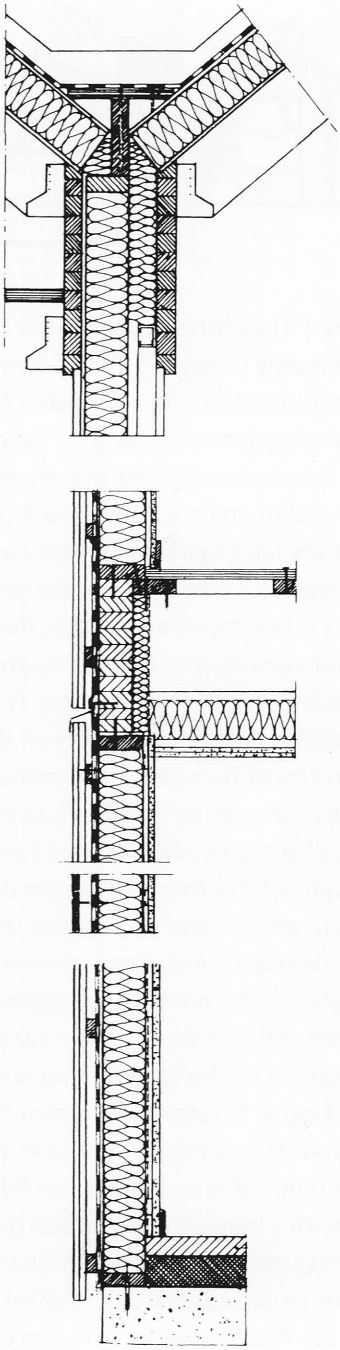












8 | Façade construction, scale 1:10. Illustrated here are an external corner and the junction with a separating wall. Façade construction from outside to inside: vertical 18 mm lapped larch weatherboarding, 25 x 50 mm counterbattens, protective sheeting, 9 mm plywood, 120 mm thermal insulation in the bays of the timber frame (115 x 115 mm columns, 115 x 38 mm intermediate studs), vapour barrier, 15 mm metal rails, 13 mm plasterboard.

9 | Roof construction, scale 1:10. The 380 x 95 mm diagonal roof beams support the 150 x 70 mm rafters which in turn carry the 120 mm sandwich decking (with 100 mm thermal insulation) and the waterproofing on top.

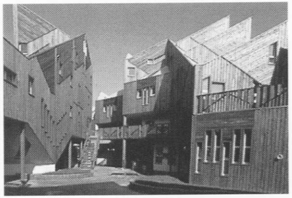
10, right | Vertical section, scale 1:20. Top: junction of roof with twin-leaf diagonal separating wall. Centre: junction of floor with external wall; the timber-frame façade connects to the main beam above and below; the inside face of the beam is provided with 40 mm insulation. Bottom: junction between base of timber façade and concrete substructure (foundation or commercial premises).

11 | Joint between internal partition and main column, scale 1:10. The separating wall has two leaves. One leaf consists of 95 x 40 mm timber framing with 10 mm plywood and 13 mm plasterboard on the room side and 100 mm insulation in the bays. The other leaf, spaced 25 mm clear of the first leaf, is formed by a framework of 40 mm steel sections onto which 13 mm plasterboard is fixed. Polyurethane foam is used to seal the joints with the columns.

tinuous 115 x 70 mm wall plates top and bottom. Glassfibre insulation batts, 120 mm thick, are placed in the bays and then covered on the interior face by a vapour barrier. On the outside the frame is covered by an airtight layer of 9 mm plywood and a protective breather paper. The weatherproofing is formed by vertical 18 mm lapped larch weatherboarding fixed to 25 x 50 mm counterbattens. The internal walls are finished with 13 mm plasterboard on 15 mm metal rails.

Internal partitions are in timber-stud construction like the external walls but here consist of 95 x 36 mm battens with 13 mm plasterboard to both sides. The separating walls between apartments are constructed in two leaves, one of which comprises 95 mm timber framing with 10 mm plywood and 13 mm plasterboard on the room side, with 100 mm insulation batts placed in the bays. The other leaf is simply a 40 mm metal frame onto which plasterboard is fixed. There is a gap of 25 mm between the two leaves. Polyurethane foam or additional insulation batts are provided at joints to prevent sound transmission.

The intermediate floors consist of the 250 x 50 mm joists already described onto which 65 x 38 mm battens are fixed in order to carry the 25 mm chipboard flooring. The ceilings are formed by two layers of 13 mm plasterboard fastened to an acoustically insulated metal frame. Insulation, 100 + 60 mm, is placed between the joists.



12 | View along a main access corridor.

13 | Looking from the 2nd floor onto a main access gallery.

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Building in wood has enjoyed considerable attention in recent years. In particular, the ecological qualities of this natural and renewable building material are of importance. Modern construction methods have greatly widened the scope for this traditional material; the technically advanced and aesthetically ambitious designs of architects like Thomas Herzog or Santiago Calatrava derive their special character from the use of timber.

However, the constructional details of such buildings remain something of a mystery; how this architecture is realized is a question not answered by the many publications available. In this book the engineering aspects come into their own. A representative selection of international projects from the past ten years is documented here, complete with working drawings, site photographs, details of sizes, materials and costs, as well as a precise analysis of the construction. The examples embrace a wide range of structures including bridges, industrial buildings, sports centres and houses, and cover many different regions and climate zones. All in all, a book which demonstrates the whole spectrum of possible applications for this fascinating material.

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