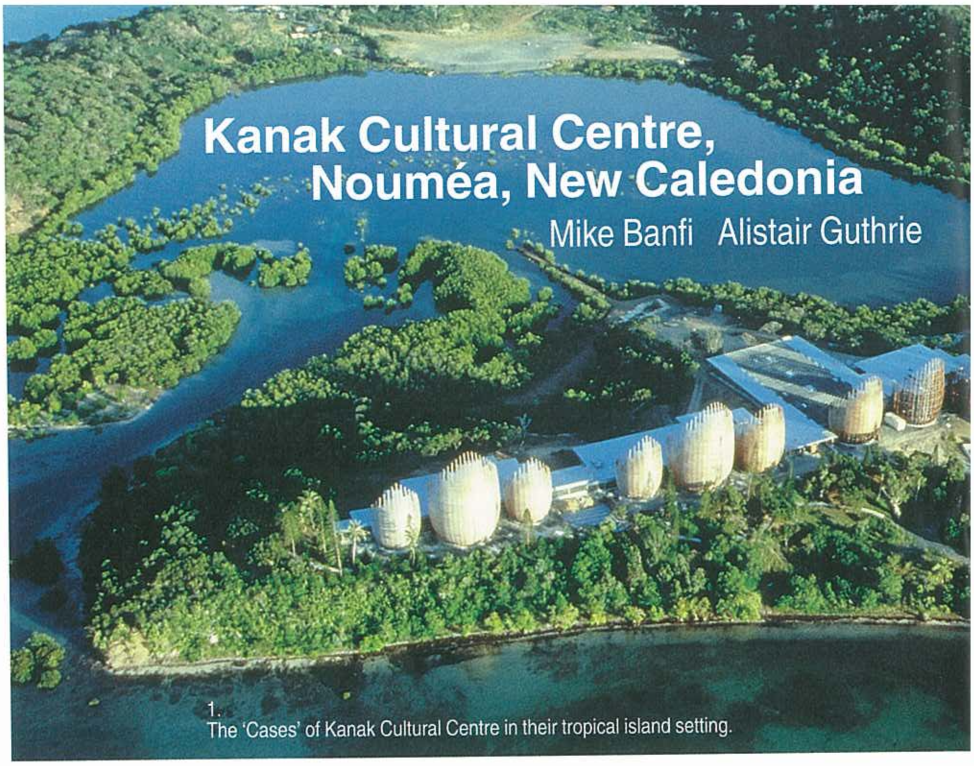
Kanak Cultural Centre, Nouméa, New Caledonia

Mike Banfi Alistair Guthrie



1.
The 'Cases' of Kanak Cultural Centre in their tropical island setting.

Introduction

New Caledonia is an island in the Pacific Ocean, some 1600km east of Australia. The Kanak Cultural Centre is situated on a thin peninsula near the island's capital, Nouméa. It celebrates the Melanesian culture of the Kanaks with its museum of living arts, and is also a memorial to Jean-Marie Tjibaou, leader of the New Caledonian independence movement, who died in 1989. It was here that Tjibaou had held the 'Melanesia 2000' festival in 1975, one of the key moments in the struggle for cultural and political recognition by France.

In 1991, an international competition was held to suggest ideas for the centre. The winning design by architect Renzo Piano, with input from Arup, employs large hut- like structures, or 'Cases', clustered together along a central spine. Housing exhibitions, study spaces and living arts, the Cases are inspired by the island's traditional construction, but employ modern technologies.

Arup was commissioned to engineer the scheme design for the whole complex and to work in detail on the structure and environmental performance of the Cases. Driving the Cases' design was the requirement for them to enhance the natural ventilation through the Centre, thus minimising the need for mechanical systems.

Climate

The climate is described as 'oceanic tropical' - generally humid throughout the year with only moderate variations in temperature from an average winter minimum of 18°C to an average summer maximum of 28°C. Relative humidity does not vary much throughout the year and is about 75% RH with average monthly maximums of 90%RH and minimums of 60% RH. To estimate the comfort conditions within the Cases, a full weather tape for a particular year was obtained from Nouméa Airport, giving details of temperature, humidity, and wind speed and direction.

Concept

The original concept was to use the giant curved structures as wind scoops, but as the design progressed it became evident that they would need to work in a variety of ways in response to the different strengths and directions of the wind.

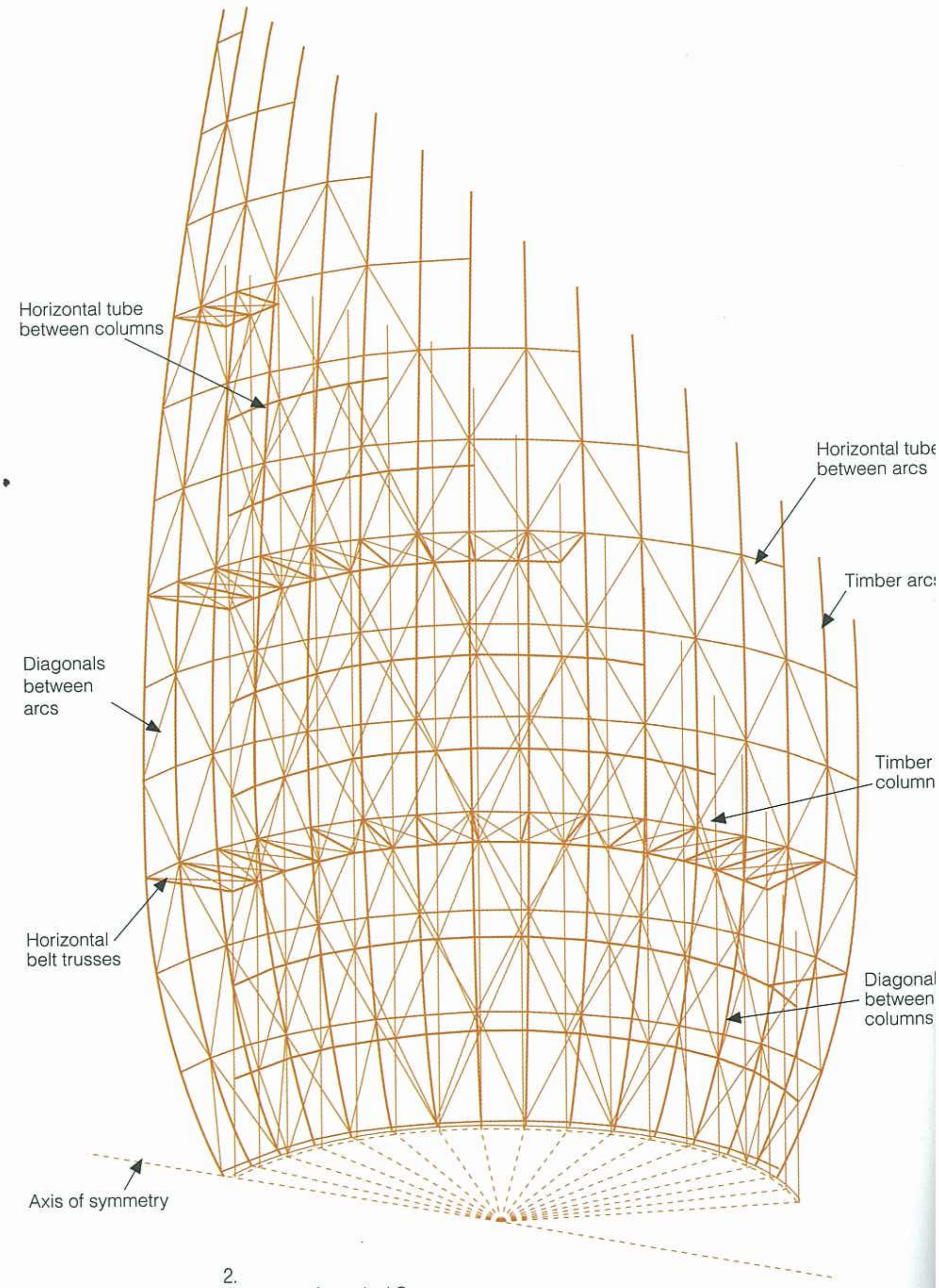
Early in the project, the client agreed that if it could be demonstrated that the spaces inside the Cases were comfortable without air-conditioning for at least 95% of the worst month of the year, then a naturally-ventilated solution should be designed. At competition stage, Arup stressed the benefits of low technology since mechanical equipment had to be imported and maintained. The challenge was to prove that natural ventilation would give adequate comfort.

Typical case geometry and modes of operation

Fig 2 shows the geometry of a typical Case, developed from the preliminary studies. The structure and cladding of the double shell is made of a renewable hardwood while the roof is an insulated panel with external shading to reduce surface temperatures.

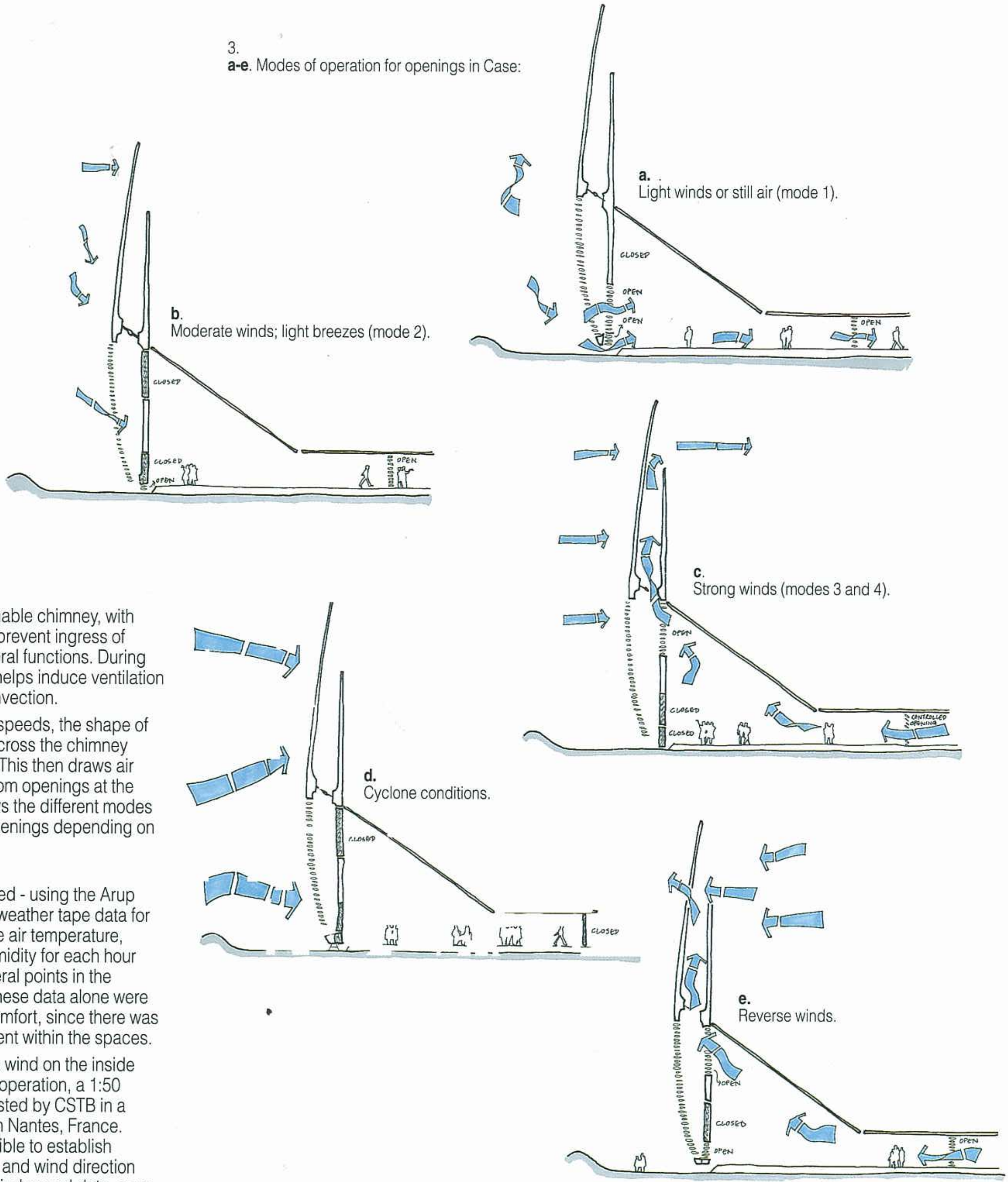
Several openings in the Case allow ventilation. Two sets are located at the front (facing prevailing winds): 2m high openable louvre windows and, at low level, 0.5m high openable louvres.

These openings are controlled automatically to either fully-open or fully-closed positions. At the back of the Case a series of openable windows allow cross-ventilation. They have three control positions and are controlled automatically to be open, closed, or half-closed. Control of the openings is based on internal air speed to maximise internal air speeds up to the limit of 1.5m/s.



2.
Geometry of a typical Case.

3.
a-e. Modes of operation for openings in Case:



a. Light winds or still air (mode 1).

b. Moderate winds; light breezes (mode 2).

c. Strong winds (modes 3 and 4).

d. Cyclone conditions.

e. Reverse winds.

At high level there is an openable chimney, with double horizontal louvres to prevent ingress of water. The chimney has several functions. During days with little or no wind, it helps induce ventilation by stack effect or natural convection.

During periods of high wind speeds, the shape of the shell directs air up and across the chimney inducing negative pressure. This then draws air through the internal space from openings at the back of the Case. Fig 3 shows the different modes of operation for the above openings depending on wind conditions.

Comfort analysis

The typical Case was analysed - using the Arup Room program linked to the weather tape data for the sample year - to calculate air temperature, radiant temperature, and humidity for each hour every day of the year, at several points in the occupied space. However, these data alone were not sufficient to determine comfort, since there was no information on air movement within the spaces.

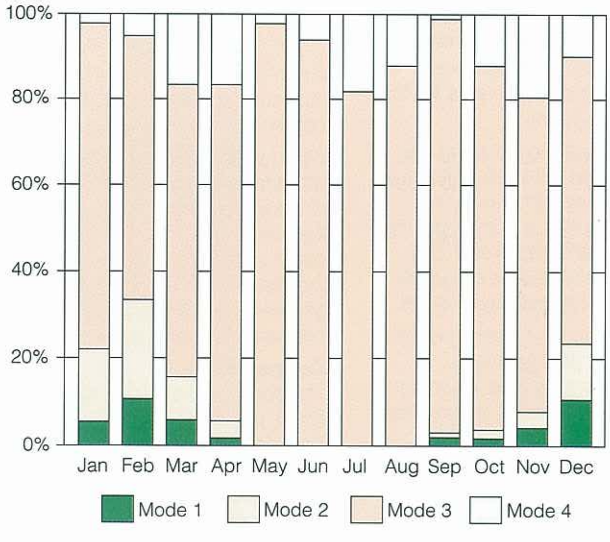
To determine the effect of the wind on the inside spaces under each mode of operation, a 1:50 scale model was built and tested by CSTB in a boundary layer wind tunnel in Nantes, France. From these tests, it was possible to establish coefficients for each location and wind direction which, when applied to the wind speed data, gave an approximation to the internal air velocity under each mode of operation.

These data were then combined with temperature and humidity calculations to arrive at a comfort index for each hour during the critical months. The resulting values were compared with both the Fanger comfort equations and the Gagge indices of effective temperature. The Gagge method was chosen, as it is the best indication for people living in naturally-ventilated conditions in a tropical climate, since it is based on experimental data from this climate type.

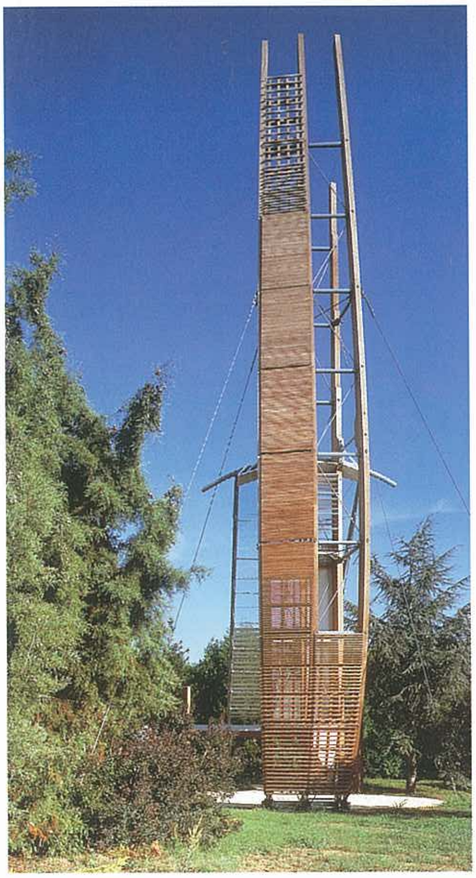
Comfort conclusions

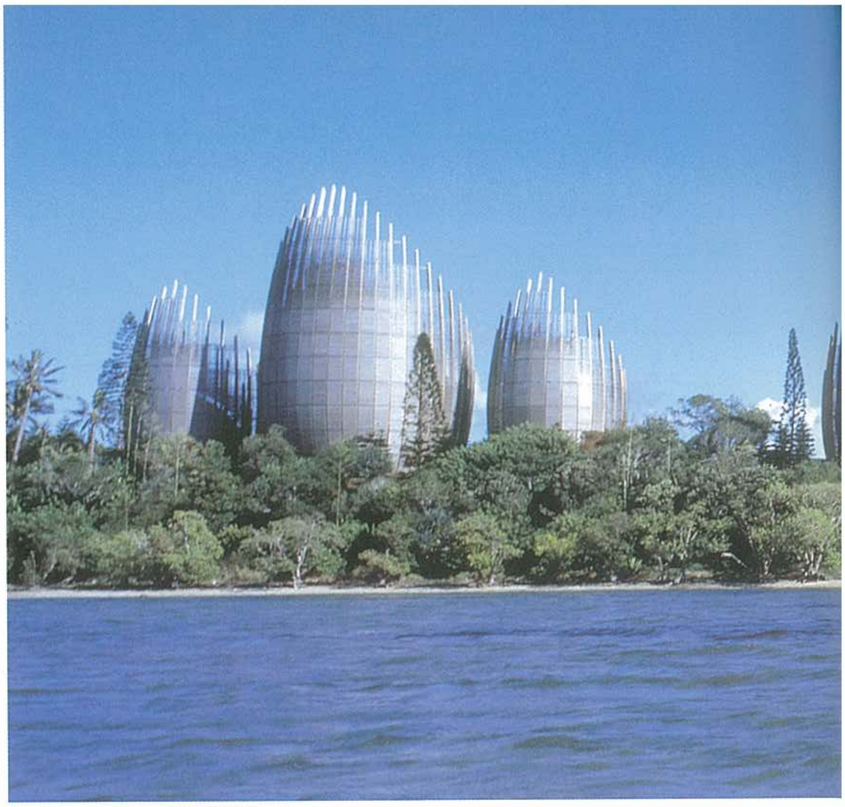
The data showed that during the hottest month, February, the Gagge acceptable comfort criteria were exceeded for only 5.8% of the occupied hours. This was acceptable to the client and formed the basis of the design. Arup also calculated the percentage of time that each mode would be in operation and found that nearly all the time mode 3 would be in operation (Fig 4). Since mode 1 was hardly ever operational the openings here would be under manual operation.

4.
Comfort analysis data.



5.
Mock-up in France of part of Case structure.





7.
In this view across the sea the massive scale of the Cases is immediately evident.

6.
Detail of structure.

Structure

The design of the structure for the Cases was shared between Ove Arup & Partners, who were responsible for the concept design and the analysis up to tender, and the French firm Agibat MTI who produced the tender documentation and carried out the final design. There are three sizes of Case - the largest is 28m high and has an internal diameter of nearly 14m - and all have a similar structure. The main structural requirement was to resist the cyclonic winds which can gust up to approximately 65m/s from any direction.

The architectural concept and ventilation strategy generated the Centre's overall form, including need for an internal wall. Options for its construction were considered, and it was decided to use a similar form to the external wall. The two concentric walls are set out from a common centre and occupy about two-thirds of a circle. The main elements of both are the glue-laminated timber sections. In the outer wall the timbers are curved into arcs; for the inner wall they are vertical columns.

To provide overall wind resistance, bracing was provided in the walls to form stiff shells. After due consideration, the chosen system was to brace the timbers together with tubes at 2.25m spacing vertically, with single diagonal ties in each bay. At the base of the inner walls, half the diagonals had to be omitted to allow for opening windows.

A structure was also required to prevent the walls distorting from the circular plan geometry. This was provided by linking the inner and outer walls together with up to three levels of horizontal belt trusses.

An alternative would have been to use the sloping roof inside the inner wall, but it was decided to keep the roof structure as light as possible, and introduce a joint so that wall movements did not stress the roof.

A non-linear program was used to analyse the structure, including provisions for any of the ties becoming slack and to include stability effects.

Wind loading from three directions was considered, with account being taken of the varying permeability of the timber slats on the outer wall. The width of the timber arcs and columns was constant but the depth varied with height to reflect the structural requirements. The bracing tubes and diagonals are generally the same dimension for each size of Case with some variations in the diagonals near the base.

Connections

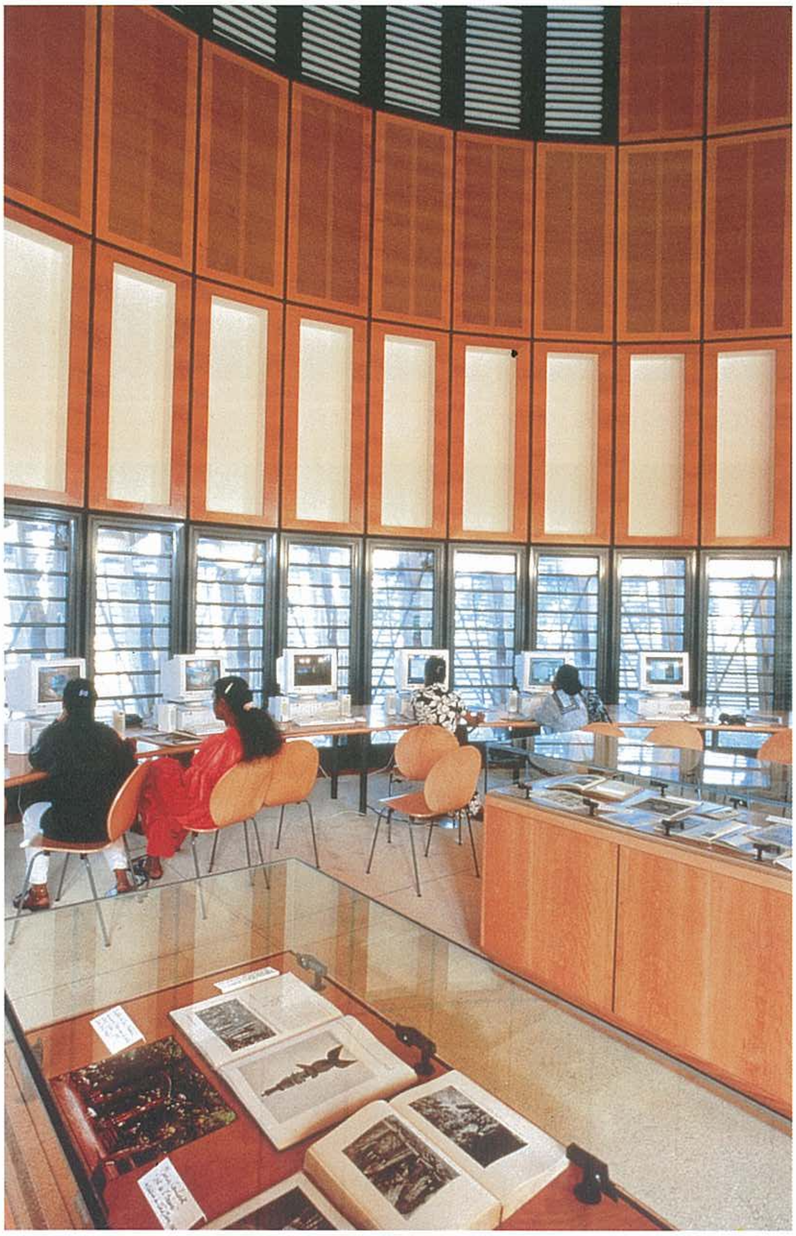
The connection between the timber arcs, horizontal struts, and diagonal ties was a major consideration. One idea was a plate slotted through the timber with steel-to-steel connections, but the geometry of the diagonals gave a large joint. Moving the ties from the centreline of the timber to the outside raised the possibility of cables with relatively simple clamped connections. However, the eccentricity at the connection had implications for the structure, and the cables on the outside would clash with the cladding. The detail chosen uses a steel casting inserted in the timber, incorporating more compact fixings for diagonal steel rods.

The connection between the timber and concrete support has a similar language, with one part of a steel casting inserted in the timber and the other forming a pinned connection to a casting bolted to the concrete.

Materials

The temperature, humidity, and proximity to the sea do not give the best conditions for the durability of materials. In selecting the timber, the possibility of termites had to be considered. The timber also had to be suitable to produce glue laminated elements in terms of its movement and suitability for gluing. Following tests carried out at the Centre Technique du Bois, the species chosen was Iroko. The steel tie rod, tubes and castings were zinc-coated.

8.
Library facilities.



Conclusion

After some delay, the project was built on site and opened in autumn 1998. It is understood that comfortable conditions have been achieved in the naturally ventilated spaces and at the time of writing further feedback is awaited.

Credits

Architect:
Renzo Piano Building Workshop, Paris

Services engineer and structural concept engineer:
Ove Arup & Partners Steve Abernethy, Mike Banfi, Mark Chown, Martin Cooper, Fiona Cousins, Rob Davis, Ed Forwood, Alistair Guthrie, Mike Holmes, Richard Hough, Alistair Lenczner, Rory McGowan, Heraclis Passades, Peter Ross, Manabu Yamada

Detail structural engineer:
Agibat MTI

Climate control feasibility:
CSTB

General co-ordination:
GEC

Illustrations:
1, 6: Gollings
2: Agibat MTI
3: Narjas Mehdi
4: Martin Hall
5: C M Denance
7: P A Pantz
8: S Horishita