02

Location: Bennelong Point, Sydney, NSW

Trustee: The Sydney Opera House Trust

Architects: Stage
1+2: Jørn Utzon
3: Hall, Todd & Littlemore

Engineer: Ove Arup & Partners

Builder: Hornibrook Pty Ltd

Constuction Date: 1973

written by: Bernard Toogood | **design:** Peter Walker

Sydney Opera House

Sydney Harbour - New South Wales

Sitting on Benelong Point in Sydney Harbour, the Sydney Opera House is one of the icons of twentieth century architecture. After winning an international competition for the design of the building, Danish architect Jørn Utzon supervised the completion of the first two stages of the project; the podium and the concrete shells. After years of experimentation, much of it in conjunction with the innovative Sydney plywood manufacturer, Ralph Symonds Ltd, Utzon was finalising the design for the interiors of the building when, after considerable controversy, he resigned in 1966. The assembled partnership of Hall, Todd and Littlemore was commissioned to finish the interiors. A change in brief and a more conservative structural approach resulted in a different design. The rich and extensive timber interiors, contrasting with the heavy concrete masonry of the exterior, remain however an exemplary example of the use of plywood and laminated hardwood in a public building.

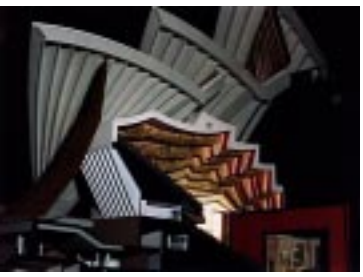
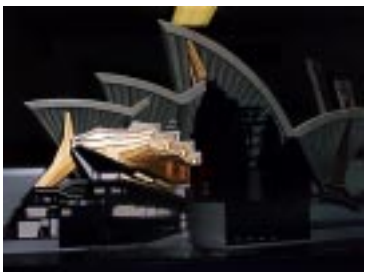
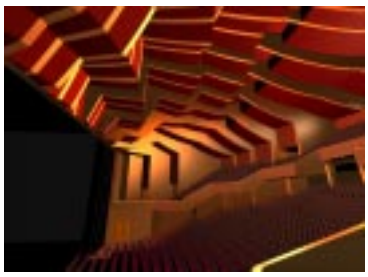
main image
the two halls of the opera house as seen from Sydney harbour

• **Utzon's Scheme** - From the beginning Utzon envisaged timber as the primary material for the interiors, with the warmth, colour and tactility of timber providing a contrast with the heavy, monochrome, load bearing concrete of the podium and sails.

The ceiling was to consist of a series of plywood **box beams** radiating out from the stage and suspended at points from the concrete arches of the shells. Each beam was to be made up of two plywood box beams bolted together, with acoustic insulation in the cavity inside each beam. Spanning horizontally between the box beams were to be panels of plywood reinforced with hot bonded aluminium. These horizontal elements were attached to the top of one beam and the bottom of the next creating a stepped form to the ceiling. On the top of these panels was to be bonded 2mm of lead for low frequency sound insulation.

Utzon saw the ceiling of the performance halls being like a floating cloud. This was to be expressed from the harbour side foyers where the waiting audience would be able to see over the banks of seating, into the gap between the top of the suspended plywood ceiling and the underside of the sails' concrete ribs.

The ceiling was designed to be divisible into large, separate elements that could be constructed with services installed and finishes applied off site then erected into position and bolted together. It was anticipated that this would add flexibility to the installation process.

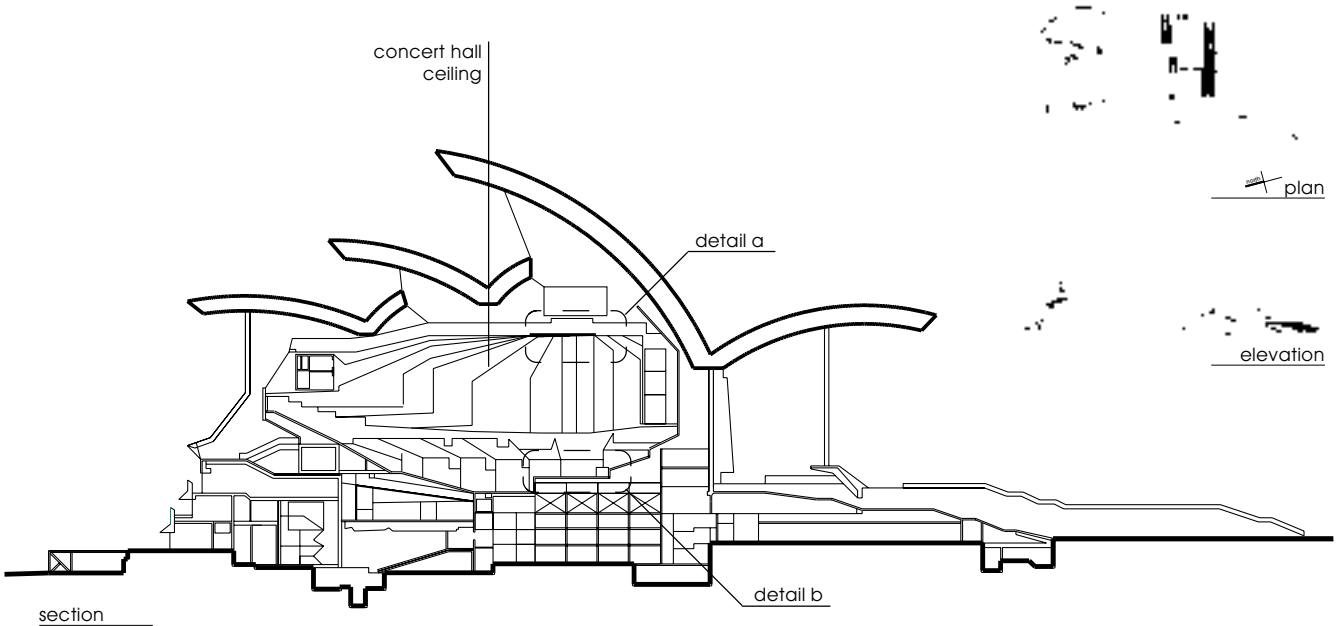





above far left + left
model of Utzon's scheme showing the gap, visible from the harbour side foyer, between the concrete shells + plywood ceiling. the mullions for the foyer glazing were intended to be made of moulded 'u' shaped plywood with a skin of hot bonded bronze laminated to the outside.

above right + near right
cad images of Utzon's intended interior for the major concert hall
images - P. Nobis

• **Built Scheme** - For many of the same reasons as Utzon, Hall, Todd and Littlemore chose timber as the dominant material for the interiors. For the timber finishes to the floors and walls, the new architects faithfully followed the direction set out by Utzon. However for the ceiling of the concert halls, while still using plywood, the design took a significantly different direction.

Throughout the interiors, prefabricated panels of laminated Brush Box were used for flooring, stair treads and risers and wall panels. An extremely hard and dense timber, Brush Box was chosen for its warm, rich colour and grain, acoustic performance and high durability.



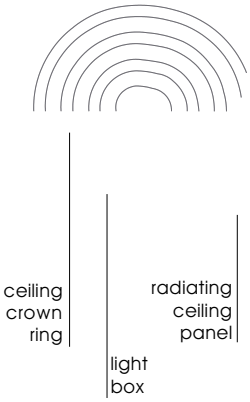
above top
site plan of opera house on Bennelong Point

above bottom
western elevation
drawings - courtesy of the Sydney Opera House Trust

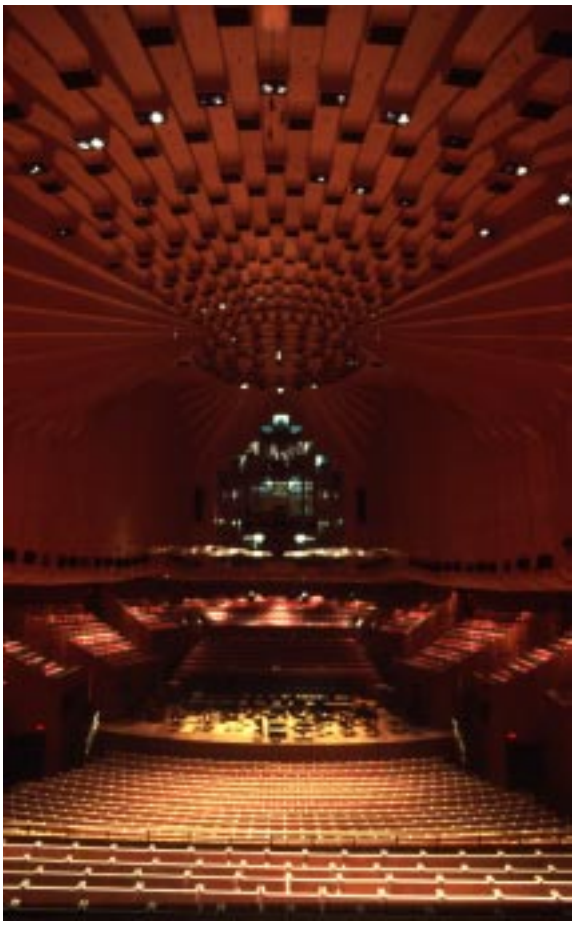
left
section through the concert hall

Made up of 38mm wide kiln dried strips of timber **glue laminated** together, each panel used in the Opera House was around 1200mm wide and varied in length depending on application. The flooring and tread panels were 51mm thick and fastened to timber joists. The wall panels were 19mm thick and fastened to steel channels. Smaller panels of laminated Brush Box were also used for balustrades, parapets, and handrails.

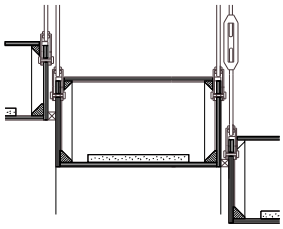
The ceilings in the Concert Hall and Opera Theatre, while differing from Utzon's intentions, are still a spectacular use of plywood. Both ceilings are constructed of White Birch plywood panels backed



with acoustic plasterboard and suspended from steel purlins. The purlins in turn are suspended from arched steel trusses in between the shells and the ceiling. With the trusses picking up all the loads of the ceiling and distributing them to the side of the shells, the ceiling itself no longer has any structural elements like the plywood beams in Utzon's scheme. A crown of plywood dominates the ceiling of the Concert Hall over the stage. Radiating out from this is a series of ribs that cascade down to their junction with the walls.



The complex geometry of the ceiling created several problems in its prefabrication. The crown alone consists of eighty separate sections of plywood all of which had to be assembled to an accuracy of 0.8mm. To cut arcs with such precision long swinging arms were developed to carry the plywood accurately through bandsaws. At various points, curved cuts had to be made into already curved pieces of plywood. A computer was used to generate the dimensions for such cuts, an early example of this technology's use in Architecture.



top left
section a-a (through concert hall ceiling)

middle left
reflected ceiling plan detail of the concert hall

bottom left
detail c (concert hall ceiling detail)

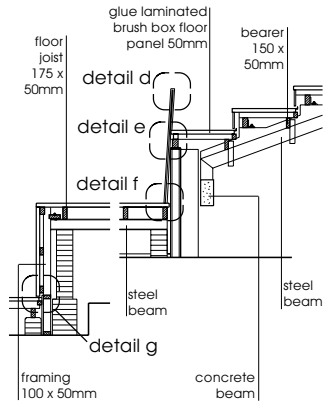
top right
main concert hall as built showing brush box acoustic panelling and the multiple curves of the plywood ceiling

middle right
detail of the crown ceiling over the stage

bottom right
view from the back of the major concert hall towards the stage
photos -courtesy of the Sydney Opera House Trust

top left
brush box flooring being installed
photo -courtesy of the Timber Development Association

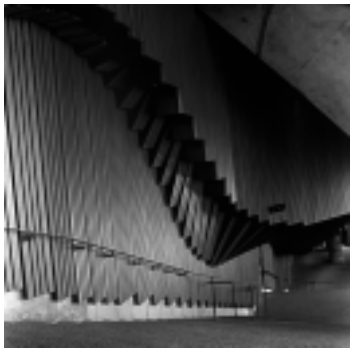
bottom (left to right)
-acoustic brush box panelling
-top hinged panelling in the corridors
-detail of concert hall ceiling



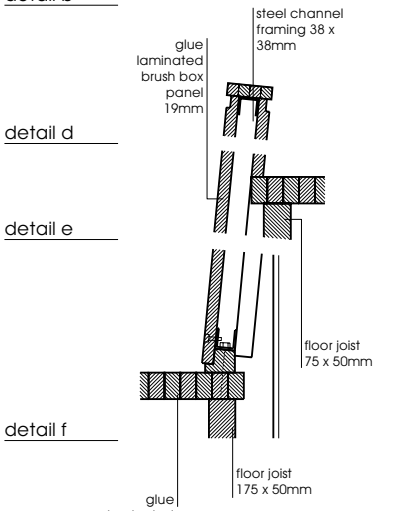
Strategy for Design in Timber

•Timber and Acoustics - Timber has historically been used for acoustic applications for a number of reasons. A timber surface does not just reflect sound, but resonates slightly, giving it a particular quality and colour. A hard surface such as concrete reflects sound with a hard and sharp quality. In the Sydney Opera House, the musicians were happy to have timber used as it was a material they understood, many of their instruments being made from timber. They were accustomed to the quality of sound timber spaces created.

Timber is well suited to the control of excessive echo or **reverberation** off surfaces in performance and public spaces. As in Brand, Denkin & Hay's John XXIII College chapel [07] a common practice is to clad walls or ceilings in lecture halls and performance spaces with spaced timber battens. This surface treatment breaks up the sound, reducing echoes. As a contrast to many of the hard concrete surfaces, sections of the walls in the foyers, the two theatres and other public spaces are lined with panels made up of spaced Brush Box battens over a sound absorbing mat.



detail b



•Quality Control - Quality control has always been an important issue in timber design and construction, especially for interiors. Timber is a natural and therefore variable material. This is what gives its surface life, compared with manufactured products. Too much variation however, especially over large surfaces, can be undesirable. With dark colours, variation in tone may not be particularly noticable but with paler tones, minor variations can present problems.

For this landmark building, the architects for the final stage of the Sydney Opera House set up a specific and rigid quality control system right from where the timber was milled. The White Birch used for the Concert Hall ceiling was graded against control samples three times: when it was cut at the mill, as it was received at the plywood plant and when the laid up sheets were received in Sydney for fabrication. Any veneers differing in tone from the control samples were rejected. To ensure matching grain in adjacent panels, each veneer was tagged as it was cut so that it could be laid out in sequence on the finished ceiling. Similarly, the Brush Box used was colour graded after milling to eliminate overly dark or light coloured strips.

•references

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Wheatland, B, 'Unseen Utzon', Architecture Australia, Nov/Dec 1994, pp 16-17

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•glossary

box beam: a built-up beam with solid timber flanges and plywood or wood-based panel product webs

glue laminated (glulam): laminated timber where laminations are joined with adhesive

reverberation: the persistent echoing of sound within an enclosure after the original source of the sound has stopped, due to repeated reflection between the enclosing surfaces

•on the internet

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