5.12 Timber Engineering & Lamination

a. mechanically laminated arches
b. the Belfast truss
c. specialised girders and systems
d. glue lamination
e. the Burge Brothers building
f. developments in lamination
g. the hyperbolic parabaloid

Engineering design in timber is not central to our concerns here, but it is necessary to make mention of some aspects, and especially of the use of lamination in both the nineteenth and the twentieth centuries. There was a surprisingly early use of horizontally laminated timber arch bridges, especially in South Australia, and the laminated arch was soon to appear in conventional buildings in various colonies.

a. mechanically laminated arches

It is not that the laminated arch was a great novelty in European terms, for arches formed of overlapping curved planks have a long history, though they were bolted or tied together, rather than glued as in the twentieth century. In the sixteenth century Philibert de l'Orme proposed to build roofs carried on arched ribs formed of short planks placed edgewise and bolted together, and this was the system later used in Halle au Blé, Paris, and the Pantheon Bazaar, London.[1]

In 1846 four vertically laminated arches were used to span the riding house at an unidentified English 'baronial estate'. They were in pairs with criss-cross pieces between them like herringbone strutting, and curved lining boards along the soffit and extrados, giving the appearance of a solid and almost square section, They were described as:

> circular ribs placed two and two, each $7\frac{1}{2}$ [191 mm] inches apart, screwed and bolted together, each single rib to be in three thicknesses, the inner one of oak and to consist of twenty-six pieces of $1\frac{3}{4}$ inch [44 mm] deal and ten of $1\frac{1}{2}$ inch [38 mm] oak, each separate piece 1 foot [300 mm] in width and to be as long as the scantling of the timber will allow, the ribs to be wrought and glued together, and at each joint to have two hard nails or $\frac{3}{4}$ inch [19 mm] screws having a good thread; the top and bottom edges of rib cut for linings, the side finished for paint. Cross pieces [spacers], $7\frac{1}{2}$ by $2\frac{1}{2}$ inches [191 x 64 mm] twelve to each pair of ribs, the whole to be bolted together.

Similar ribs were used by Charles Fowler for a sale room in St Paul's Churchyard.[2]

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1 Edward Dobson, *Rudiments of the Art of Building* (London 1849), pp 53-4.
2 C J Richardson, *The Englishman's House from a Cottage to a Mansion* (London 1870), pp 392, 394.

Horizontally laminated timber arches, by contrast, derive from the Continental tradition of building bridges in this way, begun by Wiebeking in Germany near the beginning of the century, using thick planks,[3] then taken up by Navier in his bridge over the Seine at Choisy, complete in 1810,[4] and in his others at Asnières and Argenteuil. But the bending was achieved with difficulty, and in 1811 St-Far of Strasbourg proposed the use of thin planks built up on the flat instead. In 1819 Colonel A R Emy built the roofs of two riding schools using arches using multiple layers of thinner timber,[5] and in 1825 a roof at Marac, near Bayonne, carried on horizontally laminated arches spanning 19.5 metres.[6] In 1828 he published a text on laminated arches, describing more structures and containing proposals for spans of up to a hundred metres.[7] Henri-Charles Emmery's Pont d'Ivry in Paris, completed in 1829, reverted to the use of thick timbers, which he bent under steam before bolting them together,[8] and was made of only four layers. By contrast the Australian bridges generally use about twelve layers, more consistent with Emy's principles.

The first large scale use of lamination in Britain was in John and Benjamin Green's Ouseburn and Willington Dean viaducts of 1838, on the Newcastle and North Shields Railway, five arches spanning 34.8 m each and seven of 36 m.[9] This remained a relatively novel type of construction in British buildings, though it was ultimately used in examples as notable as the Paxton's Crystal Palace, London, of 1850-1, Lewis Cubitt's Kings Cross Station of 1851-2, and Cuthbert Broderick's Leeds Town Hall.[10] It is probably no coincidence that the first Australian examples appear just after the construction of the Crystal Palace.

The first of the local bridges appears to be that over Wallis Creek at Maitland, New South Wales, built in 1851 to the design of Edmund Blacket,[11] and this was followed by the three-arched bridge over South Creek, Windsor, of 1854.[12] In South Australia the idea first appears in an unbuilt design of 1851 for a city bridge at Adelaide, by A

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3 Elton Engineering Books, *Catalogue Number 12* (London 1997), p 25: notes on H C Emmery, *Pont d'Ivry en Bois, &c* (Paris 1832).

4 M Navier, *Projet pour l'Établissement d'une Gare à Choisy* (Paris 1811).

5 Wyatt Papworth [ed], *The Dictionary of Architecture* (6 vols, London, 1853-92), sv Bent Timber, ref Emy, *Traité de l'Art de Charpenterie* (Paris 1837-1841); R S Burn, *The New Guide to Carpentry, General Framing, and Joinery* (Glasgow, no date [c 1870]), pp 54-5 & pl 39.

6 Dobson, *Rudiments of the Art of Building*, pp 54-5. This is illustrated in some detail in plates 1 and 4 of E L Tarbuck [ed], *The Encyclopædia of Practical Carpentry and Joinery, &c* (Leipzig no date [?c 1860]), a work probably accessible to practitioners in Australia.

7 A R Emy, *Description d'un Nouveau Système d'Arcs pour les Grandes Charpentes, exécutée sur un bâtiment de vingt mètres de largeur, à Marac près de Bayonne et sur la Manège de la Caserne de Liboine* (Paris 1828), cited in Charles B Wood, *Rare Architectural Books*(catalogue 100, Cambridge [Massachusetts] 1999), p 54.

8 Elton Engineering Books, notes on Emmery, *Pont d'Ivry en Bois.* Illustrated in Tarbuck, *Practical Carpentry and Joinery*, plate 12 & p 103.

9 John and Benjamin Green, 'On the Timber Viaducts of the Newcastle and North Shields Railway: brought before the British Association, by Messrs John and Benjamin Green, architects and engineers ...' (reprinted from *Transactions of the British Association*, Newcastle 1838), cited, with a reproduction of the Willington Dean viaduct, in Elton Engineering Books, *Catalogue Number 13* (London 1998), pp 22-3.

10 R S Burn, *The New Guide to Carpentry, General Framing and Joinery* (Glasgow, nd [c 1870]), p 54 & pl 36.

11 Morton Herman, *The Blackets* (Sydney 1963), pp 31-2, 47.

12 Lenore Coltheart & Don Fraser [eds], *Landmarks in Public Works* (Sydney 1987), p 50.

H Freeling and W B Hays. It was to have consisted of seven bowstring arches (presumably laminated), each of a clear span of 15.1 metres.[13] The subsequent popularity of this bridge form in South Australia may have been due to the fact that the first which was actually built, a pedestrian bridge over the Torrens, survived when (by 1856) three of the other four bridges over the river had been swept away. While most later South Australian bridges had the arch below the deck, this was of the true bowstring (untrussed) type, with the curve made of deals laminated laterally.[14]

In Melbourne the Studley Park Bridge over the Yarra, built in 1857-8 to the design of James Austin, was of a similar form but with the panels divided by a near-horizontal web, intermediate between the horizontal deck and the supporting arch.[15] This gave a cellular effect, and must have been inspired by the Greens' Ouseburn and Willington Dean viaducts of 1838, which were made up of similar spans, but that the arches were steeper and contained two intermediate webs and part of a third. The footbridge linking Swan Street to Anderson Street, South Yarra, was built in 1860 of laminated timber, but of a more complicated and elegant design, combining an upper arc with a lower one of sharper curvature. The middle third, where the arches came together, was solid, while the haunches were open and cross-braced.[16] Another bridge, which O'Connor surmises was laminated, was opened in 1859 to carry the St Kilda and Windsor Railway Line on three arches across St Kilda Road, Melbourne.[17]

In Western Australia a laminated arch bridge over the Avon River at York was proposed in 1859, but not built.[18] In New South Wales a three span bridge of bowstring trusses with laminated arches was built in 1853 over the South Creek at Windsor, and lasted until 1880;[19] then a very substantial laminated arch railway bridge was put over the Hunter at Singleton in 1869.[20]

There were eleven other timber arch bridges built in South Australia, from that over the Light River at Kapunda, of 1856, to that over the Gawler River at Angle Vale, of 1876. The Kapunda Bridge was advertised for tender in Adelaide in January 1856, and it consisted of twelve laminated deal arches, four in parallel in each of three spans. It was said to have 'a light and pretty appearance ... three arches are bent to a segment of a circle of sawn timber, bolted together, with the ends resting on iron work and tied to the abutments, the girders being latticed.'[21] The Gumeracha Bridge over the Gawler, of 1857, had one of the largest single arch spans, of 30 metres, in four parallel laminated ribs.[22] The specification for the bridge over the Onkaparinga

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13 E & R Jensen, *Colonial Architecture in South Australia* (Netley [SA] 1980), pp 93-4.

14 W B Hays, *Engineering in South Australia* (London 1856), p 26.

15 Illustrated in a watercolour by R S Kelly, 1858, owned by Maunsell & Partners Ltd, reproduced in Christine Downer & Jennifer Phipps, *Victorian Vision: 1834 Onwards* (Melbourne 1985), p 23. See also H H Paynting & Malcolm Grant, *Victoria Illustrated 1834-1984* (Melbourne 1984), p 209.

16 *News Letter of Australasia*, no 46, June 1860, cover: also reproduced in Michael Cannon, *Melbourne after the Gold Rush* (Main Ridge [Victoria] 1993), pp 162-3.

17 Colin O'Connor, *Spanning Two Centuries* (St Lucia [Queensland] 1985), p 100.

18 O'Connor, *Spanning Two Centuries*, p 214.

19 O'Connor, *Spanning Two Centuries*, p 14.

20 O'Connor, *Spanning Two Centuries*, p 4.

21 Jensen, *Colonial Architecture in South Australia*, p 227, quoting the *South Australian Register*, 2 August 1856.

22 Jensen, *Colonial Architecture in South Australia*, p 226.

at Clarendon, of 1858, calls for arched ribs of 24.4 metre span and versed sine of 3.7 metres. They were built up of twelve layers of red deal planks, each 64 mm thick, dressed and bedded in boiling hot pitch, tar and strong brown paper. Each rib was 760 mm deep by 460 mm wide, fastened through with wooden trenails at 1.2 m intervals and bolted with a pair of iron bolts and coupling straps at 1.5 m intervals. The last bridge of this type, that at Angle Vale, survives today.[23]

By contrast with the bridges, most Australian buildings used the more traditional vertically laminated arch, a type much easier to construct, and better suited to shorter spans and tighter curves. In Victoria it appeared in 1858 in the cell block of the Melbourne Gaol, and in the Maldon market house, designed by Arthur Hartley. It was again used in W B Downes's Castlemaine Market of 1861-2. In Western Australia in 1857 James Manning used laminated jarrah arches (one guesses vertically laminated) in the Fremantle Prison Chapel,[24] over a span of 12.3 metres, and he described the structure as:[25]

> a curved tie beam laminated ... sustained by tension and suspending rods, the principal rafters held in position by radiating cleets bolted through, making a very light and strong roof.

In the 1870s Manning used similar laminated jarrah arches in the Perth Town Hall.[26] The Sydney Exhibition Building of 1878-9 had arches laminated in three layers, each two inches [51 mm] thick, formed out of short lengths of timber.[27]

The exceptional Australian building was the Metropolitan Meat Market, Melbourne, in that it used horizontally rather than vertically laminated arches consisting of:

> 12 x 2" [300 x 50 mm] Oregon flitches in longest lengths procurable steamed + bent to true curve, screwed and bolted with $^{3}/_{8}$ths [9.5 mm] American coach bolts and washers 18 ins [450 mm] apart, joints close fitting and broken as directed.[28]

b. the Belfast truss

By the 1870s a form of bowstring girder filled with a diagonal lattice, like that of the Town truss, had become popular for industrial buildings in Britain. The earliest identified reference is an advertisement by McTear & Co of Belfast, in the *Dublin*

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[23] Colin O'Connor, *Spanning Two Centuries* (St Lucia [Queensland] 1985), pp 142-4.

[24] Ingrid van Bremen, ‘The New Architecture of the Gold Boom’ (PhD, University of Western Australia, 1990), p 139. John Weiler, 'Colonial Connection: Royal Engineers and Building Technology Transfer in the Nineteenth Century', *Construction History*, XII (1996), p 7, attributes the Fremantle Prison to Henderson and Wray 'possibly with Manning's assistance'.

[25] J S Kerr, *Design For Convicts* (Sydney 1984), p 167.

[26] Van Bremen, ‘The New Architecture of the Gold Boom', p 139.

[27] Peter Proudfoot, 'Management and Materials: the Genius of John Young', in Peter Proudfoot, Roslyn Maguire & Robert Freestone [eds], *Colonial City Global City: Sydney's International Exhibition 1879* (Sydney 2000), p 139.

[28] G R Johnson, 'Bill of Quantities Metropolitan Meat Market, Bank, Hotel, and Two Shops, &c' (Melbourne 1879, p 9.

Builder of 1866, for a 'durable, cheap and handsome roof for felt', said to be much used for covering mills, factories and farm buildings. The company had been specialists in patent felt and asphalt since 1843, and seems to have come to the truss business from this perspective. They claimed at this time to have staff capable of fabricating the trusses in the vicinity of every large town in Ireland, but the probability is that they licensed a local builder in each location. D Anderson Ltd were building these roofs from 1877 - perhaps in some such capacity - and had outstripped McTear & Co by the 1890s until finally, in 1908, McTears went out of business.[29].

At least as early as 1874 Ellis & Co of Liverpool specialised in this truss, or something very like it, also finished in felt. William Eassie referred to it as a 'bow and girder roof', and his illustration, though small, shows an open lattice in which the diagonals intersect only at their mid-point. The diagonals appear not to be strictly parallel but to fan out slightly, on what will be described below as the McTear principle, or something like it. Ellises recommended that the curve rise to a height about one tenth the span, and that the sizes be (in imperial dimensions):

span feet	bow inches	string inches	web feet & inches
20	2 x 1	2 1/2 x 1	4.0 x 5 x 1
30	2 x 1	3 3/4 x 1	6.0 x 7 1/2 x 1
40	2 x 1 1/4	5 x 1 1/4	8.0 x 10 x 1
50	2 1/4 x 1 1/4	6 1/2 x 1 1/2	10.0 x 12 1/2 x 1
60	2 1/2 x 1 1/2	7 1/2 x 1 1/2	12.0 x 15 x 1

The top chord or string was of two pieces of spruce in parallel, and the bottom of two pieces either of spruce or of pine. A solid web of half inch [13 mm] timber was fitted between the strings for about 20% of the span at either end. Purlins were always 3 x 2 inches [75 x 50 mm], usually made up of two pieces of 3 x 1 [75 x 25 mm] nailed together.[30]

There are a number of subtle variations in the design of Belfast and cognate trusses, and the infill was not usually a uniform lattice. Generally the lattice braces met the top chord at uniform intervals along its curvature, corresponding with the spacing of the purlins above, which meant that the spacing was not uniform as projected onto a horizontal plane, or as seen in elevation. Moreover, in McTear's trusses (according to Gould, Jennings and Montgomery) the lattice members were not parallel with each other, but radiated from two points, vertically below the points of support at the ends of the truss, typically a distance downward equivalent to about a third of the span. Anderson's version was different, for although the braces presented a rather similar radiating appearance, this was generated by the fact that they all met the top chord at an angle of 45^{o}. A later form, sometimes called a 'modern Belfast truss', had the lattice bracing uniformly at 45^{o} to the horizontal, but still spaced evenly along the curvature of the top chord. If this final idiosyncrasy is abandoned, and the spacing is

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29 M H Gould, A Jennings, & R Montgomery, 'The Belfast Roof Truss', *Structural Engineer*, LXX, 7 (7 June 1992), p 128, quoting the *Dublin Builder*, 1 October 1866.

30 P B Eassie, *Wood and Its Uses* (Gloucester 1874), pp 34-5. See also the illustration on p 153.

made uniform, Gould, Jennings and Montgomery say that it can no longer be called a Belfast truss, but is a conventional bowstring truss.[31] This seems an unduly rigorous use of the term 'Belfast truss', as well as a misuse of the term 'bowstring truss'. In the 1930s, as we shall see, the term 'Belfast roofing' was used to refer to roofing carried on segmental trusses filled with uniform latticework like a trellis.

D Anderson & Son of Belfast specialised in these trusses (presumably in the variant form discussed above), and also made roofing felt. At the Melbourne Centennial Exhibition they displayed a model of a 'wooden lattice girder felted roof'.[32] Around the turn of the century they advertised their trusses as 'More durable than iron. Cheaper for all spans up to 100 Feet' [30 m].[33] The curved top chord was made either of boards bent to follow the curve, or of boards on edge cut to create the curved profile. After the turn of the century at least three other Belfast companies made the trusses: the Northern Counties Asphalte Co; the Baltic Firewood Co (later the Baltic Timber Co); and the Rex Roofing Co, the last two being established in about 1910.[34] According to T Kenneth-Duncan the Belfast shipbuilders Harland & Woolf had a large store hangar roofed with the trusses, though it is not known whether it survives.[35]

The last major use of the trusses was in 'general purpose hangars' built at airfields during World War I, including some in Ireland which were used by the United States Naval Airforce.[36] Hangars at Croydon Airport, perhaps of this phase, survived until 1980, and a former RAF hangar south of Lincoln, with a number of superb trusses, still exists.[37] In 1936 T Partridge & Co Ltd of Walsall advertised 'Belfast Roofing' using their patented 'Elite' leaded roof glazing. They illustrated a garage in Birmingham with a 120 foot [36 m] span, using segmental girders, each filled with latticework.[38] Until at least the 1950s Imperial Chemical Industries accommodated the manufacture of black powder, samsonite and amonite in huts roofed with Belfast trusses, in which the struts were disposed on the McTear principle, but radiating from a point equivalent to a half rather than a third of the span below the point of support.[39] Belfast trusses continued to be used elsewhere in a more sporadic way, and were still being manufactured in Lagos in the 1950s.[40] They are also illustrated in a prominent British text, Boughton's *New Carpenter and Joiner*, undated but apparently post-war.[41]

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31 Gould, Jennings, & Montgomery, 'The Belfast Roof Truss', pp 127-8.
32 Centennial International Exhibition 1888-1889, *Official Record* (Melbourne 1890), p 459.
33 J E Sears [ed], *The Contractors,' Merchants,' and Estate Managers' Compendium and Catalogue* (15th ed, London 1901), p 72D.
34 Gould, Jennings, & Montgomery, 'The Belfast Roof Truss', p 128.
35 Information from T Kenneth-Duncan, 2000.
36 Gould, Jennings, & Montgomery, 'The Belfast Roof Truss', p 129.
37 Information from T Kenneth-Duncan, 2000, referring also to examples at ?Harlow Airport, the fate of which is unclear.
38 J E Sears & J E Sears, *The Architects' Compendium and Annual Catalogue*(15th ed, London 1901), p 72D
39 Information from T Kenneth-Duncan, 2000, referring also to examples at ?Harlow Airport, the fate of which is unclear.
40 Gould, Jennings, & Montgomery, 'The Belfast Roof Truss', p 129.
41 R V Boughton, *The New Carpenter and Joiner* (3 vols, London, no date [?c 1947]), II, pp 73-90.

Both the Belfast truss and the bowstring truss proper were in use in the United States early in the twentieth century, and were constructed with a top chord of planks laminated in either the horizontal or the vertical direction. The lattice type was referred to as being patented.[42] McKeown Brothers of Chicago were the most prominent manufacturers of the arched lattice truss and of the bowstring truss in which the diagonals were placed zig-zag, without intersecting.[43] Two versions of the truss are described in Bloomfield's *Australian Carpenter & Joiner*, a text which is undated but of about 1950. One is the McTear type as modified by ICI, with the points of radiation a half span below the support. The other is an apparently novel version, in which the lattice is generated by the same centre as the curvature of the top chord itself. Radii are drawn from this centre to points equally spaced along the top chord. The points where these radii intersect the bottom chord become the lower points of the lattice, which is a simple criss-cross form with an intersection only at the mid-height of each piece.[44]

There are some actual examples of the Belfast truss in Australia, but it is by no means certain when it appeared. Some are found spanning the Geelong West Town Hall of 1922-4 by the architect I G Anderson.[45] Others at the Wunderlich plant, 656 Mitcham Road, Vermont, Victoria, are believed to have been moved from the previous Wunderlich factory in Brunswick, no earlier than 1925 and probably much more recently.[46] They may well date from about 1950, for they are almost exactly the McTear type as illustrated by Bloomfield, with the purlins clamped between the ends of the diagonals.[47]

c. specialised girders & systems

Parallel chorded girders in timber are uncommon in Australia, probably because of the relatively intractable and unstable nature of the woods available. Most railway bridges were of iron or steel, and there was rather limited demand for girders for other purposes. However, Howe trusses spanning nearly five metres carry the upper floor of the stable at 'Boisdale', Maffra, Victoria, of 1890. The top and bottom chords and the diagonals are all of timber, whilst the verticals are wrought iron bolts extending through the full depth of the girder.

An extraordinary truss appeared in a building of 1922-3, the Joseph Lyddy Polish Manufacturing Co factory in Fitzroy, Melbourne. The building is attributed to the

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42 F T Hodgson et al, *Architecture, Carpentry, and Building* (5 vols, Chicago 1925-6 [1910]), I, pp 264-5.

43 Hansom, *Wood Construction,* p 488; W C Huntington, *Building Construction* (New York 1929), pp 241, 244 .

44 F C Bloomfield, *The Australian Carpenter & Joiner* (3 vols, Melbourne, no date [c 1950]), II, pp 622-4.

45 Gladys Seaton, *The Ashby Story - A History of Geelong West* (Geelong West [Victoria] 1978), pp 186, 214, kindly provided by Peter Alsop.

46 Information from David Beauchamp, 1996.

47 Photograph supplied by David Beauchamp, 1996.

architect Eric Nicholls,[48] but the truss is more consistent with the innovative approach of Nicholls's mentor, Walter Burley Griffin, and in fact has a decorative quality more suggestive of a glazing pattern than of a structural element. It is imperfectly triangulated. Vertical members which would most logically be in compression are steel rods, whereas diagonals are in solid timber. The bottom chord, which should be in tension, is of timber, and even doubled in thickness across the central panel. It seems to have been conceived in an intuitive way, perhaps more as a split beam than as a truss. However its origin is more traditional than might be supposed. P B Eassie in 1874 illustrated what would be a simple king post truss except that the internal members are reversed - the king post is replaced by a rod, as if in tension, and the diagonals were of solid timber as if they were taking compression. Moreover the diagonals do not run quite to the centre of the lower chord but are spaced apart, and between them the bottom chord is reinforced with an extra piece of timber, just as in the Lyddy truss, as if it is to take additional compression.[49] In fact the Lyddy truss is in essence the same except that is extended by two panels.

Generally, scientific attention to engineering questions was confined to strength testing until World War II, but in the 1930s there was a revival of engineering interest which has yet to be explained. It was in 1939 that the Council for Scientific and Industrial Research published Langlands & Thomas's *Handbook of Structural Timber Design*. In its initial form the book was overwhelmingly concerned with the use of improved strength data to create tables from which joists, beams and columns could be selected for any given load and condition, though it dealt also with split ring and shear plate connectors, and other forms of jointing. The foreword referred to the need for complete information in a time of national emergency, and in the years that followed there were indeed some innovative timber structures, such as large span aircraft hangars, built in Australia.[50]

Andrew Ward has attempted to investigate the wartime aircraft hangars, but with fairly inconclusive results. He illustrates that at Archerfield in Queensland,[51] which was of trussed arch construction, and so far as we know the hangars and other large span timber buildings of the war period did not rely upon lamination. In 1954 three aircraft hangers were built at Avalon Airfield, Victoria, using two pin timber truss arches of triangular section, spanning eighty-four metres. But these were not developed out of Australian wartime experience, for they were imported, and were erected by the Italian contractors.[52] Ward reproduces the advertisement in *Ramsay's Catalogue,* 1940,[53] of the Lamella Roof Company of Sydney which (according to Ward) had an arrangement with Horseley Bridge and Thomas Piggott Pty Ltd of Staffordshire, for the construction of Lamella Roofs in Australia, based on the lamella principle invented in Germany in 1923. But none has been identified in Australia.

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48 For the date and the attribution to Nicholls see D L Johnson, *The Architecture of Walter Burley Griffin* (South Melbourne 1977), p 156.

49 Eassie, *Wood and Its Uses,* p 31, fig 32. See also pp 80-81, figs 117-8.

50 Ian Langlands & A J Thomas, *Handbook of Structural Timber Design* (1st ed, Melbourne 1939).

51 A C Ward, *Proposed Australian Heritage Commission Listing of Improdex Factory at 135-137 Racecourse Road, Flemington: Comparative Examples* (Burwood [Victoria] October 1992), p 4 & following illustrations.

52 *Cross-Section*, 1 July 1954, p 2.

53 Ward, *Improdex Factory,* p 2 & appendix.

In 1941 a second edition of Langlands & Thomas's *Handbook* expanded the material on connections, and gave methods of designing spaced columns.[54] A supplement, *Large Timber Structures,* appeared in 1942, including more detail on timber connectors, and a generalised discussion of glue laminated arches.[55] This material, in a slightly recast form, was incorporated into the third edition of the *Handbook* in 1949.[56] This interest in connectors was simply a reflection of recent overseas products such as the Bulldog and Teco connectors, for the idea was not in itself novel. A British patent of 1893 had proposed something of the sort for 'belt and band fasteners'. A disc or washer punched with holes and projections was placed between two belts, and a bolt was tightened through the centre, so that the disc gripped, thus extending the area of stress from the bolt to the disc.[57] Rather similar washers were developed in some kinds of locking bolts, and the first application to timber in 1908 was referred to as a locking bolt, and indeed was not a true connector as the disc gripped only on one side.[58] The same principle was used in a system which was apparently developed by Siemens-Bauunion in Germany, and patented in Britain in 1927. The joints in a truss were made by linking straps which were attached to the face of each timber using 'claw discs' on their underside, which bit into the timber.[59] The first true timber connector was possibly that invented by G T Theodorsen. It received a British patent in 1920, but this was pursuant to a convention, presumably meaning British recognition of a pre-existing foreign patent. The illustration is problematic, but it appears that a square plate were used, slits were cut in at right angles along the periphery, and the sections between the slits turned alternately up and downwards to act as teeth. A bolt passed through the centre in the usual way.[60]

The Bulldog connector was a circular, square or rectangular steel plate with a central hole fore a bolt, and the edges turned out at right angles to create teeth, very much as in Theodorsen's design. The Teco was a steel ring about 1/4 inch thick and 3/4 inch deep [6 x 19 mm], thicker at the equator than at the edges, and split at one point on the circumference such that one edge was a squarish tooth and the other was matching shoulders.[61] By 1941 the Teco was available in Australia. The Bulldog was perhaps not available, but there was a toothed ring which used a similar principle, and there were also shear plates designed to fit into pre-cut circular grooves like the split ring, but with a tympanum or web containing a bolt hole at the centre.[62]

The idea of a disc or washer with teeth biting into the timber could be extended to rectangles and other shapes, and these might be bent to connect members meeting at

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54 Ian Langlands & A J Thomas, *Handbook of Structural Timber Design* (2nd ed, Melbourne 1941).

55 Ian Langlands, *Handbook of Structural Timber Design, Supplement No 1, Large Timber Structures* (Melbourne 1942).

56 Ian Langlands & A J Thomas, *Handbook of Structural Timber Design* (3rd ed, Melbourne '1948' [1949]).

57 Great Britain, patent no 987 to K Simpson & B G Simpson, 17 January 1893.

58 Great Britain, patent no 9,174 to P Phipps, 28 April 1908.

59 Great Britain, patent no 292,817 to L Mellersh-Jackson (communication of Siemens-Bauunion Ges Kommanditges), 1 October 1927; also no 303,397 of 1 October 1927.

60 Great Britain, patent no 159,490 to G T Theodorsen, 26 February 1920 [convention date].

61 Francis Lockyer, 'Timber as a Building Material', in John Madge [ed], *Tomorrow's Houses: New Building Methods Structures and Materials* (London 1946), pp 93, 108.

62 Langlands & Thomas, *Handbook of Structural Timber Design* (1941), pp 37, 54.

an angle. A British patent of 1922 for 'spiked plates and strips' illustrated flat plates and ones bent at right angles, and the latter seems to have been as way of joining surfaces at right angles, such as the inner faces of a timber crate, but not for joining structural members.[63] Soon afterwards a more structural spiked plate was patented, designed to connect timber shelves to a vertical surface, and therefore again being bent at right angles.[64] But of course other angles were possible, and a single plate might contain more than one bend. In 1953 the Timber Engineering Co of Sydney began marketing 'Trip-L-Grip' framing anchors, which were steel connector plates with holes for nailing, and with planes angled to each other in such ways and shapes as to suit most connections in normal framing. They were claimed to eliminate much work by carpenters and to make stronger joints.[65]

d. glue lamination

Soon the main area of innovative design was again that of lamination, but now based upon the use of glue, as developed by Otto Hetzer of Weimar, Germany. Glue laminated construction can be seen as an extension of the concept of plywood. Glue lamination on Hetzer's system is said to have been used at the Reichstag, Berlin, in 1890, and glue laminated arches are reported to have been used in 1897 at Basel, Switzerland. Whatever the truth of this, the effective inventor was Hetzer, who obtained the first patent for glue laminated wood members in 1906.[66] The system was known in many parts of Europe as the 'Hetzer System'. It achieved considerable popularity in Germany before World War I, but wartime shortages of casein glue, and the development of various mechanical fasteners, saw it largely superseded by jointed and framed systems which became cheaper. Meanwhile it was introduced to Switzerland in about 1909 and became very common there, largely because large timber suitable for principal members was scarce. It was introduced to Denmark by a Copenhagen builder in about 1913, and continued in use until about 1929, but by that time was becoming uneconomical in relation to competing methods. In 1918 a plant was built in southern Norway, and began operation under the original Hetzer patents, but a few years later it was discontinued for various reasons, including the burning of the factory building.

A plant which began operations under the Hetzer patents in 1919, on the bank of the Götha Canal at Töreboda, Sweden, and has continued ever since, introduced and patented local improvements, creating what became known in its own right as the Töreboda System.[67] The Hetzer system was also used to some extent in Austria,

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63 Great Britain, patent no 273,345 to C W Eddels, 23 February 1926.

64 Great Britain, patent no 279,187 to H E Petche, 4 Augu 1926.

65 *Cross-Section,* no 15 (1 January 1954), p 2.

66 Andrew McNall & D E Fischetti, 'Glued Laminated Timber', in T C Jester [ed], *Twentieth-Century Building Materials* (Washington [DC] 1995), p 13. Rhude refers to the Hetzer construction at the Reichstag, but his glue lamination patents date from long after this time, and Rhude says that it was the German patent of 1906 which signalled 'the true beginnings of timber arch construction'. A J Rhude, 'Structural Glued Laminated Timber: History and Early Development in the United States', *APT Bulletin,* XXIX, 1 (1998), p 11.

67 T R C Wilson, *The Glued Laminated Wooden Arch* [Bulletin 691 of the United States Department of Agriculture] (Washington 1939), p 87. Rhude, p 11, identifies G N Brekke of Norway as the man who obtained patent rights for Norway and Sweden, established the plant at

Czechoslovakia, France and Italy.[68] Glue laminated construction, presumably on the Hetzer system, had been introduced to the United States by the 1920s, where it seems to have been used for the top chords of bowstring trusses, but not for independent laminated units. The main types of truss were the McKeown Bowstring Truss, the McKeown Lattice Truss (resembling the Belfast truss), and the Summerbell Truss, and they were used for railway sheds and aircraft hangars in spans of up to 150 feet [45 m].[69]

The German Max Hanisch, who was a former associate of Hetzer, migrated to the United States in 1923 and is said to have introduced glue laminated construction to that country eleven years later in his school gymnasium at Peshtigo, Washington. This is inconsistent with the evidence of the laminated truss chords referred to above. It is true that those were nailed as well as glued, but the arches at Peshtigo were similar in this respect. What happened is that the Wisconsin Industrial Commission would not approve this experimental construction, even after Hanisch enlisted the support of the Department of Agriculture's Forest Products Laboratory at Madison. Consequently unnecessary mechanical connections were incorporated in addition to the glue.[70]

In 1935 independent laminated units relying upon glue alone were used for the service building of the Forest Products Laboratory itself, in the form of 'boomerang' arches spanning fourteen metres.[71] Over the next few years other companies, including Summerbell Roof Structures, makers of the trusses, were licensed to use Hanisch's patents. Not amongst these, apparently, was the Timber Engineering Company [Teco], which became a substantial laminator, but perhaps used methods independent of Hanisch. This company seemed to specialise in the boomerang arch, a term used to describe a section which runs vertically up the wall and turns through an angle to run up the slope of the roof, usually used in pairs with a hinge at the apex and at both feet, somewhat reminiscent of the traditional cruck frame of Europe. The company which built these units - unnamed, but probably the Timber Engineering Company - went on to laminate members for nearly a hundred other buildings in America in the years 1935-9.[72]

In 1939 the United States Department of Agriculture published a bulletin, *The Glued Laminated Wooden Arch,*[73] incorporating design stresses and specifications developed by the Forest Products Laboratory. It had its effect in Australia very quickly for, as we have seen, glued laminated timber arches were discussed for the first time in the 1942 supplement to Langlands & Thomas's *Handbook of Structural*

Mysen, Norway, and helped to establish that at Töreboda (which now operates as part of the Norwegian laminator Moelven Limtre A/S).

68 Wilson, *The Glued Laminated Wooden Arch,* pp 4-5.

69 D F Holtman, *Wood Construction* (New York 1929), pp 484, 488-9, 491. Rhude, p 11, refers to Summerbell 'nail laminated wood trusses', but Holtman, p 484, mentions the top chords of the McKeown trusses as built up of '3-in. boards, glued and nailed together.'

70 Rhude, 'Structural Glued Laminated Timber', pp 12-13.

71 Wilson, *The Glued Laminated Wooden Arch,* pp 4-5. See also Lockyer, 'Timber as a Building Material', p 101.

72 Wilson, *The Glued Laminated Wooden Arch,* p 5.

73 Wilson, *The Glued Laminated Wooden Arch,* p 135; *Timber Design and Construction Handbook* (New York 1956), p 562.

Timber Design.[74] In 1954 Furness Limited, of South Australia, were advertising glue laminated beams in sizes from 4 x 2 to 16 x 7 inches [100 x 50 to 400 x 74 mm] which used urea glue (as did their other products).[75]

The Langlands and Thomas supplement made reference to the American bulletin and was to a large extent derived from it. It is notable, however, that it speaks of butt jointing as being usual in lamination in Australia, as if practice was already well-developed by 1942, but if so this was probably in structures for war purposes, about which little is known. Lamination, like other innovative ways of achieving large spans in timber, was encouraged by the wartime demand for aircraft hangars and other large structures, active promotion by timber dealers in America, and wartime and post-war shortages of steel and other metals. These factors gave rise to a spurt of interest in innovative timber structures for large spans, which inevitably had an effect in Australia in due course. The American bulletin would have provided the necessary data for Australian designers (once adjusted for the stresses of local timbers), but it illustrates no building sufficiently similar to be regarded as the model for the first two glue-laminated arch structures in Australia.

In 1943 the West Coast Lumbermen's Association, of Seattle, Washington, published a promotional booklet in which were illustrated a number of arched roofs, carried principally on 'Teco' and 'Summerbell' bowstring trusses.[76] Technical drawings of trusses are included, and these date mostly from about 1937-9, with or without subsequent revision. The Summerbell trusses appear, from the photographs in the WCLA booklet, to have horizontally laminated top chords. The Teco (Timber Engineering Company) trusses are shown in the drawings[77] which provide for spans from 50 to 120 feet [15 to 45 m]. In each case the top chord is a double member, so that the web members can be joined within the intervening space, and in the largest truss it consists of two parallel arcs, each 16 by 4 inches [400 x 100 mm] in section. Each of these arcs is itself horizontally laminated, in this instance of eight pieces of 4 x 2 [100 x 50 mm], glued with casein glue, nailed or spiked, and reinforced at panel points with bolts. This is fabrication technology very relevant to what was to follow in Australia, but here it has been applied only within trusses, and the drawings show nothing approaching the character of an independent arch.

The most probable source of inspiration for the Australian laminated arch structures of the World War II and immediate post-war period is H J Hansen's *Modern Timber Design,* also of 1943.[78] Hansen illustrates bowstring trusses, including one by McKeown Bros,[79] as well as structures using true laminated arches. One of the latter is a building framed in twelve giant segmental arches rising from ground level, just as was to be done in the first modern laminated arch building in Sydney, and soon after at Flemington in Melbourne, but spanning as much as 45.5 metres.[80] The building is

74 Ian Langlands, *Handbook of Structural Timber Design. Supplement No. 1. Large Timber Structures* (Melbourne 1942).

75 F W Ware & W L Richardson [eds], *Ramsay's Architectural and Engineering Catalogue* (Melbourne 1954), §21/2.

76 *Timber Connectored Roof Structures of Douglas Fir* (Seattle [Washington] no date [1943]).

77 *Timber Connectored Roof Structures,* pp 32-4.

78 H J Hansen, *Modern Timber Design* (1944 [1943]).

79 Hansen, *Modern Timber Design,* p 84.

80 Hansen, *Modern Timber Design,* p 135.

not identified, but the fabricator of the arches is named as Unit Structures Inc of Peshtigo, Wisconsin (that is, Hanisch's company). The same company had fabricated giant arches for US Navy drill halls, and one of these is illustrated, along with smaller laminated members made by Timber Structures Inc and Rilco.[81] Apart from sources such as Hansen, however, Australian designers could well have been inspired by examples published in contemporary journals, or by contact with actual examples, especially during war service. Some other examples which might have been known in such ways are illustrated in textbooks published later,[82] but as the textbooks rarely date them it is hard to know which ones are relevant.

The introduction of the laminated arch to Australia, in what is referred to as the 'E.T.C. Building', was sponsored by two officers of the Department of the Interior in Sydney, Tate and Phillips, said to be 'Chief Architects and Engineers'.[83] What the E.T.C. Building was has not been definitively established, but Tate and Phillips appear to have prepared the model for the Alan Tunner Building in Alexandria, Sydney, begun in 1942. Tunner was a dyer and finisher, apparently involved in the war effort, and the building put up for him was thirty-six metres long by thirty wide, spanned by laminated arches in two parts pinned at the centre (a three pin system). It was demolished in about 1990.[84] These first arches were made by the well-known plywood manufacturer Ralph Symonds, probably early in 1943, for at the beginning of March a twelve foot [3.6 m] a section of one was tested at Sydney University. This was a coachwood arch of twenty-nine laminations, measuring 1 ft 11$^5/_8$ ins x 4 ins [600 x 102 mm], exactly as at Flemington (see below), and was tested over a ten foot [3 m] span: it failed first by crushing at the central support; secondly by a tension split at the centre of the span, and crushing and splitting on the compression side; and finally by horizontal shearing along the timber in a number of places, but none of them on the glue lines].[85]

The timber, according to Symonds, was dried and accurately machined to exact thickness prior to gluing, and

> After the glue is prepared it is mechanically applied and placed under pressure by the use of this Company’s patents which makes possible a time lag not exceeding 45 minutes. Our system of using compressed air enables the required pressure of 90 lbs per sq. inch to be applied and maintained

81 Hansen, *Modern Timber Design*, pp 140, 139, 137.

82 For example, W C Stevens & N Turner, *Solid and Laminated Wood Bending* (London 1948) [not yet sighted]; and the Timber Engineering Design Company's *Timber Design and Construction Handbook* (New York 1956), pp 193-7.

83 Ralph Symonds, Managing Director, Ralph Symonds Pty Ltd, Rosebery NSW, to H Burge Bros, Carlton, 6 June 1945, MCC building application file no 23118.

84 Ken Wyatt, 'Early Glue-Laminated Arches in Australia; the Buildings of Ralph Symonds' [typescript, edited version of a talk given to the Institution of Engineers, Sydney, 17 October 2000] (Sydney 2000), p [2], referring to a report by Peter Tzavaras, architecture student, of 1986, now lodged at the State Library of New South Wales.

85 University of Sydney P. N. Russell School of Engineering. W. H. Warren Laboratories. Transverse Test on Laminated Timber Beam for Messrs Ralph Symonds Pty. Ltd. Laminated Arch Division, Holland Street, Alexandria. Date of Test March 3rd, 1943. Date of Certificate March 12th, 1943, MCC building application file no 23118.

> simultaneously over the whole area of the arch and such pressing is done in one operation.[86]

Symonds's patent application for his 'purlin' or lateral bracing system appears to date from 1944.

Ken Wyatt has reported a related structure, the B S P Soaps (later Galmac Laboratories) Building, 75 O'Riordan Street, Alexandria, but so far it has not been possible to trace the existence of this building with any certainty to a date earlier than 1949. It uses Ralph Symonds's patent purlins, which shows that he was involved, and shows other close similarities to the Burge Brothers building, discussed below. The span is a little larger; the cross-section of the arches the same or very close to it, 600 x 100 mm; the spacing of twenty feet [6 m] is the same as proposed for Burge Bros in 1945 (though not originally). The elevation has a similar Dudokian brick character, and though it is more functional, with the upper part of the arched elevation clad in simple sheeting, the profile is very similar, and rises to a curved roof monitor.[87]

Previous methods had involved progressive cramping of the laminated arch in four or five operations, taking several days, but during the war Symonds had developed and patented a method, using thousands of 'metal hangers', together with air pressure, to complete the whole operation in forty-five minutes. The radius of curvature was never less than eighty times the thickness of the laminae, and the number of laminations in an arch never less than twenty-four. The engineer Malcolm S Stanley, who had an association with Symonds, credited him with pioneering ground-to-ground arch ribs, whereas he himself had developed flat arch construction from pier to pier.[88]

e. the Burge Brothers building

On 16 October 1943 H L Burge of H Burge Bros, bedroom furniture manufacturers of 120 Bouverie Street, Carlton, sought consent in principle from the Melbourne City Council for a building on a site in Flemington. They were yet to obtain a permit from the Department of War Organisation and Industry. It appears that the factory was to make waterproof panels, printers blocks, laminated beams, arches and columns, all of which were urgently needed for defence purposes by a number of government departments. Given that Symonds in due course supplied the arches for the Burge building, below, it may be that the whole Burge Bros proposal to begin manufacturing laminated products was predicated on some deal or agency for technology from Symonds. The site was in 'the flooded area of the Moonee Ponds Creek' but the floor level would be kept above the highest flood level. The building was to be of wood, and would be 'insulated' from both street boundaries and from

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86 Ralph Symonds, Managing Director, Ralph Symonds Pty Ltd, Rosebery NSW, to H Burge Bros, Carlton, 6 June 1945, MCC building application file no 23118.

87 Ken Wyatt, 'A Note on Early Ralph Symonds Buildings' (typescript report, Sydney 1999), passim..

88 M J Stanley, 'Glued Laminated Timber Constructions', in Phillip Mayes [ed], *The Australian Architects, Builders and Contractors Price Book and Guide* (11th ed, Glebe [New South Wales] 1951), pp 154-5.

other buildings, but not from the east boundary abutting the Moonee Ponds Creek Reserve.[89]

The drawing submitted by Burge was by C T Gilbertson, and shows the insulation or setback from the streets of eight feet [2.4 m]. It also shows the arches, not identified as laminated but very much of the ultimate form, including the pin joint at the crown. There are seven of these arches spanning 103 feet [31 m], and spaced at 14 ft 6 in [4.35 m]. The overwhelming probability is that the idea of the arches came not from Gilbertson but from Burge Brothers themselves, because of their interest in lamination. They in turn probably derived it from Ralph Symonds, who had manufactured the first such arches in Australia for the Department of the Interior, and who may well have been their mentor in lamination generally. The concept was probably based upon the sample arches referred to above, for there is no reason to suppose that any building of this construction yet existed in Australia.

Construction was delayed until 1945 when a new application was made to the Melbourne City Council, with a new set of four working drawings by Gilbertson. The construction was based upon Ralph Symonds plywood laminated arches, the dimensions of which are given as 24 x 4 inches [600 x 100 mm] in section, spanning nearly 99 feet [30 m]. By now, it appears, a structure of this sort - the E T C Building - already existed in Sydney. The engineering calculations for loading in the arches were undertaken by Malcolm J Stanley, chartered engineer, Sydney, presumably at the behest of Symonds. The specification provides as follows:

> LAMINATED ARCHES
> These are to be provided by the proprietor in half sections complete with fish plate bolts 3 x 1/8 purlin bracing, base plate, apex shoes etc.; the contractor to erect laminated arches at 20'0" centres all in accordance with the accompanying details. Provide 5" x 3" oregon top purlins, 4" x 3" oregon bottom purlins, 3" x 3" oregon queen posts at 4'0" centres as shown. Provide 2 x 1/8 flat iron strap diagonal bracing fixed between arches in four purlin bays. Straps to be secured on top of purlins to fish plate bolts. Provide 2" x 1/8" continuous flat iron strap fixed to underside of 4" x 3" bottom purlins at 20'0" centres - straps secured to purlin brace bolts at queen post line.

The Ministry of Post War Reconstruction issued its consent on 23 April 1945, and on 30 April an application was made to the Melbourne City Council for a building permit. The building now had brick perimeter walls and was built to the street frontage because, as Burge wrote on 15 June, 'It is our earnest desire to work in harmony with your building regulations'. The arches were now shown spanning 98 ft 11 ins [29.7 m], which was probably predetermined, for they were supplied by Symonds out of a batch which had been made for a building in Sydney (the ETC Building).[90] They were to be spaced 20 feet [6 m] apart, but this was not acceptable to the Council, which checked the design on the basis that stresses must not exceed those of standard grade timber. A note on the MCC file of 12 June, initialled HGB,

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89 H L Burge of H Burge Bros, to the Building Surveyor, Melbourne, 16 October 1943, MCC building application file no 23118.

90 Symonds to Burge Bros, 6 June 1945, MCC building application file no 23118.

indicates that the arches are to be reduced to a span of 96 feet [28.8 m], and the height of the building from the floor to the underside of the ribs to 27 feet [8.1 m]. Furthermore the arches would need to be spaced at 18 foot [5.4 m] centres. Burge wrote that he would abide by this if necessary, but preferred the original spacing.[91]

On 6 June Ralph Symonds himself wrote to Burge Bros referring to 'the arches forwarded to you', which were made of New South Wales coachwood, and glued with Nightingale water resistant glue, as used in aircraft construction.[92] On the 14th he wrote to stress that the materials used were of the first quality, and that both the materials and the workmanship were fully guaranteed.[93] This was apparently designed to persuade the Council that the timber should be regarded as select rather than standard grade.

The approval process was assisted by the Council for Scientific and Industrial Research (predecessor of the CSIRO). On 8 June S F Rust, officer in charge of the veneering and gluing section of the Building Material Research laboratories, wrote to Burge to report on tests on glue strength of scented satinwood (or coachwood) using 'Grasp No. 8 casein glue', which had withstood stresses about ten times the level permitted in the timber itself. Grasp No. 8 was said to be 'an approved cement for the manufacture of aircraft. It is very water resistant and providing the joints are not constantly wet, glue deterioration should not occur.' On 9 June Stanley A Clarke, Chief of the Division of Forest Products, wrote to the Melbourne Building Surveyor enclosing tentative working stresses for scented satinwood or coachwood,[94] and on 12 June he sent revised figures, which carried a note to the effect that in laminated construction the stresses could be increased 50%, as provided in the supplement to the *Handbook of Structural Timber Design.*[95] This persuaded the Council that the structural design was sound. Two sheets of amended drawings were submitted in August, in which the final facade design as resolved and minor changes were made, but the arch spacing remained at twenty feet, and this was approved on 7 August.[96]

Ward has established that the man who did the drawings was Cyril T Gilbertson, an estimator with R & E Seccull, master builders, and a personal friend of Dick Burge, the client. Gilbertson died probably late in 1988. He was, according to his wife, 'rather innovative', but she knew nothing of this building or of any other work which

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91 H L Burge of H Burge Bros, to the City Engineer, Melbourne, 15 June 1945, MCC building application file no 23118.

92 Ralph Symonds, Managing Director, Ralph Symonds Pty Ltd, Rosebery NSW, to H Burge Bros, Carlton, 6 June 1945, MCC building application file no 23118.

93 Ralph Symonds, Managing Director, Ralph Symonds Pty Ltd, Rosebery NSW, to the Chief Engineer, Melbourne City Council, 14 June 1945, MCC building application file no 23118.

94 Stanley A Clarke, Chief of Division of Forest Products, CSIR, to the Building Engineer, Melbourne, 9 June 1993, MCC building application file no 23118.

95 Stanley A Clarke, Chief of Division of Forest Products, CSIR, to the Building Engineer, Melbourne, 12 June 1993, MCC building application file no 23118. For the *Handbook of Structural Timber Design* see below.

96 The letter of approval of 7 August refers 'the plan and specification submitted to this office as now amended', but the two sheets of amended drawings on file, one inscribed ‘Final Amended Plan’, are stamped 11 August.

he might have designed using laminated construction.[97] The probability of a building estimator designing, out of the blue, an innovative structure of this sort seems slight, but it is possible that his drawing in 1943 was a private arrangement with Burge rather than a task undertaken for Secculls, for there is nothing about it, or about Burge's letter to the council, to suggest any Seccull involvement. There is one engineering drawing by Charles Ruwolt Pty Ltd which is dated March 1943 and which mentions Secculls, but this seems to be an error or a deliberate backdating for permit purposes, for March seems to early in relation to Burge’s October application, the drawing number appears to be not long before that of another Ruwolt drawing of 1945, and, most tellingly, the plan is on a twenty foot module as in the 1945 scheme.

It seems likely that the concept emanated from Ralph Symonds Pty Ltd and their consultant engineer, M J Stanley, and/or that the form and dimensions were copied from some other example, probably an overseas one which had been published. Even the façade, which is of some architectural interest, may well have had some input from an architect or some other designer more experienced than Gilbertson, whose drawings, especially that of 1943, show a degree of naivety. The core of the structure consists of six laminated arches, including one immediately against the brickwork of the façade. They are spaced at 20 foot [6 m] centres. They span 98 ft 11 ins [29.7 m] between the centre points of the supports, measure a nominal 1 ft 11 $^{5}/_{8}$ ins x 4 ins [600 x 102 mm] in cross-section, though the true width is closer to 95 mm, and are built up of 29 layers of timber butt jointed and presumably, in accordance with the practice of the day, casein glued and nailed.

The arches are not truly segmental, but flatten off across the top to carry the monitor vent, while the corrugated iron roofing reverses curvature to turn up sharply against the side of the monitor. Well up the height of each arch is a horizontal timber tie beam measuring 300 x 75 mm. This is connected up to the arch itself by vertical steel rods, spaced across the length of the beam, and is linked at right angles to the tie beams of the adjoining arches by three longitudinal tie beams, 250 x 75 mm, joining at the same panel points as the vertical rods. The beams may be an addition, as a photograph of the building under construction shows only horizontal steel tie rods, and no longitudinal members either of steel or of timber. It is difficult to make out the finer detail of the roof structure from ground level, but it seems consistent with the approved drawings, which show twenty-four Symonds patent purlins spaced at 3 ft 9 in [1.125 m] centres, with two extra ones to carry the framing for the central monitor. The roof cladding is of corrugated iron.

f. developments in lamination

A supplement to Langlands & Thomas was issued in 1948, but did not add to the aspects of concern here. In 1951 one Frank Zipfinger published an article on laminated timber construction in *Architecture,* the journal of the Royal Australian

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97 A C Ward, *Proposed Australian Heritage Commission Listing of Improdex Factory at 135-137 Racecourse Road, Flemington: Comparative Examples* (Burwood [Victoria] October 1992), p 1.

Institute of Architects,[98] but it is unclear what if any structures he may have been involved in. He was described as being a young Dutch architect who had studied interesting uses of lamination in various European countries, but there is nothing in the article to suggest that he had been involved in local lamination projects, or even knew of any. Zipfinger is now dead and his descendants remember nothing of his work. Ward has tried unsuccessfully to trace Bruno Gallace, with whom he is supposed to have practised.[99]

In 1954 a twenty-four metre revolving laminated arch designed by Ralph Symonds was constructed over Macquarie Street, Sydney, as a decoration for the royal tour, and funded by the Timber Development Association. At first the Sydney City Council withheld permission for its erection because it was 'structurally unsound' and 'might jump off its rollers', but Symonds offered a £5000 bond for its safety, tests were conducted, and ultimately permission was granted.[100] More mundane uses of lamination also became common, and in 1954 the Cecil Box Co factory at North Ryde was built with arches spanning thirty-six metres.[101] Whether it was by Symonds it is impossible to say.

The role of Ralph Symonds Pty Ltd in making the first glue laminated arches in Australia, and in the design and construction of the Turner and Burge building, has been discussed. The firm may have had its origin in a company called Panels Pty Ltd, which was in Morley Avenue, Rosebery, Sydney, in 1943. Ralph Symonds Pty Ltd were in this street in the following year, with the same telephone number and cable address.[102] In April 1946 Symonds completed his own new factory in Campbell Road, St Peters, of the same form and approximately the same construction as the Turner and Burge buildings, but it was burnt down the following September. Symonds immediately began a building on the Holland Street frontage of the same site, of the same width and again with laminated arches spanning thirty metres, but no longer of the circular shape. The upper parts were straight, creating something like a conventional pitched roof. Next he rebuilt on the site of the burnt-out building, fronting Campbell's Road.[103]

In 1955 Symonds fabricated arches spanning thirty-six metres for the Neon Industries factory in Racecourse Road, Ascot Vale, Melbourne. The building was designed by the architects Stephenson & Turner, and used bowstring tied arches on concrete columns. the arches themselves were of butt-jointed Douglas fir [Oregon] with a cross-section of 24 x 4 inches [600 x 100 mm].[104] The trusses were freighted to Melbourne under police escort. The consultant engineer was Cyril Hudspeth.[105] In

98 F J Zipfinger, 'Laminated Timber Construction', *Architecture*, XXXIX, 4 (October-December 1951), p 122.

99 Ward, *Improdex Factory*, p 2.

100 *Cross-Section*, 17 (March 1954), p 2.

101 *Cross-Section*, 21 (1 August 1954), p 2.

102 Wyatt, 'A Note on Early Ralph Symonds Buildings'.

103 Ken Wyatt, 'Early Glue-Laminated Arches, pp [3-4].

104 Stephenson & Turner records, State Library of Victoria; Ken Wyatt, 'Early Glue-Laminated Arches, pp 5, 15; inspection with Ken Wyatt, 2000. See also *Architecture Today*, I, 10 (August 1959), p 27, for an imprecisely identified illustration which appears to be this building.

105 *Cross-Section*, 30 (1 April 1955).

1956 Symonds supplied laminated arches of polished African mahogany, spanning nearly fourteen metres, for a Baptist church at Punchbowl, Sydney.[106]

In 1958 the company obtained an area of reclaimed ground at Homebush Bay, Sydney, onto which to transfer and expand its factory. Their first building was a shed, of 137 x 28 m, intended to serve as workshops for the fabrication of the main building, and subsequently to become an administration block. It was framed up on two-hinged arches of box beam construction, each formed in two halves, each like an asymmetrical T, with the longer arms meeting and joining art mid-span, and the shorter ones carrying the cantilevered eaves. The upper and lower chords were each made up of six 20 mm laminae, and the webs of 12 mm thick 'Reswood' waterproof plywood, treated for fire resistance.

The main building which followed was completed in 1959. It measured over 350 by 160 metres and was three bays wide. Each bay was spanned by three hinged arches in something resembling a Perpendicular Gothic four-centred arch shape, and these were overlapped by straight beams zig-zagging up and down to form a series of conventional gable roof sections, supported above ground by angled struts and - supposedly - by a vertical column at each trough in the zig-zag. The glue building followed, but was burned and replaced, in each case using three pin arches in the form of two boomerang sections. The main shed survives today, albeit in a decrepit state.[107] In 1960 the Woollahra Old People's Centre in Sydney was completed to the design of Steven Kalmar, a 'staggeringly inept' design in which the building appears to be more or less suspended - but quite unnecessarily so - from an oversailing arch.[108] Because Ralph Symonds Pty Ltd are cited as the principal subcontractors, it seems that the arch must have been of laminated timber.

The first works of lamination known NOT to be by Symonds were reported in 1955. In that year laminated timber trusses made by R Andrews, spanning 34.5 metres, were reported to have been used at the premises of builders' supplier Stuart Walker & Co, of Sydney. The consulting engineers were Stanley & Llewellyn,[109] and it seems reasonable to suppose that the laminated timber specialist Malcolm Stanley was a partner in the firm. A church built at Mt Beauty in the Australian Alps in 1955, to the design of the Melbourne architect Alan Robertson, had principal members in the form of boomerang arches, probably pinned at the apex. They were vertically laminated out of floor boards by an Albury builder,[110] and would seem to have been far less technically sophisticated than the arches at Flemington. This was the first of many such churches, all of which must be seen as descendants of the first United States example of the type, St Leonard's Catholic Church, Laona, Wisconsin, designed by Max C Hanisch senior in 1936. This had a clear span of 12.9 metres.[111] Lamination

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106 *Cross-Section,* 61 (November 1957), p 1. See also Ken Wyatt, 'Early Glue-Laminated Arches, pp [5-6]

107 Ken Wyatt, 'The Ralph Symonds Factory at Homebush Bay' (typescript note, 1999, kindly supplied by the author. The supposed columns in the main building are asbestos cement tubes, and serve as downpipes. In my view that is *all* they are - they are not designed to be columns, and they have no [designed] structural role.

108 *Cross-Section,* no 97 (1 November 1960), p 3.

109 *Cross-Section,* 30 (1 April 1955).

110 *Cross-Section,* 28 (1 February 1955), p 3.

111 McNall & Fischetti, 'Glued Laminated Timber', pp 138-9.

now became common in church structures. According to Ward, the Mormons built twenty-three churches throughout Australia in the 1950s, of which that at Moorabbin, Victoria, was possibly the first, and others included those at Fitzroy, South Australia, and at Blackburn, Victoria, of 1958. They used laminated timber beams made by John Sharpe's [*sic,* but presumably John Sharp's] joinery works, a subsidiary of the Kauri Timber Co Ltd, using 6 x 11 inch [150 x 280 mm] Tasmanian hardwood, scarf jointed, dowelled and pressed, which, according to Ward, closely compares with the technique used at the Burge factory. This similarity is not apparent to me from the facts cited. Walter & Morris of Port Adelaide also manufactured glue laminated beams from the 1950s.[112]

In 1958 the place of Langlands & Thomas's book was taken by Pearson, Kloot & Boyd's *Timber Engineering Design Handbook,* which included the same sorts of material, but went also into the design of trusses, glue laminated construction, and the structural use of plywood. It also illustrated innovative structures, both overseas and in Australia, and the local ones certainly give the impression that a creative buzz had developed in timber engineering during and after World War II. They included nailed trussed arches at a Laverton aircraft hangar, spanning 22.5 m; glued laminated arch sawtooth roofing in New South Wales; glued laminated boomerang arches spanning 10.5 m in a Melbourne church, and similar arches of unspecified span for a church at Meddons, South Australia.[113] There were at least two examples directly comparable to the Improdex factory, one in New South Wales using tied arches with glued laminated top chords, spanning 36 m; and the other an Adelaide factory using glued laminated arches, spanning 37.8 m.[114] These buildings are not identified with sufficient precision to locate them, but the acknowledgments for illustrations include what must be the fabricators: Laminated Timber products of Adelaide, Stanley & Llewellyn of Sydney, and the Timber Engineering Co of Sydney.[115]

In 1959 an article on 'Timber Engineering' appeared in *Architecture Today,*[116] and it was here that the illustration of the Burge factory under construction was published. The article contains little information other than a table of basic working stresses for glued laminated timber, and is really little more than a plug for Pearson, Kloot & Boyd's *Timber Engineering Design Handbook.* It does, however, illustrate two more tantalisingly under-identified Australian examples. One is a church in Adelaide with arches coming to a slight Gothic point, but of a truly curved section, and said to be of Douglas fir in the outer part and radiata pine in the inner. The other is a church hall in Melbourne with the boomerang wall/roof members.[117]

In 1958, according to Ward, H Beecham & Co fabricated bowstring trusses with glue laminated top chords for their own factory in Blackshaws Road, Altona North, Victoria, which also included a mezzanine floor carried on plywood box beams. The factory is still in existence, but Beechams did not fabricate any such structures for

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112 Ward, *Improdex Factory,* p 2. It is possible that earlier Mormon examples were imported from the United States, as I have been told by David Beauchamp, 1993.

113 Pearson, Kloot & Boyd, *Timber Engineering Design Handbook,* especially pp 224, 229, 230, 232.

114 Pearson, Kloot & Boyd, *Timber Engineering Design Handbook,* pp 228, 232.

115 Pearson, Kloot & Boyd, *Timber Engineering Design Handbook,* p 223.

116 'Timber Engineering', *Architecture Today,* I, 10 (August 1959), pp 27-9.

117 *Architecture Today*, I, 10 (August 1959), pp 28-9

customers.[118] A Beechams advertisement of 1959 refers to their various timber products but gives no indication of involvement in lamination or in any form of timber engineering.[119] According to Ward, Beechams, despite their inactivity in the field for some time after their own factory had been built, did subsequently supply laminated portal frames for churches at Beaumaris [1960s] and Frankston [early 1970s].[120]

In 1967 a pavilion with a laminated beam roof spanning 46 feet [13.8 m] was built at the Royal Showgrounds, Melbourne, for the Forestry Commission of Victoria. The beams were four inches [100 mm] wide, tapering from 26¾ to 9 inches [680 to 230 mm], and were bonded with cold setting casein glue. The architects were Marsh, Bennie & Barry, and the builders R Daniels Pty Ltd, but who was responsible for the laminated work is not recorded.[121] In the same year laminated curved ribs were used for the Australian pavilion at Expo 67 in Japan, branching out from 'hollow tree' supports and spanning 44 feet [13.2 m] to each pair. It was designed by James Maccormick and the Commonwealth Department of Works.[122]

g. the hyperbolic parabaloid

Shells of double curvature were of general interest after World War II, but were mostly carried out in shell concrete, fibreglass or other materials without a pre-established form. The hyperbolic parabaloid, however, can be formed from straight lines - though when cut on any angle out of parallel with these it shows a curved cross-section. This means that it can be formed in timber, usually of a diamond or square form in plan, with an upward curve on one diagonal, an a downward on the other.

In Australia the majority of these shells were still of reinforced concrete, fabric or other materials, but there was some use of timber. These are undocumented, but it is relevant to refer to the British situation, of which more is known. The first timber hyperbolic parabaloid in Britain with a boarded membrane was built in 1957 at the Royal Carpet Factory, Wilton, to the design of Hugh Tottenham of the Timber Development Association. Increasing numbers were built in the following years but the fashion finally died out in 1975.[123]

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118 Ward, *Improdex Factory,* p 2.
119 *Architecture Today,* I, 10 (August 1959), p 25.
120 Ward, *Improdex Factory,* p 2.
121 *Wood World,* I, 1 (August 1967), pp 11-12.
122 *Wood World,* I, 2 (November 1967), pp 1-3.
123 L G Booth. 'The Design and Construction of Timber Hyperbolic Parabaloid Shell Roofs in Britain: 1957-1975', Construction *History,* XIII (1997), pp 26-7.