6.09 Terra Cotta Block & Lumber

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Hollow terra cotta construction has played only a small role in Australia, but it has been relatively important in the United States, and its American development has had interesting Australian repercussions. It has a history in Europe going back to the Roman use of hollow pots in dome construction, but its modern use evolves from developments in the late eighteenth century, and indeed from a mid-century system of construction using thin flat bricks rather than hollow ones.

The traditional tile vaulting system used in Roussillon and Languedoc[1] has been identified as being at least related to the methods discussed by the architect Pierre de Ceremonieux of his work at the royal palace in Valencia, Spain, in 1382,[2] and as being first technically described by Lorenzo de San Nicolas in his *Arte y Uso de Arcqitectura* (Madrid 1663).[3] The Spanish brought the system to Mexico, where it became a part of the vernacular as *boveda de ladrillo.* [4] This system was subsequently promoted by the Comte d'Espie as a fireproof construction method,[5] after which d'Espie's work was translated into English, in 1758 and German in 1760,[6] and it seems that the system was intended to be used by Alderman Beckford at Fonthill in about 1754-6.[7] Later French accounts appeared in J-F Blondel and Pierre Patte's *Cours d'Architecture* of 1777 and J-B Rondelet's *Traité de l'Art de Bâtir* of 1802.[8] The form was brought to the United States by Rafael Guastavino in 1881.[9]

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1 T C Bannister, 'The Roussillon Vault', *Journal of the Society of Architectural Historians,* XXVII, 3 (October 1968), pp 163-175.

2 Philip Araguas, 'L'Acte de Naissance de la Boveda Tabicada ou le Certificat de Naturalisation de la "Voûte Catalane"', *Bulletin Monumentale,* CLVI, 2 (1998), pp 9-36, cited in Dietrich Neumann, 'The Guastavino System in Context: History and Dissemination of a Revolutionary Vaulting Method', *APT Bulletin,* XXX, 4 (1999), p 8.

3 Riccardo Gulli & Giovanni Mochi, *Bovedas Tabicadas: Architettura e Costruzione* (Rome 1995), pp 28-9, cited in Neumann, 'The Guastavino System', p 8.

4 Valeria Prieto, *Vivienda Campesina en Mexico* (2nd ed, Mexico City 1994 [1978]), p 202.

5 [Félix François] d'Espie, *Maniere de Rendre Toutes Sortes d'Edifices Incombustibles, &c* (2nd ed, Paris 1776).

6 According to the preface in the second edition, p i.

7 Elton Engineering Books, *Catalogue Number 10: Two Hundred Books on the Engineering of Architecture* (London 1995), p 21, describing Comte d'Espie [translated L], *The Manner of Securing all Sorts of Buildings from Fire* (London 1756 [1754]), p 8.

8 Neumann, 'The Guastavino System', p 8.

9 Janet Parks & A G Neumann, *The Old World Builds the New* (New York 1996), p ; Neumann, 'The Guastavino System', p 8.

a. hollow blocks

The use of hollow pots in the construction of domes was well understood in Roman and early Byzantine times, but then effectively lapsed until the eighteenth century. In 1778 J D Antoine built arcades of hollow blocks for storing archives at the Palais de Justice, Paris.[10] A systematised form of pot construction was developed by the Frenchman Eustache St-Fart in 1785, in which hexagonal pots about 180 mm long by 100 mm wide, closed at top and bottom, were set in plaster of Paris, to construct floors spanning 3.6 metres. The results were reported to the Académie d'Architecture,[11] and the system was adopted by Victor Louis in the floor of the rebuilt Palais Royal[12] and in the vault of the Théatre Français. The construction spread in France during the 1820s, and by the 1830s its use was normal in public buildings, and was about to be made requisite.[13]

In England Henry Holland used hollow blocks in the construction of Carlton House (1786-7), the Drury Lane Theatre (1792) and other buildings.[14] The English architect John Walker ordered two of the French pots and sent them to William Strutt, the cotton mill engineer and builder, in 1792. In the following year Matthew Boulton wrote to Strutt, mentioning examples he had seen in Paris and at George Saunders's premises in Oxford Street, London, and recommending the method, after which Strutt duly used for the top floor of his Derby Mill of 1792-3.[15] ‼ Sir John Soane constructed most of the vaults of the Bank of England of hollow pots, square and closed at one end, but basically circular in section, with the other end domical and containing a small opening.[16] These seem to have been referred to as 'bottle bricks'[17] and they are probably the same as the 'old French invention' described by Loudon, of arches formed from units shaped like flowerpots but without rims, four inches [100 mm] diameter at the mouth and six inches [150 mm] deep. An arch built in these might rise 150 mm in a span of 1.5 metres. This system had been used 'in that architectural deformity the new palace at Pimlico', where the space above the arch was levelled up and sealed with Lord Stanhope's composition (to be discussed

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10 Wyatt Papworth [ed], *Dictionary of Architecture* (London, published in parts 1848-1892), sv Hollow Brick.

11 C D Elliott, *Technics and Architecture* (Cambridge [Massachusetts] 1992), p 45, quoting S B Hamilton, *A Short History of the Structural Fire Protection of Buildings* (London 1958), p 7.

12 Charles Eck, *Traité de Construction en Poteries et Fer, à l'Usage des Batimens* [sic?] *Civils, Industriels et Militaires* (Paris 1836), cited in Elton Engineering Books, *One Hundred Illustrated Books, Prints and Drawings* (London 2000), p 35.; Elliott, *Technics and Architecture*, p 45, quoting Hamilton, *Short History of the Structural Fire Protection*, p 7.

13 Eck, *Construction en Poteries et Fer*, cited in Elton, *One Hundred Illustrated Books*, p 35.

14 *Builder*, VII, 326 (5 May 1849), p 212.

15 T C Bannister, 'The Roussillon Vault', *Journal of the Society of Architectural Historians*, XXVI, 3 (October 1968), p 169. They are claimed to have been used also in the arched floor of Strutt's mill at Milford of 1793: Werner Lorenz, 'Classicism and High Technology - the Berlin Neues Museus', *Construction History*, XV (1999), p 51.

16 Frederick Rogers, *Specifications for Practical Architecture* (London 1873), p 28 & pl I fig 1.

17 Christy Anderson, in a review of James Ayres, *Building the Georgian City*, in *Journal of the Society of Architectural; Historians*, LIX, 2 (June 2000), p 253.

below).[18] It appears also that the hollow pots were used in the vaulting of Stüler and Hoffmann's Neues Museum, Berlin, in the 1840s.[19]

In 1812 Bedford Denton patented a form of tubular brick for conveying air,[20] and this was manufactured in France for some time. In 1831 Packh, who had tested some of Denton's bricks, published his *New Mode of Construction with Hollow Bricks.*[21] In 1833-5 Charles Fowler (or his employee Henry Roberts) used hollow pots in the construction of Fishmongers Hall, Hungerford Market, London, with the result that Roberts later became the foremost exponent of this technology. In 1838 one Captain Greban used hollow tile arched vaults in a military warehouse and bakery on the Quai Billy in Paris, with the arch rising only very slightly, and an iron tie rod passing through its thickness. In other cases the hollow blocks actually rested on the iron members.[22]

James Frost developed a flooring system in the 1820s based on square section hollow tubes, two feet [600 mm] long, embedded in cement. They were placed in two layers at right angles to each other for a span of up to ten feet [3 m], but for larger spans he would increase the number of layers, or instead use iron joists carrying flagstones.[23] In 1839 S H Brooks, in his *Designs for Cottage and Villa Architecture,* illustrated two types of fireproof flooring system based upon arches of hollow bricks spanning between I-beams.[24] In 1843 a Clapham builder called Loat patented a flooring and roofing system based upon hollow earthenware pots laid flat, rather than arched, and without tie rods: however, this does not appear to have been on the flat arch principle of later systems, as the pots were described as of cylindrical, polygonal and other shapes.[25] In the early 1840s Thomas Sharp built two complete churches of hollow block filled with concrete.[26] H L Elmes and the engineer Robert Rawlinson, his collaborator and successor, used hollow blocks on a most ambitious scale for the ceiling of St Georges Hall, Liverpool, of 1841-50.[27] Other terra cotta blocks, the details of which are unclear, were used at the Saltaire Mill, near Bradford, in 1850-53.[28]

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18 J C Loudon, *Encyclopædia of Cottage, Farm and Villa Architecture* (London 1846 [1833]), § 1789, pp 865-6, quoting the *Mechanic's Magazine,* VIII, p 314; XVIII, p 339.

19 Lorenz, 'Classicism and High Technology', p 51.

20 Elliott, *Technics and Architecture,* p 47, gives the name as 'Deacon'.

21 Papworth, *Dictionary of Architecture,* sv Hollow Brick.

22 Theodore Turak, *William le Baron Jenney: a Pioneer of Modern Architecture* (Ann Arbor [Michigan] 1986), pp 37, 39, citing L-C Mary, *Cours d'Architecture* (Paris 1852-3), pp 289.

23 Loudon, *Cottage, Farm and Villa Architecture,* § 1788, p 865; C W Pasley, *Observations on Limes, Calcareous Cements, Mortars, &c* (London 1838), pp 164-5; *The Useful Arts Employed in the Construction of Dwelling Houses* (2nd ed, London 1851), pp 186-7. The same material appears in the first edition, cited in *Builder,* III, 101 (11 January 1845), p 17.

24 S H Brooks, *Designs for Cottage and Villa Architecture* (London, no date [c 1839]), pl liv. In one case the blocks form a true arch, and are designed to be concealed by a false ceiling; in the other a flat arch is designed to be plastered on the underside and form part of a panelled ceiling.

25 Thomas Potter, *Concrete its Use in Building* (new ed, 2 vols, London c 1894 [c 1877]), II, pp 145-6.

26 These were at Lever Bridge and Bolton-le-Moors, and were made of Ladyshore terra cotta, sold by E P Willock & Co of Manchester: *Builder,* III, 147 (29 November 1845), p 571. See also Michael Stratton, *The Terracotta Revival* (London 1993), p 51

27 Henry Roberts, *The Dwellings of the Labouring Classes* (London 1850), p 11.

28 Sara Wermiel, *The Fireproof Building: Technology and Public Safety in the Nineteenth-Century American City* (Baltimore 2000), p 85.

b. extruded blocks

It was the extrusion machine invented by the Marquis of Tweeddale in 1836[29] which simplified manufacture enough to bring hollow terra cotta into more general use. In 1843 a Frenchman, Collas, patented a mechanical means of shaping hollow bricks, probably by extrusion, and two years later Robert Beart patented an effective die for use in extrusion.[30] Then in 1844 Thomas Grimsley patented 'a new method of constructing a self-supporting fire-proof roof, and other parts of buildings, with bricks and tiles from an improved machine', which in fact appear to have been extruded hollow segmental blocks,[31] and in 1846 various developments were patented by Franklin, Ransome & Warren, and Percy.[32]

The first general commercial manufacturer of hollow blocks was Hertslet & Company, whose 'patent bonded hollow blocks or rebated tiles' were used in 1846-7 by Henry Roberts, architect for the Model Lodging House in George Street, St Giles's, London,[33] and again in 1849 for labourers' dwellings in Streatham Street, Bloomsbury. These were wedge-shaped blocks measuring 9 x 6 x 4 inches [230 x 152 x 102 mm] and were used only for segmental arches in roofs and floors, because the excise duty discouraged them in walls.[34] According to R S Burn the patentee was Roberts, not Hertslet.[35] However, Hertslet also developed wall blocks of a distinctive form. This was a tube about 100 mm across in one dimension, but with one side sloping out of square so that it had to be laid with another parallel tube which was inverted to make the slope match,[36] and it had the advantage of creating a sort of zig-zag joint down the centre of the wall rather than a continuous one. The blocks were very widely publicised as a result of being used for Prince Albert's Model Lodging Houses in Hyde Park, in 1851, when they were manufactured principally with a Clayton brick and tile machine.[37] John Taylor later developed a block of a rather similar shape, but intended as permanent formwork for a concrete wall, in that the pointed part tied it into the concrete mass.[38] A later development by Hertslet himself was a block with both sides in a vertical plane, but the top and bottom in the form of an inverted V.[39]

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29 *Mechanic's Magazine,* XXXI, 829 (27 April 1839), p 62.

30 Elliott, *Technics and Architecture,* p 49 & illustration, from British Ceramic Society, *Transactions,* February 1959.

31 *Builder,* II, 71 (15 June 1844), p 303.

32 Papworth, *Dictionary of Architecture,* sv Hollow Brick.

33 *Builder,* V, 227 (12 June 1847), pp 286-7.

34 *Builder,* VIII, 364 (26 January 1850), p 37; 365 (2 February 1850) p 49.

35 R S Burn, *Modern Building and Architecture* (London, no date [c 1870]), p 27 & p xxxi figs 16 & 147.

36 Henry Roberts, *The Dwellings of the Labouring Classes* (London 1850), p 24.

37 John Gwilt [revised Wyatt Papworth], *Encyclopædia of Architecture* (London 1888), sec 1920b, p 563; *Builder,* VIII, 405 (9 November 1850), p 540; IX, 432 (17 May 1851), p 11. Great Exhibition, *Catalogue,* p 5, extract kindly supplied by Janet Beeston, 1999.

38 Burn, *Modern Building and Architecture,* p 190.

39 Burn, *Modern Building and Architecture,* p 26 & pl xxxi fig 2: Burn spells the name 'Hertslett'.

Of less relevance to later developments are the products of Jules Borie,[40] later Norton & Borie, who by the 1850s were making 'quadruple square-holed hollow-grooved bricks' and 'tubular tiles'. The former were generally placed so that the apertures ran continuously along the wall, and the latter were flat slabs, extruded with tubular holes through them and a side joint which overlocked so as to create a continuous flat surface.[41] Their machinery appeared first in France, and then in Britain, where the firm one two gold medals at the Great Exhibition, one for the machines and one for the tubular bricks.[42] By the 1860s Norton & Borie had altered their bricks. Instead of consisting of a flat stretcher with eight (4 x 2) square hollows running across it, and a header with four hollows along the length, the header now had two large cavities and the stretcher a single one - that is, it was a square tube. They had also introduced anathyrosis - that is, a slightly raised band along the edge of the bedding plane, presumably to allow a thin joint to be formed in the facework while maintaining a substantial thickness of mortar further in.[43] In France Borie was regarded as the inventor of hollow bricks, which by the 1880s were very widely used, though by that time produced on English machines, like Ainslie's and Clayton's.[44]

In 1853 the Melbourne and Colonial House Investment Company was established with Lewis Hertslet on the board, and with the intention of exporting to Australia large numbers of buildings made of his hollow blocks, claiming that they could supply 'two-roomed fire-proof hollow cottages ... at £25 in London, or £40 in Melbourne'.[45] It is unclear, however, whether any of these arrived. The company experimented with other materials as well, including having some corrugated iron buildings made for it by Samuel Hemming, and today the only surviving structure known to have been exported by the company is one of these.[46] Hertslet's impact in America was of a different character. Not only were the Model Lodging Houses described in the many popular works published in connection with the Great Exhibition, but they were reproduced in American publications as well, such as John Bullock's *American Cottage Builder.*[47]

In the meantime there had been numerous other developments in Britain, such as Peter Thompson's church at Reigate in 1853 made of blocks which were noted for presenting a good face on both sides[48] (which is relevant to later American concerns). Most important was the development by 1853 of a flat arch system, built up of seventeen voussoirs, each of differing section, carried on inverted T-joists.[49] In 1858 Bunnett (the inventor of the revolving shutter) patented a system in which hollow blocks were joggled or keyed into each other, and tied by iron rods passing through

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40 Elliott, *Technics and Architecture*, p 45.

41 [J L Tarbuck], *The Builder's Practical Director* (Leipzig, no date [c 1858]), pp 58-9 & pl 24.

42 *Farmer's Magazine*, V (1854), pp 195-7.

43 E S Eyland, Francis Lightbody & R S Burn, *Working Drawings & Designs Architecture and Building* (Edinburgh no date [c 1863]), essay 3, p 27, & pl xxxi, figs 13 & 14; see also Burn, *Modern Building and Architecture*, p 27 & pl xxxi figs 13 & 14. These authors spells the name 'Borrie'.

44 Pierre Chabat, *La Brique et la Terre Cuite* (Paris 1886), pp 281-3.

45 *Builder*, XI, 536 (14 May 1853), p 318.

46 This is the house 'Wingecarribee' at Bowral, New South Wales.

47 John Bullock, *The American Cottage Builder* (New York 1854), p 187.

48 *Builder*, XI, 548 (6 August 1853), p 507.

49 *Builder*, XII, 581 (25 March 1854), pp 149-151.

them, so that they could not fall.[50] Commonly they were laid to a camber of about 50 mm in three metres. This was said to be 'a principle since adopted in an almost endless variety of ways, especially in America'.[51] As illustrated, the arch was substantially deeper than 1 in 60, and was restrained by a tie rod entirely exposed from below,[52] but this does less than justice to the system as properly interpreted.[53]

It was probably the Bunnett system which inspired Major J E Medley to propose the use of hollow block vaulting in Indian barracks buildings, for he had read of such vaults in the *Civil Engineer and Architect's Journal* in about 1862.[54] In the United States an experimental arch of the Bunnett type was built by the architect W W Boyington, following the Chicago fire of 1871,[55] but there is no indication that the system was taken any further in Chicago. In France Reynaud's treatise of 1867-70 illustrated three similar arches, using tubular voussoirs to form shallow arches spanning between I-beams, and with tie rods exposed below. A fourth was a true flat arch built of hollow blocks so formed as to provide a flat soffit beneath the beam.[56] In 1868 another system of the latter type (apparently without ties) was patented in France by the Roux brothers.[57] Other types were shown at the 1867 Exposition Universelle.[58]

One or two other English developments of note took place before the initiative passed entirely to the United States. In 1871 the architect Lewis Hornblower invented a system in which pottery tubes crossed the girders at right angles, and two years later he devised a much more significant type in which hollow tiles were combined with concrete in various ways. In each of these the tiles ran parallel with the girders, and each girder ran through the centre of a hollow tile, which was of a wedge-shaped section so that it served as a skewback for the tile on either side. However, in none of Hornblower's designs was there more than one hollow tile between the girders, so the voussoir principle was not really exploited. Hornblower's floors were used in the Liverpool Corn Exchange, Bradford station, and other locations in England and Scotland, and in 1874 they were subjected to fire testing at the instigation of the

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50 E S Eyland, Francis Lightbody & R S Burn, *Working Drawings & Designs Architecture and Building* (Edinburgh, no date [c 1867]), essay 1, pp 24-5; pl xxxvii, figs 16-21; Burn, *Modern Building and Architecture*, pp 24-5 & pl xxxvii fig 16-21. See also R S Burn, *The New Guide to Carpentry, General Framing and Joinery* (Glasgow, no date [c 1870]), pp 275-6; pl 129, figs 16-21.

51 Thomas Potter, *Concrete its Use in Building* (new ed, 2 vols, London c 1894 [c 1877]), II, pp 154-5; see also *Notes on Building Construction, Part II* (3rd ed, London 1887), p 369. The system was used in the Grosvenor Hotel, Victoria Station, London, of 1860-61.

52 R S Burn, *Building Construction* (London 1877), p 39.

53 See the illustrations in *Minutes and Proceedings of the Institution of Civil Engineers*, 1890-91, reproduced in Sara Wermiel, 'The Development of Fireproof Construction in Great Britain and the United States in the Nineteenth Century', *Construction History*, IX (1993), p 17.

54 Peter Scriver, 'Imperial Progress: on the Impracticality of Problem-Solving in Colonial Indian Building', *Fabrications*, XI, 2 (2001), citing *Professional Papers in Indian Engineering*, IX, 7 (1868); also Scriver, p 42, n 23, citing Lieutenant-Colonel Fife, RE, 'Memorandum on Vaulting Roofs with Hollow Voussoirs without the aid of Centering', *Indian Engineering*, I, 5 (November 1864), pp 411-421.

55 Elliott, *Technics and Architecture*, p 46, quoting P B Wight, 'Origin and History of Hollow Tile Fire-Proof Floor Construction', *Brickbuilder*, VI (March 1897), p 74.

56 Léonce Reynaud, *Traité d'Architecture* (2 vols, Paris 1867-70), II, p 373, reproduced in Turak, *Jenney*, p 42.

57 Illustrated in the *Brickbuilder*, 1897, reproduced in Turak, *Jenney*, p 162.

58 Turak, *Jenney*, pp 159-60.

Liverpool Fire Insurance Office, from which they emerged quite undamaged.[59] By now serious development had begun in America.

c. American systems

According to John Bullock, F B Taylor and Joseph B Holmes, Director of the Machine Department of the New York Worlds Fair, had invented a machine for producing such hollow bricks.[60] It does appear that hollow blocks were the subject of a United States patent taken out in 1855 by the architect F A Peterson, and that he had used them on an experimental basis in 1853 in part of the Cooper Institute Building, New York. Here, however, they were not extruded, for each tile was individually hand-made.[61] Even this was doubtless an exceptional case, for according to J K Freitag hollow tile was first introduced as a building material following the great Chicago fire of 1871. A system resembling Peterson's is said to have been patented in England and the United States by a Frenchman, Maurice Abord. It consisted of a flat arch made of voussoir-shaped tiles, running between what were shown in the British patent as wooden beams, and in the US one as iron I-beams.[62] Another US patent was taken out by Balthasar Kreischer, a firebrick manufacturer of Staten Island, New York, and G H Johnson, a Chicago engineer, in which broad tubular blocks are shown between pairs of I-beams. This has been claimed to resemble Peterson's earlier patent, though the connection is not obvious.[63]

The Chicago interest in fireproof construction of course stemmed from the great fire of 1871. One building which conspicuously survived was the uncompleted Nixon Block, which had an internal metal structure encased in plaster and cement.[64] Joseph Bunnett sent over components for the construction of a hollow tile floor, which was put up on display on a vacant lot in Chicago.[65] The *American Railway Times* suggested the future use of the French method of fireproofing,[66] though in fact similar systems had already been pioneered in the United States just before the time of the fire. As has been said, the Chicago Terra Cotta Company had been established in 1869, with Sanford Loring as President, and in 1870 he appointed as superintendent William Taylor, a former employee of Blashfield in England.[67] Taylor's experience was with ornamental work, which was probably the main interest of the Chicago company at this stage, until, as with other companies, the destruction of 1871 diverted its attention to fireproofing and structural issues.

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59 Henry Reid, *A Practical Treatise on Natural and Artificial Concrete* (London 1879), pp 277-289; Potter, *Concrete*, II, pp 159-160; *Notes on Building Construction, Part II*, pp 373-4.

60 Bullock, *American Cottage Builder*, p 187.

61 W H Rowe, 'The Cooper Union (1853-59)', in John Waite [ed], *Iron Architecture in New York City* (New York 1972), p 61, quoting P B Wight, 'Origin and History of Hollow Tile Fire Proof Flooring', *Brickbuilder*, VI (March 1897), pp 53-4.

62 Elliott, *Technics and Architecture*, p 46.

63 Elliott, *Technics and Architecture*, p 46.

64 F A Randall, *History of the Development of Building Construction in Chicago* (Urbana [Illinois] 1949), p 61; C W Condit, *The Chicago School of Architecture* (Chicago 1964 [1952]), p 23; Jordy, *infra*, attributes the fireproofing of this building to Johnson.

65 Wermiel, *The Fireproof Building*, p 51.

66 Turak, *Jenney*, p 159.

67 Stratton, *The Terracotta Revival*, pp 147-8.

George H Johnson had developed hollow tile partitions and flooring systems even before this fire, and immediately afterwards five new buildings were fireproofed on his principles.[68] In 1872 Johnson patented a system of flat hollow tile arches[69] and is said to have introduced it in Chicago, while at about the same time a similar but heavier construction was used in the corridors of the Post Office Building, New York.[70] Also in New York, Heuvelman, Haven & Co began manufacturing Kreischer floors under licence,[71] and a third business, the Fireproof Flooring Company of New York, was established by the engineer and architect Leonard Beckwith, manufacturing terra cotta floors under licence from Johnson. However, there is no reason to suppose that any of the systems were a material advance upon the British one of two decades previous, or the more recent system of the Roux Brothers.

In the Equitable Building, Chicago (1872-3), the hollow tile flat arches were close to what became the canonical form: one skewback section with a rebated base to fit over the flange of the iron joist, one wedge-shaped keystone, and two raking sections for voussoirs.[72] Later, as in the Home Insurance Building, Chicago, of 1884, all the voussoirs were parallel-sided and identical. All the sections were divided up and strengthened by internal webs, which had not been used in the Equitable Building, and a small terra cotta fillet was made to key in below the iron joist (which in earlier versions was filled with plaster, which might discolour).[73] This element, the 'shoe tile', had been introduced by P W Wight in 1883.[74] The Doulton-Peto system, which is very similar to the one described, seems to have been introduced in Britain in 1885.[75]

Like others in the field Johnson increasingly turned to terra cotta for all aspects of fireproofing, and he established a number of small enterprises which are said to have culminated, shortly after his death, in the Pioneer Fireproofing Company.[76] This is somewhat puzzling, however, as the Pioneer Co and Johnson & Co are soon reported as being separate enterprises. Moreover the Pioneer Fireproof Construction Co was reportedly founded by George M Moulton of the Guaranty Construction Co, the

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68 W H Jordy, *Progressive and Academic Ideals a the Turn of the Twentieth Century* (New York 1972), p 7, referring principally to C W Condit, *The Chicago School.*

69 US patent no 132,292 to G H Johnson & W Freeborn, 15 October 1872, reproduced in Turak, *Jenney*, p 163.

70 J K Freitag, *Architectural Engineering* (2nd ed, New York 1909 [1895]), p 90.

71 Wermiel, *The Fireproof Building*, p 88. However, according to Wermiel, p 100, the business had wound up by the 1880s.

72 Freitag, *Architectural Engineering*, p 91. Randall, *Building Construction in Chicago*, pp 10, 60, 77, surprisingly, quotes this (under its later name as the Kendall Building) as the first instance of hollow tile fireproofing, but of arched form, and cites a description in the *Land Owner*, July 1872, p 115. He identifies the first flat tile arch as the of the Montauk Block, 1882: Randall, pp 10, 95.

73 Freitag, *Architectural Engineering*, pp 91-2.

74 Turak, *Jenney*, p 248.

75 It was said to have been used in the London Pavilion, Whitleys [*sic*, for Whiteleys?], and a four storey building at Doulton's factory, and was reported in the *Builder*, 19 December 1885, p 877, and the *Transactions* of the RIBA, 1886, p 130. Joseph Gwilt [ed Wyatt Papworth], *Encyclopædia of Architecture* (London 1899 [1842]), p 568; Potter, *Concrete*, II, 214.

76 W H Jordy, *Progressive and Academic Ideals*, p 7, referring principally to Condit, *The Chicago School.* Wermiel, *The Fireproof Building*, p 100, similarly refers to the Pioneer Fireproof Construction Company as the successor of George Johnson's company. It had a substantial plant at Ottawa, Illinois, with water and steam powered machinery.

architect Peter B Wight, and others,[77] but this is equally confusing as there was apparently a Wight company operating in competition with Pioneer. The leading American manufacturers by the 1890s were, in addition to the Pioneer Company, Johnson & Co and the Wight Company, all of Chicago, and in New York the Raritan Porous Brick Company and Maurer & Sons.[78]

In the arches made by the Pioneer Fireproofing Company of Chicago, and most of its competitors, the voids ran parallel with the joists, whereas running the voids running transversely made more efficient structural use of the terra cotta.[79] This is referred to in the United States as 'end' construction, as distinct from the earlier 'side' construction.[80] End construction blocks had previously been used in England, and had been the subject of some United States patents in the 1870s, but they had not been actually manufactured in that country until the 1880s, when a flat end construction arch was tested in Chicago. By the end of the decade it had been used in a number of buildings in Chicago and the west,[81] and it was the basis of the 'Lee' arch, patented in about 1890.[82] In December 1890 Thomas A Lee's product was tested against those of three prominent companies, and beat them decisively in terms of both strength and fire resistance, and this caused most major manufacturers to turn to this form of block.[83]

Hollow terra cotta block partitions developed over the same period, and their first use in Chicago was in the Kendall (later Equitable) Building of 1872-3, mentioned above.[84] In 1874 Wight & Drake had developed a system of fireproofing iron columns, in which the columns were cruciform and the angles were filled with wedges of timber.[85] By 1876 Wight & Drake had developed an iron columns which was still essentially cruciform, though with a tubular core, of terra cotta, designed to be clad with quadrants of terra cotta fitting between the flanges. These became common in the 1880s,[86] and something similar could be done with a Phoenix column.[87] In 1881 the Grannis Block was built in Chicago with columns fireproofed in 2½ inch [64 mm] terra cotta, though the precise form is unclear.[88] It may have been a circular column clad in semi-cylindrical terra cotta blocks of the type known

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77 Joseph Siry, 'Adler and Sullivan's Guaranty Building in Chicago', *Journal of the Society of Architectural Historians,* LV, 1 (March 1996), p 10.

78 Potter, *Concrete,* II, p 210. Maurer's company had started in 1875 after he obtained a patent for the use hollow tile in semi-fireproof construction, and the Raritan Hollow and Porous Brick Company was established in New Jersey in 1882.

79 Freitag, *Architectural Engineering,* pp 92-3.

80 Conrad Paulson, 'Structural Clay Tile', in Thomas Jester [ed] *Twentieth-Century Building Materials* (Washington [DC] 1995), p 152.

81 Wermiel, *The Fireproof Building,* p 160.

82 Conrad Paulson, 'Structural Clay Tile', in Thomas Jester [ed] *Twentieth-Century Building Materials* (Washington [DC] 1995), p 152.

83 Wermiel, *The Fireproof Building,* pp 160-2.

84 Randall, *Building Construction in Chicago,* p 77.

85 C J H Woodbury, *The Fire Protection of Mills; and Construction of Mill Floors, &c* (New York 1895 [1882]), pp 110-111, including an illustration. Woodbury credits these developments to Wight only, but Wermiel, *The Fireproof Building,* pp 95-6 credits Wight and Drake, and reproduces a plate from J K Freitag, *The Fireproofing of Steel Buildings* (New York 1899).

86 Woodbury, *Fire Protection of Mills,* p 133; Wermiel, *The Fireproof Building,* pp 95-6.

87 Woodbury, *Fire Protection of Mills,* pp 133-4.

88 Randall, *Building Construction in Chicago,* p 94.

as a 'protected iron column', which does not seem to be attributed either to Wight or to any other specific inventor.[89] By this time terra cotta had been used also used for beam protection, and for exterior belt courses, sills, caps, ornamental panels and modelled work, in both America[90] and Australia. At a later date terra cotta blocks were to be used as the infill of waffle concrete slabs. a development which will be discussed in the context of reinforced concrete.

d. terra cotta lumber

'Porous terra cotta' was a distinct development, in which sawdust or other vegetable matter was mixed with the clay, and burnt out during the baking so as to give a lighter and more porous material. It seems to have been first developed in Britain,[91] but to have fallen into abeyance until it was reinvented in the United States in 1874 by the architect Sanford Loring, and made in Chicago by his Chicago Terra Cotta Company.[92] There seems to be rather fine distinction between porous terra cotta in general and the terra cotta 'lumber;' patented by Charles D Gilman of Iowa in 1881, so called because it could be sawn or nailed.[93] The distinction is surprising because the English product was also claimed to be able to take nails,[94] though whether it could be sawn or otherwise worked is not clear. It is said to have been first manufactured by the New York Terra Cotta Lumber Company at Perth Amboy, New Jersey, in 1882, after which the process was licensed to other manufacturers,[95] but there is some doubt about both the date and the primacy of the New Jersey operation.

It was also reported that terra cotta lumber was first introduced by the International Terra Cotta Company of Chicago, which took out patents worldwide,[96] and which appears to be identical with the International Terra Cotta Lumber Company. This company held four 'bedrock' United States patents taken out by C C Gilman, which were the basis of the manufacture, as well as about thirty other patents on subsidiary aspects.[97] Terra cotta lumber is reported to have been manufactured on a large scale in New York in 1884,[98] and in 1888 Gilman, as president of the company, was in New Orleans with his vice-president, Rice, seeking to establish a terra cotta lumber plant in the old Crescent City,[99]

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89 Woodbury, *Fire Protection of Mills*, pp 111-112.

90 Freitag, *Architectural Engineering*, pp 23-4.

91 Potter, *Concrete*, II, p 210.

92 *American Architect and Building News*, I (30 December 1876), p 421; Wermiel, *The Fireproof Building*, p 93.

93 Wermiel, *The Fireproof Building*, p 96. However the invention is credited to A D Gilman of Eldora, Iowa, by S B Hamilton, 'Building Materials and Technology', in Charles Singer et al, *A History of Technology, Volume V: the Late Nineteenth Century c 1850 to c 1900* (Oxford 1958), p 481.

94 Potter, *Concrete*, II, p 210.

95 Wermiel, *The Fireproof Building*, p 97.

96 *Australasian Builder and Contractor's News*, 28 April 1888, p 266, quoted Alfred Barbara, 'Terra Cotta in Sydney Architecture 1788-1914' [2 vols, BArch, University of New South Wales, no date (1978)], II, pp 51-2.

97 *Pittsburgh Terra Cotta Lumber Company* (brochure, Pittsburgh [Pennsylvania] no date [c 1891 on the basis of dated testimonials quoted]).

98 Hamilton, 'Building Materials and Technology', p 481.

99 *International Fire-Proofer*, I, 3 (November 1888), p 37.

The International Company apparently licensed or sold the rights on a regional basis to individual manufacturers, such as the Illinois Terra Cotta Lumber Company, which was established in 1885 with the sole right for the manufacture and sale of terra cotta lumber in the state of Illinois. The company's works were at Pullman, and the offices in the Tacoma Building, Chicago. Its products included hollow flat and arch tiles for iron construction, flooring tiles for wooden joists, ceiling tiles, partition tiles, wall firring and deafening, and column, girder and beam casing. These were used in the Rookery, the Auditorium, the Chamber of Commerce and the Monadnock Building.[100] By this time there were already moves to establish a factory in Melbourne, and Gilman's first New South Wales patent appears to date from 1884.[101]

By 1887 there was a report on the New York Terra Cotta Lumber Company works at Perth Amboy, New Jersey, where resinous sawdust was mixed with the clay, and the material was ground, mixed, compressed, and extruded in the required form, then baked.[102] By early 1888 there were twelve licensed manufacturers in the United States and Canada,[103] and by September there were twenty licences and another dozen about to be issued. In this month the International Terra Cotta Lumber Co published the first number of its journal, the *International Fire-Proofer.* The president of the company was C C Gilman, and there were representatives in different parts of the United States and in England, France and the Australian colonies - the latter being H H Turner. The material had been used in Adler and Sullivan's Auditorium Building, Chicago, which featured permanently on the cover of the journal.[104]

In 1890 William B Owen, who had been manufacturing terra cotta for three years, established the Denver Terra Cotta Lumber Company at Denver Colorado.[105] Presumably the New York and Denver companies operated under licence from the International Terra Cotta Company, as certainly did the Pittsburgh Terra Cotta Lumber Company by 1891.[106] The same was doubtless true in Canada, where by mid-1889 the Rathbun Company of Deseronto, Ontario, was reported to have immense works piled high with 'contracted wares, waiting shipment to Toronto and Montreal'.[107] In 1891 the Montreal Terra Cotta Lumber Co was able to advertise that its product had been used in twenty-six different Montreal buildings. At about the same time the Rathbun Company, now of Naponee Mills, supplied terra cotta lumber for the Ontario Legislative Building and other prominent structures.[108]

Terra cotta lumber was first used for hollow tile arches when it was manufactured in the appropriate form by Henry Maurer, in the early 1880s.[109] It was also used for hollow block partitions and for the fireproof casing of columns.

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100 *Industrial Chicago,* II (Chicago 1891), p 798. Extracts kindly supplied by Professor Ron Schmitt of the University of Illinois at Urbana-Champaign.

101 *Building and Engineering Journal*, 18 April 1891, p 153.

102 C T Davies, *A Practical Treatise on the Manufacture of Bricks, Tiles, Terra Cotta, &c* (Philadelphia 1884), pp 308-310.

103 *Australasian Builder and Contractor's News,* 28 April 1888, p 266.

104 *International Fire-Proofer,* I, 1 (September 1888), cover, inside cover, pp 1 & 4.

105 Davies, *Treatise on Bricks, Tiles, Terra Cotta &c*, p 652.

106 *Pittsburgh Terra Cotta Lumber Company,* op cit.

107 *International Fire-Proofer,* I, 9 & 10 (May & June 1889), p 81.

108 Thomas Ritchie, *Canada Builds 1867-1967* (Toronto 1967), pp 216-7.

109 Wermiel, *The Fireproof Building,* p 97.

e. Australian manufacture

What is surprising in Australia is that terra cotta lumber came into use earlier than conventional hollow terra cotta block, for local rights were first acquired in the 1880s by the Victoria Terra Cotta Company of Barkly Street, Brunswick, Victoria.[110] A prospectus was published in 1885 in the name of the Terra Cotta Lumber Company Limited, with directors including J B Carter, who was to manage the works, and a number of local architects and builders. Its purpose was to acquire the Victorian rights to 'Gillman's Process for Manufacturing Terra Cotta Lumber' as already established in the United States.[111] It seems that this was the parent company, which licensed the Victoria Terra Cotta Company and subsequent operators. A later report suggested that the Brunswick works was actually established at about the beginning of 1887.[112] By July 1887 they were in production and were visited by a group of architects and others, to whom their thermal and other properties were satisfactorily demonstrated.[113]

Gilman's three patents in New South Wales appear to have dated (counting back fourteen years from their expiry, to 1884, 1886 and 1887. The first was for mixing a grit-free clay with sawdust and water, moulding and burning it; the second provided for the mixture of fibrous vegetable material rather than sawdust; and the third extended this to include the shaping of the material with tools of any form.[114] Similarly a South Australian patent for 'porous earthenware' was granted to C C Gilman of Edwards, Ohio, in 1887.[115]

The activities of the Victoria Terra Cotta Company have been studied in detail by Lynne Dore, who has found that the Brunswick site was still rated in the name of the former owner, the prominent brick and terra cotta maker, Alfred Cornwell, until 1886-7. After this Carter is listed as manager of the works, and then in 1889 the Victoria Terra Cotta Company is listed as owner.[116] The Victoria Terra Cotta Company showed its products at Centennial Exhibition of 1888-9, and was awarded a first order of merit.[117] A report in April 1888 indicates that the company had been in production for a year, so it can be inferred that the first lumber was produced in early to mid 1887. At the time of the report H H Turner, from the Chicago works, 'was on a short visit ... superintending the machinery and manufacture',[118] which seems odd, given that the machinery had been fully installed and in operation for a year. According to Turner's report, however, it had been decided to erect a new plant at a

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110 *Australasian Builder and Contractor's News*, 28 April 1888, p 266.

111 *Argus*, 7 February 1885, p 6. See also p 11..

112 The *Bendigo Advertiser*, 19 January 1889, speaks of the factory having been established for about two years: quoted in the *International Fire-Proofer*, I, 5 & 6 January & February 1889), p 61.

113 *Australasian Builder & Contractors' News*, 9 July 1887, pp 140-141.

114 *Building and Engineering Journal*, 18 April 1891, p 153.

115 *Australasian Builder & Contractors' News*, 23 July 1887, p 171.

116 L R Dore, 'Terra Cotta Lumber: an Archaeological Study of Rural Trade' (Archaeology, final honours, La Trobe University 1996), p 11.

117 Centennial International Exhibition, Melbourne 1888-1889, *Official Record* (Melbourne 1890), pp 607, 746, 747.

118 *Australasian Builder & Contractors' News*, 28 April 1888, p 266.

new location, with the much greater capacity of a hundred tonnes per day, and for this four Wallace presses had been ordered. A new company had been floated, the shares of which, according to Carter, had advanced to more than double the issue price. Turner had agreed to stay on until April 1889 to oversee the installation.[119] The Wallace Press, called the 'Little Wonder', was the new invention of one Cunningham, superintendent of the Wallace Manufacturing Co. It was said to be the first machine specifically designed for working porous earthenware mixtures, for up to now ordinary brick and drain tile presses [probably meaning extrusion machines] had been used for the purpose.[120]

It appears that Turner's overall mission on behalf of the International Company was to licence and encourage the establishment of factories throughout the Australian colonies. He reported in 1888 that orders were flooding in, and he had been able to reduce the cost of sawdust from thirteen to fourpence a sack. A single order had been received for five million four inch partition blocks, and the noted architect 'Charles' [*sic*, for George] Jobbins had been in to discuss the possibility of building flat arch flooring with twelve foot [3.56 m] spans. In response Turner built a flat arch of this span, using nine inch [230 mm] partition blocks, and was gratified to find that it failed only at 575 lb per square foot [27.5 kPa]. Another test was conducted at the Fire Commissioner's office in Flinders Street, to show how little heat was transmitted: a blowlamp flame was applied to one side of a 3/4 inch [19 mm] slab, while the opposite face remained cool enough to touch.[121] At the beginning of 1889 Turner was able to report that the Melbourne plant had greatly increased its capacity 'but is all under water with orders ahead'.[122] He envisaged the establishment of no less than ten plants in different parts of Victoria, and visited Bendigo to promote the idea of a local factory which would service Echuca, Swan Hill, Dunolly and Heathcote.[123]

It was reported in April 1889 that R P [*sic* for R B] Harper had been appointed manager, and a branch had been opened in Town Hall Chambers, Swanston Street. Walter Reagh remained consulting engineer to the company and manager of 'the works'.[124] In July 1889 Harper delivered a paper on 'Porous Earthenware, known as Terra Cotta Lumber' to the Victorian Architectural and Engineering Association', but this was of a very general nature and shed no light upon the company's operations. The only point of interest is the appearance of the term 'brickwood' as a synonym for terra cotta lumber.[125] In December Harper attended the Association's *conversazione* and exhibited the company's products, though no particulars are reported.[126]

In January 1889 Turner wrote home to Chicago from Wandong, Victoria, where, he assured his gullible compatriots, 'to-day the thermometer marks 156 degrees in the sun, and 141 degrees in the shade.' He was there because the Victorian Terra Cotta

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119 *International Fire-Proofer,* I, 1 (September 1888), pp 7-8.
120 *International Fire-Proofer,* I, 1 (September 1888), pp 8, xi.
121 *International Fire-Proofer,* I, 1 (September 1888), pp 7-8.
122 *International Fire-Proofer,* I, 5 & 6 (January & February 1889), p 57.
123 *International Fire-Proofer,* I, 5 & 6 (January & February 1889), p 61.
124 *Australasian Builder and Contractor's News,* 6 April 1889, p 318.
125 *Australasian Builder and Contractor's News,* 27 July 1889, pp 93-5.
126 *Australasian Builder and Contractor's News,* 21 December 1889, p 593. The report couples Harper with Graham Ferry, of the Patent Terra Cotta Works in Albert Street, Brunswick, and those products which are named sound as if they belong to the latter.

Lumber Company planned to build 'plant No. 2', while others were to follow at Ballarat and Yarrawonga.[127] The Ballarat works was to be established by Robert A Robertson, a local sawmiller of Canadian origin,[128] but it does not seem to have proceeded. Those at Wandong and Yarrawonga did, and as Robertson had sawmilling interests in both areas, it is clear that this program of development was tailored to suit him: what is not clear is whether he had bought out the Melbourne company.

In April 1889 the *International Fire-Proofer* reported that Robertson of 'Tarrawanga' [that is, Yarrawonga] was the latest licensee of the Australian parent company.[129] It was not at Yarrawonga that Robertson began operations, but at Wandong, where his sawmill provided sawdust to the new works. If Robertson was simply a new licensee he would presumably be a competitor of the Brunswick operation, and the name of his company, the Victoria Terra Cotta Lumber Co, differed from those of the Victoria Terra Cotta Co and the parent Terra Cotta Lumber Company Limited, which suggests a discrete operation. However the company is reported to have 'moved that operation from Melbourne to Wandong', and reference is made to the strength test conducted in Melbourne 'of fireproof flooring manufactured by the company', as if the Brunswick product was their own.[130]

The branch at Wandong began operation late in 1889, but it is unclear whether the Brunswick works actually ceased to operate in 'late 1888' or 'by 1891' - that is whether the whole operation moved, or the two works continued for a time in parallel. The site at Wandong occupied twelve hectares, with extensive clay beds, said to be the best in the district for the purpose. The reason for moving from Brunswick was not only that the clay was better, but that sawdust was free for collection at the sawmills. Production began in October 1889, and two machines were installed, though only one was working by the end of the year. Together they could produce in a day 15,000 blocks of the same size as ordinary bricks, but they also had the capacity to produce larger blocks, up to twelve times the volume of an ordinary brick, as well as other shapes, such as the cornice sections at that time being made for the Registrar General's Office in Melbourne. Common bricks and other terra cotta products were also made at the site.[131]

In due course the Australian Seasoned Timber Co absorbed the Terra Cotta Lumber Co, and in about 1891 Robertson established a second terra cotta works at Yarrawonga, though this had a chequered history and was finally liquidated in 1897.[132] A possible hypothesis is that the works at Brunswick were left intact but inoperative until 1891, when the plant from there was moved to Yarrawonga.

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127 *International Fire-Proofer*, I, 5 & 6 (January & February 1889), p 57.

128 *International Fire-Proofer*, I, 5 & 6 (January & February 1889), p 61.

129 *International Fire-Proofer*, I, 7 & 8 (March & April 1889), p 65.

130 *Australasian Builder and Contractor's News*, 28 December 1889, p 630.

131 *Australasian Builder and Contractor's News*, 28 December 1889, p 630. This is a report of a visit to the site by shareholders, reporters &c, and it was said to have been in production about two months, meaning early October if measured from date of the visit on 7 December, or late October if measured from the publication of the report on 28 December. An opening in August had been anticipated in a report in the *Australian Builder and Contractor's News*, 6 April 1889, p 318. The date of October 1888 given by Dore, 'Terra Cotta Lumber', pp 13-14, is incorrect.

132 Dore, 'Terra Cotta Lumber', pp 14-19.

Meanwhile, in July 1892, Robertson became joint proprietor of the Australian Seasoned Timber Company at Wandong - discussed above. His subsequent financial difficulties doubtless stemmed from the depression, and they seem to have come to a head late in 1893. In July his wife Mary agreed to provide security of £500 to the Equitable Life Assurance Society on behalf of the Yarrawonga Saw Mills and Brick Company Limited, upon the basis of property in Ballarat. It appears that the Yarrawonga company was supplying materials for the construction of the Equitable headquarters in Collins Street, Melbourne (later the Colonial Mutual Life building). It failed to meet its obligations under the contract, and in January 1894 was obliged to surrender the whole of the Yarrawonga property to Equitable, though this may have been only a lease designed to allow the contract to continue. In February, however, the contract was formally determined by the architect, E E Raht, and it is possible that Raht now turned to another supplier. In 1895 materials were obtained from the Walkerden Patent Brick and Tile Company Limited - a business not known from local sources, and perhaps even an American manufacturer.[133]

Much less is heard of terra cotta lumber in the twentieth century, but in 1928 it was still being advertised by two Melbourne companies, the Eureka Terra Cotta & Tile Co, and Hoffman Brick & Potteries Ltd.[134] By 1931 the Eureka company had been joined by the Builders' Roofing and Trading Co, of Mitcham, though it is unclear whether Hoffmans were still making the material. In Sydney the Liverpool Tile and Terra Cotta Co was making the 'L.T.C.' brand.[135]

f. local use of terra cotta lumber

The house 'Balclutha', in the Melbourne suburb of Alphington, was built in 1887 to the design of George Johnson, and is said to contain terra cotta lumber,[136] though this seems early and has not been confirmed. Apart from this, some of the first local uses of the material were in 1887 in the Arcade building of the Freehold Investment Co in Swanston Street, Melbourne, by David Wormal, 1887; the Temperance and General Building, Swanston Street, by Alfred Dunn, 1888; and the Empire Buildings, Collins Street, by T J Crouch, 1888[137] (all now demolished); and in a cool storage shed at Nhill in the Wimmera.[138] A list compiled in February 1889 shows the material being used fairly extensively for partitions and, interestingly, at the Ballarat Fine Art Gallery, where it was specifically designed to allow picture hooks to be nailed into it. It was used for some fireproof floors and ceilings, and in one ceiling it is specifically described as being laid between iron joists. As yet there is no reference to it being used to encase columns or other structural members.[139]

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133 Blake & Riggall collection, Melbourne University Archives: Equitable Life Assurance Society papers.

134 J S Gawler [ed], *The Architects' and Builders' Index (Victorian Edition)* (Melbourne 1928), p 35.

135 W L Richardson [ed], *Ramsay's Architectural and Engineering Specifications [Volume 1]* (Melbourne, no date [1934]), p 59.

136 Information from Allan Willingham, 1991.

137 *Australasian Builder & Contractors' News,* 28 April 1888, p 267. For James's building see also Alexander Sutherland [ed], *Victoria and its Metropolis* (2 vols, Melbourne 1888), II, pp 583-5.

138 *Building and Engineering Journal,* 6 July 1888, supplement p 3.

139 *International Fire-Proofer,* I, 7 & 8 (March & April 1889), p 79.

In July 1889 the Victorian Railways Department accepted nine tenders for cool [rendered as 'coal'] storage sheds of which terra cotta was a major component,[140] and at about the same time a small amount of terra cotta lumber was used as partitioning in the No 3 Goods Shed at Spencer Street railway yards,[141] which is perhaps - save 'Balclutha' - the oldest surviving example in Australia. At the Commercial Bank of Australia building in Collins Street the specification of 1890 called for terra cotta lumber '9" bed and 14" x 6"', presumably meaning a nine inch [225 mm] course height and fourteen by six inch [355 x 150 mm] plan dimension.[142] Also in 1890 the National Mutual Life Association headquarters in Melbourne were specified to have terra cotta lumber partitions, 1½ inch [38 mm] encasing of girders, and floors carried on voussoir arches between rolled iron beams.[143] There were also to be 1½ inch slabs forming a complete layer over the rafters, with battens for slating on top.[144] In 1904 the internal walls of the Natural History Museum, Melbourne were built of fourteen inch [350 mm] terra cotta, but not necessarily terra cotta lumber.

One of the earlier local examples of metal framing protected by terra cotta, and its first known use in New South Wales, was the George Street extension of the Mutual Life Association Building at George and Wynyard Streets, Sydney, built in 1888-90 to the design of John Sulman of Sulman & Power.[145] This was probably terra cotta lumber, as the material was used in the same building for shelving and pigeonholes in the strong room, as a safeguard against fire, and for the office partitions of the upper floors.[146] In 1891 the Mutual Store in Melbourne was reported to have all columns and joists protected from fire by a two inch [50 mm] coating of terra cotta.

By October-November 1889 a terra cotta floor, presumably on the flat arch principle, had been tested in Brisbane.[147] In 1890 the house 'Coronal', in the Melbourne suburb of Malvern, was built using terra cotta flat arch construction, apparently in all levels. This was because the owner, Joseph Higgins, had had a previous house burn down, and was especially concerned that it should be fireproof.[148] The blocks are not fully

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140 *Building and Engineering Journal*, 9 July 1889, p 3; also the *Victorian Government Gazette*, 1889, cited in Dore, 'Terra Cotta Lumber', p 15.

141 Victorian Railways No 3 Goods Shed and Offices at Spencer Street Goods Depôt. Contract No 4007, drawings exhibited from 22 July 1889, contract signed 4 September 1889, revised drawings signed 25 September 1889. Public Transport Corporation, Victoria.

142 G W Blackburn, 'The Commercial Bank of Australia Limited New Premises, &c.' [bill of quantities] (Melbourne 1890), p 14.

143 Wright, Reed & Beaver, 'Specification for Erection of Premises for the National Mutual Life Association of Australasia. Corner of Collins & Queen Streets Melbourne' (Melbourne 1890), pp 7, 11.

144 Wright, Reed & Beaver, 'Specification for National Mutual Life', p 16.

145 *Australasian Builder and Contractor's News*, 10 March 1888 (*sic* - for 1889?), p 163, quoted by L J Dockrill, 'Developments in Architecture in New South Wales during the Victorian Period' [6 vols, PhD, University of New South Wales, 1983], I, p 125. NB - I seem to have a direct reference to the 1888 date from the index, but it's not on file.

146 *International Fire-Proofer*, I, 3 (November 1888), p 33, quoting 'a local paper'. NOTE: if this is NOT in the *ABCN* report, come back to this one for other material on glazed bricks, prismatic lights &c.

147 *Building and Engineering Journal*, 25 July 1891, p 52.

148 'Coronal' is in Lewes Drive, Malvern, and Di Foster of Stonnington has reported that the terra cotta blocks can be seen on the underside of the ground floor slab, from the cellar. This is presumably flat arch construction, and the same at every level.

visible, but are reputedly 150 x 200 mm in section, with six cores, and 400 mm long. They are placed in four or five rows between and parallel with wrought iron or steel beams.[149] In 1890-91 terra cotta lumber on rolled steel joists was used for the floors of the National Mutual Building in Collins Street, Melbourne,[150] and in 1892 terra cotta blocks were used in the floor, and terra cotta casing on at least some of the circular cast iron columns of the National Mutual building in George Street, Sydney. The floor blocks were fifteen inches [375 mm] deep, and spanned 975 mm between the wrought iron secondary beams.[151] In 1898 terra cotta lumber between rolled steel joists was used in the George Street extension of the General Post Office, Sydney.[152]

In 1891 the architect W S Law specified flat arches with cores in the transverse direction - that is, 'end construction' - to floor the balcony of the house 'Benvenuta', Melbourne. He nominated the lumber of the Victorian Terra Cotta Company, in a size of eight by four inches [800 x 100 mm] with two hollow cores. Each flat arch consisted of three pieces, those at the end cut to a profile to fit against the iron girders which framed the back and front of the balcony, and the central block with angled ends in the form of an elongated keystone. At intervals of 1.35 metres tie rods ran between the blocks to connect the girders together, and over the top tiles were laid to create a finished floor.[153]

Even the Victoria Terra Cotta Lumber Company and its successors made some blocks of ordinary terra cotta, for which precisely the same machinery was required, and it can be difficult to determine which material was used in any particular building. But it seems likely that the patent restrictions worked, and that until about 1898 no other company was making the lumber. Anyone could make regular terra cotta, and in 1888 Ungher & Co of Sydney submitted for the inspection of the New South Wales Institute of Architects 'hollow tiles which were of a very useful character'[154] - make no reference to terra cotta lumber.

From the late 1890s a number of Sydney manufacturers seem to have gone into terra cotta and even terra cotta lumber blocks. In 1898 the iron and steel frame of the Queen Victoria Building was fully encased in terra cotta lumber reported, somewhat improbably, to be fifteen inches [375 mm] thick.[155] According to Warwick Gemmell it was made by Leon Jaubert, who manufactured terra cotta at Woonana until 1903.[156] An early illustration of terra cotta partition blocks appears in the 1902 catalogue of Goodlet & Smith, Sydney,[157] and the Doonside Brick Co reportedly made terra cotta blocks at the site more recently occupied by the State Brickworks.[158] By 1910 the

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149 Information from Stevan Stefanopoulos, 1997.

150 Robert Haddon, 'Australian Planning and Construction' in G A T Middleton [ed], *Modern Buildings* (6 vols, London, no date [c 1911), V, p 152.

151 Emery Balint, *Record of Commercial Buildings Constructed in the Victorian Era in N.S.W.* (3rd ed, 1987), p 152, ref *Building and Engineering Journal,* 6 August 1892, p 4; 6 July 1895, p 215.

152 Clive Lucas, Stapleton & Partners Pty Ltd, *General Post Office, Sydney* (Sydney 1991), p 33.

153 W S Law, 'Specifications of Residence Drummond St. Carlton for Mrs. L. Abrahams' (Melbourne 1891), p 6.

154 *Australasian Builder and Contractor's News,* 10 November 1888, p 431.

155 Balint, *Record of Commercial Buildings,* p 295.

156 Warwick Gemmell, *And So We Graft from Six to Six* (North Ryde [NSW] 1986), p 58.

157 Reproduced in Ian Evans, *The Australian Home* (Glebe [NSW] 1983), p 40.

158 Information from Lynne Dore, 1996.

Liverpool Steam Brick Co was advertising terra cotta lumber for fireproof floors, partition walls, &c,[159] and the Commonwealth Bank in Sydney, of 1914, has partitions of four inch [100 mm] terra cotta block - presumably lumber - supplied by this company.[160] In Brisbane terra cotta lumber was being marketed by Shannon's as late as 1936, perhaps because there was no locally produced cinder concrete block to compete with it.[161]

g. terra cotta buildings

In the United States the use of terra cotta for entire buildings, including the external walls, is especially associated with the National Fire Proofing Company, which was purportedly 'organized' in 1889,[162] though it was probably not at that stage involved in making wall blocks. However, Natco was not the first in the field, for as early as 1888 a three storey office block entirely of terra cotta lumber had been built in Cincinatti.[163] By 1891 complete terra cotta block buildings had been made by William B Owen of the Denver Terra Cotta and Lumber Company, who built several houses at his works in Hobart, Colorado, as well as his own country house.[164]

The idea of building of complete buildings rather than merely partitions, of terra cotta or terra cotta lumber, seems to have emerged in Victoria almost as early as in the United States. St Michael's Roman Catholic Church at Wandong is dated 1891 on the foundation stone, and is of terra cotta construction,[165] as are some other buildings in the area.[166] Some or all of these appear to be of solid terra cotta rather than lumber, which is unsurprising, given that precisely the same extrusion equipment could be used. Some terra cotta buildings seem to have been constructed at nearby Kilmore, and at Clonbinane a seven roomed brick and terra cotta villa was built in 1891,[167] presumably with a brick outer leaf and a terra cotta inner leaf. In quite a different category was a very substantial house built near Frankston, by the architect Peter Matthews. It was described as being of 'American lumber', but given the brick and cement foundations this seems to mean terra cotta lumber, not timber.[168]

A surviving house in the Melbourne suburb of Kensington, probably from about the turn of the century, is built of hollow square tubes - apparently of normal terra cotta rather than lumber - which are laid in stretcher bond and fully exposed externally. They are about 700 mm [2 ft 4 in] long and 115-120 mm high, and possibly square in

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159 *Building*, 12 December 1910, p 118.

160 Balint, *Record of Commercial Buildings*, p 186.

161 *Architectural and Building Journal of Queensland*, April 1936, p 28.

162 Their publications, such as *Fire Proof Construction* (5th ed, Pittsburgh [Pennsylvania] 1911), state 'Organized 1889' on the title page.

163 *International Fire-Proofer*, I, 3 (November 1888), p 25, followed by a detailed report on p 29, not sighted by the present writer.

164 *Industrial Chicago*, op cit, II, p 652.

165 J W Payne, *Pretty Sally's Hill* (Kilmore [Victoria] 1981), p 58 & illustration. Payne refers to it as being of terra cotta lumber, but inspection suggests that it is normal terra cotta.

166 These are readily visible, and some are identified by Dore as the Frisch house, Wandong Avenue; 'Youlden', on the Wandong-Kilmore Road; and the Wright house, Rail Street.

167 *Argus*, 28 February 1891, p 14: R Jennelly, CE, of Kilmore, calls tenders this villa at 'Clinbinbane' for Kenneth McKenzie.

168 *Argus*, 24 January 1891, p 3.

section, though that cannot be confirmed from inspection. They form a long party wall on the north-east flank of the house, which is a property boundary, and it seems that they must have been used so as to create a waterproof wall on the exposed face, for the rest of the house is of conventional brick.[169] The drawings for the Wimmera Inland Freezing Co Works at Murtoa, Victoria, of 1920, show the building entirely walled in terra cotta hollow 'tile', though framed in reinforced concrete. The outer walls consist of six inch [150 mm] tile in panels between the structural columns, than a twelve inch [300 mm] cavity filled with pumice, and then an inner leaf of four inch [100 mm] tile.[170]

In New Zealand there was a quite separate but partly analogous system of construction from about the turn of the century, in the form of R O Clark's patent stoneware blocks. these were not unlike concrete blocks in scale and appearance, and were glazed inside and outside to make them, it was claimed, non-absorbent and absolutely damp-proof.[171]

h. face blocks in the USA

In February 1894 hollow terra cotta blocks were subjected to strength tests, and at about that time the Frey-Sheckler Co of Bucyrus, Ohio, obtained exclusive patent rights to manufacture a device for ornamenting hollow building blocks and bricks, and placed this machine on the market. This development meant that the blocks could be given a finish with patterns such as diaper, vermiculation, rock face and crinkle, so that a stucco rendering would not be seen as necessary. The Ohio Hollow Block Co of Canton, Ohio, made use of this process and reported, in about 1894, that hollow tiles had begun to be used for walls especially in Ohio and Illinois, even for large business buildings and factories. They illustrated a seventeen inch [430 mm] wall of this construction, a s well as one in which the blocks were bonded like conventional cavity brickwork, in two leaves joined with hoop iron ties.[172]

The Frey-Sheckler plants, patterns, patents and goodwill, together with those of J W Penfield & Son of Willoughby, Ohio, were sold on 1 September 1896 to the American Clay-Working Machinery Co, which continued operations at both Bucyrus and Willoughby.[173] Amongst a wide range of brick and tile-making equipment, hollow block machinery occupies a remarkably small proportion of the company's

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169 59 Bayswater Road, Kensington, discovered by Terry Sawyer, 1996. This is in other respects a conventional single storey single fronted terrace-type house (though actually built detached) of late nineteenth century style.

170 J Wildridge & Sinclair Ltd [engineers, Melbourne & Sydney], 'Wimmera Inland Freezing Co. Works, Murtoa, Vic', drawings of 24 May 1920, 8 July 1920 &c, kindly supplied by Anne Douglas.

171 G W Phillips, *Designs for New Zealand Houses & Residences* (Christchurch [New Zealand] no date [c 1910]), unpaginated. Peter Sheppard of Auckland tells me that the Clarks were a farming family who began producing terra cotta ware for drainage and other purposes of their own in about 1893-5, and expanded from there.

172 *The Ohio Hollow Block Co* [brochure] (Canton [Ohio] no date [but c 1894 from the test results and testimonials included]).

173 *The American Clay-Working Machinery Co* [catalogue, Bucyrus [Ohio] no date [1898]), p 5.

catalogue.[174] However, the concluding pages include material on 'Durant's ornamented, Lap-jointed terra cotta blocks' or 'rock-faced hollow blocks', and illustrates houses and a 'business block' built of them, as well as the company's own pattern store and foundry buildings, which are built of plain-faced Durant hollow blocks. Also illustrated is a range of blocks with ornamental finishes, including the diaper &c already mentioned.[175]

It is apparent that the Durant connection has been inherited from the Frey-Sheckler company, for a colour plate showing a 'Romanesque' cottage built of these blocks still bears the name of Frey-Sheckler as the sole manufacturer of Durant dies. The text identifies the patentee as E G Durant of Pasadena, California, who it is said, wishes to licence only those makers who have suitable clay, and in limited numbers according to district. It is stated that the block industry has only 'been fully launched' in the present season, and that the most valuable improvements have been made within the last three months. Since the company's 1896 catalogue, it is claimed, the new developments have been such as to turn block construction into complete system, rather than just the use of simple blocks.[176] Rather surprisingly, given that this product never became a primary structural material in Australia, it was very quickly adopted in New Zealand in the form of 'Clark bricks', which were extruded hollow blocks approximately square in section. These were manufactured by Rice Owen Clark from the late 1890s to the Great War.[177]

In about 1930 Raymond Hill's McGraw Hill Building in New York was faced with terra cotta units of the sort which became known as 'ashlars', for they were substantial hollow-cored blocks, designed to be laid like bricks, although they were in reality no more than a facing for the real structure. A number of important American buildings at about this time were similarly faced in smooth-faced plain glazed terra cotta units - the reverse of the ornamental forms which had characterised the material in earlier decades.[178] This development does not seem to have reached Australia, where modern buildings used only tile-like terra cotta facings.

Terra cotta found limited acceptance as a walling material in England, and certainly was used very little, if at all, as an exposed finish. But systems approved in 1919-20 by the Standardisation and New Methods of Construction Committee included the Combined Concrete Construction Co's use of two leaves of hollow tile wall, filled with cement grout; William Higgins & Sons' interlocking terra cotta block; Walter Jones & Sons' 'Interloc' system of hollow terra cotta blocks; the National Brick Co's

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174 *American Clay-Working Machinery Co,* op cit, illustrates, p 42, an auger brick machine arranged for hollow ware; p 82, a cutting-table for hollow ware (in which the blocks are shown with a textured face); p 84, a board delivery carriage for hollow ware; p 85, another such for end construction hollow ware; and p 88, an 'Improved Centennial' machine (still bearing the Frey-Sheckler brand) for the production of tile, hollow building blocks, fire proofing and terra cotta lumber.

175 *American Clay-Working Machinery Co,* op cit, pp 271-293.

176 *American Clay-Working Machinery Co,* op cit, pp 271-293

177 Information from Jeremy Ashford of Auckland, 1993.

178 Susan Tunick, 'The Reign of Terra Cotta in the United States ... 1930-1968', *APT Bulletin,* XXIX, 1 (1998), pp 43-6.

hollow terra cotta interlocking blocks; and J H Thompson & Sons' hollow terra cotta blocks.[179]

i. Natco

There is something inconsistent in the claim that the National Fire Proofing Company was established in America in 1889, for a report in 1905 sets out its profit figures starting in 1902, when there is no reserve or previously established surplus, as if this was the first year of business.[180] The company's first identifiable publication dates from 1903, though I have yet to get access to a copy.[181] An advertisement of 1906 promotes the use of hollow terra cotta in the form of blocks for fireproof floors, sections of terra cotta to encase columns and girders, firring blocks for wall surfaces, and load bearing partition blocks, but there is as yet no hint of the material being used as the principal structure of the building, or for external walls of any sort.[182] In 1908 the company produced the first edition of its *Fireproof Construction for Houses and other buildings of Moderate Cost.*[183] The fifth edition, published in 1911, illustrates a house in Oak Park of the material, designed by Frank Demony of Chicago,[184] which tends to suggest that the material would be known to Frank Lloyd Wright, as this was in his stamping ground.

The Natco House for Six Thousand Dollars,[185] of 1912 consists of two parts: firstly, the prizewinning designs from a competition to design a house for $6,000 in Natco Hollow Tile, and secondly illustrations of houses built in this material, including at least one by Wright's erstwhile associate W B Griffin. Griffin is known to have designed a number of terra cotta tile houses, such as the Harry E Gunn house at Tracy, Chicago, of 1909,[186] but those that can be attributed so far are of tile made by the Denison Fire-Proofing Co of Mason City, Iowa, rather than by Natco.[187] The Denison Company appears to have developed for the first time the 'Denison "H" Walltile', which was extruded in an overall H-section in varying sizes and with

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179 R B White, *Prefabrication* (London 1964), pp 113-6.

180 *Clay Record* [Chicago)] XXVII, 4 (28 February 1905), p 41.

181 Henry L Hinton, *Catalogue of the National Fire Proofing Company of Pittsburgh, U.S.A.* (abridged ed, New York 1903) is held in stack at the Engineering Library, Columbia University, New York.

182 *'Sweet's' Indexed Catalogue of Building Construction* (1st ed, New York 1906), pp 89-92.

183 The 1911 edition states that the first edition was in 1908.

184 National Fire Proofing Company, *Fireproof Construction for Houses and other buildings of Moderate Cost* (5th ed, Pittsburgh [Pennsylvania] 1911 [1908]), pp 19-20.

185 National Fire Proofing Company, *The Natco House for Six Thousand Dollars* (Boston 1912), cited in a collection of Natco material offered for sale in Nancy Sheiry Glaister Fine and Rare Books, *List 15: Heavenly and Unheavenly Mansions* [New York, no date, but apparently distributed from 1 March 1990], items 139-143. It seems possible that Griffin was a winner in the competition. Peter Harrison states that in 1913 he won a competition for a model brick cottage for the Clay Products Exposition in Chicago, and this was built for $2,000: Peter Harrison, (Canberra 1995), p 63.

186 D L Johnson, *The Architecture of Walter Burley Griffin* (South Melbourne 1977), pp 46, 47.

187 C E White, *Hollow Tile* (Scranton [Pennsylvania] 1919), illustrates what is in fact Griffin's Rule house in Mason City, though it is not identified, and credits the photographs to the Denison company.

varying numbers of voids. It was not confined to Iowa but was sold, for example, by the Hay Walker company in Pittsburgh, Pennsylvania.[188]

In *The Natco Tex-Tile One-Family House* of 1917 are designs submitted in a competition, mostly of a retrograde cottagey nature, but for one in a pure Prairie School manner submitted - extraordinarily - by George E Elgh of 395 Collins Street, Melbourne.[189] The address is that of Griffin's office, and Elgh was an American who went to Australia to work for Griffin in 1913, though so little is known of him that until now even the spelling of his name has been in doubt. This serves further to confirm, even if indirectly, Griffin's own connection with the material. Natco was still using the term 'Tex-Tile' in 1928, which seems to be the date of its booklet *Tex-Tile Home Plans*, though the designs are of little interest either stylistically or technically.[190] So far as Natco was concerned the term was designed to stress the quality of the tile surface, for as C E White put it:[191]

> Textile is a form of hollow tile that combines the features of the hollow-tile blocks with those of face brick. The Textile block is a hollow-tile block in which the exposed faces are finished like a rough face brick. .... The wall has the appearance of being built of very large bricks, which gives it a peculiar attractiveness.

In this there is no specific resemblance to Wright's 'textile block', seemingly so named for the way the blocks were knitted together.

Frederick Squires, in *The Hollow-Tile House* of 1913, derives much of his material from Natco and rather confusingly refers to the 'Texture-Tile House', though most of the illustrated designs are stuccoed or roughcast to conceal the blocks. He discusses, amongst other things, the use of terra cotta blocks with the cores running vertically so that some can be filled with concrete, which he calls 'the grouted wall'. The blocks must be so designed that they can be laid staggered and still provide continuous vertical cores.[192] Except for this staggering of the blocks this much resembles Wright's textile block system. This is still more true when vertical steel reinforcing is introduced as well, as illustrated by Squires, though not described in the text.[193] The system also resembles Natco's 'imperishable silo' construction, in which the blocks are curved so as to create a cylinder, but are again laid staggered. The difference here is that the cores run through the blocks horizontally, as does the reinforcing. The horizontal edges are grooved, and into these grooves slots a flat bar, linking the courses above and below it, and is grouted in place with mortar.[194] American terra cotta silos - and it must be presumed that the reference is to the Natco type - were

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188 Hay Walker Brick Company, *Architectural Details* (Pittsburgh [Pennsylvania], no date [?c 1920]).

189 National Fire Proofing Company, *The Natco Tex-Tile One-Family House* (Pittsburgh [Pennsylvania] 1917), p 50.

190 National Fire Proofing Company, *Tex-Tile Home Plans* (Pittsburgh [Pennsylvania] no date [1928]).

191 White, *Hollow Tile*, p 26.

192 Frederick Squires, *The Hollow-Tile House* (New York 1913), pp 92, 97.

193 Squires, *The Hollow-Tile House*, p 120.

194 National Fire Proofing Company, *Natco Imperishable Silo built of Vitrified Hollow Clay Tile* (Pittsburgh [Pennsylvania] 1915), p 14.

reported in Australia in 1919 as an idea which might be useful here,[195] but there is no indication that anything came of it.

These American developments remained prominent after Australia had forgotten its own history of terra cotta block construction. In 1949 D V Isaacs and J W Drysdale of the Experimental Building Station in Sydney, reported that American 'structural tiles' were potentially useful in Australian building. What they reported on was a new product - a hollow extruded block measuring $11\frac{3}{4}$ x $5\frac{1}{16}$ x $3\frac{3}{4}$ inches [298 x 129 x 95 mm], so as to replace three of the small size American bricks. It had a glazed surface said to be little inferior to that of glazed tiles.[196] Nothing seems to have come of this recommendation, and the Australian relevance of Natco and similar American companies is more or less confined to their effect upon W B Griffin and his 'Knitlock' construction, discussed below.

j. Wunderlich structural blocks

By 1943 the Wunderlich Company in Australia, already well experienced in the manufacture of glazed ceramic facings, was producing 'ceramic glazed structural blocks' for construction purposes, designed to be 'a wall and finish in one'. The blocks were apparently extruded with hollow cores, while the facing was in a range of plain and mottled pastel colours, as well as black and white.[197] One can only infer, from the lack of subsequent reference to them, that they failed to penetrate the market.

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195 *Building*, 12 September 1919, pp 136-141.

196 D V Isaacs & J W Drysdale, *Building Techniques and Building Research* (Sydney 1949), p 37 & fig 2.

197 Wunderlich Ltd, *Wunderlich Limited, Melbourne Branch, Trade Price List* (Melbourne 1953), p 27.