7.03 Fireproof Construction

a brick vaulted construction
b French systems
c. Fox & Barrett's system
d Fairbairn's system
e Wilkinson's system
f Dennett's system
g John Sulman

Concrete was to be a major component of fireproof flooring systems, whether in combination with terra cotta elements, as discussed above, with timber, with iron or by itself. Other systems primarily dependent upon metal, such as Hartley's fire plates, Traegerwellblech iron, and buckled plates, are discussed below in the general context of metals. Fire protection devices are considered in the context of services. Other applications of cement for fireproofing purposes, such as 'Indian Dyphoor' are also duscused elsewqhere,

a. brick vaulted construction

Fireproof vaulted construction was originally devised in the cotton mills of northern England. William Strutt designed the Derby mill of 1792-3 specifically to be fireproof, and his Milford and Belper West mills followed soon afterwards. In these the shell was of conventional masonry, the columns were of cast iron, the beams and skewbacks were of timber sheeted with metal for protection, probably under David Hartley's patent (see below), and there were segmental brick vaults between the beams. Strutt's acquaintance, Charles Bage, designed the Benyon Marshall & Bage flax mill at Shrewsbury, of 1796-7, using cast iron beams for the first time, and essentially the same construction was used in the more famous Salford Twist Mill of 1799-1801, by Boulton & Watt.[1] It would seem that such vaulted fireproof construction was also used occasionally in private houses, for S H Brooks in about 1839 published a design for a small villa using segmental brick vaulting carried on cast iron girders, concealed from below by panelled plaster ceilings.[2] Parts of Charles Barry's Reform Club, London, of 1838-41, are similarly constructed,[3] and this sort of construction was to become common in public buildings in the United States.[4]

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1 A W Skempton & H R Johnson, 'The First Iron Frames', *Architectural Review,* CXXXI (March 1962), passim.

2 S H Brooks, *Designs for Cottage and Villa Architecture* (London no date [c 1839]), plates LIII, LIV. A similar system is mentioned in [J L Tarbuck], *The Builder's Practical Directo*r (Leipzig [c 1858]), p 100.

3 Sara Wermiel, 'The Development of Fireproof Construction in Great Britain and the United States in the Nineteenth Century', *Construction History,* IX (1993), p 7, ref

In Britain there was little advance in the principles of vaulted flooring as used in the cotton mills up to 1844 when William Fairbairn was commissioned by Samuel Holme of Liverpool to report upon fireproof construction, which Holme advocated should be used for all warehouses in that city. The arched vaults between the beams were to be formed of brick and filled over with lime concrete and laid with stone flags or tiles, except where a wooden floor was required, for which timber sleepers were cast into the concrete.[5] The system arrived belatedly in the United States, an early example being an engine room at the Charlestown Naval Yard in 1834-7, but even after this it was rare, as iron members were mostly imported, and very expensive, until about 1850.

Fireproof flooring of brick arches on cast iron girders: William Humber. *A Practical Treatise on Cast and Wrought Iron Bridges and Girders, &c* (E & F N Spon, London 1857), plate 56.

b. French systems

There were two French systems of fireproof flooring, the *Vaux* and the *Thuasné,* neither of which can have had much direct impact in Britain, still less Australia. But they are repeatedly referred to in British literature, and a paper by Thuasné was translated and read to the Royal Institute of British Architects.[6] Their indirect influence upon later systems developed in Britain cannot be discounted. It is not entirely clear whether they preceded or followed a rather looser proposal by J C Loudon in Britain, for roofing of concrete with iron rods embedded in it.[7]

The French systems are said to have arisen in 1840 because there was a strike of carpenters in Paris, as a result of which these two forms of concrete floor, both based upon plaster of Paris rather than cement, were used.[8] In the Vaux system round rods were placed close together and the ends hooked

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Edward Barry, 'An Account of the New Palace at Westminster', RIBA *Sessional Papers* (1857-8), pp 86, 90-1.

4 *Specifications for Building the Custom-House at Wheeling, Virginia* (Washington [DC] 1856), reproduced in *APT Bulletin,* V, 1 (1973), pp 79, 99.

5 William Fairbairn, *On the Application of Cast and Wrought Iron to Building Purposes,* (London 1854), pp 114-131.

6 William Humber, *A Practical Treatise on Cast and Wrought Iron Bridges and Girders, &c* (London 1857), p 105. In fact, according to Bernard Jones [ed], *Cassell's Reinforced Concrete* (London 1913), p 5, both systems were described in a paper to the RIBA by G R Burnell in 1849, and then more fully in a paper by H H Burnell in 1854.

7 Jones, *Cassell's Reinforced Concrete*, p 5. I have not so far been able to locate the reference in Loudon.

8 Jones, *Cassell's Reinforced Concrete*, p 5. Thomas Potter, *Concrete: its Use in Building* (new ed, 2 vols, London c 1894 [c 1872]), II, pp 159-150, mentions the strike in 1840 and the fact that forms of plaster of Paris cement flooring, which had been used on a small scale for a century, now came into their own: but he does not name the systems. R S Burn [ed], *The New Guide to Carpentry, General Framing and Joinery* (Glasgow, no date [c1870]), pp 331-2, describes and illustrates the Thuasné system, and he also refers to a strike in Paris (in 1846 rather than 1840), but does not connect this with the invention of the Thuasné system, still less the Vaux, which he does not mention at all.

over flat wrought iron bars placed 600 to 750 mm apart. Smaller bars were laced across and between the rods to create a network. Then flat boards were placed below as formwork, and a plaster of Paris slab cast around the iron elements.[9]

The Thuasné system: William Humber. *A Practical Treatise on Cast and Wrought Iron Bridges and Girders, &c* (E & F N Spon, London 1857), plate 57.

In the Thuasné system iron joists were used, and stirrups hung upon them to carry reinforcing rods. As described at a later date, the joists were wrought iron I sections, spaced apart one metre and given a slight upward camber. At one metre intervals each joist was encircled by a wrought iron band, and slots in the band on each side provided sockets for transverse rods spanning between the joists. On these in turn were placed light rods or *fautons,* parallel with the joists. Centring was placed beneath and a plaster slab about 75 mm deep cast around the transverse rods and fautons.[10] In each case we are really talking about an iron structure embedded in a plaster concrete, which itself could probably take very little compression even if the design allowed for it. In the same year another such system was patented by Louis Leconte, with some sort of iron plate truss from which rods were suspended to carry iron mesh for plastering.[11]

c. Fox & Barrett's system

The Fox & Barrett system: William Humber. *A Practical Treatise on Cast and Wrought Iron Bridges and Girders, &c* (E & F N Spon, London 1857), plate 57.

Generally fireproof floor construction was an expensive luxury of which few private owners availed themselves, but Dr H H Fox developed a new system of fireproof construction, and tried it out in about 1833 at his own house and private lunatic asylum near Bristol.[12] He patented it in 1844,[13] and he and his

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9 Humber, *Iron Bridges and Girders,* p 105.

10 *Notes on Building Construction,* part II (3rd ed, London 1887), p 376; also ibid (new ed, London 1901), p 150. The illustration (as is explained in 1887 but not in 1901) erroneously shows the *fautons* as flat rather than square.

11 Frederick Rings, *Reinforced Concrete Theory and Practice* (London 1910), pp 1-2; Bernard Jones [ed], *Cassell's Reinforced Concrete* (London 1913), p 5, gives the patent date of 9 July 1840. Potter, *Concrete,* II, p 137, dates Leconte's invention to 'about 1820'.

12 H H Fox & George Barrett, *On an Improved Method of Constructing the Floors, Ceilings and Roofs of Buildings* (London 1850 [paper read at the Society of Arts, 19 December 1849]), p 9.

13 Potter, *Concrete, II*, p 151. B L Hurst, 'Concrete and the Structural Use of Cements in England before 1890', in Frank Newby [ed], *Early Reinforced Concrete* (Aldershot [Hampshire] 2001), p 39, note 35, cites British patent no 10,047 of 1844 to H H Fox for 'Fire-Proof Roofs, Floors and Ceilings'.

partner George Barrett believed that the system could be used at no increase over ordinary building costs.[14] The system was not in fact entirely novel, for decades earlier Lord Mahon (later Lord Stanhope) had proposed something very similar for use between timber joists. Fillets of timber were nailed to their sides, short lengths of lath laid across between them, and a layer of rubble concrete placed on top of the laths.[15]

In December 1849 Fox and Barrett read a paper to the Society of Arts on the method. The ceilings were flat rather than vaulted, and they had the advantage of not requiring tie rods to resist lateral thrust. Cast iron joists of an inverted T-section were used in place of the usual timber ones, and close-set strips of timber or other material were laid between them, resting on the flanges. Over these strips a bed of mortar was placed, and then a mass of concrete extending well past the upper edges of the joists. Onto the concrete a wood or other floor was placed, and the underside of the assemblage was plastered.[16] It has been claimed that wrought iron joists were used in Fox & Barrett's system by the early 1850s,[17] and certainly William Humber's illustration of the system in 1857 shows symmetrical I-section rolled wrought iron joists, though oddly enough alternating between 6 inches [150 mm] and 4 1/2 inches [115 mm] in depth.[18]

Fox and Barrett's system was used in Parliament House, Ottawa, and is clearly represented in a drawing by the English-born architects Thomas Fuller & Chilion Jones, of 21 October 1859, with rolled I-beams in which the bottom flange was larger than the top one.[19] The system was apparently specified by name in 1859 and 1863 for the construction of the East and West blocks of the Departmental Buildings in the parliamentary complex Ottawa,[20] designed by Thomas Stent and Augustus Laver.[21] In 1865 J Fuller proposed Fox &Barrett's system for the upper floors of the Bombay Police Courts building.[22]

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14 Fox & Barrett, *Improved Method of Constructing Buildings,* p 13.

15 Association of Architects, *Resolutions of the Associated Architects; with the Report of a Committee by them appointed To consider the Causes of the frequent Fires, &c* (London 1793), pp 114-131.

16 Fox & Barrett, *Improved Method of Constructing Buildings,* passim. See also Tarbuck, *Builder's Practical Director,* pp 110-111.

17 Sara Wermiel, *The Fireproof Building: Technology and Public Safety in the Nineteenth-Century American City* (Baltimore 2000), p 59, citing Lawrance [*sic*] Hurst, 'The Age of Fireproof Flooring' (publication details not apparent), p 35.

18 Humber, *Iron Bridges and Girders,* p 103 & pl 56.

19 Reproduced in C E Peterson, 'Inventing the I-Beam', in H W Jandl [ed], *The Technology of Historic American Buildings* (Washington 1983), p 91.

20 Canada, Heritage Conservation Program, Architectural and Engineering Service, Public Works Canada, *Architectural Conservation Technology Volume VII Period Construction Technology* (Ottawa 1994), section 3, pp 5-6, citing Canada, Department of Public Works, Specification and addendum for construction of Fox and Barrett fireproof floor (apparently a description of two documents, not a title), 1859 & 1863. The East Block is apparently referred to in the 1859 document, and the 1863 document, which apparently names the Fox & Barrettt system, I take to refer to the West Block.

21 Eric Arthur & Thomas Ritchie, *Iron: Cast and Wrought Iron in Canada from the Seventeenth Century to the Present* (Toronto 1982), p 158. Dorothy Mildenhall has advised, 2009, that Arthur & Ritchie's attribution of the buiilding to Frederick and Augustus Laver is incorrect. These authors are also incorrect in describing the original

The range of materials which could be used in place of timber strips was limitless. At the Liverpool Exchange, in the 1850s, a foreman is said to have suggested triangular terra cotta tubes, and these were used between I-beams, but are said to have bonded poorly with the plaster on the under surface.[23] According to Humber, however, Barrett himself recommended 'drain pipes of triangular section' in place of strips of wood.[24] The advantage was of course that the materials were entirely incombustible. Despite some superficial resemblance, Fox & Barrett's system is quite distinct from that in which iron joists carry large flagstones, which had been used in 1811-14 at the Chatham Dockyard, and elsewhere in Britain over the next three decades.[25]

The first Australian example is probably the roof in the two storey portion of the Sydney Mint buildings. The coining hall and other buildings were completed in 1855 behind the existing south wing of the old Rum Hospital, which became the administration block, and the iron structural components were supplied by John Walker of London.[26] The buildings were stone walled, but with iron columns, upper floor and roof structure, and there is every reason to suppose that the Fox and Barrett system was part of the original conception. It is not open to proper inspection, but it appears that iron members (which are probably inverted Ts, though only the underside of the flange is visible) are spaced at about 300 mm, and carry pieces of slate resting on the flanges, and then a crude layer of concrete perhaps about 80 mm thick.[27] The records show that Kirk & Parry, of Britain, supplied thirty-five squares [465 sq m] of 'slate with sawn edges and joints 12 inches wide in lengths of [?] inches and upward and averages half an inch in thickness.'[28] Fox and Barrett's system is also reported to have been used in the main floors of Parliament House, Brisbane, as built in 1865-6.[29] However, it is

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Fox & Barrett system as using wrought iron beams, for that was a substantially later development.

22 J Fuller, 'Designs for Bombay Police Courts', in Royal Engineers, *Professional Papers on Indian Engineering,* no LXXXV (c 1865-6), p 325.

23 C D Elliott, *Technics and Architecture* (Cambridge [Massachusetts] 1992), pp 45-6, quoting S B Hamilton, *A Short History of the Structural Fire Protection of Buildings* (London, HMSO, 1958), p 14. Elliott also illustrates the system, from the Institution of Civil Engineers, *Proceedings,* 1890-1891.

24 Humber, *Iron Bridges and Girders,* p 104.

25 Wermiel, *The Fireproof Building,* pp 41-2, quoting Jonathan Coad, *The Royal Dockyards 1690-1850* (Aldershot [Hampshire] 1989), pp 54, 237-9.

26 The buildings are described in the *Illustrated Sydney News*, 28 April 1854, p 203. The surviving records are the Royal Mint, Sydney Branch: Letters received 1853-1855, Archives ref 2/763-2/765, at the Mitchell Library, Sydney. The Deputy Mitchell Librarian has kindly had the material checked, and extracts have now been reproduced in Fiona Starr et al, *The Royal Mint, Sydney (1853-1926): a Survey of the Documents Associated with the Mint* (Sydney 2001), passim.

27 Inspection 1994, and information from Eddie Butler-Bowdon of the Powerhouse Museum, based upon his further archival research.

28 Invoice of Kirk & Parry, 2 December 1853, Archives Office of New South Wales 2/763, p 2, cited in Starr, *The Royal Mint,* p 18.

29 *Builder,* XXIV, 1243 (1 December 1866), p 885.

impossible to be sure that it was the original system rather than one of the improvements which were by then current, and had reached Australia.

In Cheyne's system corrugated iron strips were bolted onto the base of iron girders in place of the wooden strips of Fox & Barrett,[30] but as the original invention envisaged the use of material other than wood it is not clear how this could be a substantial innovation. In Cooper's system, likewise, the wooden strips were replaced by corrugated iron, resting on the flanges, and Eyland & Burn illustrate versions of Fox & Barrett's system using deep I-sections rather than inverted Ts.[31] Burn later illustrates a version of Cooper's system similarly modified by the use of I-sections.[32]

A version of Cheyne's or Cooper's system was used in J J Clark's Treasury Building, Melbourne, of 1857-62: so far as inspection has been possible, it consists of cast iron inverted T joists, across the flanges of which rest sheets of five inch [127 mm] pitch corrugated iron, on which is a thin layer of loose limey concrete, though this is shallow and does not cover the joists. There is a quite separate timber floor structure above this. Remarkably, however, this work at the Treasury predates Cheyne's patent, of 1863: the date of Cooper's invention has yet to be established. Elsewhere in this building arched corrugated iron is used between joists, and the concrete is filled up to become a screeded floor surface, but this form is more directly related to the iron vaulted system invented by James Nasmyth, which will be discussed below.

Something of the sort was also used in South Australia, though it is unclear what material supported the concrete, or indeed whether removable formwork was used. this was at the Parkside Lunatic Asylum, which the Government Architect was determined to build fireproof, and the structure consisted of rolled wrought iron joists spaced about two feet [600 mm] apart, filled between with cement concrete. The upper surface was either paving stones or cement, or where a timber floor was required, this was carried on joists bedded in the cement, so that the fireproof principle was not compromised.[33]

d. Fairbairn's system

In the years immediately following his report for Holme, Fairbairn, like I K Brunel, became an advocate of wrought iron in construction. In 1854, when he published his *On the Application of Cast and Wrought Iron to Building Purposes,* Fairbairn reproduced his report for Holme, but also proposed a sensible scheme in which the columns were of cast iron, well adapted to compression, and the beams of wrought iron, a far better material in bending.

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30 Potter, *Concrete,* II, p 157.

31 E S Eyland, Francis Lightbody & R S Burn, *Working Drawings & Designs Architecture and Building* (Edinburgh, no date [c 1863]), essay 1, p 4, & pl xxxvii figs 1-6; R S Burn, *Modern Building and Architecture* (London, no date [c 1870]), p 24 & pl xxxvii figs 1-6; R S Burn, *Building Construction* (London 1871), p 39.

32 Burn, *Building Construction*, p 39.

33 Burn, *Building Construction*, p 39.

The vault was formed of curved plate iron, rather than of brickwork, and again filled above with concrete. The tie rods to resist the spread of the arched vaults would normally be at the springing point, but Fairbairn located them above the crown of the vault, because he thought that they spoiled the appearance of the vaulted ceiling below. By doing so he fortuitously ensured that they were completely encased in concrete and protected from fire, for when fully exposed they would have been the weakest link in the system.[34] The system does not appear to have been Fairbairn's own invention, but rather that of James Nasmyth, as will be discussed below.

e. Wilkinson's system

A number of systems were developed in England by William Wilkinson of Newcastle-on-Tyne who obtained a patent in 1854 which includes segmental concrete vaults, but reinforced with horizontal bars, or with draped wire cables.[35] In the latter we can now see that he had arrived intuitively at a very effective system of taking the tension, in the fashion of true reinforced concrete. Even in the nineteenth century he was recognised as the first person to devise a floor of concrete, which itself carried most of the load, and in which such iron as there was not visible.[36] W B Wilkinson & Co, using broken coke, sand and Portland cement, which was stronger, and allowed a wider spacing of the joists. Wilkinson's system is said in a slightly later text to be 'very like Dennetts' (which is discussed below) 'but the arches are of concrete granite and the ceilings formed with fibrous plaster slabs.' It had been used at Edinburgh University, in several stations on the North-Eastern Railway, by the War Department, and in many warehouses.[37]

f. Dennett's system

The next system, developed in 1857 by Charles Colton Dennett of Nottingham,[38] also used concrete without any brick or iron vault beneath. This was known as the 'Dennett arch', and was not particularly radical except

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34 South Australia, Government Architect, *Report from Government Architect* (Adelaide 1870), no page.

35 British patent no 2293 to W B Wilkinson, 1854, for 'Construction of Fireproof Buildings, &c', cited in B L Hurst, 'Concrete and the Structural Use of Cements in England before 1890', in Frank Newby [ed], *Early Reinforced Concrete* (Aldershot [Hampshire] 2001), p 40, n 28; R J M Sutherland, 'Pioneer British Contributions to Structural Iron and Concrete: 1770-1855', in C E Peterson [ed], *Building Early America* (Radnor [Pennsylvania] 1976), p 114, referring to Joyce M Brown, 'W B Wilkinson (1819-1902) and his place in the History of Reinforced Concrete', *Transactions of the Newcomen Society,* XXXIX (1967).

36 Potter, *Concrete,* II, p 155.

37 *Notes on Building Construction: Part II* (new ed, London 1901), p 140.

38 British patent no 685 to C C Dennett, 1857, for 'Floors and ceilings', cited in Hurst, 'Concrete and Cements'', p 39, n 17; Potter, *Concrete,* II, pp 155-6.

for the fact that it was made with calcined gypsum plaster, rather than cement. It was described in general and rather imprecise terms as follows:[39]

> They execute a groin, dome, or circular ceiling of any length, width, or height, without tie rods or intermediate supports, at much less cost than can be done by any other fireproof material. .... Very few iron girders are required. For floors, although in an arched shape, it is in reality a beam, as a complete floor can be turned from wall to wall, resting on a projection of brickwork, and the material be left without any abutment. Its durability equals stone; and its strength is equal to brickwork .... The material (a concrete of broken stone or brick embedded in gypsum calcined at a red heat) ...

A second and somewhat improved patent was taken out by Dennett in 1863,[40] and it is to this that a description published later in the century, must relate:[41]

> Dennett's Fireproof Floor consists of concrete arches supported where they abut upon the walls by projecting courses, and at intermediate points by rolled or rivetted iron girders ...
>
> The arches should have a rise of 1 inch to every foot of width up to spans of 10 or 12 feet, and are sustained by centering until they are thoroughly set.
>
> The concrete used has sulphate of lime (gypsum) for its matrix. It has been proved that this substance does not lose its cohesive power even when it is raised to a white heat and then drenched with cold water.
>
> The floor above the arch may be formed by simply bringing the concrete itself to a smooth surface. Joists may be nailed to fillets laid upon the concrete ... or the
> surface may be paved ...
>
> The soffit of the arch may be finished at once with the setting coat of plastering; or, if a flat ceiling is necessary, joists must be fixed to the lower flanges of the girders to carry the lath and plaster.

According to R S Burn, Dennett's arches could span from 6 to 12 feet [1.8 to 3.6 m], and would vary in depth, according to the span, from 3 to 5 inches [76 to 130 mm] at the crown, and 5 to 10 inches [130 to 255 mm] at the haunches.[42] Elsewhere Burn illustrates them in entirely different proportions - the drawings are not scaled, but if the rolled joists are taken to be as large as

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39 Joseph Gwilt [ed Wyatt Papworth], *An Encyclopædia of Architecture* (London 1899 [1842]), p 566.

40 Potter, *Concrete,* II, pp 155-6.

41 *Notes on Building Construction: Part II* (3rd ed, London 1887), pp 372-3.

42 R S Burn, *The New Guide to Carpentry, General Framing and Joinery* (Glasgow, no date [c 1870]), pp 336-7, pl 129.

300 mm deep, the span of the arch is less than a metre, and the probability is that both dimensions are smaller. Henry Conway used Dennett flooring at St Thomas's Hospital, London, and Thomas Hardy sketched this in his notebook, in what look like the smaller dimensions shown by Burn.[43] Dennett took out an American patent for his concrete arch in 1870,[44] and it was soon afterwards being used in Australia.

Clark used Dennett's system, or something very like it, in the Registrar General's office, Melbourne, of 1874-89. There, inspection shows that the bottom flanges of the beams are visible, with an apparent division line along the centre, suggesting that they are built-up from at least two smaller sections. Round bolt heads spaced at intervals support this interpretation. The surface of the segmental vault between appears, by looking at points where it is penetrated by later fixtures, to be of plaster and/or concrete without any layer of metal. Another more or less scientifically designed fireproof floor was that of the Central Grain and Produce Stores in Sussex Street, Sydney, of 1885. Here the refrigerating system in the cellar was a fire hazard, and the architects, Kenwood & Kerle, were reported to have roofed it using 'Dennett's Arching', consisting of iron joists carrying arched plates, with concrete over.[45] The problem with this is that the use of arched iron plates is characteristic not of Dennett's system but of the earlier floors of Fairbairn and others.

J J Clark was to use Dennett's system again for the Brisbane Treasury, where the specification calls for[46]

> All coke concrete floors and ceilings to have strong framed centres, accurately formed on strong supports, and not struck until permitted. Where allowed, a portion of centering can be available for continuation of similar work.
>
> ....
>
> The arcades and all floors, tinted light blue on Ground, First, Second, and Third Floor Plans, also all floors of earth-closet buildings, to be formed with coke concrete, as follows:-
>
> Four parts of coke broken to about one-inch cubes, two parts of clean-washed sand, and one part of cement, as before described.

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43 Thomas Hardy, *The Architectural Notebook of Thomas Hardy* (Dorset Natural History and Archaeological Society, Dorchester [Dorset] 1996), p 60 (sketch) and unpaginated note towards the end. Richard Fellows, *Edwardian Architecture: Style and Technology* (Lund Humphries, London 1995), p 52, identifies the building.

44 US Patent 989, 571 of 4 January 1870, cited by Wermiel, 'Development of Fireproof Construction', p 19.

45 *Town and Country Journal,* 13 September 1873, p 196, 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 82. Dockrill illustrates Dennett's arching, p 145.

46 *Specification of the Material and Works required in the erection of Public Offices, Brisbane, &c.* (contract signatures 27 April 1886) (held by the Historic Places Branch, Brisbane), pp 22, 38. Reference is made, pp 16-17, to drawings 8 and 9 for the arcaded concrete floors over the first and ground floors, drawing 10 for those over the corridors. These I have not sighted .

> The concrete to be pressed firmly into the flanges of girders, chases, and in every part, and firmly consolidated on the centering; and centering not to be struck until permitted by the Colonial Architect.
>
> The surface to finish within 11/4 inches of the floor, formed truly to the falls indicated, and channels and openings left as required.
>
> The arched concrete to be 6 inches thick at the crown, and flat concrete 7 inches all through.

In Adelaide the Sands & McDougall Building in Light Square, of 1888-9, designed by D Garlick & Son, used what sounds like Dennett's system, 'arches turned in cement concrete and resting on iron joists', which rendered it almost fire resistant, according to the Mayor's report in 1889.[47] However, the fact that the bottom flanges of the joists were exposed to fire was a weak point of both Dennett's and Wilkinson's systems. Dennett & Ingle, as the firm seems to have become, by 1901 had a 'system' of encasing both the columns and the girders in concrete, though the system consists of little more than just that - putting concrete around them.[48] The encased columns are reminiscent of those at the Brisbane Treasury, though the girders are not. Dennett & Ingle were still advertising the original fireproof floooring system in 1904.[49]

In South Australia the Government Architect's Department designed the Parkside Lunatic Asylum in 1870 to be fireproof, 'with milled iron girders from the Dowlais works, in South Wales, placed as joists, about two feet apart and the spaces filled up with cement concrete'.[50] This is not a sufficient description to identify it with any specific overseas type, but it suggests that the joists were at least largely encased in the concrete, which is advanced practice for the date.

g. John Sulman

In 1888 John Sulman presented a paper to the Australian Association for the Advancement of Science in which he discussed ways of making construction fireproof or fire retardant. One of these was to place concrete between timber floor joists, better still to form a continuous concrete soffit 25 to 50 mm below the joists, and better again to bind the supporting iron girders with hoop

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47 Susan Marsden et al [eds], *Heritage of the City of Adelaide* (Adelaide 1990), p 68.

48 *Notes on Building Construction: Part II* (new ed, London 1901), p 152.

49 Wiiliam Laxton, *Laxton's Price-Book for Architects, Builders, Engineers & Contractors* (87th ed, Kelly's Directories, London 1904), advertisements p 50.

50 Report from Government Architect, 21 March 1870 (extract from official printed papers, unpaginated)

iron and wire netting and to cast cement onto this.[51] A technique which is found in Toowoomba, Queensland, at about the turn of the century, and which can probably be attributed to the local architect Harry Marks, was to pour lightweight breeze concrete between the studs of a conventional timber frame, rather in the manner of brick nogging.[52]

Coke breeze aggregate, as we have seen, had been used by Fairbairn, mentioned in Wilkinson's patent, and employed locally by James Barnet and J J Clark. It was favoured both because of its lightness and because it would not explode in extreme heat: in fact coke breeze concrete was already being widely used over arched iron sheets even in floors where the structural iron was exposed, and therefore vulnerable.[53] Such construction, and the use of Traegerwellblech iron in particular, is discussed below under the heading of 'structural corrugation'.

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51 John Sulman, The fireproofing of City Buildings', *Australian Association for the Advancement of Science*, 1888, p 575, quoted in Emery Balint et al, *Warehouses and Woolstores of Victorian Sydney* (Melbourne 1982), pp 100 ff.

52 Morag Papi, *James Marks and Sons, Architects, Toowoomba* (no place or date [?Brisbane]), p 32.

53 Lands Department Building, Sydney, of 1876, cited in [Diane Kell], 'Concrete in Australia', special issue of *Constructional Review*, L, 4 (November 1977), p 12; galleries of the Rialto Building, Melbourne, 1888; CML. Building, Sydney, 1892, details drawn by Robert Irving reproduced in Balint, *Warehouses and Woolstores,* p 104.