7.02 Concrete

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a. flooring and paving

We have discussed above various forms of earth flooring, which might contain cupola ashes, iron filings, ox blood, and milk or fat, but which, according to the proportion of lime or cement, gradually approached the character of true concrete. Similarly, Major Mitchell noted that a very hard mortar for use in pointing might be made by adding coal ashes and iron filings, or the sweepings from a forge.[1] In Britain more sophisticated products based upon the newly available Portland cement were used to make flagstones, and were referred to as 'artificial stone', though they were not capable of being used in the more ornamental forms later associated with that term. One which was available in Britain by the mid-century was 'Buckwell's Granetic [*sic*] Breccia Stone', reportedly made of natural stone chippings and Portland cement, formed into slabs under hydraulic pressure. This could be used for paving, water tanks, stair treads and other purposes, and it was made by William Buckwell at the Phoenix Stone Works, East Greenwich.[2]

'Victoria stone' was another material used to make precast flagstones. According to an English description it was made from four parts of washed and finely powdered granite and one of Portland cement, allowed three days to set, and then immersed for seven to eight weeks in a sodium silicate solution. In 1854 it was advertised in Melbourne as follows:[3]

VICTORIA ADAMANTINE STONE COMPANY

> It is alleged that the stone manufactured by this company is superior to the finest Yorkshire stone, inasmuch as being void of stratification it will not wear into holes. Slabs can also be made from one to ten or fifteen feet [0.3 to 3 or

[1] Sir Thomas L Mitchell Memoranda Book, 1827-1829, Mitchell Library, manuscript ML C38, reel CY 1992.
[2] Robert Burn, *The Mason's, Bricklayer's, Plasterer's and Decorator's Practical Guide* (London, no date [c 1850]), pp 15, 18-19.
[3] *Argus,* 13 June 1854.

> 4.5 m] square, of any thickness. It is also admirably adapted for stables, halls, sewerage and pavement gutters.

The company hoped to be commissioned to pave the city streets, and had already laid a section of paving in Elizabeth Street. The material was shown at the Melbourne Exhibition of 1854, and was also claimed to be suitable for large building blocks,[4] but it does not appear to have achieved any success.

In 1859 cast cement elements were used in the South Australian Institute Building in Adelaide.[5] In 1859 a patent application was made in Victoria for a paving and flooring material which was again a form of concrete: 'road metal or broken stones covered with Portland cement and sand, ultimately washed over with a solution if alum'.[6] This resulted in an indignant protest from Joseph Sullivan, who pointed out that several people including himself had been making these 'artificial stone' floors for some years, one example being the Lennox Street brewery which was then nearing completion. Furthermore, according to Sullivan, Waugh had put down one of his floors in the Houses of Parliament, Melbourne, and it had been a decided failure.[7] Waugh and Hyslop's patent was nevertheless granted, which suggests that their practice was significantly different.

Concrete was fairly readily accepted for flooring in Australia. In Sydney it was used in 1870 by the City Engineer, Edward Bell, for some of the peripheral rooms at the exhibition building in Albert Park, and in 1871 for the main market area of the Council's Woolloomooloo Fish Markets.[8] It was especially favoured as the basis for laying tessellated tiles, and St Mary's Cathedral Sydney had a concrete floor of which the northern end was poured in about 1880.[9] Henceforward there were still only occasional concrete walls, or complete buildings, but concrete foundations and fireproof floors became fairly standard.

b. artificial stone

'Artificial stone' was a term commonly used for materials such as the Victoria Adamantine Stone and the paving discussed above, but especially for materials which could be cast into ornamental forms, and which were usually, but not always, cement-based. The phrase had originally be used in Britain to refer to forms of terra cotta, but by the mid-nineteenth century it was generally understood to be a hard and non-absorbent mixture of a hydraulic cement and sand cast in moulds, or else a patent compound of silicates. An early variety, given a reward by the Society of Arts in

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4 *Official Catalogue of the Melbourne Exhibition, 1854* (Melbourne 1854), p 17. Patrick Hayes of Sandridge (Port Melbourne) was named as the manufacturer.

5 Information from Bruce Harry, 1991.

6 No 221 to Michael Waugh & Andrew Hyslop, 16 May 1859; also reported in the *Australian Builder*, 21 May 1859, p 159.

7 *Australian Builder*, 28 May 1859, p 164.

8 *Sydney Morning Herald*, 30 August 1871, p 5; *Town and Country Journal*, 23 September 1871, p 400, quoted by L J Dockrill, 'Developments in Architecture in New South Wales during the Victorian Period' (6 vols, PhD, University of NSW, 1983), I, p 80.

9 Howard Tanner, 'Early Reinforced Concrete Frame Buildings in Sydney' (BArch Architectural Science thesis, University of Sydney, no date), p 3.

1813, was Wilson's composition for artificial stone chimneypieces, the constituents of which are not known.[10] In the following year Felix Austin of New Road, London, perfected the use of Roman cement in an artificial stone used for architectural ornaments, but in 1819 he changed over to Atkinson's (Yorkshire, or Mulgrave) cement, and then by 1830 was using Portland cement.[11] Austin's products were substantially promoted in Loudon's *Architectural Magazine* in the 1830s.[12] Austin was succeeded in the business by J Seeley, under the style of Austin & Seeley,[13] and by the 1840s the firm were advertising ornaments in artificial stone 'of their own peculiar Composition, without either the use of Roman Cement or the application of Heat.'[14] This is slightly confusing because a John Sealy had been associated with Eleanor Coade junior in her manufacture of artificial stone, in this case not a cement-based material but a form of moulded terra cotta, which has been discussed above.[15]

At this point the imprecision of the terminology becomes a more general problem. William Ranger, a builder in Brighton, England, was - as will appear below - a pioneer of both concrete blocks and monolithic construction, and he called his product 'artificial stone', though it can have been little more than common concrete. In France Manpar used the same term in 1826 to describe a composition invented by Dihl, which was plastered over brick basins and orange tree boxes. It was made of porcelain or salt glaze potsherds ground fine and mixed with boiled linseed oil. When set it resembled polished white marble, and it would ring like a bell if struck with a trowel.[16] A later French type, known as Sorel stone, was made by calcining magnesite and mixing it with sand or powdered marble, wetting it with a waste liquid from saltworks, which contained magnesium chloride, and stamping it into moulds.[17] Yet another artificial stone invented on the Continent was Furse's mineral cement. It was used in drainage, fortification works, and as mortar, but it could also be cast into slabs for use as flooring. It was dark-coloured, non-absorbent, durable and very hard.[18] It was in fact rather comparable with the 'Victoria Stone' discussed above.

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10 Wyatt Papworth [ed], *Dictionary of Architecture* (in parts, London 1853-92), sv Artificial Stone.

11 Papworth, *Dictionary of Architecture*, sv Austin's Artificial Stone.

12 *Architectural Magazine,* I (1834), pp 122-3, 159, 163, 216 [here his foremame appears], 295-302; II (1835), pp 123-6. For 'Austin's Artificial Stone', see also Joseph Gwilt [ed Wyatt Papworth], *An Encyclopædia of Architecture* (London 1899 [1842]), [§ 1903e], p 56, [§ 1677p], p 482.

13 Papworth, *Dictionary of Architecture,* sv Austin's Artificial Stone. Alison Kelly, *Mrs Coade's Stone* (Upton-upon-Severn [Worcestershire] 1990), p 51, has Seeley first joining Austin in 1843, and later succeeding to the business.

14 *Builder,* I, 1 (31 December 1842), pp 12-13: this appears to be the same firm and the address is still in New Road. In 1853 chimney pots were still being advertised by J Seeley of Austin & Seeley's Stone Works, Keppel Row, New Road: *Builder,* XI, 539 (4 June 1853), p 366.

15 This original John Sealy had died in 1813, but it is possible that the Sealys and Seeleys were in fact the same family. The name certainly caused confusion, for Robert Robson, for example, refers to Coade's partnership with Seeley, at Belvedere Road, Lambeth; Robert Robson, *The Mason's, Bricklayer's, Plasterer's and Decorator's Practical Guide* (London, no date [c 1850]), p 15.

16 Papworth, *Dictionary of Architecture,* sv Austin's Artificial Stone; Andrew Ure, *A Dictionary of Arts, Manufactures and Mines* (London 1839), sv Mortar.

17 *Notes on Building Construction .. Part iii: Materials* (London 1879), p 76.

18 Papworth, *Dictionary of Architecture,* sv Furse's Cement; *Builder,* VII, 316 (24 February 1849), p 95; IX, 432 (17 May 1850), p 322; *Illustrated Exhibitor* (published in parts, London 1851), p xxxviii.

The use of Sullivan's 'artificial stone' in Melbourne for both stucco and flooring has been mentioned already, but in 1859 Joseph Sullivan won a prize offered by the Melbourne City Council for the design of a fountain, and he proposed that it should be built of his 'Imperial Stone', which 'from its lasting and non-vegetative properties' was claimed to be very suitable, and less than half the cost of real stone.[19] Later in the year he informed the gentry, architects, surveyors, artists &c that they could be supplied with statues, fountains, vases and architectural enrichments made of his[20]

> Improved Artificial Stone, which surpasses in durability and appearance any yet produced; it is of a light tint and requires no painting or colouring, and is equal to the finest Portland: exposure to the atmosphere gives to the composition the hardness of granite, improves the colour, and renders it quite impervious to damp; it is not affected by the most severe frost or heat; it is unlike the spurious article that is imposed on the public under the name of Artificial Stone.

The most widely advertised and possibly the best known artificial stone of the period was not based on cement at all. It was patented in England in 1844 by Frederick Ransome,[21] the inventor of the equally well-known silicate indurating process. It was made by cementing broken or pulverised stone with a solution of silica in caustic alkali - that is, water glass - and moulding it under pressure to produce a dense compound suitable even for grinding. It had a crushing strength of about 64 to 73 MPa, which was 800% stronger than Caen stone and nearly 25% greater than Darley Dale stone, one of Britain's toughest freestones.[22] As 'artificial silica stone' in the forms of urns and a balustrade it won a gold medal for Ransome & Parsons at the Great Exhibition of 1851.[23]

In 1853 or 1854 the recently arrived architect Charles Maplestone wrote to Frederick Ransome, seeking to be appointed as the local agent for his artificial stone, but was given the brush-off, as a result of which, Maplestone claimed, 'several good opportunities for introducing his stone are lost'. Ransome's company did, however, ship out fifty-three chimneypieces to another agent, through whom they were offered to Maplestone, but he could not afford to buy them.[24] The agents in question were probably the importers F B Franklyn & Co, who at the Melbourne Exhibition of 1854 showed 'Specimens of Patent Siliceous Stone Manufactures comprising bust of Sir Robert Peel, Ornamental mantel-pieces, imitation marble tiles, and Urn stand.'[25] The prominent London architect J D Sedding designed a fountain intended to be made in Ransome's Patent Stone and sent to Australia,[26] but if it arrived it has not so far been identified.

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19 *Australian Builder*, 26 March 1859, p 92.

20 C B Mayes, *The Victorian Contractor's and Builder's Price-Book* (Melbourne 1859), p G.

21 *Builder*, II, 93 (16 November 1844), p 573.

22 Wyatt Papworth [ed], *Dictionary of Architecture* (in parts, London 1848-92), sv Ransome's Artificial Stone.

23 *Illustrated Exhibitor* (serial, London 1851), p xxxviii: see also the *Illustrated London News*, XIX, 512 (23 August 1851), p 253.

24 Charles Maplestone to Marianne Miller, 27 April 1854, in [Charles Maplestone], 'Diary and Letters of Charles Maplestone on the Outward Voyage and in the Colony of Victoria' (no date, 1934, Archives, Melbourne City Council, no 2353/1), pp 53/5, 61.

25 Melbourne Exhibition 1854, *Official Catalogue* (Melbourne 1854), p 20.

26 Michael Darby, *John Pollard Seddon* (London 1983), p 104.

The first local patent application for a siliceous stone was made in 1861 by the architect James Robertson, but it was refused,[27] and a year later Ransome himself obtained a Victorian patent.[28] Not long afterwards another patent was granted to A C L De Lacy for the use of 'certain chemical fluids and operations' to produce, *inter alia,* an artificial stone,[29] but whether this was an extension of Ransome's product or a rival one is not apparent. An artificial stone patented in New South Wales by Nicolle and Mort of Sydney - presumably before 1877, as the patent had expired by 1891 - was made by mixing sixty parts of clean sand, eight of aluminium silicate; four of lime, and one of hydraulic lime.[30] By now, however, the term 'artificial stone' was dying out, and most ornamental castings were based upon Portland cement, as will appear below.

c. mass concrete

The first use of mass concrete in Britain was for foundations, beginning with the Millbank Penitentiary. William Ranger of Brighton (England) subsequently developed a method of building in concrete, and used it in 1832 in a wall for Lawrence Peel of Kemp Town. He used the lime of the nearby Downs in his mixture, moulded into blocks with 'all the nobleness of stone' in appearance, and he could also cast it as a solid mass *in situ.*[31] Ranger applied for a patent for it, as 'Ranger's Artificial Stone'.[32] Then the first all-concrete house seems to have been that built in 1835 by the cement manufacturer J B White at Swanscombe, Kent. All decorative and other details, including even the window frames, were of cement concrete.[33] In the United States Joseph Goodrich's 'Milton House' at Milton, Wisconsin, of 1844, was designed to be proof against incendiarism by the Indians, and used Portland cement imported from England.[34] In Australia, as elsewhere, mass concrete construction received a boost from the American phrenologist Orson S Fowler, who in 1854 published a book, *Homes for All,*[35] in which he argued for houses of 'gravel concrete' on an octagonal plan (which he saw as being phrenologically correct).

Occasionally by the 1840s complete concrete houses were built in Australia, but (to judge from the oldest surviving ones of the 1850s) they would have been crude structures with thick walls, and the concrete more like a rubble bound in inferior lime, or a form of pisé, than anything we would recognise as concrete today. In 1851 Charles Mayes saw concrete houses at Norwood near Adelaide, and in 1860 believed

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27 Victorian patent application no 501, not granted to James Robertson, 15 October 1861.

28 Victorian patent no 593 to Frederick Ransome, 20 November 1862.

29 Victorian patent no 602 to Alan Cameron Lyster De Lacy, 30 December 1862.

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

31 *Mechanic's Magazine,* XVIII, 484 (17 November 1832), p 112, quoting the *Brighton Gazette.*

32 *Mechanic's Magazine,* XVIII, 498 (29 December 1832), p 224.

33 A C Davis, *A Hundred Years of Portland Cement* (London 1924), p 64; C J Stanley, *Highlights in the History of Concrete* (Slough [Buckinghamshire] 1980 [1979]), p 17.

34 F A Randall, *History of the Development of Building Construction in Chicago* (Urbana [Illinois] 1949), p 16.

35 O S Fowler, *A Home for All, or the gravel Wall and Octagon Mode of Building* (New York 1854).

them to be still standing.[36] In 1852 Charles Pitt and his family built a concrete house in Adelaide, on the south bank of the Torrens near the site of the Felixstowe Bridge. It was made of river sand, gravel, rocks, and lime from Abbot's kiln, nearby at Payneham.[37] The architect C McCarthy designed the first church at Campbelltown, South Australia, of concrete with brick quoins, as well as concrete walls for the cellar of the East Torrens Winemaking and Distillation Company, both in late 1858.[38] At least one house was built in South Australia before 1860 of concrete on Edmund Coignet's system as discussed below. In Melbourne there survives a concrete house of the 1850s, at 23 Woolley St, Essendon, and another, probably of the 1860s or 1870s. at 10 Middle Crescent, Brighton. Another concrete building which survives in particularly good condition is 'Craiglee' at Sunbury in Victoria, built by J S Johnson in 1865.[39] Here, however, chemical analysis has suggested that the concrete was made with Roman or natural cement, rather than common lime.

Later in the nineteenth century concrete was if anything less favoured for rural buildings, but it persisted in remote areas. At Koonya, Tasmania, the architect Alexander North built in the 1880s a small 'rubble and concrete' house,[40] predecessor of the reinforced concrete structures with which the architect would later experiment. In rural New South Wales Morris Simpson, who had been impressed by the concrete breakwater at Aberdeen, built a concrete house with 300 mm thick walls at the property 'Stonehenge', which he acquired in 1886.[41] In 1888 the Townsville architects Tunbridge & Tunbridge reported that they had prepared plans and specifications for large concrete stores and offices in Darwin.[42] These were for the Townsville-based merchants Aplin Brown & Co, but it is unclear whether they were actually built. In Townsville itself a concrete house was built in German Gardens (later renamed Belgian Gardens) in about 1903, following a cyclone, but the details of the construction are not known.[43] At Broome, Western Australia, the customs house of 1889 appears to be of formed concrete (of unknown ingredients) and the old police lock-up of 1894 is of concrete and iron.[44] During the gold boom in Western Australia the government experimented with a form of concrete made with the *pindan* or rich red soil of the north-west. It provided the fines in a mix with cement, gravel and coarse sand, and produced a durable building material of a rich earthy colour. This was used for shuttered concrete walls at Broome and for blocks at Roebourne and Cossack.[45]

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36 Charles Mayes, 'Essay on the Manufactures more immediately Required for the Economical Development of the Resources of the Colony', in *Victorian Government Prize Essays 1860* (Melbourne 1861), p 493.

37 'Albert George William Pitt', anonymous undated typescript kindly supplied by Don Langmead of Adelaide.

38 E & R Jensen, *Colonial Architecture in South Australia* (Adelaide 1980), p 119.

39 Alan Gross, *History of the Shire of Bulla* (Melbourne 1962), p 24. A concrete house at the corner of New St and North Rd, Brighton [Victoria], was advertised for sale in 1876: *Argus*, 1 February 1876, p 2.

40 Peter McFie, 'The Retreat of Alexander North' (brief chapter from an unidentified publication, supplied by John Maidment, 2003), p 16.

41 G N Griffiths, *Some Northern Homes of N.S.W.* (Sydney 1954), p 119.

42 W F Morrison, *The Aldine History of Queensland* (2 vols, Sydney 1888), II, unpaginated appendix, sv Townsville.

43 Information from Peter Bell, 1991.

44 Information from Robin Campbell and Ingrid van Bremen.

45 Ingrid van Bremen, 'The New Architecture of the Gold Boom', (PhD, University of Western Australia 1990), p 151.

Portland cement concrete was now a generally viable option, and was listed, along with lime concrete and 'coke concrete for arches' in Mayes's price book for 1883.[46] Mass concrete was used also in increasingly major engineering works, culminating in the Beetaloo Dam in South Australia: when completed in 1888 this was the largest concrete dam in the southern hemisphere.[47] The major use of cement, however, remained cosmetic rather than structural, for stucco rather than structure. Local limes began to be used to a considerable degree for mass concrete in engineering works, but the introduction of cement for such purposes had generally to wait upon local manufacture being initiated.

d. béton coignet

It is necessary to appreciate the distinction, imprecise though it may be, between concrete and the French *béton.* Béton was said to be always made with hydraulic lime or cement, but concrete not necessarily so, and French practice was to make a cement slurry and then add the aggregate, whilst British was to add the water last.[48] British concrete was sometimes not much more than stabilised earth, whilst French béton more closely approached the engineering properties of what we call concrete today. The *Mechanic's Magazine* did not insist upon hydraulic lime or cement for béton, but said, on the contrary:

> The French *béton* is nearly identical with the English *concrete,* the main difference being the manipulation; thus *béton* is composed of lime, sand, and small pebbles, or broken stone, *taken separately,* and successively mixed together, the pebbles being added last; while *concrete* is usually formed of lime, mixed directly with gravel, *containing naturally* about the due proportion of *pebbles and sand;* proper quantities of water being used, and the factitious stone resulting, in both cases, being in effect the same.[49]

Edmund Coignet took out a French patent in 1859 for a béton in which lime, sand and water were mixed into a grout and poured over gravel.[50] Leonard Beckwith, one of the United States commissioners for the Paris Exposition of 1867, published a useful account of Coignet's material. First he defined common béton, which was a mixture of sand, pebbles, broken stones, common lime and water, except that hydraulic lime was used where it was for marine purposes. Béton-coignet, in contrast, was an 'artificial stone', and consisted of sand, lime and water - that is, no coarse aggregate. These were the same elements as in common mortar, but the proportions and the method of making it produced a different result. Less lime was used, and only enough water 'for quick assimilation with the lime', so that the mixture was barely moist. It could be handled with shovels, and transported in carts and wheelbarrows, like sand. The material was commonly mixed by an elaborate machine, which will be

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46 Charles Mayes, *The Australian Builders' Price-Book* (4th ed, Melbourne 1883), p 27.

47 [Diane Kell], ‘Concrete in Australia’, special issue of *Constructional Review*, L, 4 (November 1977), p 15.

48 Papworth, *Dictionary of Architecture*, sv Concrete.

49 *Mechanic's Magazine*, XXXVII, 1036 (17 June 1843), p 495..

50 Thomas Potter, *Concrete: its Use in Building* (new ed, London c 1894 [c 1877]), p 9.

discussed below, and when placed it was best compacted slightly with 'light hand pestles'. It had been used for a number of works in and near Paris - as mass concrete in the railway station at Suresnes, houses at St-Denis, and a church at Vésinet; in the form of arched structures on the northern railway line, in the new prison of Madelonottes, the Barracks of Nôtre-Dame, supporting the machinery of a sawmill at Aubervilliers, and in underground ventilation tunnels to the Exhibition building at the Champ-de-Mars; also for a lengthy embankment on the Avenue de l'Empereur and for forty kilometres of main sewers in Paris.[51]

Coignet's *béton aggloméré* was still regarded around 1870 as a novel material, its main advantage being economy, as only one part of hydraulic lime was used for eight parts of sand, though one part of Roman or Portland cement might be added as well. Again, much less water was used than in English concrete. The sand, and lime (and cement, if any) were mixed dry, then moistened slightly, put into a pugmill and ground to a paste, then pulverised in a stamping mill before being finally placed. Modern understanding of these materials suggests that the procedure was almost wholly misguided, particularly in relation to any cement which might be added. Nonetheless, Coignet's method was highly regarded, and a number of structures were built by it for the Paris Exposition of 1870.[52] It was known to anglophones almost from the outset, and an account of a railway station built by Coignet's method was published in England in both the *Builder* and the *Engineer* during 1859.[53]

Our first detailed description of it use in Australia is of a house extension built in Adelaide by the engineer B H Babbage,[54] son of the famous English mathematician Herschel Babbage. It measured 6.4 by 2.7 metres, and was built against the cob (mud) wall of the existing building, which was faced with a thin layer of concrete, and an existing cob garden wall which was incorporated. Thus two new walls were built, and these were 0.45 metres thick. The foundations were dug out to this width and the same depth, and filled with a concrete made of one part of North Adelaide lime to seven parts of sand and gravel from a nearby creek. Above this was placed wooden formwork of the sort already regularly used in Adelaide for *pisé de terre* construction, and concrete was thrown into this and rammed down in 0.3 metre layers. The concrete for the walls was mixed on Coignet's recipe in the proportions of seven parts of sand and gravel to three of common earth and one of unslaked lime, together with enough water to slake the lime and produce the consistency of a paste. The walls of Babbage's building were only a little over two metres high, but there was a solid concrete roof which arched up higher at the centre, the recipe for this being the same as for the foundations.[55] This structure may not have lasted long, and a complete concrete house, 'The Rosary', which Babbage built for himself in Daws Road in the 1870s had completely disintegrated by 1936.[56]

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51 L F Beckwith, *Report on Béton-Coignet, its Fabrication and Uses* (Washington 1868), passim.

52 R S Burn, *Modern Building and Architecture* (London, no date [c 1870]), p 77.

53 Potter, *Concrete,* p 9. Probably the railway station at Suresnes.

54 For Babbage, see D A Cumming & G C Moxham, *They Built South Australia: Engineers, Technicians, Manufacturers, Contractors and their Work* (Adelaide 1986), p 19.

55 *Builder*, XVIII, 922 (6 October 1860), p 638.

56 Jensen, *Colonial Architecture in South Australia*, p 175. St Martin's Church of England at Campbelltown, built in 1859-60, is said to have been of concrete with brick quoins, though an illustration seems to show complete masonry walls. A concrete-walled cellar is also supposed to have been built for the East Torrens Winemaking & Distilling Company.

e. foundations and engineering works

Concrete was probably much more widely used in foundations than for complete concrete buildings, as was the case at Sir Robert Smirke's Millbank Penitentiary of 1817.[57] 'Foundation', rather than footing, is an appropriate way to describe what was really a mass of rubble mixed with lime, or in some cases hydraulic lime or cement) upon which a wall was built, as opposed to a modern reinforced concrete footing, which is a self-contained structural unit forming a part of the wall itself. By 1846 Loudon could report that concrete foundations were 'now very general'. A trench was dug about eight inches [200 mm] wider than the lower course of brickwork which was to rest upon the foundation, and deep enough to reach firm soil. About 100 mm of coarse and fine gravel were thrown in, then they were grouted with thin hot lime and rammed hard. Course after course was laid in the same manner until the required depth was reached.[58] Even in South Africa concrete was used for both the foundations and the ground floor surface of a military blockhouse built at Durban in 1846.[59]

In Adelaide the Post Office was built in 1866 with concrete foundations, but they were criticised. It appears that water was put into the trenches, then the dry ingredients added. A critic wrote that the 'force of the water' would wash out a large proportion of the lime which was slaked in the mixing process, whereas if it were done properly only half the amount of lime would be needed.[60] A Roman Catholic schoolroom in Daly Street, Port Adelaide, completed in 1869 to the design of Wright, Woods & Hamilton, had concrete three feet [0.9 metres] thick, 'Swan River and Jarrah timber being used where required.'[61] This seems extraordinarily substantial for a building only 4.8 metres high. and deliberately built with hollow walls to keep it light, and was a response to the poor bearing capacity of the soil.

Examples in New South Wales included the foundations of Farmer & Co's Victoria House, Sydney, in 1873, and of the Lewis Brothers Flour Mill at Tamworth in 1873. The former, designed by the architect Horbury Hunt, were described as 'strata of cement concrete, varying from 18 inches to 3 feet [450-900 mm] (known as béton to the engineers) [which] cover the whole area of the main trenches',[62] and the latter, by Hilly & Sapsford, were 1.2 metres deep.[63] J H Pender used concrete for the foundations of the Wallsend School of Arts in 1878, the largest measuring three feet by 2 ft 6 in [900 x 750 mm].[64] It is of some interest to consider the specification for a

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[57] C W Pasley, *Observations on Limes, Calcareous Cements, &c* (London 1838), appendix pp 26-8.

[58] J C Loudon, *Encyclopædia of Cottage, Farm and Villa Architecture* (London 1846 [1833]), § 2433, p 1245.

[59] Brian Kearney, *Architecture in Natal* (Cape Town 1973), p 17.

[60] *South Australian Register,* 15 & 19 September 1866, quoted Jensen, *Colonial Architecture in South Australia,* p 328.

[61] *Southern Cross and Catholic Herald,* 25 October 1869, p 384.

[62] H M Franklyn, *A Glance at Australia in 1880* (Melbourne 1881), p 347.

[63] *Australasian Town and Country Journal,* 13 September 1873, p 689, quoted Dockrill, loc cit.

[64] J W Pender et al, The Pender Collection (Collection of architectural drawings by J W Pender and his successors, Maitland, NSW [at Maitland when inspected in 1999, but due for removal to Newcastle University]).

private house built in Melbourne in 1885. The foundation trenches were again 450 mm deep, but a little wider than the walls above. Into them was placed a concrete consisting of one part of lime to one of sand, one of gravel and four of 50 mm blue metal, mixed and tempered until the lime was slaked, thrown into the trench while still hot, and rammed in 150 mm layers.[65] There is no evidence in Australia of the use of hot water, as was sometimes done in Britain with a view to retarding the set.[66]

Although concrete foundations were commonly made with lime, for all hydraulic cements had (almost always) to be imported, there were exceptions where the work required special engineering properties. A major instance of this was the Alfred Graving Dock, built in 1868 to 1872 at Williamstown, Victoria, where a bed of 600 mm of concrete was placed below a 1.5 metre thickness of stone flooring. As it was described in 1873:[67]

> every bit of cement had to be hydraulic; it had to be in the proportion of one of cement to one of sand, measured like gold. Every barrel was tested; one bad barrel would have burst the dock. Secondly, it required to set very quickly on account of the pressure of water, and of course to make that water-tight was costly.

However a correspondent of *Castener's Rural Australian* in 1877 recommended Portland cement as the norm for foundations, using one part to one of sand and five of a coarse aggregate such as granite spalls, blue metal or broken crockery. These ingredients were to be mixed dry, then wetted, placed and tamped or rammed.[68]

The Alfred Graving Dock had been one of the first uses of concrete for strictly engineering purposes, but others soon followed, and in 1887 the Green Cape Lighthouse, the largest concrete structure in Australia, was completed to the design of James Barnet.[69] Late in 1887 James Barnet let the contract for the telegraph office and signalmen's quarters adjoining Gabo Island Lighthouse, in which the external and internal walls, as well as the surrounding garden wall, were all of mass concrete.[70]

f. New Zealand

In New Zealand there seems to have been far more use of concrete than in Australia. Geoffrey Thornton reports a cottage described in the *Lyttleton Times* in 1852 as being nearly complete. It was made from small gravel, sand and quicklime, in the ratio of 4:3:1.[71] Concrete was used for the piers and abutments of the Waiwakaiho River

65 Miles Lewis, '83 Walpole Street, Kew' (mimeographed typescript report, Melbourne 1981), p 4.

66 J B Papworth [ed], *The Dictionary of Architecture* (London 1853-92), sv Concrete.

67 Evidence of A G Todd, 11 June 1873, in Victoria, *Public Works Department. Report of Royal Commission* (Melbourne 1873), p 63.

68 *Castener's Rural Australian*, September 1877, p 16.

69 *Australasian Builder & Contractor's News*, 5 January 1889, p 17.

70 Ivar Nelson, Patrick Miller & Terry Sawyer, *Conservation Plan. Gabo Island Lighthouse. Victoria* ([Melbourne] 1992), p 20.

71 Geoffrey Thornton, *Cast in Concrete* (Auckland 1996), p 22, quoting the *Lyttleton Times*, 17 April 1852.

bridge at New Plymouth in 1859, and it thought that the oldest complete building may date from 1861.[72] 'Invermay' near Mosgiel is a very substantial two storey concrete house said to date from 1862.[73] Thornton identifies many examples in the following years, and in Auckland 'Clifton House' was extended with a concrete tower in 1872-3.[74] The powder magazine at Magazine Bay, Lyttleton Harbour, was built in 1874 with concrete walls and a brick vaulted arch. The most extraordinary concrete building is 'Goldie's Brae', commonly known as the 'Banana House' at Wadestown near Wellington, finished in 1876 and consisting of ten rooms built in a segment of a circle, with an attached conservatory running around the inner side of the curve.[75] *Brett's Colonist's Guide* of 1883 recommended as a normal thing that, in a neighbourhood where rubble, sand, scoria ash or shingle was available, the material should be used with Mahurangi lime to make concrete for building barn walls.[76]

There are many other examples from the 1870s onwards, which have been summarised by Thornton, including other concrete houses such as Judge Chapman's 'Woodside', Dunedin, built in 1876 to the design of F W Petre. Petre was sometimes known as 'Lord Concrete', and his most important concrete building was St Dominic's Priory, Dunedin, opened in 1877. One of the earliest public buildings in concrete was the oldest portion of the Sunnyside Asylum, a two storey structure planned by Benjamin Mountfort in 1871 and completed in 1880, when it survived a fire that destroyed much of the asylum. In 1877 J C Wason planned a whole village for his estate at Barhill in Canterbury, using concrete for the village centre buildings, of which St John's Church of England, school and teacher's house are still standing.[77] Enormous quantities of concrete were used by the architect S C Farr in a rebuilding program at 'Glenmark' station, North Canterbury, begun in 1875.[78] Huge concrete stables built in 1881 survive there.[79] The Firth Tower at Matamata is a concrete blockhouse built for defensive purposes in 1881-2 by J C Firth, a local businessman.[80]

g. patents and inventions

The latter half of the nineteenth century was a great period of inventions and patents in the colonies, as it was in Britain. Concrete began to be seen not just as a low

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72 G G Thornton, 'Early Concrete Structures in New Zealand', *Fourth National Conference on Engineering Heritage 1988, Sydney 5-8 December 1988, Preprint of Papers* (Barton (ACT) 1988), p 86. Thornton, *Cast in Concrete*, p 28, reports that the musterers' quarters at Lake Cole ridge station, Canterbury, is said to have been built in 1861 and was certainly extant in the 1870s.

73 Lois Galer, *Historic Buildings of Otago and Southland* (Wellington 1989), p 76; Thornton, *Cast in Concrete*, pp 23, 25.

74 P R Wilson, 'The Architecture of Samuel Charles Farr 1827-1914' (MA, University of Canterbury, 1982), p 62; Thornton, *Cast in Concrete*, pp 26-7.

75 Michael Fowler & Robert Van De Voort, *The New Zealand House* (Auckland 1983), p 101; Oroya Day et al, *Historic Buildings of Wellington* (Wellington 1986), p 32; Thornton, *Cast in Concrete*, pp 41-2.

76 F W Leys [ed] *Brett's Colonist's Guide* (Auckland 1883), p 11.

77 Thornton, 'Early Concrete Structures in New Zealand', pp 86-7-; Thornton, *Cast in Concrete*, pp 43 ff.

78 Wilson, 'Architecture of Samuel Charles Farr', p 67; Thornton, *Cast in Concrete*, pp 46, 49-50.

79 John Wilson, *AA Book of New Zealand Historic Places* (Auckland 1984), p 160; Thornton, *Cast in Concrete*, pp 62-4.

80 Wilson, *New Zealand Historic Places*,, pp 58-9.

grade mass material, but one capable of ornamental and structural use. In Victoria a form of concrete breeze block was patented in 1864.[81] One of the first local patents was taken out by Charles Mayes in 1854 for a form of hollow wall construction which could be executed in 'beton pise' (made of hydraulic lime, sand, and gravel or similar aggregate), 'concrete pisé' (of common lime, sand or loam, and gravel, moderately rammed), 'cob pisé' (clay or rich black mould with chopped straw &c, rammed). The sides of the mould were flat sheet iron, and the material was placed on the wall *in situ*. The cores were of sheet iron, in plan either circular, elliptical, or rectangular with curved corners, and about one third of the width and two thirds the length of the unit,[82] and another method of making hollow concrete blocks mechanically from lime and sand was patented in 1857,[83] and will be discussed below in the context of sand-lime bricks. This seems surprising since the official invention of the hollow cored block, which revolutionised the industry, was stills nearly forty years away.

The recently arrived Brisbane architect C L Depree put up a concrete building in 1870 next to his own house in Fortitude Valley, so as to demonstrate the potential of the material. In this he appears to have been successful, as he obtained commissions for various projects in concrete. In 1871 he was granted a patent for a system of moveable formwork for concrete construction, and in 1875-7 as resident engineer for the Stanthorpe Railway Extension, he built the first concrete tunnel and culvert in Queensland.[84] It seems likely that he was an agent for either Tall's or Drake's system, and that it was for this that he received the patent. In 1889 Peter Minehan, a Queensland railway superintendent and engineer, patented a method of making concrete pipes, which were then manufactured by Rooney Brothers of Townsville, as his agents.[85]

In 1887 the architect David Ross spoke of his experience in New Zealand with scoria aggregate in concrete 'blocks'.[86] In Sydney the Colonial Architect, James Barnet, began to make regular use of concrete, and in the first stage of the General Post Office in George Street, of 1868-74, there were vaulted ceilings and dome vaulting in coke breeze concrete, allegedly for the first time in Australia.[87] Barnet then used the material in vaults over the arcading and for the observatory dome of the Lands Department building, of 1876-91, constructed by the builder John Young.[88] Young himself used it for his extraordinary houses at 258-266 Johnston Street, Annandale.[89] In 1877 *Castener's Rural Australian* recommended that a mixture of five parts of coke to one of cement and one of sand be used for balcony, corridor and other floors. This may have been inspired by the work of Barnet, or it may mean that the practice was already widespread, though it is difficult to imagine that coke was readily available in

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81 Victorian patent no 702 to Patrick Hayes, 23 March 1864.

82 Victorian patent no 0 (under the old Act) granted to Charles Mayes, June 1854.

83 Victorian Patent no 18 to Walter Malcolm Scott, 11 April 1857.

84 Donald Watson & Judith McKay, *Queensland Architects of the 19th Century* (Brisbane 1994), p 54.

85 Watson & McKay, *Queensland Architects of the 19th Century,* pp 126, 156.

86 *Australasian Builder & Contractor's News*, 6 April 1887, p 204.

87 Clive Lucas, Stapleton & Partners Pty Ltd, *General Post Office Sydney* (Sydney 1991), p 19; and *Sydney Morning Herald*, 2 September 1974,

88 *Architecture,* November 1924, p 9, quoted in L J Dockerill, 'Developments in Architecture in New South Wales', I, pp 79-80.

89 Illustrated in Miles Lewis, *Two Hundred Years of Concrete in Australia* (Sydney 1988), pp 2-3.

many rural areas.[90] Groined concrete vaulting - unusual in Australia - was used in the New South Wales Electric Light and Power building in Kent Street, Sydney, in 1888, where it was a carried on iron girders, and was intended to dampen the vibrations caused by the machinery.[91]

h. mixers

In 1857 Louis Cezanne had invented the first mechanical mixer, a cylinder 3.9 m long by 1.2 m in diameter, inclined at an angle between 6º and 8º, and made to rotate at twenty revolutions per minute.[92] Something very similar was later used in England, at the Birkenhead Docks, and was claimed to be the invention of the resident engineer, Le Mesurier.[93] In France Coignet devised a special machine called the 'malaxator' for preparing his *béton aggloméré.* It had a chamber like a pair of cylinders overlapping in parallel, with no division between them. Each contained an archimidean screw turning simultaneously in the same direction, so that they overlapped but did not clash. The whole was placed at an angle of about 25º and the raw materials fed through hoppers at the lower end, while the mixed concrete was drawn off at the top.[94] Another machine was the 'Greyveldinger mortar mill', a rather simpler device on the same basic principle. It consisted of a cylindrical trough containing a single archimidean screw, the whole again angled at about 25º, with the raw materials fed in at the lower end.[95] By 1868, however, something more akin to the vertical pugmill of the brickmaker was being used for *béton coignet,* as described by L F Beckwith in 1868. The basis of it was a mixing cylinder, which was essentially a pugmill, consisting of a vertical metal tube within which a vertical spindle revolved, carrying projecting arms in a helical arrangement. Other short arms projected in from the side of the tube, doubtless counteracting the tendency of the mix to move around as a solid spiral. The materials were carried up at an angle by means of a bucket elevator, and discharged through a chute into the top of the cylinder.[96]

These mixers were used only for large engineering works, and less so in Britain than in France. Even in 1894 Thomas Potter stated that it had not yet been found practical to replace manual labour with machines, except in large scale engineering works, for which machines had been devised in Britain.[97] At a more general level mechanical mixers gradually began to supersede hand mixing only from 1902 onwards.[98] Before the Great War one could buy in Sydney not only the Eureka mixer, for which F A Winter held the agency, and another mixer imported by F Lassetter & Co Ltd, but

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90 *Castener's Rural Australian,* September 1877, p 16.

91 *Australasian Builder & Contractor's News,* 3 November 1888, p 403.

92 Akira Satoh [ed Ralph Morton], *Building in Britain, the Origins of a Modern Industry* (Aldershot [Hampshire] 1995 [1986]), p 229, note 24, citing Henry Reid, *A Practical Treatise on Natural and Artificial Concrete* (London 1879), p 93; Hans Straub [translated E Rockwell], *A History of Civil Engineering* (Leonard Hill 1970), § 268; Kenneth Hudson, *Building Materials* (Longman, London, 1972), p 60.

93 Henry Reid, *A Practical Treatise on Natural and Artificial Concrete* (London 1879), pp 301-3.

94 Reid, *Treatise on Concrete*, pp 164-6.

95 Reid, *Treatise on Concrete*, pp 177-8.

96 Beckwith, *Report on Béton-Coignet*, pp 7-9 & pl 1.

97 Thomas Potter, *Concrete: its Use in Buildings* (2 vols, London c 1894 [1877]), I, p 134.

98 G W Mitchell, *Genesis and Development of Reinforced Concrete in Australia* (Sydney 1922), p 11.

also the purportedly Australian designed 'Multimix' mixers, pavers and placing plants sold by Arthur Leplastrier.[99] Later Lightburn & Co of Brisbane emerged as the leading Australian makers of concrete mixers, and in the 1950s were advertising both hand and power operated models in sizes from one to $3^1/_2$ cubic feet [0.03 - 0.1 m^3] in, it as claimed, three types, seven models, and twenty-eight different combinations (of model, motor &c).[100]

In 1914 Mayes illustrated an unidentified small mixer;[101] the Eureka machine, which was commonly worked with a petrol engine;[102] the Chicago continuous batch mixer, which was sold by Elliott Maclean & Co and claimed to be the best American type;[103] a chain belt mixer made by William Adams & Company;[104] and the 'Coltrin Portable continuous self-proportioning mixing machine' sold by the Australian Metal Company Limited of Sydney.[105] The Australian Metal Co also sold 'Milwaukee' batch concrete mixers;[106] other mixers, both batch and continuous, were sold by J B Wallis & Co of Sydney;[107] and Elliott Maclean & Co sold the British 'Ransome' batch mixer.[108]

Ready mixed concrete was first used in Germany in about 1905, and then taken up in the United States and Denmark.[109] However, early experiments with premixed concrete failed because it frequently began to set while being transported to the site it is said to have been only when the first truck mixer was introduced in the United States in 1926 that the idea became a viable one. The first ready mixed concrete plant in Britain was established at Bedford, Middlesex, in 1930.[110] In 1939 Ready Mixed Concrete Limited opened its first premix plant on Glebe Island, Sydney, delivering with a truck carrying a rotating horizontal cylinder on a tray which could be tipped, known as a 'tumble bug'.[111] By 1954 there were subsidiaries in New South Wales, Victoria, Queensland, South Australia, Western Australia and the ACT.[112] Another pre-mixed concrete company, Conmix, opened in the Melbourne suburb of Burnley in 1956, using trucks controlled by two-way radio.[113] Other developments in premixed concrete followed, but they are most relevant to major constructional and engineering projects, and need not be further pursued here.

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99 Tanner, 'Early Reinforced Concrete Frame Buildings in Sydney', p 3.
100 See, for example, Lightburn & Co. Limited, *How to do Cement and Concrete Jobs around the Home* (Brisbane, no date [1950s]), advertising pages.
101 C E Mayes, *The Australian Builders & Contractors' Price Book* [8th ed, Sydney 1914], p 89.
102 Mayes, *Australian Builders Price Book* [1914], p 97 & advertisements p 14.
103 Mayes, *Australian Builders Price Book* [1914], p 97 & advertisements p 6.
104 Mayes, *Australian Builders Price Book* [1914], p 98 & advertisements p 7.
105 Mayes, *Australian Builders Price Book* [1914], p 98 & advertisements p 9.
106 Mayes, *Australian Builders Price Book* [1914], p 98 & advertisements p 6.
107 Mayes, *Australian Builders Price Book* [1914], p 98 & advertisements p 36.
108 Mayes, *Australian Builders Price Book* [1914], advertisements p 11.
109 Kinninburgh, *Dictionary of Building Materials* (London 1966), p 218.
110 Stanley, *Highlights in the History of Concrete*, pp 34-5.
111 [Diane Kell] 'Concrete in Australia' [special issue of], *Constructional Review*, 4 (November 1977), pp 52-3.
112 F W Ware & W L Richardson [eds], *Ramsay's Architectural and Engineering Catalogue* (3rd ed, Melbourne 1954), § 3/2.
113 *Cross-Section*, no 46 (1 August 1956), p 3.

i. J T Knox

One of the more eccentric advocates of concrete was James T Knox (1889-1967) of Leongatha in Victoria. He was a civil engineer who had been employed by the Shire of Bulla and other councils and is claimed, at least according to family tradition, to have designed various important reinforced concrete structures. In 1916 he and his wife acquired South Gippsland Quarries and, when the quarry was threatened by rising water levels, bought a bluestone deposit at Chalmer's Hill. When rising freight charges began to make the metropolitan market a less profitable one Knox turned to developing his land as a model farm so as to keep his staff employed. In 1922 Knox visited the United States to investigate scientific dairy farming, and he returned with the agency for the American-made Louden Machinery Company of Iowa, makers of farm equipment.[114]

As a machinery agent Knox had extensive dealings with Gippsland farmers, and as the proprietor of the South Gippsland Quarries he sold concrete products, as well as designing and building concrete structures himself. He advertised free plans and advice for concrete block houses, silos and milk-houses.[115] In 1926 Knox set about building his own farm structures to Louden designs, out of concrete, and with some alterations to suit local conditions. They comprised two large milking sheds each measuring 30 by 11 metres, a lower building containing pens, machine rooms and stores, measuring 36 by 10 metres, a piggery, and two silos with water tanks on top. The milking sheds are extraordinary in appearance, with strangely peaked gambrel roofs, and the silos are capped with battlements. The farm operated at full bore for only a few years, reducing solely to a dairy operation as a result of the 1929 depression, and ceasing entirely at the onset of World War II.[116]

j. lightweight concrete

Lightweight concretes are created by the inclusion of air in some form. No fines concrete omits the fine aggregate, which results in small air-filled voids; aerated concrete has entrained bubbles of air, creating a cellular structure; and lightweight aggregate concrete uses aggregates such as pumice or artificially expanded minerals.

'No fines' concrete enjoyed a vogue after World War II, though it had originated in Holland in the 1920s,[117] and was introduced to Britain in 1923. This was a concrete made with a coarse aggregate - 3/8 to 3/4 inch [10-19 mm][118] - and had an open-

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[114] J Murphy, 'Knox's Rockhill Farm', Leongatha Historical Society, no 4 (1979); and, for Knox's dates, Celestina Sagazio, 'Research into Knox's Rockhill Farm' (mimeographed report for the National Trust of Australia (Victoria), 1986).

[115] *South Gippsland Quarries* (broadside, Leongatha [Victoria], no date).

[116] Murphy, 'Knox's Rockhill Farm', and Sagazio, 'Research into Knox's Rockhill Farm', for the date of the buildings.

[117] Amongst the earliest known uses were some two storey houses built at Scheveningen in 1921, and these were followed by about fifty no-fines concrete houses built in Edinburgh in 1923. Both groups used clinker aggregate, and those at Edinburgh were constructed by the Coralite Building Co of London: R B White, *Prefabrication* (London 1965), p 84, ref R H Macintosh, J D Bolton & C D Muir, 'No-Fines Concrete as a Structural Material', *Proceedings of the Institution of Civil Engineers,* V, part 1, no 6 (November 1956), p 677.

[118] William Kinniburgh, *Dictionary of Building Materials* (London 1966), p 175.

textured gravelly appearance. Whilst it had little tensile or shear strength, it had the advantages of economising on cement, being about 30% lighter in weight, and - most importantly - having no capillary passages to suck up water.[119] By 1946 the Experimental Building Station, influenced by examples in England and Scotland, had built their first walls of it and had begun the construction of a complete house, and it was thought that it might result in considerable savings in cases where a number of houses were built together.[120] Following overseas trips in 1947-8 D V Isaacs and J W Drysdale, of the Station, reported on the Wimpey's No-Fines system in use in England, which involved special equipment and reusable formwork for the construction of two-storey houses. They concluded that the system would need modification for use in Australia to build single storey houses of non-standard type, that groups of less than ten houses were unlikely to be viable, but that subject to these qualifications it should be competitive with brick construction.[121]

No fines concrete was in fact tried out in Australia for the walls of houses and small buildings, and was used to some extent by architects, but was never really taken up by the building industry as a whole. One of the most significant examples was St Joseph's Church, Picton, Western Australia, where in 1955 'concrete without coarse aggregate' was delivered mixed, and placed in trenches in which screenings were already laid. The slurry was poured on using a swinging boom, and contained a penetrating and bonding agent. The aim was to minimise deliveries and make pouring easier.[122] The fashion for no fines concrete did not persist in the regular building industry, but in subsequent years it has sometimes been used in engineering works as a permeable base which will allow water to drain out through it.

Aerated concrete seems to have found little application in Australia. Commercial production began in Sweden in 1929, based upon the work of Axel Eriksson, though the basic principles had been established at the beginning of the century. It contained no aggregate other than a filler, ground as fine as the cement powder itself, so that it was really a mortar rather than a concrete. Air or other gas was introduced in such a way that it set as a uniform cellular material, but it only achieved its full potential when it was steam cured - meaning, of necessity, in precast units rather than *in situ* applications.[123] By 1953, however, Foam Concrete Ltd of Adelaide were marketing an air-entrained concrete floor slab, called 'Floorlite' for its good insulation properties. The contractors Weiss & Jolly doubled the size of their plant so as to be able to deliver four houses per week of air-entrained concrete.[124]

Cinder or coke breeze concrete will be mentioned below for its use in a range of concrete blocks and other precast products, and it will be mentioned again below as the material most commonly used to fill in over Traegerwellblech iron arches. An important example is the reservoir at Centennial Park, Sydney, an underground chamber with a forest of four hundred brick piers supporting shallow concrete cross-

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119 H E Hope, *The Use of No-Fines Concrete* (duplicated document no 10, Commonwealth Experimental Building Station, Sydney, July 1947).

120 Australia, Department of Works and Housing, Directorate of Housing, *Australian Housing, Bulletin 10* (Melbourne, September 1946), p 174.

121 D V Isaacs & J W Drysdale, *Building Technique and Research* (Sydney 1949), p 32.

122 *Cross-Section*, no 34 (1 August 1955), p 3.

123 Kinniburgh, *Dictionary of Building Materials*, p 10-11.

124 *Cross-Section*, no 42 (1 April 1956), p 3.

vaulting. There was a fenced oval on top, and the reservoir was ventilated through the hollow iron fenceposts. Alternative schemes for the vaulting were prepared in Monier reinforced concrete and in mass concrete, of which the latter got built. The concrete contains coke breeze, doubtless to lighten it. The use of coke breeze in conventional monolithic concrete construction must have been more limited, but in 1918 P G Gilder recommended it for the construction of farm buildings, notwithstanding the fact that very few of these can have been within convenient distance of the sources of coke, which he names as coke ovens, foundries, gasworks and railway locomotive sheds. Gilder recommends the material for small farm buildings, cottages, floors and surface drains, and specifically describes a dairy built of it.[125]

Cinder concrete came increasingly into use on the world stage from the time of the Great War onward. It appears that Germany may have pioneered the technology, but have been only indirectly influential in Australia due to the war. In France the architect Le Corbusier began making 'Briques Aéro-Scorie' at the factory which he had founded at Alfortville in 1917, using ash aggregate from the neighbouring power station and coal furnaces, until the closure of the works in 1921.[126] Some form of coke breeze concrete construction was also developed in Holland in about 1923, and then reached Britain under the name 'Corolite'.[127] In Australia, however, the importance of cinder concrete rather declined, except for a new development, the Cindcrete block, which will be discussed below.

Other lightweight aggregates have yet to be properly documented in the Australian context, but they all derived from overseas experience. Vermiculite had first been exfoliated during World War I, using material mined in Colorado, and was used mainly as loose fill insulation in roofs. However, from about 1940 it began to be used as a concrete aggregate, and other deposits were opened up in South Africa, Australia and the USSR.[128] In Australia Vermiculite became better known as an acoustic and insulating material than as a concrete aggregate, and in that context will be discussed below. Expanded shale was also produced in the United States, by crushing the rock and heating it to a high temperature, and was used as an aggregate in concrete ship building during World War I.[129] An expanded shale known as 'Haydite' was patented in 1919, and used in block making in 1923. A blast furnace slag known as 'Pollsco' (later 'Celocrete') was introduced in about 1930, and later in the 1930s a slag expanded with steam was introduced under the name of 'Waylite'.[130]

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125 P G Gilder, *The Farmer's Handbook* (Sydney 1918), p 225, kindly drawn to my attention by Deborah Kemp.

126 Bridget Jolly, "Solomit in Australia and its European Context" (PhD submission, University of South Australia, 1998), p 76.

127 G E Emery, 'General Manager's Report to the Commissioners [State Savings Bank] on his visit to Great Britain to enquire into Housing, December 1925' (in David Moloney's research notes for the Inter-War Housing Project, National Trust, Victoria, cited by Roser, 'Concrete House in Victoria', p 19.

128 Kinniburgh, *Dictionary of Building Materials,* p 106.

129 Kinniburgh, *Dictionary of Building Materials,* p 105.

130 P H Simpson, H J Hunderman & Deborah Slaton, 'Concrete Block', in T C Jester [ed] *Twentieth-Century Building Materials* (Washington [DC] 1985), p 82.

In Britain the price of coke breeze rose rapidly during the 1920s, and made other materials relatively more competitive. Pumice was available in some locations, but attempts to expand waste roofing slate proved uneconomical. Expanded clay, on a Danish process, succeeded in establishing itself despite its cost, but foamed slag derived from steelworks was the most successful of these products on the British market.[131] Perlite, a natural volcanic glass, related to pumice, but dense and nodular, had been to since 1836 to have the capacity to expand, but was not brought into commercial use as aggregate until 1946.[132]

In 1949 D V Isaacs and J W Drysdale were able to report a number of lightweight aggregates and mixtures being investigated in Britain, and concluded that most could be produced or obtained in Australia, but few of them in large quantities and at reasonable cost. They were:

(1) clinker
(2) fly ash
(3) expanded vermiculite
(4) foamed slag
(5) expanded clays, shales and slates
(6) cellular cement mixture, with or without vermiculite
(7) 'Ytong', a steam-cured mixture of shale-lime and aluminium powder
(8) diatomaceous earth and cement
(9) sawdust-cement
(10) wood wool
(11) 'Durisol', consisting of wood shavings, cement and a proprietary chemical.
(12) 'Pyrok', a proprietary mixture of expanded vermiculite, lime and cement.

Imported vermiculite was already being sold in Australia by the Neuchatel Company,[133] and Australian agents had been appointed for Durisol.[134]

In the 1950s a number of Australian manufacturers appear to have begun producing expanded perlite. The blue shale revealed at the bottom of many Melbourne clay pits had been found to expand satisfactorily, and proved to be an important resource. Expanded clay was also regarded as holding great promise, but was still not in commercial production in this country.[135] The first local makers of Perlite were Yeomans Pty Ltd of Botany, in 1954, using a rock from Mullumbimby and Brunswick Heads to produce grades from 2 to 7 kg/m^2.[136] At the end of that year it was reported that the CSIRO's Building Research Division at Highett, Melbourne, had developed a lightweight aggregate from heat bloated clay, weighing about a third as

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131 K Hajnal-Kónyi & H Tottenham, 'Concrete', in Eric de Maré [ed], *New Ways of Building* (London 1958 [1948]), p 29; Marian Bowley, *Innovations in Building Materials* (London 1960), pp 210-212.

132 Kinniburgh, *Dictionary of Building Materials*, p 106.

133 F W Ware & W L Richardson [eds], *Ramsay's Architectural and Engineering Catalogue* (Melbourne 1949), § 26/5. In Britain vermiculite was sold be Vermiculite (London) Ltd under the 'Kayex' brand, but its origin is unclear: Evelyn Drury et al [eds], *Architects', Builders' and Civil Engineers' Reference Book* (London 1950), facing p 301.

134 D V Isaacs & J W Drysdale, *Building Technique and Research* (Sydney 1949), p 38.

135 *Building Research in Australia 1952-1954* (no place [Melbourne] 1955), pp 11-12.

136 *Cross-Section*, no 22 (1 August 1954), p 2.

much as the usual crushed rock, and that clays and shales suitable for this process were available at Melbourne, Sydney and Brisbane.[137]

[137] *Cross-Section*, no 26 (1 December 1954), p 2.