

## 7.04 Portland Cement

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### a. artificial cements

The success of natural or so-called 'Roman' cement naturally led to experiments aimed at artificially matching or improving upon the naturally occurring proportions of clay and lime. Edgar Dobbs obtained a patent in 1810 for mixing chalk or limestone with clay, burning it, and grinding the clinker, which if done correctly in terms of proportions and temperature, could have produced an artificial or Portland cement.<sup>1</sup> However, Dobbs specifically avoided vitrefaction.

In France L J Vicat had already succeeded in creating:

a factitious Roman cement by making bricks with a pasty mixture of 4 parts of chalk, and 1 part of dry clay, drying, burning and grinding them ... its efficiency is somewhat doubtful; though it has, for want of a better substitute, been much employed in Paris.<sup>2</sup>

According to Skempton the description of it as 'factitious Roman cement' is an exaggeration, for what Vicat created was an artificial hydraulic lime, though this was in itself sufficient to encourage others to experiment with artificial cements.<sup>3</sup> Skempton may or may not be right, but certainly N E Pelouze, writing in 1829, proposed the creation of an artificial cement to reproduce the qualities of the Roman cement made by Parker. He clearly distinguished hydraulic lime [*chaux hydraulique*] as a different substance, and acknowledged Vicat as the pioneer in the field.<sup>4</sup>

Vicat published his *Recherches Expérimentales* in 1818, followed by *Résumé des Connaissances Positives Actuelles sur les Qualités, &c*, in 1828. The London builder James Frost went to France to study Vicat's cement, which was now in production at Meudon,<sup>5</sup> then took out a patent in 1822 for his 'British cement', which was largely

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<sup>1</sup> A C Davis, *A Hundred Years of Portland Cement* (London 1924), pp 26-7.

<sup>2</sup> Andrew Ure, *Dictionary of Arts, Manufactures and Mines* (London 1839), sv Mortar.

<sup>3</sup> A W Skempton, 'Portland Cements, 1843-1887', in Frank Newby [ed], *Early Reinforced Concrete* (Aldershot [Hampshire] 2001), p 131.

<sup>4</sup> N E Pelouze, *Art de Fabriquer en Pierre Factice très-dure et susceptible de recevoir le poli, &c* (Paris 1829), pp 32-40

<sup>5</sup> Skempton, 'Portland Cements', p 75.

inspired by Vicat.<sup>6</sup> In 1825 Frost established a factory at Northfleet (Swanscombe) to manufacture it,<sup>7</sup> and then in about 1830, by increasing the clay content from 15% to 30%, succeeded in producing what Skempton calls an artificial Roman cement.<sup>8</sup> However A C Davis was later to claim that Frost had produced what we know understand by the term 'Portland cement'.<sup>9</sup> These differences are impossible to resolve, given that contemporary records are limited and that Portland cement had yet to reach its canonical form. In 1833 Frost retired to the United States, and sold the factory to Francis, White & Francis, who in turn transferred it over the next four years to the control of White & Son.<sup>10</sup> Later still the company became J Bazley White & Sons,<sup>11</sup> then by 1853 John Bazley White & Brothers,<sup>12</sup> whose cement was specified for Parliament House, Ottawa, in 1859,<sup>13</sup> and exhibited at Sydney in 1879, both in its own right and in the form of W H Lascelles's prefabricated cottage.<sup>14</sup>

Portland cement is more generally regarded as the invention of Joseph Aspdin, who is claimed to have made an hydraulic cement for the first time in 1813, by lightly calcining a mixture of clay and limestone, substantially the same as Vicat's, but significantly different from, and inferior to, what was later called Portland cement. A C Davis was to refer to this as being 'ground hydraulic lime',<sup>15</sup> but Aspdin called it 'Portland' cement from a fancied resemblance to the appearance of Portland stone, patented it under that name in 1824,<sup>16</sup> and established a factory in 1825, subsequently run by his elder son, James. In 1828 Marc Brunel used Aspdin's cement, for the first time on a major scale, in the construction of the Thames Tunnel, but its origin is unclear.<sup>17</sup>

The systematic experiments of Major-General C W Pasley at the Chatham Naval Dockyard, from 1826 onwards, grew largely from the experiences of Vicat and Frost, and advanced the understanding of cement out of all measure. Most of Pasley's experiments were conducted using White's cement, the successor of Frost's, which at this stage was made of mixed Harwich and Sheppey nodules, and would not qualify

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<sup>6</sup> British patent no 4,679 to James Frost, 10 August 1822, reproduced in Davis, *A Hundred Years*, pp 234-5. See also C W Pasley, *Observations on Limes, Calcareous Cements, Mortars, &c* (London 1838), appendix pp 13-16.

<sup>7</sup> Pasley, *Observations on Cements*, appendix pp 13-16.

<sup>8</sup> Skempton, 'Portland Cements', p 75.

<sup>9</sup> Davis, *A Hundred Years*, p x.

<sup>10</sup> Pasley, *Observations on Cements*, pp 13-16.

<sup>11</sup> London, Great Exhibition of the Works of Industry of all Nations, 1851, *Official Descriptive and Illustrated Catalogue* (3 vols, London 1851), I, p 134; also an illustration of their test beam, facing p 104. See also Davis, *A Hundred Years*, pp xviii-xix, 31, 33.

<sup>12</sup> *Builder* (London), XI, 529 (26 March 1853), p 208.

<sup>13</sup> Allegedly referred to as B White & Co: Thomas Ritchie, *Canada Builds 1867-1967* (Toronto 1967), p 31.

<sup>14</sup> Sydney International Exhibition 1879, *Official Catalogue of the British Section* (London 1879), pp 51, 50.

<sup>15</sup> Davis, *A Hundred Years*, pp x, xviii.

<sup>16</sup> William Aspdin, in *Builder*, VI, 292 (9 September 1848), p 443; Butler, *Portland Cement*, pp 1-3.

<sup>17</sup> P B Butler, *Portland Cement, its Manufacture, Testing and Use* (London 1899), p 1. He attributes the tunnel to Isambard Brunel, but at this stage Brunel junior had only recently entered his father's office. Pasley refers to the use of cement here, but says nothing of its origins. In 1839, however, Isambard Brunel wrote that he himself had used Francis's cement for the greater part of the tunnel: Davis, *A Hundred Years*, p 73.

as Portland cement.<sup>18</sup> An artificial cement was potentially much better than a natural one because the optimum proportions of clay and limestone could be selected, but its development was retarded by the fact that early experimenters, instead of calcining it to the point of incipient vitrification, tended to assume that this was undesirable, and even to sort and remove any vitrified lumps.<sup>19</sup> The first certain evidence of the material being burnt to near vitrefaction, and thus being effectively Portland cement in the modern sense, is at White's factory some time after 1840.<sup>20</sup> It may have been as late as 1845, for it has also been claimed that at that date Isaac C Johnson, works manager of J B White & Sons, first burnt the materials at a high enough temperature to produce what was later understood by the term 'Portland cement',<sup>21</sup> and in particular realised the importance of grinding and using the clinker rather than discarding it.<sup>22</sup>

By the 1840s, when Aspdin's patent had expired, a number of 'Portland' cements were on sale, one of which, 'Pulham's Portland Stone Cement or Artificial Stone' was claimed to have been first used in about 1821, and likewise to have been named from its close resemblance to Portland stone in colour, hardness and durability.<sup>23</sup> Gwilt dates the appearance of true Portland cement to 1843, and refers to it as being made from the mud of the Medway mixed with chalk, and the ashes of former makings, and calcined at a high temperature almost to vitrification. This seems to be a reference either to the cement now produced by Maude & Co, or to the development work undertaken by Pasley).<sup>24</sup> Late in 1843 Maude & Co announced that they had made arrangements with Joseph Aspdin's younger son, William, to manufacture an improved version of Aspdin's cement at Rotherhithe. It was explained that Aspdin's original cement, though generally regarded as superior, had been used only to a limited extent in London because of the cost of transport.<sup>25</sup> William Aspdin entered the partnership of Maude, Jones & Aspdin at Rotherhithe,<sup>26</sup> and a remark in 1845 that 'Maude's' cement had not been in use long enough to assess it serves to confirm that they were now producing a different material.<sup>27</sup> William Aspdin was later a member of Robins, Aspdin & Co,<sup>28</sup> but whether this company was the legal successor of Maude, Jones & Aspdin is unclear. By 1855 William Aspdin's Patent Portland Cement was being made by Aspdin, Ord & Co.<sup>29</sup>

Other makers had entered the market as well, and by 1852 there were six in all:

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<sup>18</sup> Pasley, *Observations on Cements*, Preface, unpaginated, and p 157.

<sup>19</sup> Butler, *Portland Cement*, p 1.

<sup>20</sup> Davis, *A Hundred Years*, pp xix, 49-53.

<sup>21</sup> Skempton, 'Portland Cements', p 117.

<sup>22</sup> S B Hamilton, 'Building and Civil Engineering', in Charles Singer et al [eds], *A History of Technology, Volume IV: the Industrial Revolution c 1750 to c 1850* (Oxford 1975), p 117, quoted in Hanut Dodd, 'Lime and Victorian Buildings' (Master of Planning & Design, University of Melbourne, 1997), p 31.

<sup>23</sup> James Pulham, in the *Builder*, III, 113 (15 April 1845), p 160.

<sup>24</sup> See Pasley, *Observations on Cements*.

<sup>25</sup> Skempton, 'Portland Cements', pp 129-130, citing a circular issued by Maude & Co late in 1843.

<sup>26</sup> *Australasian Builder & Contractor's News*, 12 October 1889, p 346.

<sup>27</sup> James Pulham, in the *Builder*, III, 113 (15 April 1845), p 160.

<sup>28</sup> Robins, Aspdin & Co of Northfleet showed their Portland cement at the Great Exhibition of 1851: Great Exhibition, 1851, *Catalogue*, I, p 113; *Australasian Builder & Contractor's News*, 12 October 1889, p 346, gives it as Robins, Aspdin & Co.

<sup>29</sup> *Builder* (London), XI, 529 (26 March 1853), p 208.

Joseph Aspdin, Wakefield  
 J B White & Sons, Swanscombe  
 Robins & Co, Northfleet  
 Charles Hilton, Faversham  
 I C Johnson, Rochester  
 Aspdin & Son, Gateshead<sup>30</sup>

By 1853 they included also Thomas Freen & Co of Wouldham-on-the-Medway; R Greaves, near the Avon, who sold through Charles Richardson of London, and James Weston of Millwall, Poplar.<sup>31</sup>

The first Portland cement manufactory was established in France in 1840 and the first in Germany in 1853 at Zülchow near Stettin, by the brothers Bleipetrene,<sup>32</sup> coming into full production in 1855. Others soon followed, and although they initially modelled their works upon British ones, the Germans then introduced great improvements, and by the 1880s their cements were 50% stronger than the British.<sup>33</sup> Frost established himself in New York, and by 1841 succeeded in making on a commercial scale a fine greyish-white cement, which he had been able to achieve only on experimentally in England, and which he claimed was three to six times as hard as marble.<sup>34</sup> This venture seems nevertheless to have died, for it is reported that production did not begin in the United States until the 1870s, and even then the majority of the market was supplied by imports from Britain and Germany.<sup>35</sup> The first of these next generation manufacturers was David O Saylor at Coplay, Pennsylvania, from 1871.<sup>36</sup> It was more than another decade before manufacture began in Australia.

### *b. Victoria Hydraulic Freestone*

In the 1880s 'Patent Victoria Hydraulic Freestone' was marketed by a company of that name, and this seems to have been based upon Portland cement.<sup>37</sup> It was used especially by the Melbourne architects Crouch & Wilson, for water tables and other details of their many churches. The material was first exposed to public examination in 1881 at the Artificial Stoneworks at the corner of St Andrew and Church Streets, Middle Brighton. It was reported to be manufactured according to R H Stone's patent. The architect Michael Egan appears to have been an active partner, and

<sup>30</sup> Skempton, 'Portland Cements', p 129.

<sup>31</sup> *Builder* (London), XI, 529 (26 March 1853), p 208.

<sup>32</sup> C Kersten [translated N C Ricker], *Der Eisonbetonbau* (2 vols in 1, Urbana [Illinois] 1916 [from the 10th German edition, 1915, originally 1906] [typescript in the Ricker Library, University of Illinois at Urbana-Champaign].

<sup>33</sup> Skempton, 'Portland Cements', pp 82-3, 89.

<sup>34</sup> *Mechanic's Magazine*, XXXVI, 975 (15 April 1842), pp 310-11.

<sup>35</sup> Sara Wermiel, 'The Development of Fireproof Construction', *Construction History*, IX (1993), p 19.

<sup>36</sup> Geoffrey Thornton, *Cast in Concrete* (Auckland 1996, p 16).

<sup>37</sup> The material seems to be unconnected with the 'Victoria Stone' patented in England in 1868, which was made of granite chippings and Portland cement cast in moulds, then steeped in 'a solution of silica': Wyatt Papworth [ed], *The Dictionary of Architecture* (London 1853-1892), sv Victoria Stone.

Charles Webb and Evander McIver are referred to as well.<sup>38</sup> The works were moved two years later to Sandridge [Port Melbourne], where they were officially opened on 1 October 1883.<sup>39</sup> The patentee was apparently a local man, R Holden Stone, for he wrote to the *Argus* to state that no chemicals were used in the process, and that therefore, unlike other artificial stones, no soluble salts were produced.<sup>40</sup>

The scientific community was enthusiastic. J Cosmo Newbery found that the stone

contains no soluble constituents which would cause disintegration, or exfoliation, and that the more it is exposed to moist atmosphere the harder it becomes; in fact the stone has hydraulic properties.

R W E McIvor also found that it seemed to harden during exposure, rather than to deteriorate, that it performed well under other tests, and that it was 'admirably suited for building purposes'.<sup>41</sup>

The first reported use of the Victoria stone was in the new premises of David Munro at 154 Queen Street, corner of Little Lonsdale Street, in 1882,<sup>42</sup> and it was used in 1884 for Terry & Oakden's E S & A Bank, Brighton, and for Evander McIver's Presbyterian Church, Brunswick.<sup>43</sup> Also in 1884 T J Crouch mounted an appeal against the Melbourne City Council's refusal to allow the use of the material in a city building façade, and surprisingly enough he was successful: the referees determined the material was a stone within the meaning of the *Melbourne Building Act*.<sup>44</sup> The most extensive use of the material was in the Presbyterian church in Alma Road, West St Kilda, built in 1885-6 to the design of Wilson & Beswicke. The body is of bluestone, but the dressings, water tables, enrichments, mouldings, tracery and pinnacles, and the whole of the prominent spire, are of Victoria stone.<sup>45</sup>

### *c. cement castings*

A material based upon Portland cement, like the Victoria Hydraulic Freestone, seems a natural enough extension of the earlier 'artificial stones' based upon lime or natural cement. Indeed, by the 1880s one hears little of specific patents, though the amount of ornamental cement casting increases exponentially, using the extensive range of Portland cements now available on the Australian market. Nor do we hear much of the specialist casters and modellers involved, though a fountain at 11 Redmond Street, Kew [Melbourne], probably contemporary with the house, of 1887-9, is branded:<sup>46</sup>

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<sup>38</sup> *Argus*, 5 August 1881, p 3

<sup>39</sup> *Argus*, 2 October 1883, p 9.

<sup>40</sup> *Argus*, 3 October 1883.

<sup>41</sup> *To Architects, Contractors, &c* [trade circular, apparently Melbourne c 1883], in John Beswicke papers, copy kindly supplied by Mr Ken Bethell.

<sup>42</sup> *Argus*, 2 September 1882, p 9; 12 December 1882, p 10.

<sup>43</sup> *Argus*, 20 October 1884, p 6

<sup>44</sup> *Argus*, 20 March 1884, p 5.

<sup>45</sup> *Argus*, 18 October 1884, p 10.

<sup>46</sup> Reported by Helen McCarthy, 1999.

C[...]D[...]

Moreover the architect Norman Hitchcock, first of Melbourne and then of Fremantle, was one of the few whose ornaments are so characteristic that it seems certain that he owned not only the designs but also the actual moulds.

The most revealing document in this context is the specification for the Melbourne mansion 'Benvenuta', of 1891. It has particularly fine classical figures standing on the parapet, and the oral tradition that they were imported from Italy by the owners is more believable than in most cases, given that they were specified as being supplied by the 'proprietary', Leah Abrahams. A number of other details are specified, including the cornices with 'modillions (face leaf planted on)'.<sup>47</sup> However all the other 'enrichments' of the exterior were provided by the local modeller Otto Waschatz - egg and dart mouldings and scrolls on the chimneys; large scrolls and a 'loft' on the tower; egg and dart and running leaf moulds on the tower cornice and architrave; an ornamental head, corners and festoons, also on the tower; balusters in the parapet; figure modelling in the pediments (partly detached); 'small flower and leaf on plate' in the pedestals; modillions with leaves planted on in the upper and lower cornices, distorted to suit the curve of the central pediment, with mitre leaves and acorn drops at the corners of the modillion course; further friezes, architraves, archivolt, spandrel sprays at the arch springings; corinthian capitals; enriched panels in the window spandrels; deep foliage and shell panels in canopies over doors and windows; an enriched impost course; festoons; and foliated keystones. There were also four stock vases to be provided by the principal contractor, not by Waschatz, with holes in the bottom to receive 3/4 inch [19 mm] galvanized iron pipe fixings.<sup>48</sup> Truly, Portland cement must be seen as the main generator of the Boom Style.

Cement casting did not end with the Boom Style, but in the twentieth century the imperative was to achieve a better verisimilitude of real stone, and this was done by the use of colouring agents and crushed rock finishes. One such was the Architectural Pre-Cast Stone produced in Victoria and Tasmania by Picton Hopkins & Son, who stressed that the facing was cast integrally with the body of the block.<sup>49</sup> Precast elements and concrete pipes are discussed elsewhere.

#### *d. imported cement*

Portland cement was generally available in the Australian colonies by the middle of the nineteenth century,<sup>50</sup> and was imported in increasing quantities for the next forty

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<sup>47</sup> W S Law, 'Specifications of Residence Drummond St. Carlton for Mrs. L. Abrahams' (Melbourne 1891), p 46.

<sup>48</sup> Law, 'Specifications of Mrs. L. Abrahams', pp 46-9.

<sup>49</sup> F W Ware & W L Richardson [eds], *Ramsay's Architectural and Engineering Catalogue* (Melbourne 1949), § 5/1; F W Ware & W L Richardson [eds], *Ramsay's Architectural and Engineering Catalogue* (Melbourne 1954), § 5/1.

<sup>50</sup> For example at Adelaide in 1851: E & R Jensen, *Colonial Architecture in South Australia* (Adelaide 1980), p 107.

years. It was first listed in Melbourne in 1857,<sup>51</sup> but the Co-Operative Society of Plasterers had in the previous year recommended it as the best material for external use<sup>52</sup> - doubtless meaning render. In March 1857 Charles Laing specified it for the stucco of buildings at Brighton,<sup>53</sup> and it was also used at 'Glass Terrace', Fitzroy, built in stages during the 1850s, where it survives.<sup>54</sup> In 1862 Dyer's Lime & Cement Stores, of Melbourne, advertised four British brands: Wouldham's; Knight, Bevan & Sturges's; White's; and Hilton's.<sup>55</sup> In 1863 the Sydney importer Richard Wynne negotiated with another manufacturer, Booth & Co of Borstal, on the Medway near Rochester, in Kent. He was concerned with issues of quality, price, freight rates and quality of barrels,<sup>56</sup> but there is no positive evidence that anything came of this, for there is no report of the use of Booth's cement in Australia. In 1871-2 Portland cement was used at the Alfred Graving Dock in Williamstown, though the fact that contemporary reports mention only 'hydraulic cement'<sup>57</sup> suggests that a common terminology had not gained currency. In Darwin Portland cement was used by J G Knight for concrete flooring and for the foundations of government buildings, as mentioned above, notwithstanding the fact that shell lime could be obtained locally and was used in other parts of the same buildings.

In 1881 the current prices listed in the *Australian Engineering and Building News* named three British brands, Knight Bevan's, White's, and Gostling's,<sup>58</sup> and the current price list in the *Australasian Builder & Contractor's News* in 1888 named 'British Lion', 'Tunnel', Hilton's and Francis & Co's 'Nine Elms'.<sup>59</sup> But this gives no idea of the range available. The brands either advertised locally, or at least shown at the trade exhibitions, by 1888 included:

Alsen & Sons' [Alensche Portland Cement-Fabriken, Hamburg]<sup>60</sup>  
 'Anchor', *see* Brooks, Shoobridge & Co  
 F C Barron & Co, London<sup>61</sup>  
 Breitenberger Portland Cement-Fabriken, Hamburg<sup>62</sup>  
 'British Lion'<sup>63</sup>  
 Brooks, Shoobridge & Co's 'Anchor' brand, England<sup>64</sup>

<sup>51</sup> *Melbourne Prices Current and Shipping List*, 14 April 1857, quoted Dodd, 'Lime and Victorian Buildings', p 37.

<sup>52</sup> *Australian Builder and Practical Mechanic*. 25 September 1856, p 236.

<sup>53</sup> Dodd, 'Lime and Victorian Buildings', p 37.

<sup>54</sup> Dodd, 'Lime and Victorian Buildings', p 73.

<sup>55</sup> C B Mayes, *The Australian Builders' Price-Book* (2nd ed, Melbourne 1862), p viii.

<sup>56</sup> Information from Irene Wynne, 7 September 2004.

<sup>57</sup> Dodd, 'Lime and Victorian Buildings', p 33.

<sup>58</sup> *Australian Engineering and Building News*, 1 May 1881, p 216.

<sup>59</sup> *Australasian Builder & Contractor's News*, 22 December 1888, p 582.

<sup>60</sup> Charles Mayes, *The Australian Builders' Price-Book* (5th ed, Melbourne 1886), advertisements, p xvi, and p 97; Centennial International Exhibition, Melbourne, 1888-1889, *Official Record* (Melbourne 1890), p 423.

<sup>61</sup> Centennial Exhibition, *Official Record*, pp 853, 981.

<sup>62</sup> Centennial Exhibition, *Official Record*, pp 423, 853, 953.

<sup>63</sup> *Australasian Builder & Contractor's News*, 22 December 1888, p 582.

<sup>64</sup> Mayes, *The Australian Builders' Price-Book* (1886), p 96. Brooks Shoobridge were reported to be one of the largest manufacturers, and their cement had been subjected to testing in New South Wales: *Australasian Builder & Contractor's News*, 22 June 1889, p 594. The Melbourne agents were George Wood & Co, consulting and hydraulic engineers: *Australasian Builder &*

'Buffalo'<sup>65</sup>  
 Casebourne & Co, West Hartlepool, England<sup>66</sup>  
 'Castle', *see* Levett's  
 'Crown A1', *see* Siebel & Matthaei  
 'Crumb'<sup>67</sup>  
 J De Man, Antwerp<sup>68</sup>  
 Dufosse & Henry, Cronfestu, Belgium<sup>69</sup>  
 'Faucus' cement, England<sup>70</sup>  
 Fewer's 'Globe'<sup>71</sup>  
 Francis & Co's 'Nine Elms'<sup>72</sup>  
 Gibbs & Co Limited, Grays, Essex<sup>73</sup>  
 'Globe', *see* Fewer  
 Gostling's, England<sup>74</sup>  
 Hilton's,<sup>75</sup> or Hilton, Anderson & Co<sup>76</sup>  
 Johnson & Co, London<sup>77</sup>  
 N Jossen & de Langle, Anvers<sup>78</sup>  
 Knight, Bevan & Sturge, England<sup>79</sup>  
 William Lee, Son & Co, London<sup>80</sup>  
 Levett's 'Castle' brand, England<sup>81</sup>

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- Contractor's News*, 10 September 1887, p 286; Centennial Exhibition, *Official Record*, pp 853, 980.
- <sup>65</sup> Mayes, *Australian Builders' Price-Book* (1886), advertisements p xxxii.
- <sup>66</sup> Centennial International Exhibition, Melbourne, 1888-1889, *Official Record* (Melbourne 1890), pp 854, 981.
- <sup>67</sup> *Australasian Builder & Contractor's News*, 14 May 1887, p 5.
- <sup>68</sup> Centennial Exhibition, *Official Record*, p 853.
- <sup>69</sup> Centennial Exhibition, *Official Record*, pp 853, 980.
- <sup>70</sup> Mayes, *Australian Builders' Price-Book* (1886), advertisements, p viii, and p 15.
- <sup>71</sup> Mayes, *Australian Builders' Price-Book* (1886), advertisements p xxxv. This was apparently Edward Fewer of Lägerdorf near Itzehoe, Germany; Centennial Exhibition, *Official Record*, pp 23, 853.
- <sup>72</sup> *Australasian Builder & Contractor's News* 22 December 1888, p 582.
- <sup>73</sup> Centennial Exhibition, *Official Record*, pp 853, 981.
- <sup>74</sup> *Australian Engineering and Building News*, 1 May 1881, p 216. Made by J C Gostling & Co of London, and the Phoenix Cement Works, Kent, apparently since 1864, and shown at the Sydney International Exhibition of 1879 and the Melbourne Exhibition of 1880: Sydney International Exhibition 1879, *Official Catalogue of the British Section* (London 1879), p 51; Melbourne International Exhibition, 1880, *Official Catalogue of the Exhibits* (Melbourne 1880), pp 317-18.
- <sup>75</sup> Advertised by Dyers of Melbourne in 1862; Mayes, *The Australian Builders' Price-Book* (1862), p viii. See also *Australasian Builder & Contractor's News*, 22 December 1888, p 582.
- <sup>76</sup> Jules Renard & Co, sole agents for Victoria: *Building and Engineering Journal*, 1 February 1890, supplement, p 7.
- <sup>77</sup> Mayes, *Australian Builders' Price-Book* (1886), p 96.
- <sup>78</sup> Mayes, *Australian Builders' Price-Book* (1886), p 96.
- <sup>79</sup> Advertised by Dyers of Melbourne in 1862; Mayes, *The Australian Builders' Price-Book* (1862), p viii. See also *Australian Engineering and Building News*, 1 May 1881, p 216; Mayes, *The Australian Builders' Price-Book* (1886), p 96.
- <sup>80</sup> Centennial Exhibition, *Official Record*, p 853.
- <sup>81</sup> Mayes, *Australian Builders' Price-Book* (1886), p 15; *Australasian Ironmonger*, 1 October 1886, advertisement p ix; and *Australasian Builder & Contractor's News*, 27 July 1887, p 253, where it is reported that the Department of Public Works (NSW) had issued a certificate of its tensile strength to the local agents, MacDonnell & Busch. Previously William Levett & Co of London had shown their 'Portland Silicate Cement' at the Sydney International Exhibition of 1879, but it is not clear that this is the same product: Sydney Exhibition 1879, *Catalogue of British Section*, p 51.

'Lighthouse', *see* London Cement Co  
 London Cement Co's 'Lighthouse'<sup>82</sup>  
 J McEwan & Co, London<sup>83</sup>  
 McLean & Co, Rochester, England<sup>84</sup>  
 Mannheimer Portland Cement-Fabriken, Mannheim<sup>85</sup>  
 'Nine Elms', *see* Francis & Co  
 Portland Cement-Fabriken Hemmoor<sup>86</sup>  
 Previte & Greig, London<sup>87</sup>  
 Prussing, Planck & Co, *see* Vorwohler Portland Cement Fabrik  
 Red Cross: *see* Wouldham's  
 Robin's<sup>88</sup>  
 Schifferdecker & Söhne, Heidelberg<sup>89</sup>  
 Siebel & Matthaei's 'Crown A1', Hamburg<sup>90</sup>  
 Star, Stern, *see* Toepffer, Grawitz  
 Stettinger, Stettin<sup>91</sup>  
 Toepffer, Grawitz & Co's 'Stern' or 'Star' cement, Stettin<sup>92</sup>  
 'Tunnel'<sup>93</sup>  
 Vorwohler [or Vorwehler] Portland Cement-Fabrik Prussing, Planck &  
 Co, Holzminden<sup>94</sup>  
 J B White & Brothers, London<sup>95</sup>  
 Wouldham's Red Cross<sup>96</sup>

There are in fact only a handful of British brands which are not recorded locally, amongst them: Ashton & Green's 'Castle' brand<sup>97</sup> (unless this is somehow cognate

<sup>82</sup> Mayes, *Australian Builders' Price-Book* (1886), advertisements p xxviii.

<sup>83</sup> Centennial Exhibition, *Official Record*, p 853.

<sup>84</sup> Centennial Exhibition, *Official Record*, pp 853, 980. McLean & Co of St Helen's Wharf, Southwark, showed their cement at the Sydney Exhibition of 1879: Sydney Exhibition 1879, *Catalogue of British Section*, p 51.

<sup>85</sup> Centennial Exhibition, *Official Record*, pp 853, 980.

<sup>86</sup> Centennial Exhibition, *Official Record*, pp 424, 853, 953.

<sup>87</sup> Centennial Exhibition, *Official Record*, p 459.

<sup>88</sup> Mayes, *Australian Builders' Price-Book* (1886), advertisements p xxxv; Centennial Exhibition, *Official Record*, p 460.

<sup>89</sup> Mayes, *Australian Builders' Price-Book* (1886), p 96.

<sup>90</sup> Mayes, *Australian Builders' Price-Book* (1886), advertisements, p viii, and p 15.

<sup>91</sup> Mayes, *Australian Builders' Price-Book* (1886), p 96.

<sup>92</sup> Mayes, *Australian Builders' Price-Book* (1886), advertisements, p viii, and pp 96-7. The company's works are illustrated in Henry Reid, *A Practical Treatise on Natural and Artificial Concrete* (London 1879), facing p 300. Reid reports, pp 308-12, on the superiority of the product over all others, as established at the Philadelphia Exhibition of 1878, and by a number of tests in Germany from 1876 onwards.

<sup>93</sup> *Australasian Builder & Contractor's News*, 22 December 1888, p 582.

<sup>94</sup> Centennial Exhibition, *Official Record*, pp 424, 853, 953.

<sup>95</sup> Advertised by Dyers of Melbourne in 1862; Mayes, *The Australian Builders' Price-Book* (1862), p viii. See also Sydney Exhibition 1879, *Catalogue of British Section*, p 51; *Australian Engineering and Building News*, 1 May 1881, p 216; Mayes, *Australian Builders' Price-Book* (1886), p 96. In 1879 J R Cattell & Co were the agents in Sydney.

<sup>96</sup> Advertised by Dyers of Melbourne in 1862, when at 22 shillings a barrel it was the most expensive type. It is surprising little heard of here, given that it was very prominent in Britain: Thomas Potter, *Concrete: its Use in Buildings* (2 vols, London c 1894 [1877]), I, p 181.

<sup>97</sup> Ashton & Green, Limited, *Ashton & Green, Limited, Slate, Tile, Brick, Cement, Marble, and Iron Manufacturers and Merchants* (London 1887), p 20.

with Levett's); that of Coles, Shadbolt & Co,<sup>98</sup> 'Earle's', by Thomas & George Earle of Hull;<sup>99</sup> and the Rugby Portland Cement Co's 'Rugby' brand.<sup>100</sup>

These imported cements continued to be used quite routinely well into the twentieth century - Knight Bevan Sturge's, for example, was specified for additions to a Melbourne shop in 1907,<sup>101</sup> and was used again in Australia's most remarkable reinforced concrete structure, the Dennys Lascelles Austin Wool Store at Geelong, of 1920-11.<sup>102</sup> It is presumably the 'K.B.' cement still being advertised by James Moore & Sons in 1913, along with a previously unrecorded 'Black Eagle' brand.<sup>103</sup>

The prominence of German brands reflects the position in Britain itself, where A C Davis complained of the fact that 'our Continental neighbours' were now making a first class cement at a price low enough for it to be shipped 'not only to this country [Britain] but to the very centres of the export and colonial trade which English manufacturers once thoroughly relied upon as their own market.'<sup>104</sup> The importation of German cement to Australia was worth £20,000 prior to World War I, but then decreased to zero, whereas imports from Denmark rose from £261 in 1914-15 to £20,502 in 1915. This gave rise to the not unnatural suspicion that the German product had simply been rerouted. However the Danish Consulate pointed out that there were large cement works in Denmark, and that the establishment of a direct steamship service had enabled the product to be brought onto the market. There was no possibility that any was of German origin.

There seem to have been substantial differences between the brands, not merely in terms of their engineering properties, which were rarely critical before the advent of reinforced concrete, but their appearance. A major function of Portland cement in the 1870s and 1880s was the surfacing of buildings and the casting of architectural ornaments. The specification for a South Australian bank in 1878 directs:

Every care must be taken in putting on the last coat to keep it of a uniform tint. "Goslings" [*sic*] or "Johnstons" [*sic*] brand is to be used in the setting coat, and in the event of this not proving satisfactory to the Architects the work must be neatly distempered of an uniform approved tint.<sup>105</sup>

#### *e. local manufacture*

It is impossible to define the point at which a true artificial cement was manufactured in Australia, still less one which can reasonably be described as 'Portland'. Hughan's patent of 1861 had in fact used the word, and was an artificial mixture. The

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<sup>98</sup> Said to have been established in 1850: *Building News*, 20 April 1888, p xxvii.

<sup>99</sup> *Building News*, 20 April 1888, p xxviii.

<sup>100</sup> *Building News*, 20 April 1888, p xxviii.

<sup>101</sup> L J Flannagan, 'Specification .. for Shop Additions in Heidelberg Road, Ivanhoe', July 1907, p 18, Melbourne University Architectural Collection, State Library of Victoria.

<sup>102</sup> E G Stone, *Reinforced Concrete in Australia* (no place, 1920), p 11.

<sup>103</sup> James Moore & Sons Pty. Ltd., *Price List 96 August 1913* (Melbourne 1913), p 5.

<sup>104</sup> Davis, *Portland Cement*, p 1.

<sup>105</sup> Reed & Barnes, 'Specification of Work to be done and Materials to be used in the Erection of Banking Premises at "Kooringa S.A." for the Bank of Australasia' (Melbourne 1878), p 48.

Schnapper Point company's cement was certainly an artificial mixture. In 1871 the word 'Portland' again appeared in the patent of W H Malyon,<sup>106</sup> but whether this was of local origin is unclear. In 1873 J M Robertson, who had previously patented a way of manufacturing hydraulic cement, received a further patent for improvements in the manufacture of hydraulic or 'so-called Portland cement'. Infusorial limestone from Waurn Ponds, Moorabool or elsewhere was ground with basalt in a ratio between 2:1 and 4:1, mixed with water, formed into bricks, calcined, and ground again into powder.<sup>107</sup>

The first sustained attempt at artificial cement manufacture seems to have been made in South Australia. William Lewis, a lime burner, is said to have experimented for some years with mixtures of limestone and clay, and at last produced a material which was claimed to be 'but little inferior to Portland cement'. He appears to have received advice from an English visitor, J C Gostling, of Gostling's Portland Cement Company in London.<sup>108</sup> Gostling won a first award for cement at the International Exhibition in Melbourne, but representations were made on behalf of the German 'Stein' cement that the tests had been carried out by officials who knew the identity of the specimens. Although no actual fraud was proved, it did seem clear that the 'Stein' was the better cement.<sup>109</sup>

It was Gostling who turned the first sod of a new cement works at Gawler on 6 October 1882.<sup>110</sup> What became of this, and whether it was linked with Lewis's activities, are not clear, but on 12 December following Lewis's Marino Cement Works were opened on the 39 hectare site at Brighton. The new venture struggled financially, unable to compete with imported cements, and closed down in the following year, but new works were to be built on the same site in 1892. These used the same raw materials, and more than a million tonnes of Portland Cement were produced there in the ensuing sixty years.<sup>111</sup> Meanwhile it was reported late in 1888 that the British and Australian Coke Gas and Electric-Light Company planned to manufacture Portland cement, among other activities, at its site at Port Pirie,<sup>112</sup> though nothing seems to have come of this. In 1889 William Shearing - whose natural cement has been mentioned - placed several samples of Portland cement before the Adelaide Chamber of Commerce, to show the progress he had made in this direction, though he was not yet in commercial production.<sup>113</sup>

While Lewis was struggling in South Australia, the first Portland Cement was manufactured at Warkworth in New Zealand in 1884 by John Wilson, after he had read Henry Reid's *Science and Art of the Manufacture of Portland Cement*. However Wilson had trouble maintaining standards, and had not developed a fully successful

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<sup>106</sup> Victorian patent no 1548 to William Henry Malyon, 29 August 1871.

<sup>107</sup> Victorian patent no 1725, 1725A to James Moeller Robertson, 29 January 1873.

<sup>108</sup> Philip McKay, 'The History of the Cement Industry to 1939; an essay' (mimeographed report for the Cement & Concrete Association of Australia, no place 1977), p 1.

<sup>109</sup> Melbourne International Exhibition, 1880-1881, *Official Record* (Melbourne 1882), pp 82-94; see also Charles Mayes, *The Australian Builders' Price-Book* (4th ed, Melbourne 1883), p 83.

<sup>110</sup> McKay, 'Cement Industry to 1939', p 1.

<sup>111</sup> D W Penn, *How Firm the Foundation* (Sydney 1977), passim.

<sup>112</sup> *Australasian Builder & Contractor's News*, 10 November 1888, p 414.

<sup>113</sup> *Australasian Builder & Contractor's News*, 20 April 1889, p 391.

process until the 1890s.<sup>114</sup> A number of works followed in New Zealand in the next few years.<sup>115</sup> Soon afterwards manufacturers began to spring up in almost every one of the Australian colonies. The Cullen Bullen Company claimed to have made Portland Cement in New South Wales in 1884, though they did not achieve commercial production for some years.<sup>116</sup> In 1886 there was a proposal to float W Penn Smith & Co Limited to manufacture cement at Rosedale, South Bridgewater, Tasmania.<sup>117</sup> Specimens had been made and successfully tested, but nothing more is heard of the venture. In the following year the Maria Island Company was formed by A D Bernacchi and the Victorian politician and financier M H Davies, to manufacture cement on the eponymous island off the east coast of Tasmania. Some of the product was displayed at the Centennial Exhibition in Melbourne in 1888, but manufacture proceeded 'under great disadvantages in the absence of adequate machinery', and for a long time amounted to nothing much. In Brisbane Robert Ferguson was experimenting with Portland cement manufacture in 1890, and applied for a patent for his improvements in the process.<sup>118</sup>

The more or less enduring enterprises were the Australian Portland Cement Co<sup>119</sup> set up in 1889 and the Victorian Cement Works in 1890, both in Victoria; in South Australia, Shearing's Portland Cement Co in 1892 (which immediately became the South Australian Portland Cement Co); and in New South Wales, the Cullen Bullen Lime and Cement Company (later Commonwealth Portland Cement) in 1889<sup>120</sup> and Goodlet & Smith, who began production in 1893.<sup>121</sup> Another pioneering maker is said to have been John Try, a building contractor who owned a joinery works and a lime plant at Portland, near Mudgee. His Lion brand cement was produced at his Granville works, but apparently using lime from Portland. Some of the brands were appropriately nationalistic ones, such as the emu for the Cullen Bullen Company, and the kangaroo for the Victorian Cement Works.

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<sup>114</sup> John Wilson, *AA Book of New Zealand Historic Places* (Auckland 1984), p 29; G C 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; Geoffrey Thornton, *Cast in Concrete* (Auckland 1996), pp 87-8.

<sup>115</sup> Geoffrey C Thornton, *New Zealand's Industrial Heritage* (Wellington 1982), pp 125-6. For example, Rutherford & Co began manufacture in 1886 on Limestone Island, Whangarei: *Australasian Ironmonger*, I, 7 (1 October 1886), p 155.

<sup>116</sup> McKay, 'Cement Industry to 1939', p 6.

<sup>117</sup> Report of the Government Architect, April 1886, quoted in Mayes, *Australian Builders' Price-Book* (1886), p 191; see also *Australasian Ironmonger*, I, 7 (1 October 1886), p 159.

<sup>118</sup> Donald Watson & Judith McKay, *Queensland Architects of the 19th Century* (Brisbane 1994), p 68.

<sup>119</sup> The company was apparently established at Portland in Western Victoria, but leased land at Fyanstown near Geelong, with limestone available not far away at Batesford. It did not come into production until well into 1890. *Australasian Builder & Contractor's News*, 7 December 1889, p 152.

<sup>120</sup> McKay, 'Cement Industry to 1939', pp 2-4; Sarah Johnstone, 'Australian Cement Industry' (typescript article for a forthcoming publication of the Institution of Engineers, Sydney 1987), pp 2-3.

<sup>121</sup> Goodlet & Smith commenced production of Australian Portland cement at their Granville works in 1893 under the 'Rock' brand. The cement was burnt from limestone brought by rail from Mudgee, where the company owned large deposits, using patent kilns and, from 1901, rotary furnaces. A W Johnson, 'Goodlet and Smith Ltd. Brickworks, Roofing Tile Manufacturers, Cement Works & "Benedict Stone" Manufacturers. Granville, N.S.W. (1886-1982)' (3 vols, major project for Historical Archaeology II [University of Sydney] 1982), pp 2,6.

An English expert, R D Langley, was associated with the establishment of some of these enterprises. He claimed to have made Portland cement in Brisbane in 1889, he assisted David Mitchell in establishing the Victorian Cement Works in 1890, and he was in partnership with William Shearing in Adelaide in 1891,<sup>122</sup> subsequently managing Shearing's South Australian Portland Cement Company from 1892 to 1895,<sup>123</sup> when it was liquidated. Stanley Fraser, who was his chemist and clerk during that period, was a member of the syndicate which then purchased the works at Brighton, and in 1896 was appointed manager of the reconstituted South Australian Portland Cement Company. When it was further reconstructed in 1902 as a limited company he was appointed manager for three years.<sup>124</sup>

These companies operated with somewhat mixed success, for the industry was still fairly primitive and there was difficulty in maintaining consistent quality in the product, which became an increasingly important consideration with the rapid expansion of reinforced concrete construction after 1900. Much of the mechanical equipment was adapted from other industries, like edge rollers and millstones for grinding the stone, pugmills for mixing the materials, and jaw crushers, Chilean mills and millstones for pulverising the clinker.<sup>125</sup>

The manufacturing process generally involved forming the limestone and alumina mixture into bricks, which were then calcined and ground, and a local patent for this system was granted to J A Jenet in 1868.<sup>126</sup> Early plants generally used the wet process, which tends to be less efficient than the dry because much of the kiln heat is used up in drying out the slurry, though this disadvantage is counteracted to a greater or lesser extent by the greater ease of mixing the materials. The wetting is said to have been unavoidable with the vertical shaft kilns which were at first in general use, as it was necessary to form the mix into blocks for stacking, but this was to become unnecessary with the introduction of rotary kilns.<sup>127</sup> However a New South Wales patent for a dry process similarly consolidated the materials 'into dense dry blocks ready for burning.' The patent, in the name of G R Dibbs, MP, and F H Thomas, probably dated from 1883, for it expired in 1897, and it may have been its expiry which accelerated the introduction of the process.<sup>128</sup> The introduction of rotary kilns by the Commonwealth Portland Cement Company, of New South Wales, enabled it to reduce prices so greatly that the South Australian Portland Cement Company could not compete, and closed its works in 1904, opening two years later, almost entirely re-equipped, and soon with its own rotary kiln.<sup>129</sup>

In 1938 Atlas Portland Cement (Australia) Limited was floated in Sydney as a public company. The stated intention was to establish at a site on the Parramatta River a

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<sup>122</sup> McKay, 'Cement Industry to 1939', pp 6-7.

<sup>123</sup> D W Penn, personal communication, 22 February 1988.

<sup>124</sup> D A Cumming & G C Moxham, *They Built South Australia: Engineers, Technicians, Manufacturers, Contractors and their Work* (Adelaide 1986), pp 64, 120.

<sup>125</sup> McKay, 'Cement Industry to 1939', pp 4-5, 10, 12; Johnstone, op cit, pp 2-3.

<sup>126</sup> Victorian patent no 1023 to John Adolphus Jenner, 16 July 1867, for the manufacture of artificial cement.

<sup>127</sup> Information from Diane Hutchinson, 1988.

<sup>128</sup> *Building and Engineering Journal*, 18 April 1891, p 153.

<sup>129</sup> D W Penn, *How Firm the Foundation: a Historical Survey of an Independent Venture that Founded the Portland Cement Industry in Australia* (Sydney 1977), pp 62-71.

modern wet process cement works with an initial capacity of 60,000 tonnes, principally to supply the Sydney market. Ancillary acquisitions were the Wollondilly Colliery, west of Camden (from the Wollondilly Bulli Collieries Pty Ltd), and limestone leases and lime burning plant at Marulan, together with as burning plant (from Marulan Lime Pty Ltd). The business was already in production, presumably as a private company, and £8000 had been spent on plant, buildings and development in the previous eighteen months. It was claimed that economical layout, cheap power, favourable cost of coal, and other factors, would ensure a manufacturing cost which compared favourably with that of existing companies.<sup>130</sup>

### *f. technical developments*

By the 1860s a German, Lipowitz, had developed an endless kiln for cement burning, based upon the Hoffman brick kiln and offering similar advantages,<sup>131</sup> but it never became important because the rotary kiln appeared very soon afterwards. A rotary kiln was patented in Britain by T R Crampton in 1877,<sup>132</sup> and another by Frederick Ransome in 1885.<sup>133</sup> A Ransome rotary kiln was installed at Arlesey in 1885 and operated under the direction of F W S Stokes. Neither this nor other experimental rotary kilns of the time proved very successful,<sup>134</sup> but an improved version was patented by Stokes in 1888.<sup>135</sup> Next Frederick Ransome's rotary kiln in England and Henry Mathey's in the United States both caught the attention of Jose de Navarro, who established the Mathey Cement Co, effectively the ancestor of the Atlas Cement Co.<sup>136</sup> Meanwhile the Americans E H Hurry and H J Seaman took out a British patent in 1895-6 for an improved process of cooling the clinker, and in 1900 the new Associated Portland Cement Manufacturers began building a number of rotary kilns in the United States under Hurry & Seaman's patent.<sup>137</sup> By the turn of the century the rotary kiln was universally used in the United States, though still rare in Britain.<sup>138</sup>

The credit for first introducing rotary kilns in Australia, to produce cement clinker under more uniform burning conditions, is in some dispute, but Goodlet & Smith did so in 1901, together with ancillary tube and ballmills. Two rotary kilns were acquired in 1902 by Commonwealth Portland Cement, one in 1905 by Victorian Cement and in

<sup>130</sup> Atlas Portland Cement (Australia) Limited, *Prospectus* (Sydney 1938), passim.

<sup>131</sup> A Lipowitz [translated W F Reid], *The Practical Manufacture of Portland Cement* (London 1868), p 37-44.

<sup>132</sup> A C Davis, *A Hundred Years of Portland Cement* (London 1924), pp 163-4. British patent no 2438 to Thomas Russell Crampton, provisional specification 22 June 1877, complete specification 21 December 1877, reproduced in Davis, pp 236-242.

<sup>133</sup> Davis, *A Hundred Years*, pp 164-5. British patent no 5442 to Frederick Ransome, provisional specification 2 May 1885, complete specification 29 January 1886, reproduced in Davis, pp 243-8.

<sup>134</sup> Davis, *A Hundred Years*, pp 164-5; Davis, *Portland Cement*, p 40.

<sup>135</sup> Davis, *A Hundred Years*, pp 163-6. British patent no 9986 to Frederick Wilfrid Scott Stokes, provisional specification 9 July 1888, complete specification 5 April 1889, reproduced in Davis, pp 249-264.

<sup>136</sup> E J Hadley, *The White Powder* (New York 1945), p 31.

<sup>137</sup> Davis, *A Hundred Years*, pp 166-7.

<sup>138</sup> Davis, *Portland Cement*, p 40. This is very different from the picture given by Skempton, 'Portland Cements', p 138 - essentially that the Germans led the way in improving kiln design, which was a pre-requisite for the for the increase of CaO content to 62% or more, and that the rotary kiln was introduced in the early twentieth century.

1907-8 one was installed by South Australian Portland Cement.<sup>139</sup> The Warkworth works in New Zealand developed largely in parallel with Goodlet & Smith. W J Wilson, its engineer, and son of the founder, visited the United States in 1899 to study developments in cement manufacture. After his return two 18.3 x 1.8 m rotary kilns and a 6.7 x 1.5 m tube mill were installed, and there was apparently a ball mill already in place. A new and much larger rotary kiln was installed in 1907.<sup>140</sup>

New companies formed just before the Great War included Adelaide Cement, New South Wales Cement, Lime and Coal (later Kandos) and Queensland Cement and Lime.<sup>141</sup> However, Commonwealth, the successors of Cullen Bullen, were to prove the most aggressive of all the manufacturers, penetrating the markets of all the states and controlling about 45% of the Australian market by the time of the war.<sup>142</sup>

The importation of overseas cement virtually ceased with the war, and before it was over compartment mills had been introduced, at least in South Australia. Goodlet and Smith of New South Wales went out of business in 1919,<sup>143</sup> but in the following years there was a considerable expansion of the local industry, including the establishment of the first manufacturer in Western Australia (West Australian Portland Cement, later to become Swan), and two companies in Tasmania. One of the latter was National, on the old site at Maria Island, but it proved a failure.<sup>144</sup> Surprisingly enough, Knight Bevan & Sturge's English-made cement, Pyramid brand, was again being advertised locally in the 1920s.<sup>145</sup>

A new wave of technical development took place in the 1920s, when rotary kilns increased in size, compartment mills were introduced for grinding, and the whole process from quarrying through to packing and distribution was extensively mechanised.<sup>146</sup> The Kandos works is amongst the best documented at this date, for the company issued a well illustrated brochure<sup>147</sup> describing the process and the major items of equipment, including the electric substation, churn drill, electric power shovels, railway locomotives and trucks, the American-made Traylor crusher (then the largest in Australia), pulverising mill, aerial ropeways, rotary driers, combination mills, Bates bagging machine, Krupp combination two stage mill for pulverising coal, and the powerhouse equipment and generating turbines. The capacity of the plant was determined by the kilns, as all the other equipment allowed a margin over them in throughput.

Standards became a major issue at this time. Earlier cements often contained a significant proportion of quicklime, as yet unslaked by the atmosphere, and accordingly had suffered by comparison with maturer imported products.<sup>148</sup> In 1925 the first draft Australian Standard Specification for Portland Cement was published,

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<sup>139</sup> McKay, 'Cement Industry to 1939', pp 12,16, 18, 22.

<sup>140</sup> Geoffrey Thornton, *Cast in Concrete* (Auckland 1996), p 88.

<sup>141</sup> McKay, 'Cement Industry to 1939', pp 28, 31, 34.

<sup>142</sup> McKay, 'Cement Industry to 1939', pp 14-16.

<sup>143</sup> Information from Diane Hutchinson, 1988.

<sup>144</sup> McKay, 'Cement Industry to 1939', pp 45-51.

<sup>145</sup> *The South Australian Building & Allied Trades Directory and Register* (Adelaide 1926), p 2.

<sup>146</sup> Johnstone, op cit, pp 3-4.

<sup>147</sup> Kandos Cement Company Limited, *The Manufacture of Portland Cement* (Sydney nd [c 1924]).

<sup>148</sup> McKay, 'Cement Industry to 1939', p 9.

and it was adopted in 1926 as Australian Standard A.2. The analysis of the raw materials, and indeed the role of the chemist in quality control throughout the process, became much more important. There were at this time about eleven companies operating in Australia, but David Mitchell's Victorian Cement Works, now operated by the Mitchell Estate, withdrew from production during the 1920s, and the struggling National in Tasmania sold out in 1928 to Australian Cement. Not a single company died as a result of the Depression in 1929-34,<sup>149</sup> though in 1929 there occurred the first of many mergers, that between Australian Cement Ltd of Victoria and Kandos Cement of New South Wales.<sup>150</sup>

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<sup>149</sup> McKay, 'Cement Industry to 1939', p 78.

<sup>150</sup> Johnstone, *op cit*, pp 3-4.