Second National Conference
on Engineering Heritage,
Melbourne, 20-22 May 1985

Monier and Anti-Monier: Early Reinforced Concrete in Australia

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SUMMARY The Monier system of reinforced concrete was the dominant one in Australia from 1895 to 1914, but it was not alone. Evidence is found of the use of the Wunsch, Melan, Kahn/Truscon, Turner and Considere systems, and surviving examples are discussed.

1. INTRODUCTION

The Monier system, as developed by the patents of Wayss and Bauschinger, was introduced to New South Wales in 1895-6 by Carter Gummow and Co. with W.J. Baltzer. It was brought to Victoria and South Australia in 1897-8 by the engineers Monash and Anderson, and then by Monash's Reinforced Concrete and Monier Pipe Construction Co. Pty. Ltd. Opposition to the virtual monopoly of the Monier system was led by George Taylor, editor of Building magazine, and it appears to have been principally in an attempt to circumvent the Monier patents that alternative reinforcement systems (mostly inferior to or parasitic upon the Monier system) were adopted by local engineers. By 1909 Taylor was denouncing the purported Monier patent rights as a bluff, and they were soon being ignored. Once the Great War was over little was heard of any of these systems, but standard reinforcing design derived principally from the Hennebique and Monier systems.

2. AUSTRALIAN AND OVERSEAS USE OF REINFORCED CONCRETE

The two decades 1895 to 1914 were remarkable in Australia for innovative concrete engineering, and while advances in reinforced concrete design theory and a rapid expansion in the use of the material were international phenomena, the Australian situation deserves attention for specific reasons. Although no significant theoretical developments were actually conceived in this country, many European and American advances were adopted with surprising speed, largely because of the competition between the Monier System and its rivals. Some of the structures which resulted were, if not the first of their types, at least amongst the earliest in the world: certainly some were outstanding as being the largest.

Internationally, the development of reinforced concrete had occurred principally upon the continent of Europe, and secondarily in the United States, the first significant patents being the French ones of Coignet in 1855 and Monier in 1867. From about 1870 there were a number of empirical innovations, especially in the form and the placing of reinforcement, and from the late 1880s a number of systems of calculation were developed. The first of these was that of the Germans, Professor J. Bauschinger of the Munich Polytechnic, who published papers on the Monier system in 1885, and G.A. Wayss, who had purchased the Monier rights in Germany, and published experimental findings in 1887. (Jones, 1913, 6-9; Collins, 1959, 60-1.) The most prominent French system was that of Francois Hennebique, who became a contracting engineer on an international scale. His system was distinguished by the introduction of stirrups and of cranked-up reinforcing bars to resist shear, but was not markedly different in principle from the Monier system. Hennebique tended, more than other engineers of his day, to exploit the material to produce frame constructions, and to express this frame visibly in the elevations of his buildings: in detail he tended to use haunched beams, and chamfered edges to both beams and columns.

To single out these prominent systems is to ignore the enormous number of competing ones, some of which one would hardly recognise as reinforced concrete from today's viewpoint. Cottancin's system was effectively reinforced brickwork more than it was reinforced concrete. Joseph Melan's system, for bridges, used relatively heavyweight bars around the arch, apparently taking compression, though embedded in a complete mass of concrete. Even in Australia there were some relatively primitive essays in the direction of reinforcing. Mass concrete had been used from at least the 1890s, especially for rural and more or less primitive structures but these were based on hydraulic lime or, in at least one Australian instance, so-called Roman cement. ('Craiglee', Sunbury, Victoria.) Portland cement and various patent materials might be used for special purposes, such as urns for parapets, and such components were sometimes reinforced by having an iron rod up the centre. According to one account Kilminster and Co. of Sydney used reinforcement in the manufacture of cement fireplaces, (BEMJ, 1902, 158; Building, December 1907, 33) and a more serious claim can be made for Angus McLean's patent of 1873, which was for an ornamental column resembling the standard cast iron type used for shop and house verandahs, but made of a tube of galvanised iron with a wrought iron core and cement and sand packed between the two. (Mayes, 1908,33.) These were soon exported from Victoria to the adjoining colonies, and even overseas.

Local Portland cement manufacture was begun in

Tasmania by the Maria Island Company, which was formed in 1887, and was able to show specimens at the Melbourne Exhibition of 1888. In 1890 Portland cement began to be made in New South Wales by the Cullen Bullen Lime and Cement Company ('Kangaroo' brand) and Victoria David Mitchell ('Emu' brand) and the Australian Portland Cement Company at Geelong. In 1891 Goodlet & Smith began manufacture in New South Wales (re-equipping with new plant in 1893), amd in 1892 two companies began manufacture in South Australia, Shearing's Portland Cement Co. Ltd., and the South Australian Portland Cement Co. (McKay, 1977, 2-8; ABCN, 1890.) Already the largest concrete dam in the world, the Beetaloo Dam, had been built in South Australia in 1888,(Const. Rev., 1977,15.) and the way was now opened up for a series of major engineering structures, first in mass concrete, and then in reinforced concrete.

Joseph Melan's system for building bridges was extremely successful in the United States, beginning with the Franklin Bridge at Forest Park, St. Louis, of 1898, (Condit, 1961, 249) but I am able to identify only one example in Australia, and that only on the grounds of appearance: this was a small bridge at Mansfield, Victoria, which apparently no longer survives. (Building, December 1907, 37.) The rather more logical system of the Hungarian Robert Wunsch, however, was used here even before the Melan system in America. Wunsch used a system of iron or steel members, not only following the arch, as in the Melan method, but running horizontally at the top, and connected with wrought iron angles to make complete frames in the vertical plane. In 1895-6 a bridge of this sort was built at Lamington, near Maryborough in Queensland, over the Mary River. The designing engineer was Alfred Brady and he used Vignoles pattern railway line for the principal reinforcing members: the bridge was regarded as the most notable example of the system outside Europe, and consisted of eleven spans of 24.2 metres each. (Brady, n.d.) Until 1904 these spans were exceeded only by the single span of 25.36 metres of the Emperor Bridge at Sarajevo in Bosnia (now Yugoslavia), though whether the Emperor Bridge itself pre-dated the Lamington Bridge, I am unable to establish. (Buel & Hill, 1906, 242-4.)

3. THE MONIER SYSTEM IN AUSTRALIA

The Wunsch system is still not reinforced concrete in the modern sense of a system in which the concrete takes only compression, and the steel is disposed accurately to take the tension and the shear, and, in some cases, a proportion of the compression as well. Of the two principal European systems which conformed to this definition, the Hennebique is not known to have come to Australia in any distinct and recognisable form, but the Monier did. By 1895 W.J. Baltzer, an engineer with the New South Wales Public Works Department, had become aware of the system and worked on it in conjunction with the civil engineers and construction contractors Carter Gummow & Co., who acquired the Australian rights to the Monier patents. They were contracted to build two test arches, and then the major sewage aqueduct at Forest Lodge, Sydney, in 1896; (Constr. Rev., 1977, 12-14,20) not long afterwards, it would seem, they built an overhead bridge on the deviation of the Southern Railway between Hilltop and Colo Vale. (BEMJ, 1898, 42) Baltzer left the government employ to join Carter Gummow & Co., and in 1897 the Melbourne engineer J.T.N. Anderson, of Monash and Anderson, met F.M. Gummow and secured the Victorian agency for the Monier system. (Serle, 1982, 131) Anderson's partner, John Monash, went to Sydney in March 1898 and was thoroughly coached in Monier Construction. The first Victorian works were the Anderson Street, Fyansford and Creswick bridges, designed by Anderson in 1897-8 and carried out under Gummow's close supervision, but the partners rapidly mastered the field, and in 1905 the Reinforced Concrete and Monier Pipe Construction Co. Pty Ltd. was established under John Monash, with the financial backing of the builder and cement manufacturer, David Mitchell. (Serle, 1982, 134-5, 154-5) In 1906 Monash established the South Australian Reinforced Concrete Co. Ltd., (Serle, 1982, 164) and its early works included the Hindmarsh railway bridge at Victor Harbour, of 1907 (the first reinforced concrete railway bridge in Australia), (Building, January 1908) and in 1908 a wharf at Port Adelaide and some commercial buildings. (Serle, 1982, 164).

Monash broke into the field of conventional city building by constructing a building to house the head quarters of his financial backer, David Mitchell, as well as his own company. (Building, October 1907, 58; Building, December 1907, 59.) Here, for the first and last time, he was able not only to construct the typical Monier frame, now with octagonal columns and no haunches, but to carry this through to the facade and fill it only with windows and non-structural spandrels. This is not remarkable in the light of Hennebique's Tourcoing Mill of 1895, which seems to be the source, though Hennebique's edge beam with a panel in the face has been expanded into something more like a spandrel, and more crudely at that. Monash's building was also preceded by Frederick Ransome's patent of 1902, (which exploited the structural advantages of continuing the floor slab a little way past the faces of the external columns, and of integrating it with spandrels above and below), (Banham, 1983, 384-5) and buildings by Ransome like the United Shoe Machinery Co., Beverly, Massachusetts,(Buel & Hill, 1906, 190-1; Reid, 1907, 479; Banham, 1983, 383, 385) the second stage of Pacific Coast Borax at Bayonne, New Jersey, both of 1903, (Reid, 1907, 275, 473, 479; Banham, 1983, 385-7) and the Kelly & Jones Machine Shop, Greensburg, Pennsylvania, of 1903-4. The Oliver Lane building is, however, remarkable in the local context, for it seems to have slipped under the guard of the authorities late in 1905: for at least the next year or two they disallowed such structures and required external walls of a thickness appropriate to load-bearing masonry, whether they were load-bearing or not.

The next city building in Melbourne with a Monier frame may have been commissioned in 1904, though it took a considerable battle with the Building Surveyor's Department of the Melbourne City Council before it was able to be built in 1905-6. (Serle, 1982, 154) Here the exterior, by the architects Tunbridge and Tunbridge, was, above the rusticated ground floor, a fairly austere treatment in face brick to which a limited amount of classical elaboration was applied: the north flank, of sheer brick punctured extensively with rectangular openings at different heights, is distinctly interesting, if largely fortuitous. The interior concrete probably shows the hand of Monash more than that of the architects, for the system is in essence much like that he used elsewhere: primary beams join the columns continuously with an angled fillet - here not so much a haunch of the beam as a flare of the column. This is very much as in the archetypal Hennebique system, and here, too, both the primary and the secondary beams (here four per bay, but later usually three) have chamfered arrises. The unusual element here is a doubling up of primary beams with arches between them, reflecting the corridor arrangement of most floors. (Building, December 1907, 42).

Although there were no more exposed or expressed frames for the present, there were other innovations by Monash, such as the construction of sawtooth roofs in reinforced concrete at the Central Telephone Exchange, 447-457 Lonsdale Street, Melbourne, of about 1907-9, (Monier file 741) and at the woolstores of the Australian Mortgage Land & Finance Co., Ltd., Lloyd Street, Kensington, about 1907-8. (Monier file 605). It does not seem that Sydney was more advanced than Melbourne, at least so far as the exposed frame is concerned. A prominent building, Challis House in Martin Place, of about 1907, had concrete floors, but steel girders and stanchions, and was encased in conventional masonry. (Building, September 1907, 21-2) A six-storey factory in Castlereagh Street, by Charles Slatyer, was of reinforced concrete fireproof construction throughout, but encased in brick and with a stone front. (Building, September 1907, 16) In Adelaide, however, the first reinforced concrete building in Adelaide was put up in King William Street for William Kither in 1907. It stands today as 29-31 King William Street, its original curtain wall obscured behind a modern facade, and most of its interior construction concealed by remodelling. It is six storeys high and on an 11.2 metre frontage: conventional masonry walls would have had to be 590 mm thick as opposed to 186 mm in concrete, so that, as Monash pointed out, the internal width was 10.830 as opposed to 10.020 metres. (Building, September 1907, 11; Building, January 1908, 59).

Monash's building in Oliver Lane seems to have had an effect, for in October 1907, at about the time it was being completed, H.E. Morton, the Melbourne building surveyor, proposed revised regulations for what was referred to as 'curtain wall' construction (different from the more specific sense in which this term was later used). The essence was that neither the internal nor the external walls were load-bearing, the load being carried through a frame of either reinforced concrete or steel. (Building, October 1907, 58) One other building in which Monash was able to express the qualities of his material was a private house at Beaumaris, beyond the reach of the city building surveyor, and for another enthusiast, his friend and colleague George Higgins. It was built in 1912 and is thought to have been the first reinforced concrete house in Victoria: (Serle, 1982, 179) its nature is expressed in flat decks and low pitched roofs with integral gutters, square water spouts, and panelled walls and eaves. It compares favourably enough with Thomas Edison's monolithic houses in the United States, of 1906-9 which had been reported locally. (Collins, 1959, pls.27A,27B; Building, January 1908, 43).

4. THE KAHN/TRUSCON SYSTEM

By and large it was not the Monier system but its opposition which produced the most interesting concrete architecture. A hint of rivalry comes with a report in 1902 that George Taylor of Sydney had invented a new system of reinforcing concrete. It was in fact an impractical enough concept involving reinforcement with parallel frameworks of bars in a vertical plane, but the significance of the publicity is its reference to other systems such as those of Cottancin, Hennebique, Milan (sic), Ransome and Bonna - upon all of which it purported to be an improvement - but the absence of any reference at all to Monier. (BEMJ, 1902, 158) Taylor was to become an increasingly influential proponent of reinforced concrete in Australia, but an opponent of the virtual Monier monopoly.

The only overseas systems to offer a direct challenge to Monier were expanded metal and the Kahn Patent Trussed Bar, both marketed by Elliott, Maclean & Co. of Sydney and, in due course, Reid Brothers and Russell Proprietary Limited of Melbourne, W. & T. Rhodes of Adelaide, Paul Gray Ltd. of Brisbane, and W.H. Kidston Co. of Perth (these perhaps being sub-agents of Elliott Maclean). (Building, October 1907, 14) Expanded metal had been invented by the American J.T. Golding in 1883, but conceived originally only as lathing for plaster. (Jones, 19B, 8; Hocl, 1913, 169).

A more complicated version of the expansion principle was 'Rib Metal', marketed in the United States by the Trussed Concrete Steel Co. (Hool, 1913, 170) Rib metal may have been the invention of the architect Albert Kahn, for he was the orginator of the Kahn Bar in 1902 and, with his brothers, was joint proprietor of the Trussed Concrete Company. The bar was a rolled section with projecting flanges along each side, which were slit so as to form strips which could be bent upwards to act as shear reinforcement and, if required, to wrap around any top bars. The American company formed an association with the English firm of Holland & Hannen to set up an English Truscon Company, beginning operations in 1907. (Truscon, 1957, 5,7) Presumably it was this company which licensed the various Australian agencies, though Elliott McLean & Co. seem to have published a booklet, Expanded Steel, at an earlier date. This work was said to have been for some time the only information on reinforced concrete construction available to local practitioners. How much these patent products were used locally is not clear, but they seem to have been more in demand for special components than for complete reinforced concrete framed buildings. (Building, September 1907, 16).

In 1907, however, two major concrete structures were reinforced with expanded metal. The South Melbourne Gasworks was designed by the engineer of the Metropolitan Gas Company, P.C. Holmes Hunt, on a giant raft measuring 73 X 9.3 metres, on which were diaphragm walls, then a secondary raft, 150 mm thick, the space between being filled with building waste. (Building, January 1908, 53) At about the same time, or slightly earlier in 1907, the Fertilizer House of Borthwick's meat works at Brooklyn, near Melbourne, was constructed with walls as well as floors of concrete reinforced with expanded metal. The building was designed by the architect and engineer C.A. D'Ebro, and the rather unlikely use of expanded metal as the reinforcement of walls probably reflects the difficulties facing engineers when the local Monier company claimed the exclusive rights to more suitable systems. The unusual thinness of the walls in this case was counteracted by the provision of full height buttresses, tapering as they rose. (Building, November 1907, 31) Stylistically this was analagous with a recent English house, C.F.A. Voysey's 'Perrycroft' of 1893.

The original Borthwick building does not survive today, but there remains another, the Sheep and Lamb Dressing Floor, apparently built by the same engineer-architect about a year later. Here the attempt to make expanded metal reinforced walls has been abandoned: there are steel stanchions, with concrete only as infill panels between, and there are also steel girders and knee braces, but they support a remarkable concrete structure for the upper floor, consisting of two parallel slabs, each of 150 mm and more, at varying distances, up to about 1.5 metres, and diaphragm walls running vertically between them at intervals. The structure is confused by the changes of level, by the integral casting-in of drains to remove blood and waste from the slaughtering floor, by the cutting of holes through the diagphragm walls, and the superimposition of multiple layers of concrete on the top surface. Nevertheless the intention can be inferred, especially bearing in mind the contemporary South Melbourne Gasworks raft reinforced on the same system. The Borthwicks building is conceived as a sort of hollow slab, or the slab equivalent of a box girder, though the dimensions are such that it can hardly have been effective in this mode.

These buildings were based on the expanded metal marketed by Elliot Maclean & Co., but their other product, the Kahn bar, was to present the major challenge to the Monier monopoly. The domed reading room of the Melbourne Public Library , the story of which was first told by David Saunders in 1959, (Saunders, 1959) was designed on the assumption that it would be built by Monier, and certainly John Monash gave advice to N.G. Peebles, of the architects, Bates, Peebles and Smart, and to the trustees. (Serle, 1982, 166) His preliminary drawings, dated May 1908, have only recently been discovered. (by John Thomas, of Kew) But it was now that local building contractors fought back, ably supported by the journal Building and its editor, George Taylor who, as we have seen, was an early advocate of reinforced concrete and an early promoter of systems other than Monier. In February of 1908 Building reported that the Master Builders Association had discussed the increasing use of prime costing in both government and private work, and contractors like J.W. Swanson had spoken strongly against it. (Building, February 1908, 15) Their main target seems to have been the library dome, which, with a span of 34.8 metres, was to be the largest in the world. Taylor's comment was that 'The utilisation of reinforced concrete construction is certainly not beyond the intelligence of the Australian builder'. (Building, February 1908, 66) By June Taylor was becoming more emphatic, using a four-tiered heading 'The Combine System: Its Grave Danger in Building Construction: How it has worked in America: A warning to Australia'. (Building, June 1908, 37).

The campaign was successful. On 17 February 1909 a deputation from the Master Builders Association met the trustees of the library, who agreed to open the reinforced concrete work to competition. (Building, March 1909, 44) New specifications were drawn up, fresh tenders were called, and that of J.W. and D.A. Swanson for 66,914 pounds was accepted. (Armstrong & Boys, 1932,10) The new reading room when completed was a magnificent space, but stylistically unadventurous: its most dramatic feature was the great area of glazing within the dome, and today all this has been covered over. Below this grand space at ground floor level was a much less pretentious area for the newspaper room, and a basement below that. In the newspaper room the nature of the concrete work is more clearly apparent than above. It is octagonal like the reading room, but is a single volume without the annulus of spaces around the outside. In the ceiling is a grid of beams supporting the slab above and carried on a central column, from which the principal beams radiate, and subsidiary columns placed below the inner wall of the annulus overhead. The columns are octagonal and angle out at the top into octagonal cone heads which meet rather unsatisfactorily with the grid of beams, but were to be used more appropriately in another Melbourne building very shortly. The library took possession early in October 1913 and the new building was formally opened on 19 November. (Armstrong & Boys, 1932, 21-2) Swansons, the builders, had brought in the English Truscon company as contracting engineers for the reinforcing work, and this was the first major local use of the Kahn bar. (Constr. Rev., 1977, 23) A comparison of the building with the recently discovered Monash drawings shows clearly that the detailed form of the building, including the shape of the Columns and the disposition of the beams is that originally conceived by Peebles and Monash.

5. THE TURNER SYSTEM

While the library was building, changes had been taking place. Taylor had continued his campaign, announcing, when the Monier company tried to assert its control over certain patents, that Monash was bluffing. (Building, May 1909, 23-4) Monash did not accept the challenge to go to law, and from 1910 reinforced concrete construction was effectively open to all. (Serle, 1982, 166) Two structures of particular interest were built during the period of transition. In March of 1909 it was announced that the engineer Henry Crawford was building Melbourne's first complete concrete building in Drewery Lane, off Swanston Street. This claim seems to ignore the Monier building in Oliver Lane, but the general point was well made that such buildings were inhibited by the ambiguity of the regulations, and that even in this case the walls had to be made much thicker than structurally necessary, and the pillars and floors stuffed with metal. The designer had been presented with a choice of waiting for the adoption of newly proposed regulations which would no longer require reinforced concrete walls to be as thick as load-bearing masonry, but which would also severely reduce the building height permissible in such a narrow street as Drewery Lane, and he had chosen to proceed under the existing constraints. (Building, March 1909, 45)

Crawford's building was for Sniders & Abrahams, manufacturing tobacconists, and was to house nine hundred cigarette makers. It was at first planned to have a standard beam and slab structure, but after construction had begun it was decided to change to the flat plate or 'mushroom' system of the American C.A.P. Turner, allegedly because of the saving in the cost of formwork for the beams. Although the construction was in some respect heavier than necessary because of the requirements of the building regulations, the slab was less than 200 mm thick for a span more than 5.7 metres, or nearly 8 metres on the diagonal. (Building, June 1910, 23, 57-60, 62) Where the columns in the original American system were cylindrical, with a head at the top that flared outwards in a curve, with a rather fussy band at top and bottom, (Condit, 1961, 169) the columns of the Melbourne building were octagonal, with simple octagonal cones for the heads. This was the same as the shape used in the lower level of the Public Library, and was probably copied from it.

Turner's first structure of this type, the Lindeke-Warner Building at St. Paul Minnesota, dates from 1908-9, and I am unable to find that it survives, so that the Sniders & Abrahams building, begun before the Lindeke-Warner building was finished, may be the oldest existing building of the type. It also pre-dates the rather similar system of the Swiss engineer Robert Maillart, which is supposed to have been developed in 1908-10, but was used only in 1912 for the Federal Grain Storehouse at Altdorf, Switzerland. Maillart's flared head is more elegant than either Turner's or Crawford's, though more expensive than Turner's to form. The substantial difference is that Turner has reinforcement running in four directions across the column head, thus decreasing the effective depth of the slab where they overlap, so that any benefit from the diagonal reinforcement is lost. Maillart, by contrast, confines himself to the usual two directions, but spaces the rods more closely over the column, and better approximates the real structural requirements. (Bill, 1969, 154,158-9) A further refinement on the Turner system, which was to become quite widespread in Australia, was to lay a grid of hollow terra cotta lumber blocks in the slab, the overall thickness of which was greater, but the amount of solid concrete less: this made it effectively into a sort of waffle slab except over and near the column heads, where the whole depth of solid concrete was retained, a much more efficient disposition of material. This version, the Innes-Bell system, was used for a number of garages in the Sydney area, and for other buildings until at least the Second World War.

6. THE CONSIDERE SYSTEM

Undoubtedly the most extraordinary of all the Australian examples is the Denys Lascelles Wool Store at Geelong. It was designed in about 1909 by the Sydney engineer E.G. Stone, who had previously taken out various patents for improvements in reinforced concrete, none of which are known to have been significant. At Geelong he used a distinctive system of reinforcing which is undoubtedly that of the French engineer Armand Considere. Considere had been chief engineer with the Ponts et Chaussees in France (Collins, 1959, 79) but resigned to exploit his system, known in English as 'hooped concrete'. He established himself in the firm of Considere, Pelnard & Lodier of 103 and 128 Boulevard de Montparnasse, Paris, and took out patents including German no.149,944 of 1902, (Colby, 1909, 123) and United States no.752,523 of 1904. (Ransome & Saurbrey, 1910, 46-7) Before 1906 he had established a London agency in the name of the Considere Construction Company at 3 Victoria Street, Westminster. (Marsh & Dunn, 1906, 42,563; Collins, 1959) Following repeated independent tests, Considere's system was recognised in the regulations of France, Germany and Austria. (Adams & Matthews, 1911, 259).

The Considere system was distinguished by its use of spirally wound reinforcement - hence the name 'hooped concrete' - a development of the ideas of Lee & Hodgson (Collins, 1959, 54) and of Cottancin. (Collins, 1959, 83, 116; Marsh & Dunn, 1906, 42) Considere, however, used a single helical rod or wire rather than a mesh, substantiated his system by an extensive programme of experimentation, some of it apparently in conjunction with Hennebique, (Marsh & Dunn, 1906; 177-243, 277, 318; Buel & Hill, 1906, 80-84; Twelvetrees, 1907, 289-195 &c.; Ball, 1913, 20,49,69; Martin, 1912, 22-3,91-107; Brooks, 1911, 109 ff.) and developed a method of calculation. (Marsh & Dunn, 1906, 342,390) The system was illustrated in an English text of 1910, (Rings, 1910, 135) and described in another of 1913 as follows:

> Beams and Slabs. -This system is well-nigh devoid of fanciful methods of shaping and arranging the reinforcement, and is claimed to rest entirely on a scientific basis. In the case of minor beams, the tensional reinforcement takes the form of round bars, some of which are horizontal throughout, and others are bent up at the ends. Where a compression member is required, a spiral coil of round steel is inserted near the top surface. Occasionally beams are additionally reinforced against shear by means of thin steel rods, which are lapped round the tension and compression bars. In addition to the above, Considere sometimes inserts an extra reinforcement (a spiral coil of round steel laid nearly horizontal) in that part of the concrete which is in compression near the supports of a continuous beam. The slab reinforcements between the beams consist of round bars bent up over the supports at each end, there being, in addition, round bars which cross the other reinforcements at right angles. In large girders and trusses, as employed in bridge construction, the tension members are reinforced in the manner already described, whilst the compression members are reinforced with longitudinal bars and spiral coils.
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> Columns.- Columns are generally circular, octagonal, or square in cross section, and the vertical reinforcements are straight round bars from 4 in. to 6 in. apart, whilst the transverse reinforcements consist of round rods in the form of coils wound spirally round the vertical reinforcements, the ends of the coils being bent inwards.
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> Piles.- Considere has devoted much attention to the construction of reinforced concrete piles on scientific principles. His general form of pile is octagonal, with longitudinal reinforcing rods, generally numbering about eight, inside a continuous spiral winding of round steel rods, the pitch of the spiral being about 2 in. at the middle and diminishing to about $1\frac{1}{2}$ in. at both head and foot. The head is of cylindrical shape and for about 4 in. is bound with steel coils closely pitched, this reinforcing the head to such an extent that it will not fracture under the driving shock, even though a cap or dolly is not used. (Jones, 1913, 217).

The Considere system was first used in the United States in 1903-4 by the American reinforced concrete pioneer E.L. Ransome, for the Kelly & Jones machine Shop, Greensburg, Pennsylvania, (Ransome & Saurbrey, 1910, 13; Collins, 1959, 63; Buel & Hill, 1906, 190,192,213; Reid, 1907, 472-3) similarly in extensions to the Pacific Coast Borax Factory, (Reid, 1907. 275,473,474) and the United Shoe Machinery Company building, Beverley, Massachusetts, (Buel & Hill, 1906, 190,191; Reid, 1907, 474) all referred to above. In England the system was used for Gordon and Gunter's Royal Insurance Building in Lombard Street, London, of 1910, (Jones, 1913, 358-60) almost contemporary with the Dennys Lascelles Austin stores. Whether the system was used in Australia other than at the Geelong building is not known, except that Stone also employed it in one other structure at Geelong. It would not appear that he had used it in the concrete house he built at Iandra, New South Wales, in 1910, as this has the appearance of mass concrete construction. (Building, March 1910, 73-75) Overseas, the system was again used for Leonard Stokes's Roman Catholic Cathedral at Georgetown, Demerara, of 1914, (Collins, 1959, 95) but it is not clear whether it survived as a

distinct system after the Great War.
The Dennys Lascelles Austin building has never, so far as is known, been previously identified as being built on the Considere system. However, a contemporary report refers to the casting of the concrete in wooden boxes,

> in the centre of which are long steel rods spirally wound with stout wire. These contrivances confuse (sic, for confine) the reinforcement.... (News of the Week, 14 April 1910, 18).

Later a photograph was published showing the reinforcing cage which, although the columns were cast square in section, had the vertical rods disposed octagonally and wound with the characteristic spiral hooping. (News of the Week, 2 November 1911, 16) In the roof trusses the top chord and verticals are actually cast octagonal in section, and similar reinforcing has been exposed by spalling. It does not, however, appear that the helical reinforcing is so great as Considere would have advocated, for in some examples the diameter of the coil equalled that of the longitudinal rods. It is, nonetheless, too substantial to be regarded merely as a continuous ligature.

The Dennys Lascelles Austin building has a roof structure over the main area of six reinforced concrete girders tied together in pairs like three parallel bridges.

Their form was based closely upon bridges built by Considere in France, which tends to support the thesis that the reinforcing system is also his. The overall design of the structure, which was by far the largest reinforced concrete roof span in the world, is itslef fascinating, but not the subject of the present paper. Stone followed it with another structure on the Considere system, the almost equally remarkable sewerage aqueduct over the Barwon River at Geelong, of 1914-15: this, however, was based upon Fowler and Baker's Forth Bridge, Scotland.

7. CONCLUSION

The Monier monopoly was under challenge especially from 1909 onwards, and the challenge succeeded, for nothing was heard of these patent rights once the Great War was over. But the Monier system prevailed. The only one of its rivals which persisted in a recognisable form was that of Turner, which was adapted into the Innes-Bell system of flat plate flooring, incorporating hollow terra cotta blocks. While the Monier system has not survived in name, it is the one to which modern reinforced concrete design most closely approximates.

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