Innovation in the modern Australian concrete building business: The introduction of pre-stressed concrete, 1945-1970

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Introduction

The introduction of new technologies for building structures is dependent on the ability of individuals to understand and use new materials and tools in new ways. In the modern era, ideas can be spread through scientific articles and books, and knowledge can be organized within international companies guarded by patents.

To illustrate the innovation process in contemporary society with its deep and complicated agglomerated technologies, we can divide the the development into in a four stage process [1]: the first stage is the idea generation in the form of inventions and their resulting patents, the second stage is advocacy and screening of practical use, the third stage is a maturing phase, and the last is the commercialization phase.

By the 1930s the technology for building strong structures using pre-stressed concrete was ready to be introduced worldwide. This technology brought new possibilities. It saved on raw materials (skyscrapers could be built in a few months) and the pre-stressed concrete provided a lighter construction. With this came more substantial bridges and halls for industry, made possible by wider roof beams with longer spans. Especially in large bridges, the use of pre-casted concrete beams made the construction work at the building site much easier. (Fig. 1)

Figure 1. Pre-stressed concrete beams changed the construction work, as here at O'Shea's Crossing Bridge, John Holland Constructions 1977. Photo: Wolfgang Sievers, National Library of Australia, nla.obj-143341980.

In this paper the development of the Australian industry will be compared to that in Europe, where the technology originated.

Idea generation

Use of pre-stressing dates back to the 19th century. Pre-stressing is steel reinforcement that has tension induced into it either after curing or before. This reduces stress and cracks. [2] One of the first patents for pre-stressed concrete was granted in 1888 to a system invented by German C. F. W. Döhring, where threads of steel wire reinforcement are stretched (tension is thus induced) in a row, after which concrete is cast around the threads. When the concrete hardens, the threads are held inside the concrete. [3] However, it took years before the principle was ripe for commercial exploitation. One particular problem needed to be solved: much of the tension in the steel wire was lost. A solution came from French Eugène Freyssinet, who filed a patent application in 1928 for using high tension steel. [4] Now the groundwork for the practical use of the ideas was made, and development went in two different directions.

The first is the pre-tensioned concrete. It is based on the invention of Ewald Hoyer in Germany, who patented a method in 1937 based on the ideas of Döhring but with use of quite thin threads of 2-4 mm.

The other is the solution when the pre-stressing is done after the structure is cast (post-tensioning). The key element in the post-tensioned concrete solution was the anchors; Eugène Freyssinet invented it in 1939 (Fig. 2). The method was subsequently improved on by others. The first was the Belgian Gustave Magnel (named the Blaton-Magnel system) (Fig. 3) [5]. He completed his first bridge in 1944 [6] and a large factory in 1948. [7]

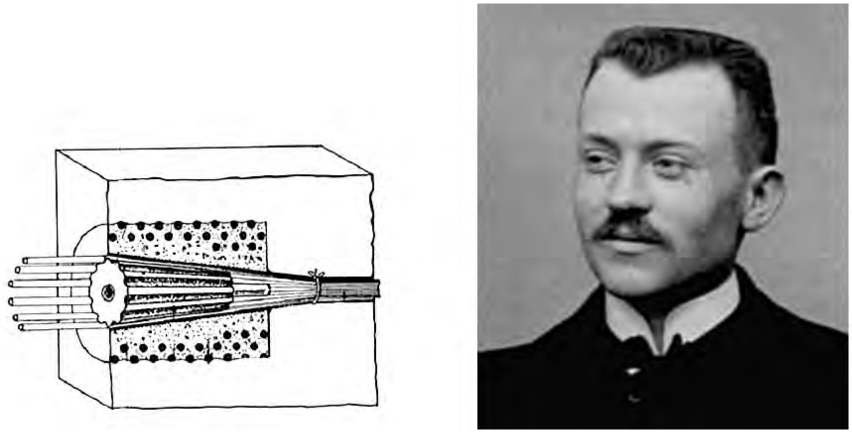

Figure 2. Anchor system invented by Eugène Freyssinet. Photographer unknown; from Essential-Architecture, Architect Eugène Fryssinet.

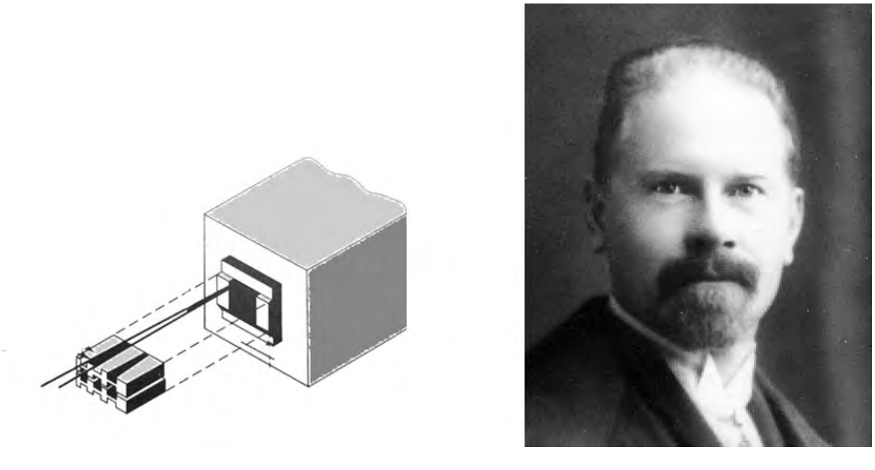

Figure 3. Anchor system invented by Gustave Magnel. Photographer unknown; from Collectie Universiteitsarchief Gent.

In Germany the company Wayss & Freytag entered into a licence agreement with Freyssinet in 1934. The director of the company, Karl Mautner, experimented together with Freyssinet, and in 1938 a first 32 m road bridge was erected designed by Freyssinet. [8]

In 1937, a new company in England got a licence from Freyssinet, but only became successful when Karl Mautner became manager. He was a Jew, and when he escaped from Germany he took his experimental results from France and Germany with him. [9]

Advocacy and screening

In Australia everybody could know about the developments in Europe from scientific journals. We have no knowledge of the extent to which this happened. Knowledge had become strategic, as neither Germany nor England wished to be spied upon in wartime, as both countries used the technique. This slowed down the spread of knowledge. [10]

The first time you could read about pre-stressed concrete in Australia was in 1941, when an English newspaper was quoted as saying that cement could replace steel for the building of merchant ships, and the paper would wait for the perfected method from ”Freyssinet and his fellow Enthusiasts” [11].

Water tanks are important in the often drought-stricken Australia, and a magazine for the construction industry mentioned in 1944 the construction of pre-stressed concrete tanks according to Freyssinet's principles included in America's war program. [12] After the war, news on pretstressed concrete continued to appear. In 1949 the Australian magazine "Building and Engineering" contained several articles, occasionally cited in more popular publications. The references were often based on experience in Europe or were simply reprints or translations of European articles. [13]

Promotion of the advantages of the new methods became so widespread that the leading architect of S.A. Housing Trust took a study trip to Europe in 1949 to examine the latest developments. [14] Sydney Technical College had been quick to investigate the technology, and in 1950 the Commonwealth Experimental Building Station exhibited pre-stressed concrete cast at the station. [15] A report from the Commonwealth Scientific and Industrial Research Organization (CSIR) was published after many of the institution's employees had returned from trips abroad gathering data. CSIR could also advise manufacturers and investigated how building materials were affected by the Australian climate. [16]

It became clear that the technique could be used for bridges, and a bridge engineer from the Country Roads Board in Victoria travelled abroad in 1950 to see the technique used in practice. [17] The director of Public Works in Tasmania travelled for six months to see the new technology.

The Railway Commission was even more practical in its pursuit of the new knowledge. In 1950, it purchased precast concrete railroad sleepers from abroad to test them. [18] Later, more tests were done with different types. In 1960 the Commonwealth Railway ordered some 10,000 Monier-type sleepers based on a French patent from the French Railways. [19] In 1951 knowledge from British Building Research on how to set up a pre-stressed concrete factory was promoted by the State Building Liaison Service. [20]

In 1953 everybody was aware of the technology. Architects started to pay attention for pre-stressed concrete, and the Royal Australian Institute of Architects showed two French films. [21] Public administration engineers also had the opportunity to receive information at meetings of the Association of Local Government Engineers [22], or from presentations by local suppliers. [23] Engineers could inspect the first constructed works, such as a reservoir in Brisbane. [24]

The major public breakthrough in engineering circles took place at a symposium in Sydney devoted to pre-stressed concrete organized by the Cement & Concrete Association of Australia. They expected 250 people, but 470 came. There was only standing room in the packed hall, where a series of lecturers spoke about ongoing projects. The chief source of inspiration was Great Britain, where 15% of all cement construction was then done using pre-stressed concrete. [25] Participants visited the six-storey 30 m high ice tower at the partially built Warragamba Dam with all its pillars and beams joined together by Freyssinet wires, which was announced to be the first totally pre-cast and pre-stressed multi-story building in the world. [26] (Fig. 4)

Figure 4. The ice-making plant for concrete casting at Warragamba Dam. Sydney Morning Herald 13 October 1957, p. 8.

Maturing

Buildings

For a long time no concise consensus of practice was available for those intending to design in pre-stressed concrete, even the politicians soon realized the benefits of the technology. The Head of Government (the Premier) in South Australia in 1949 stressed the need to learn foreign experience to save on materials. [27] In 1951 a town council in Queensland could not find engineers with practical knowledge of pre-stressed concrete, and the engineers of the town were asked if they should learn the new technology. [28]

When the chairman of the Architects' Board of SA in 1952 returned from a trip to Europe, he stated that local authorities should make new politics on regulating the housing area. [29] A similar problem arose in New South Wales (NSW) in 1953 when members of the Royal Australian Institute of Architects wanted to build houses embodying modern features discouraged by the regulations. [30] The Australian Building Industry Productivity Team concluded in 1954 after a study tour that multi-story buildings could not be built in Melbourne. [31] Even the new mayor was unsatisfied with the building regulations. [32] Professor A. J. Francis from the Melbourne School of Engineering gave an explanation on the severe conditions. Bad building regulations were one thing, but the local cement of bad quality was another. [33]

In Australia, the Commonwealth Experimental Building Station was the first authority to study the techniques of pre-stressing. It published a report on tests carried out on pre-stressed concrete panels in 1947, and subsequently gave valuable assistance in its practical development by private industry and by State public utilities. This included tests at a laboratory for measuring the fire resistance of building materials. These ratings were used as guides for the framing and building regulations. [34] In 1955 a report about rules for the design of pre-stressed concrete and rules for the guidance of designers and manufacturers was written at the request of the Council of the City of Sydney. [35]

However, there were still many years when people remained uncertain and it was not until 1964 that an official standard appeared for the use of pre-stressed concrete which was accepted by the Standards Association. [36]

Other constructions

In 1952 in Brisbane in a scheme for a 49 mile-long water pipe, the council asked not only for constructions in steel but in pre-stressed concrete too. [37] However not all local authorities dared to use the new technology. For instance The Electricity Commission of NSW bought the old versions of pipes. [38] A town council in NSW had similar doubts when the local NSW Mining Co. wanted a bridge and decided, that the mining company should take the economic risk the new form of construction. [39]

The same conservative attitude is evident in the case in Redcliff in 1953, when a tender for a two-million-gallon water tank was announced to be built in steel, concrete or pre-stressed concrete. The council chose the ordinary concrete at a cost of £42,000. After complaints were made to the local Government Department the council was made to accept the cheaper pre-stressed solution instead – only £35,400 [40].

The large companies with strong technical expertise could sometimes be more adventurous. The same year 1953, when Snowy Mountains Hydro-Electric Authority asked for tenders for a bridge - they stipulated it must be pre-stressed concrete. [41]

The railways meanwhile were rather conservative. When the railway from Sydney to the Blue Mountains needed to be electrified, the Main Road Board demanded a test of the bridges with two 26-ton filled rail cars; even though the railways had no plans to drive with such heavy loaded cars. [42]

In 1953 when Brisbane gave a permit for building of a water reservoir, the town council demanded a guarantee on £ 10,000 to cover the pre-stressed concrete construction. [43]

The confidence in pre-stressed concrete bridge building was overwhelmingly positive after 1953. Victoria's Country Roads Boards planned 15 new such bridges. [44] Even a small shire in NSW decided to build pre-stressed concrete bridges, even though the shire was in the centre of the hardwood tree area. [45]

From 1954 onwards Australia had its own experts in the combination architecture and pre-stressed concrete when Dr H.J. Cowan became professor in architecture in Sydney. He came from the University of Sheffield, where he had developed a modern laboratory for reinforcement of concrete. [46] At the University of Adelaide Professor F. B. Bull started research in pre-stressed concrete. It was not possible to copy all elements from Europe. For instance, the sand in Australia was different from that in Europe. South Australia did not have much sand, and therefore experiments with crushed cliff were made. [47]

Commercialization

Buildings

1949 saw a very early use of pre-stressing in a 244 m long factory building in Newport, NSW. The columns were pre-cast and reinforced with cables and anchorage cones according to the Freyssinet system. [48]

There was more press coverage for the first pre-stressed concrete floor which was laid at a slaughterhouse in Victoria in 1953. The 3,000 pre-stressed concrete joists and 10,000 floor slab units were casted by B.P.M. Concrete Pty, at a new pre-stressing and steam-curing plant in Melbourne. [49] That same year pre-stressed girders were used at St. Lucia University – the first time in Queensland. [50] Soon after the Metropolitan Water, Sewerage and Drainage Board in Sydney used pre-stressed concetere to make the first multi-story building in the town. [51]

Taller buildings soon followed. At that time high houses were only permitted to be 12 m high, except in special cases when they were allowed to be up to 40 m – because that was as high as a fire ladder could go. [52] The Caltex House broke in 1957 the height limit in Sydney with its 20-story tower (72 m). [53] It became the tallest building in Australia, but the next year saw the ICI House in Melbourne which was slightly higher. (Fig. 5) Soon similar tower blocks sprang up. [54] One of the large builders was The Housing Commission of Victoria, which until the 1970s raised around 27 pre-cast 20 to 30-story buildings. [55] The most impressive was pre-stressed building was the terminal in Melbourne Airport, Tullamarine, built in the middle of the 1960s and the then largest building in the Southern hemisphere. [56]

Figure 5. ICI House during construction, East Melbourne, 1958. Photo: Wolfgang Sievers, National Library of Australia, nla.obj-160508495

Bridges

One of the first bridges was a 32 m long road bridge at Gatton Shire near Brisbane, built in 1953. [57] In the same year a new bridge was erected in Bowral, NSW. [58] The construction of the first bridge with several spans in Teven, NSW was more complicated than normal, and a British company completed the engineering work. [59] In 1957 a 88 m long bridge was built near Cooma, NSW which had girders cast in Villawood, 270 miles away and transported on a special railway car. [60]

The bridges became progressively larger. In 1959 a new bridge with a 275 m span was to be built in Canberra using 120 ton girders casted on situ. The design by Maunsell and Partner, London (engineers) and British William Holford (architect). [61] In 1964 a 250 m bridge were completed in Nelligen over Clyde River, NSW. [62]

In 1965 several small bridges were under construction on a road link in Western Australia designed by the Australian company Rankine and Hill. [63] Many more bridges were constructed in those years, and when the NSW minister of Public Works in 1966 opened two new bridges, he announced the plan to build around 300 more bridges over the next two years under a new bridge subsidy scheme. [64] Victoria also built around 120 small pre-stressed bridges in 1963. [65]

By the late 1960s pre-stressed concrete had become a technology accepted by authorities and readily handled by local companies. Still there were reasons for concerns about its use – such as when in 1968 a new railway bridge in Queensland collapsed just after a train passed over it. [66] The more advanced and technically complicated bridges were still being designed and built with the help of companies from abroad. Foreign contractors came to Australia to help with their expertise such as the Danish company Christiani and Nielsen who worked on the almost 400 m long Narrows Bridge in Perth, Western Australia which opened in 1959 – another bridge designed by Holford and G. Maunsell and Partners – at that time the largest pre-stressed concrete bridge in the world. (Fig. 6) Another world record was the then-longest railway bridge at 339 m. for the New South Wales Railroad at George River designed by Donovan H. Lee & Partners, London. [67]

Figure 6. Narrows Bridge in Perth, Western Australia under construction in 1958 with the casting of elements at right. Photo: E.W. Digby, Wikipedia.

The Gladesville Bridge in NSW opened in 1964 with a 305 m span reinforced concrete arch. It was accredited at the time of completion as being the then longest span structural arch in the world, [68] and again designed by G. Maunsell & Partners. The arch was calculated in 1956 by computer. [69] (Fig. 7)

Figure 7. Gladesville Bridge in Sydney under construction circa 1960. Photo courtesy of NSW Roads and Maritime Services.

Other constructions used pre-stressing too. When the Preload Corporation in 1953 wanted to build a water reservoir in Canberra it used Australian steel wire from Australian steel works. [70] In 1955, a production of particularly strong steel wire began at a cold drawing in a factory jointly owned by Australian Industrial Steels and English MacAlloy. [71]

In 1958 the Sooley Creek Dam in NSW was post-tensioned, [72] and when the Catagunya Power Station in Tasmania opened in 1962 its dam was strengthened with pre-stressed ground anchors. [73]

Pipe manufacturers

Rocla

The Australian manufacturers of pipes had a special role to play in the introduction of pre-stressed concrete. One of the three key companies was Rocla established in 1926. Its production was based on vertical cast of tubes cast from an inner and outer mould. In 1943 the company introduced a roller-suspension process. The technology was very close to the pre-stressed concrete previously mentioned in this article, and Rocla had bought the wolrd rights for the patent from Lionel Fitzpatrick Frank which had improved an invention by Freyssinet from 1936. [74] Rocla's system was based on a wire stretched through a pre-formed hole in the concrete, and then grouted so transfer of stress was by bond, whereas other systems had wires anchored only at their ends. [75] In the following years, the method was improved and the technology was exported abroad. [76]

In its first years the Rocla company competed against suppliers of steel pipes, but still had an advantage when it came to the manufacture of large pipes, which were uneconomic in steel. Rocla continually improved its production, and larger diameters were continuously brought out. In 1952, 51" pipes for sewers were produced. [77] The company reported a 45% savings compared with pipes of steel, even though the new pipes could handle the double pressure. [78] At that time in 1954, Rocla had 12 factories in Australia. [79]

Rocla used two different methods of pre-stressing depending on the diameter of the pipe being made. Pipes up to 30" were pre-stressed by subjecting the reinforced pipe wall to internal pressure before the concrete set. The large pipes were made by a method similar to the preload process used for big tanks. [80]

A company had in 1952 won a contract to build two water reservoirs in Brisbane and wanted to build them in pre-stressed concrete, which would have meant that the wall thickness could be reduced from 23" to 14". It was initially not permitted to use pre-stressed structures, but after a resubmission of the application Brisbane City Council gave permission. [81] The tanks were made by the new company Preload Corp (Aust.) established by an Australian company with 70% of the share capital, while the US company Preload provided its patented method and associated machinery. [82] (Fig. 8)

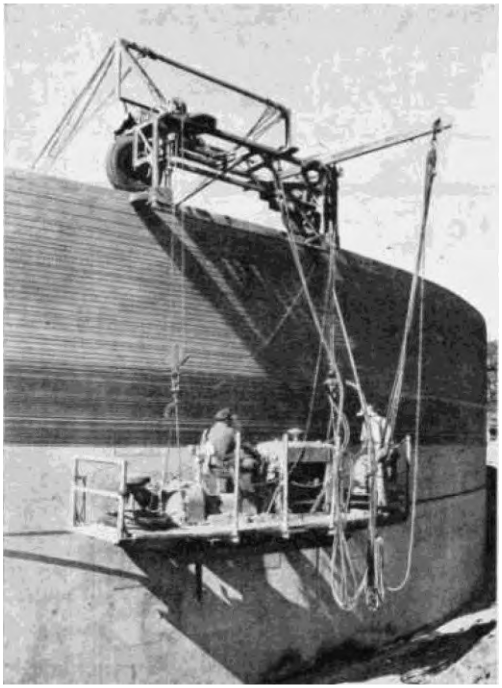

Figure 8. Pre-stressing of a circular concrete tank by the Preload system. Building, Lighting and Engineering 24 April 1954, p. 55.

Humes

The pioneer of concrete pipes was Hume Pipe Company which used a method invented in the early 1900s employing a centrifugal casting into a spinning mould around the wire reinforcement. A huge production was made for the large irrigation systems, and the centrifugal spinning process was licenced overseas in many countries. [83]

In 1950, Humes was able to offer both ordinary pipes and pipes produced by pre-tensioning by a 51’ pipe tender. [84] At that time, there was still a steel shortage, so concrete pipes could save imports of expensive steel pipes. [85]

Even when the local pipe manufacturers had a strong market position, foreign companies tried to bid on tenders on water pipes to Brisbane as a French company did in 1952. [86] When Tasmanian Hydro-Electric in 1954 wanted large pre-stressed concrete pipes, offers were sought not only from Australia but from Italy, France and Great Britain too. [87]

Monier

The third big company was Monier formed in 1897 to produce concrete pipes based on a Monier machine from Europe. It took over the trademark *Monier* in 1911. After a time in public ownership, it was privatized in 1941. [88] The major player in pre-stressing was Concrete Industries, a subdivision in the Monier group established in 1936. The cement foundry could produce pre-stressed concrete by 1953, and among the first orders were girders for the construction of a shopping centre in Cronulla, NSW. [89] It delivered pre-stressed lintels to go over windows too. [90] (Fig. 9) As a subcontractor, the company supplied beams for the first bridge built with pre-stressed concrete in Bowral. [91] In 1957, Concrete Industries was stated to have 33 subdivisions. [92]

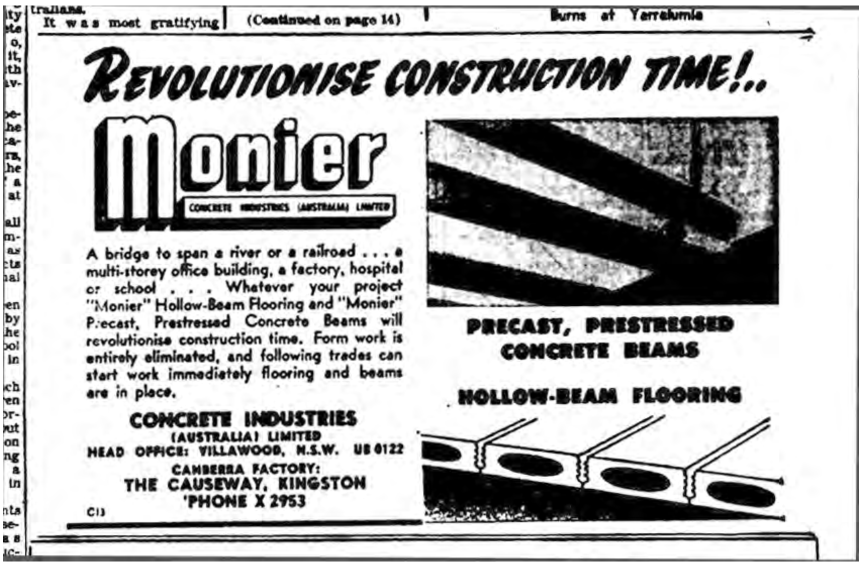

Figure 9. Monier with its daughter company Concrete Industries delivered many small and large pre-cast and pre-stressed elements from its factories. Canberra Times 28 Jan 1958, p. 11.

The patents

In the first years, the planning of construction was largely on foreign hands. The company Prestressed Concrete (PSC) in England was behind the first bridge in Bowral with Alan Harris as the central figure. He had worked for Freyssinet in Paris. In 1949 he returned to England to PSC that owned the Freyssinet licence in England. Mautner was at the time the important designer of pre-stressed concrete, and when he died Harris succeeded him. [93]

Another patent appeared in Australia when the Stressed Concrete Design (SCD), London formed the Australian company Stressed Concrete Pty together with the pipe manufacturer Humes and Ready Mixed Concrete in 1951. Magnel was manager of SCD and owned a licence for use of the Blaton-Magnel anchor. [94]

Preload Corporation got a licence for Australia and New Zealand for use of the Lee-McCall anchor system from Macalloy Ltd in Sheffield which used steel bars rather than wires. [95]

Conclusion

The introduction of pre-stressed concrete occurred late in Australia. While several countries in Europe had experimented around 1940, 10 years went by in Australia, and it was not until 1960 that the knowledge of the technology became fairly widespread and the necessary production facilities were established.

The knowledge spread through the printed media, and around 1950 engineers, business leaders, and officials travelled abroad to learn how it was done in practice. When the technology had demonstrated its advantages, the spread of knowledge became more organized with education and conferences. Around 1955 the technology began to spread all over Australia. (Fig. 10)

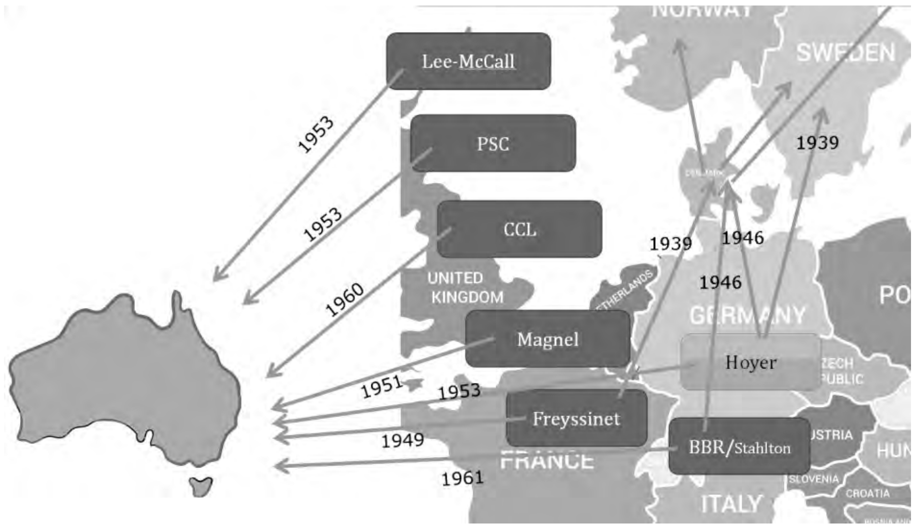

Figure 10. The year for the first use of central patents on pre-stressed concrete to Scandinavia and to Australia. Compiled by the author.

The technology was developed in Germany and France, and spread to the surrounding countries. Belgium, Denmark, England and Sweden gained the technology through stand-alone engineers as important catalysts. Belgium had French-speaking Magnel who was in contact with the central developer of pre-stressed concrete, French Eugène Freyssinet; Denmark's Christen Ostenfeld had worked in the Freyssinet's research laboratory . England had Karl Mautner, while Sweden had Ewald Hoyer. [96]

Australia had no such technological catalysts. No theorist or practitioner had the capacity to market the new technology for many years, though the technology was comparatively well-described in the scientific literature. No Australians apparently had any personal contacts with the relevant individuals in Germany or France, where the ideas were developed.

The technology was transferred to Australia mainly through British firms licenced in the key patents.

In one area, however, Australia truned out to be a leader: pipes and tanks. The companies Humes, Rocla and Monier had a high level of expertise and a broad network through their many branches. They established joint ventures with foreign companies. Rocla succeeded in achieving success with its technology as a multinational company.

New building processes involve many actors, and the building owner is particularly visible in the public sector, where politicians and civil servants must be convinced of the value and security of new processes. Contracts from local governments began to stipulate the use of pre-stressed concrete, and the technology was thereby slowly but more broadly accepted and spread from town to town.

The small local towns and shires came relatively quickly to master the technology for small bridges, and many of the country's wooden bridges were replaced. Larger bridges required greater technical knowledge, and here the projects frequently still relied upon foreign engineering companies and architectural firms.

In the construction of houses, architects were more aware of new technology and put it into use. However, the lack of building regulations and standards slowed down the development.

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