ULTRA

Positions and Polarities Beyond Crisis

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Image: Michaelmore, Roeger & Russell, *Chester House*, Belair 1966, State Library of South Australia BRG 346/28/6/2.

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Seeds of Concrete Progress: Grain Elevators and Technology Transfer between America and Australia

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Abstract

Modern concrete silos and grain elevators are a persistent source of interest and fascination for architects, industrial archaeologists, painters, photographers, and artists. The legacy of the Australian examples of the early 1900s is appreciated primarily by a popular culture that allocates value to these structures on aesthetic grounds. Several aspects of construction history associated with this early modern form of civil engineering have been less explored.

In the 1920s and 1930s, concrete grain elevator stations blossomed along the railway networks of the Australian Wheat Belts, marking with their vertical presence the landscapes of many rural towns in New South Wales, Queensland, Victoria, and Western Australia. The Australian reception of this industrial building type of American origin reflects the modern nation-building aspirations of State Governments of the early 1900s. The development of fast-tracked, self-climbing methods for constructing concrete silos, a technology also imported from America, illustrates the critical role of concrete in that effort of nation-building.

The rural and urban proliferation of concrete silos in Australia also helped establish a confident local concrete industry that began thriving with automatic systems of movable formwork, mastering and ultimately transferring these construction methods to multi-storey buildings after WWII.

Although there is an evident link between grain elevators and the historiographical propaganda of heroic modernism, that nexus should not induce to interpret old concrete silos as a vestige of modern aesthetics. As catalysts of technical and economic development in Australia, Australian wheat silos also bear important significance due to the international technology transfer and local repercussions of their fast-tracked concrete construction methods.

Introduction

During the twentieth century, wheat silos were an instrument of modern aesthetic propaganda and a recurrent source of architectural interest and debate. Notoriously, the bare and utilitarian appearance of concrete silos in North America inspired the European pioneers of the Modern Movement, like Gropius, Le Corbusier and Mendelsohn, who wished to adopt the iconography of industrial buildings into their purist architectural experiments. In the influential book *Concrete Atlantis*, Reyner Banham has elucidated well the essence of this inter-continental exchange between industrial engineering and modern aesthetics.[1] The Modern Movement used images of American factories and silos instrumentally, selectively, rather than for their functional substance tout court. Industrial concrete buildings from the other side of the Atlantic appealed especially to European avant-garde architects because they contrasted with the lingering Beaux Art culture of the 1920s. The American batteries of cylindric silos generated powerful images, suggesting a possible symbiosis between timeless sculptural formalism and modern concrete technology. Not seldom, as Banham noted, the industrial imagery chosen for the propaganda was borrowed from other publications, manipulated or photo-edited to align with the aesthetic agenda of the modern masters.[2]

1. Reyner Banham, *A Concrete Atlantis: U.S. Industrial Building and European Modern Architecture, 1900-1925* (Cambridge, Mass: MIT Press, 1986).

2. Banham, 16.

Occasionally, the iconography was provided first-hand with fieldwork trips. Such was the case of Erich Mendelsohn, who, after visiting Buffalo in New York, reported enthusiastically with a notorious letter to his wife about the fulfilment of his American dreams:

> Mountainous silos, incredibly space-conscious, but creating space. A random confusion amidst the chaos of loading and unloading of corn ships, of railways and bridges, crane monsters with live gestures, hordes of silo cells in concrete, stone and glazed brick. […] I took photographs like mad. Everything else so far now seemed to have been shaped interim to my silo dreams. Everything else was merely a beginning.[3]

3. Erich Mendelsohn, *Letters of an Architect,* edited by Oskar Beyer (London - New York: Abelard-Schuman, 1967), 69.

Acknowledging this lineage with the heroic narratives of modernism is *de rigour*, since contemporary academic interest for grain elevators continues to depend on the influential precedent of *Concrete Atlantis*. The architectural fascination for grain elevators lingers on, inspiring, above all aesthetic readings. Echoing Mendelshon's words, recent research has emphasised grain elevators as an oneiric aesthetic anomaly evoking oppressive political power in totalitarian regimes.[4] In Australia, there is vivid interest in Australian silos about their artistic potential through the 'reactivating' intervention of graffiti art.[5] Following the graffiti-intervention line of thought, modern concrete silos seem to have become an empty canvas calling for visual rectification - to be performed, conceivably, as a foil to their context-indifferent conception. It has been shown, however, that the architectural analysis of modern grain elevators can foster other avenues of cultural and archaeological interpretation. For example, by investigating their typological variations in industrial, urban or rural settings,[6] or their thriving socio-economic function in the fabric of a city at large.[7]

4. Owen Hatherley, "Silo Dreams: Metamorphoses of the Grain Elevator," *Journal of Architecture* 20, no. 3 (4 May 2015): 474–88.

5. Athanasios Tsakonas, "Victoria's Silo Art Trail," *Fabrications* 29, no. 2 (2019): 273–76.

6. Lisa Mahar-Keplinger, *Grain Elevators* (New York: Princeton Architectural Press, 1993).

7. Thomas Leslie, "Chicago's Other Skyscrapers: Grain Elevators and the City, 1838-1957," *Journal of Urban History* 48, no. 1 (2020): 3-34.

This paper intends to explore this industrial type of building from a

different standpoint, a technological perspective that relates the economic purpose of silos – i.e. the mechanical storage and handling of large quantities of granular or liquid produce – with the engineering and construction challenges posed by tall and hollow concrete structures.

Modern concrete grain elevators hold a prominent place in construction history because they were catalysts of substantial progress in concrete building and engineering. Their influence resulted from transnational economic endeavours generated by two modern technological themes: the bulk handling of food production and the mechanisation of concrete construction.

American Genesis

All silos must be designed to resist significant inward and outward pressures, including those for emptying their content, during which the sudden creation of voids may cause implosion. Wheat silos pose an additional problem for the potential of self-ignited explosions, which high concentrations of grain dust can trigger. The earliest American silos for bulk handling were built primarily in wood, steel, bricks or tiles.[8] Although wood and steel silos were relatively quick to assemble, their ease of construction did not resolve but only shifted risks of loss of product – and life – for dust explosions. By the turn of the twentieth century, once sufficient confidence was gained with reinforced concrete construction, it became clear that concrete was the ideal choice for storing wheat for strength and fire-resistance properties. In 1899, Frank Peavey and Charles Haglin - a grain company owner and a building contractor from Minneapolis - erected a twenty-one-metre-tall experimental grain elevator that is credited to be the first tubular concrete silo erected in the world.[9]

The most practical construction techniques of concrete silos, however, did not develop suddenly with one experiment. The first attempts to build concrete silos presented substantial issues with the erection of scaffolds, lifting large shutters, and pouring fresh concrete inside hollow structures of considerable height. Many US patents from the early 1900s suggest how these construction challenges were far from being resolved at the time of the Peavey-Haglin experiment, revealing a widespread concern to conceive formwork systems suitable for the efficient erection of concrete bins.

The earliest methods of concrete silo construction used traditional static formwork systems with overlapping steel shutters raised by a crane. Several American concrete engineers and builders devoted their attention to improving these costly formwork methods filing patents explicitly concerned with the construction methodology of silos. For example, one system from Indiana in 1907 proposed shutters and platforms connected with ties to the top of a mast placed at the centre of the silo.[10] In 1910, an invention for a lifting device of shutters from Kansas showed the use of lost steel rods to be placed inside the formwork with the scope of assisting the lifting up of formwork shutters; once the concrete inside walls had set, the rods became part of the wall, thus allowing the connection of another set of rods supported by the wall just completed below. The system was self-climbing in a structural

8. Mahar-Keplinger, *Grain Elevators*, 18-35.

9. Banham, *A Concrete Atlantis*, 140-141; Ruth J. Hefelfinger, "Experiment with Concrete: a Pioneer Venture in Grain Storage," *Minnesota History* (March 1960): 16-18.

10. Walter C. Polk, "Apparatus for Building Concrete and Other Like Structures," U.S. Patent no. 908,326, September 18, 1907.

sense, albeit still reliant on the lifting of shutters from a central mast acting as a derrick.[11]

Step by step, several inventors, primarily based in the Midwestern US, worked towards a point of cumulative synthesis that is marked by the invention of the movable formwork system known as slip forming. Slip forming is a self-climbing concrete formwork that slides vertically, extruding concrete slowly and continuously without necessitating the use of derricks or cranes. As the pouring proceeds upwards, the hardened wall previously constructed below supports the moving formwork above. With slip forming, monolithic structures, in the form of circular or boxed sections, can be cast in a relatively short time with one single apparatus, using a continuous cast-in-situ process that eliminates – or at least reduces - cold joints between different sections of the wall.

One of the earliest inventions that illustrates slip forming is from Allen D. Whipple from Milwaukee, Wisconsin. Whipple's patent, filed in 1911, shows guiding timber yokes used for 'rising' concrete formwork through a hand-operated screw-jack mechanism that allowed the 'endless or continuous' casting of walls in silos.[12] The system is consistent with similar methods of climbing formwork for silo construction, possibly antecedent and depicted in an American civil engineering handbook of the 1910s: the US MacDonald system, and the Canadian Stewart Company system.[13] Although different for methods of hand-operated jacking, these two systems were very similar in principle, and they reflect the characteristics associated with the mature formwork apparatus known as slip-forming illustrated by Whipple's patent (Figures 1and 2).

11. James H. Spencer and John Simpson, "Lifting Device," U.S. Patent no. 980,020, December 27, 1910.

12. Allen D. Whipple, "Means for Constructing Concrete Walls," U.S. Patent no. 1,075,454, October 14, 1913.

13. Milo S. Ketchum, *The Design of Walls, Bins and Grain Elevators* (New York: McGraw Hill, 1919), 389-391.

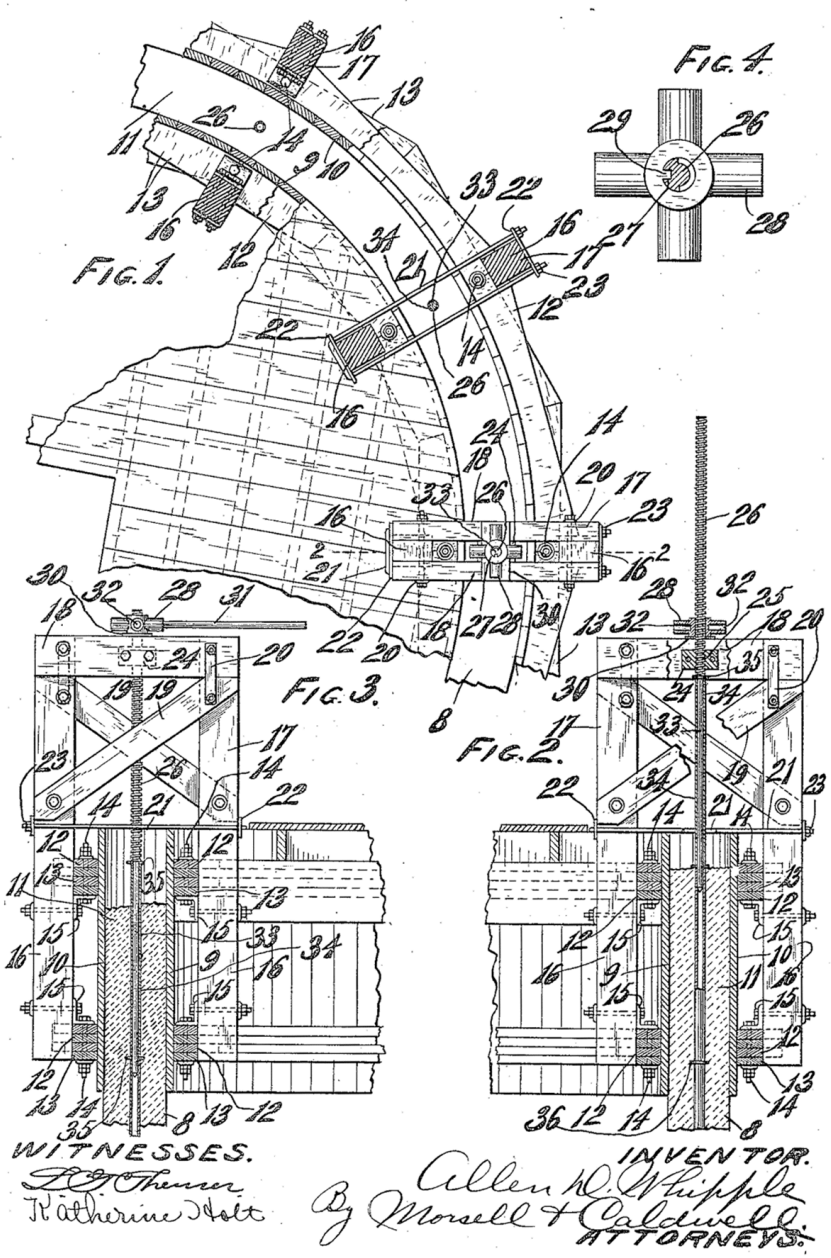

Figure 1: Patent drawings of early slip-forming system for concrete silo construction, 1913. Reproduced from: A.D. Whipple, U.S. Patent no. 1,075,454.

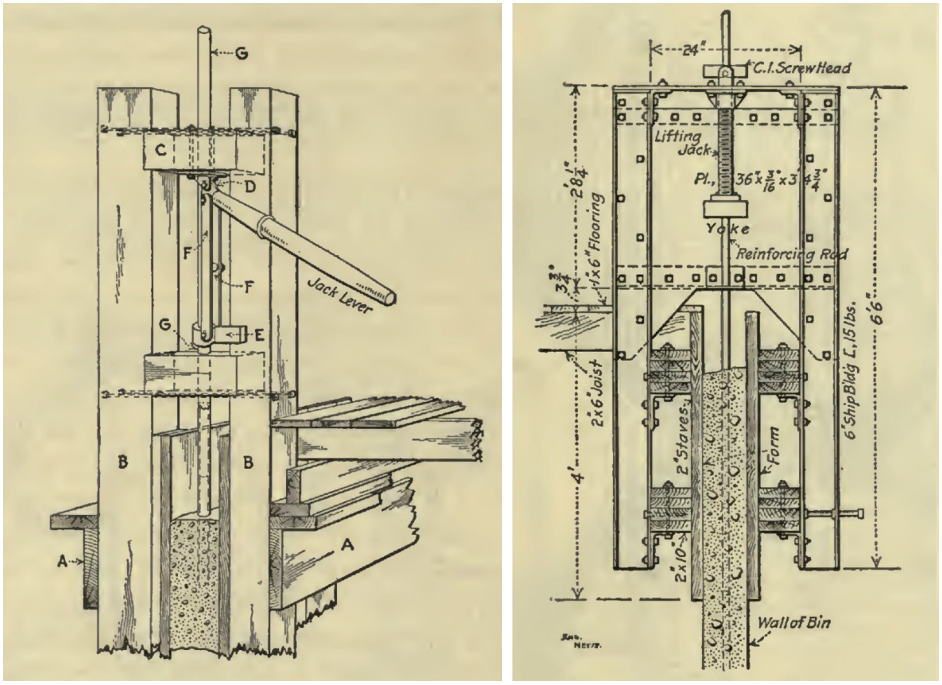

Figure 2: Hand-operated slip forming systems used in the North American grain elevators: MacDonald Engineering system (left) and Canadian Stewart System (right), (1907-19). Reproduced from Milo S. Ketchum, *The Design of Walls, Bins and Grain Elevators*, New York, 1919.

Wheat Bulk Handling in Australia

While these inventions marked the genesis of slip-forming in America, the bulk handling system of grain was still a matter of debate in Australia. A temporal lag suggests that Australia followed, rather than anticipated technical developments from overseas, but the evolution of Australian silo construction methods presents nonetheless some meaningful local implications.

The business of bulk handling wheat in large silos was first adopted in Australia in the late 1910s, following practice established in the US, Canada and Argentina since the late 1800s. Bulk handling gave significant growth opportunities for farmers who were able to connect from country towns to city terminals through railways or waterways, prospering from the export of their product to international markets. Wheat farming with bulk handling used elevator technologies inside silos with mechanical systems of hoppers and conveyor belts for feeding into and discharging from stations scattered around the countryside and connected by nationwide networks of supply and distribution.

The American experience with these methods of industrial farming showed how the mechanical handling of grain in large quantities, as opposed to the traditional handling and storing in jute bags, gave significant economic advantages for producers, due to savings in labour, better sorting according to price and quality, protection from vermin and deterioration, and long-term storage in times of oversupply.

In the early 1900s, Government-sponsored initiatives were set in Australia with the scope to investigate the benefits of bulk handling, sending experts to visit and report from Argentina, Canada and the

US. The idea to transition to bulk handling, however, was received with hesitance by many Australian wheat farmers, stirring political debate and causing delays in decision-making.[14] The main obstacle against adoption concerned the significant capital required to construct the infrastructure, which entailed the establishment of silo stations and upgrading existing country roads and railway networks. Reports from overseas indicated how the economies of scale of Canada and the US had allowed the successful implementation of bulk handling, dwarfing by comparison the capacity of Australian wheat production. A most discouraging observation derived from the state of ownership of the American infrastructure, which was built and managed, including the railways, mainly through private ownership.[15]

Challenged by overseas competitors and missing out opportunities for international growth, the Australian wheat industry could only overcome this infrastructure lag through sizeable public investment and political involvement. Starting in 1916 in New South Wales, State Governments began establishing Grain Elevator Boards, the public agencies responsible for introducing and overseeing all the activities connected with the supply and storage of wheat production. The Boards were responsible for managing, stowing, and distributing grain from rural areas to shipping terminals. In 1920, the State Wheat Board of Queensland was also established, followed by the Grain Elevators Board of Victoria in 1937 and similar initiatives in 1939 in Western Australia and South Australia.[16] By the late 1920s and through the 1930s, the Australian wheat industry had grown to represent seventy per cent of the total area cropped in the country[17] (Figure 3).

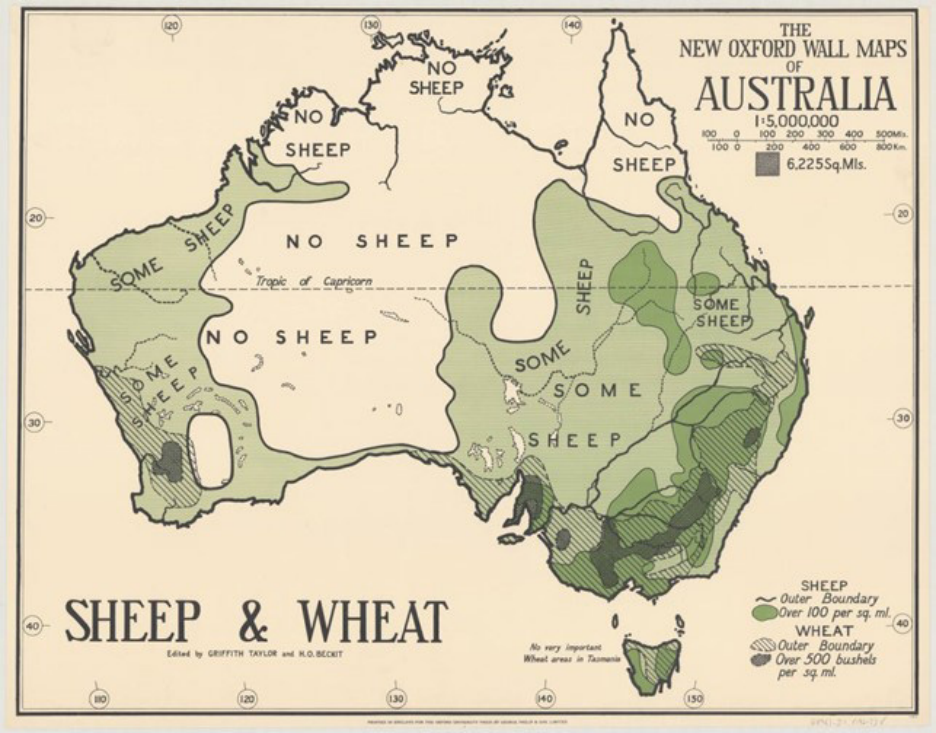

Figure 3: The Australian Wheat Belts. Reproduced from the *New Oxford Maps of Australia* (National Library of Australia, 1920s)

The construction of the infrastructure of grain elevators and rail networks that supported this growth was a considerable part of Australia's nation-building efforts in the inter-war period. The ambitious public building program that ensued faced extraordinary challenges,

14. State Library of Victoria, Department of Agriculture (Victoria), *Report of Conference on The Elevator System in the Handling and Shipping of Grain*, 5 June 1901.

15. 'The Grain Elevator System,' *The Pastoralists' Review 18*, no. 1 (16 March 1908): 36.

16. Farley, Edwina. "Analysis: Who Owns Australia's Grain?" ABC Rural, 1 May 2013, https://www.abc.net.au/news/rural/2013-05-01/grain-industry-amalgamation/4661664 (accessed 28 June 2021).

17. A.A. Lee, "The Wheat Belt of Australia," in *The National Handbook of Australia's Industries*, edited by Ambrose Pratt (Melbourne: Specialty Press, 1934), 30-31.

requiring fast but also relatively straightforward construction methods. These conditions offered a fertile terrain for introducing new building technologies, among which concrete emerged as the material solution to the problem.

One of the very first examples of silos built in concrete for the program was in the small rural centre of Peak Hill, NSW, in 1918.[18] Although not the first example of concrete silos built in Australia,[19] Peak Hill signals the beginning of an intense phase of modern concrete construction. Growing from the public building program managed by the Grain Elevator Boards, rural concrete silos flourished thereon, especially during the 1930s along railway lines connecting inland country towns in the Eastern Wheat Belt, the crescent-shaped region stretched from the northern border of New South Wales to the eastern regions of South Australia. Urban silos completed the network with large terminal installations for shipping in city harbours, like the NSW silo terminals at Newcastle[20] and White Bay, Sydney,[21] or the Geelong terminal in Victoria, a facility with twenty-eight, 200-feet-high circular storage bins built in 1937.[22] Just before the material shortages of WWII intervened to slow down this nation-building program,[23] the economic weight of the Australian wheat industry had materialised itself with these prominent structures in cities and the countryside, leaving a permanent sign of modernity, with structures not dissimilar to the more notorious American examples that were publicised in Europe by the pioneers of modern architecture.

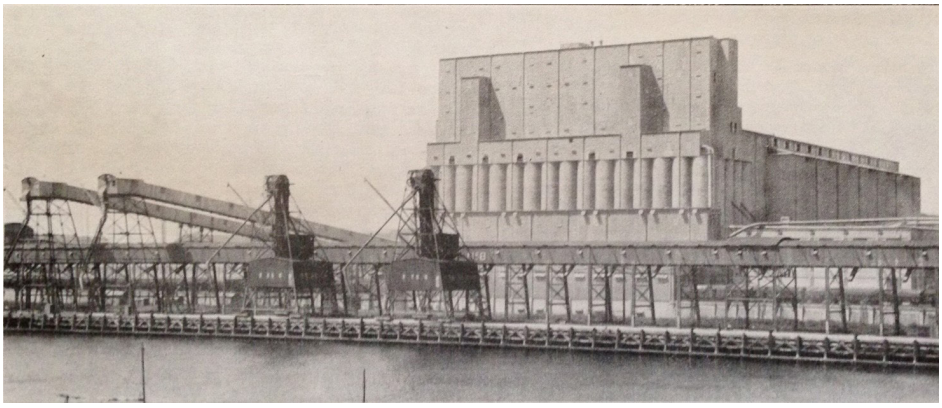

Figure 4: White's Bay Grain Elevator Terminal, Sydney, c.1930 Reproduced from: Lee, *The National Handbook of Australia's Industries*, 1934.

The Adoption of Slip Forming in Australia

Australian State Governments, through the creation of the Grain Elevator Boards, established the infrastructure necessary for bulk handling with hundreds of rural and urban silo stations on the Wheat Belt. The material of choice for this public nation-building effort was slip-formed concrete construction, which was quickly learnt from America and adopted in Australia around 1920.

The technology transfer link with America is corroborated by the work of divulgation of an Australian civil and structural engineer, Leslie Boyd Mercer. After graduating with a thesis on the bulk handling of wheat at the University of Melbourne, Boyd Mercer travelled overseas in the late 1920s to study the implementation and construction of grain elevator

18. Hal Pratt, "NSW Silos Photographs," https://nswsilos.com.au/history/ (accessed 29 December 2018).

19. Miles Lewis, "Forms & Systems," in *Australian Building: a Cultural Investigation*, 7.08, http://www.mileslewis.net/australian-building/ (accessed 29 December 2018).

20. "Newcastle (N.S.W) Terminal Grain Elevator 850,000 Bushel Capacity," *Building 55*, no. 329 (January 1935): 57–61.

21. Lee, "The Wheat Belt of Australia," 31.

22. "Geelong Grain Elevator: Large Contract Let," *The Argus*, April 13, 1937, 13.

23. State Library of Victoria, Grain Elevators Board Victoria, Parliamentary Public Works Committee (Victoria), *Progress Report from the Parliamentary Public Works Committee*, 1950.

networks, above all in North America and Argentina. Upon returning to Australia in the early 1930s, Boyd Mercer became a leading expert in bulk handling and slip form technology.[24] Following his promotional effort,[25] slip forming became principal technique used for the construction of Australian silos through the 1930s.

A patent filed in 1933 by Alfred Horan and Thomas Crossan, two engineers from Parramatta, NSW, illustrates the state-of-the-art of silo construction in Australia before WWII. The patent shows a well-developed slip form apparatus with two sets of adjustable steel rings used for supporting an annular array of shutters, and yokes lifted by a hand-operated screw-jack system.[26] Horan and Crossan were not mere inventors, but engineers commissioned to design several grain elevators in NSW, and their apparatus has substantial analogies with earlier slip form patents of the screw-jack type filed in the US two decades earlier. (Figure 5)

It is reported, however, that slip-formed concrete silo works took place in Australia at least since the 1920s, as evidenced by the maize grain elevators at Atherton in Far North Queensland.[27] The Atherton complex was built in two stages: the first group of three bins was completed in 1924, followed by a six bins addition in 1933.[28]

The Atherton maize silos demonstrate how concrete slip forming was instrumental for constructing grain elevators in remote Australian areas. Coverage by the journal Building for the second stage of works describes the Atherton silos as 'the largest in Queensland' with a maximum storage capacity of 4,500 tons of maize.[29] The builder, W.M. Doyle, completed the entire project in approximately five months, with the great majority of time being absorbed by groundworks. The erection of the six seventy-feet-high concrete silos was an expedited process that Doyle completed in a week, with each bin progressing vertically through slip forming with a pace of ten feet per day. As described by Building, the slip forming apparatus was 'typically American', yet reliant on the specific technical recommendations diffused in Australia by Boyd Mercer.[30]

24. Leslie Boyd Mercer, *Bulk Handling of Wheat and the First Principles of Elevator Design - A Lecture Delivered at the Melbourne University* (Melbourne: Melbourne University Press - Oxford University Press, 1934), 3.

25. Leslie Boyd Mercer, "Sliding Formwork: Its Use in Silo Construction," *Building 52*, no. 310 (June 1933): 86–90.

26. Alfred Arthur Horan and Thomas Henry Crossan, "Apparatus for use in the construction of cylindrical silos and like structures," Department of Patents, Commonwealth of Australia 14,313/33, September 7, 1934.

27. Lewis, "Forms and Systems," 4-5.

28. "Silo Construction in Queensland: Sliding Formwork Used." *Building 53*, no. 314 (October 1933): 90–91.

29. "Silo Construction in Queensland", 90.

30. "Silo Construction in Queensland", 91.

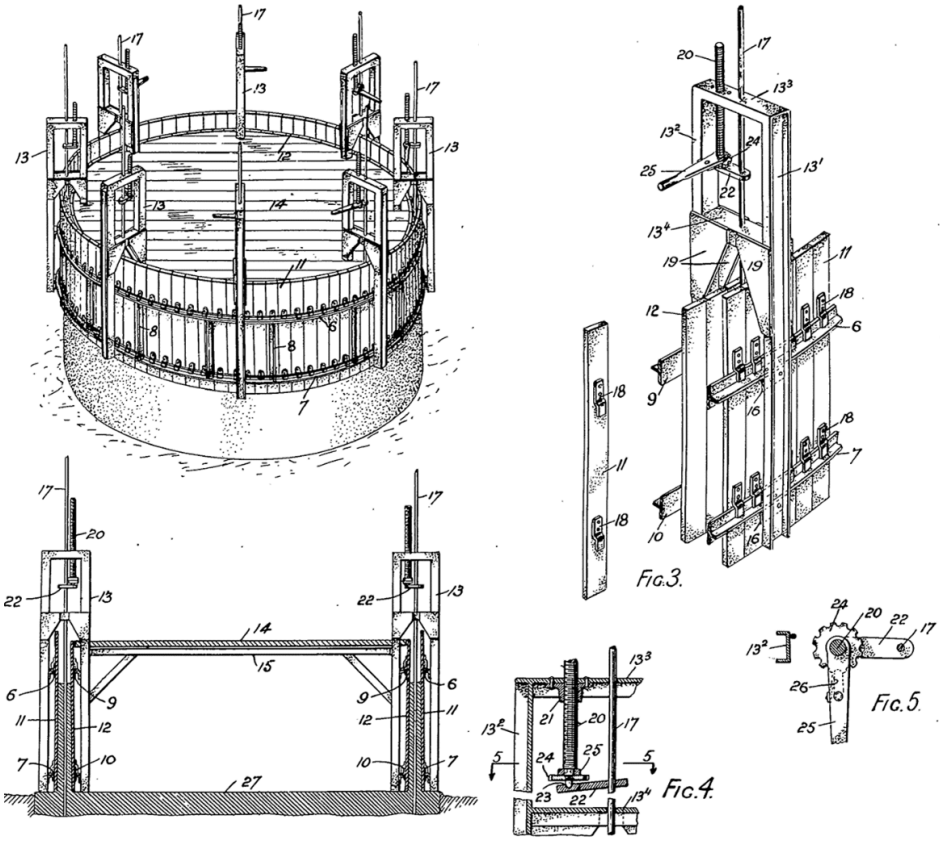

Figure 5: Australian designed slip-formed system for grain elevators,1933. Reproduced from A.A. Horan and T.H. Crossan, Australian Patent no. 14,313.

Ninety construction workers erected the silos working around the clock in three shifts of thirty men. In each shift, three gangs worked simultaneously from moving timber platforms situated inside the bins and suspended from the yokes of the slip forms. The first gang was responsible for jacking up the sliding forms with hand-turned screw-jack levers, operating in a synchronised effort that moved the entire apparatus upwards by a quarter of an inch with each full turn of the jacking screws.

31. "Silo Construction in Queensland", 91.

A second gang was responsible for placing steel reinforcement and jacking rods between the shutters and a third for the handling and pouring of concrete inside the moving forms. Another group of concreters followed, working on an external platform suspended from the external legs of the yokes, rendering and removing imperfections from the freshly formed surface with a cement wash. The bulky ingredients necessary to prepare the mix on-site, cement and aggregates, were transported to the remote location by rail, using the same infrastructure in place for the bulk handling of maize, the local agricultural produce. Concrete was fed to a site mixer and elevated by a hoist tower for pouring at the top of the working platforms.[31] (Figure 6)

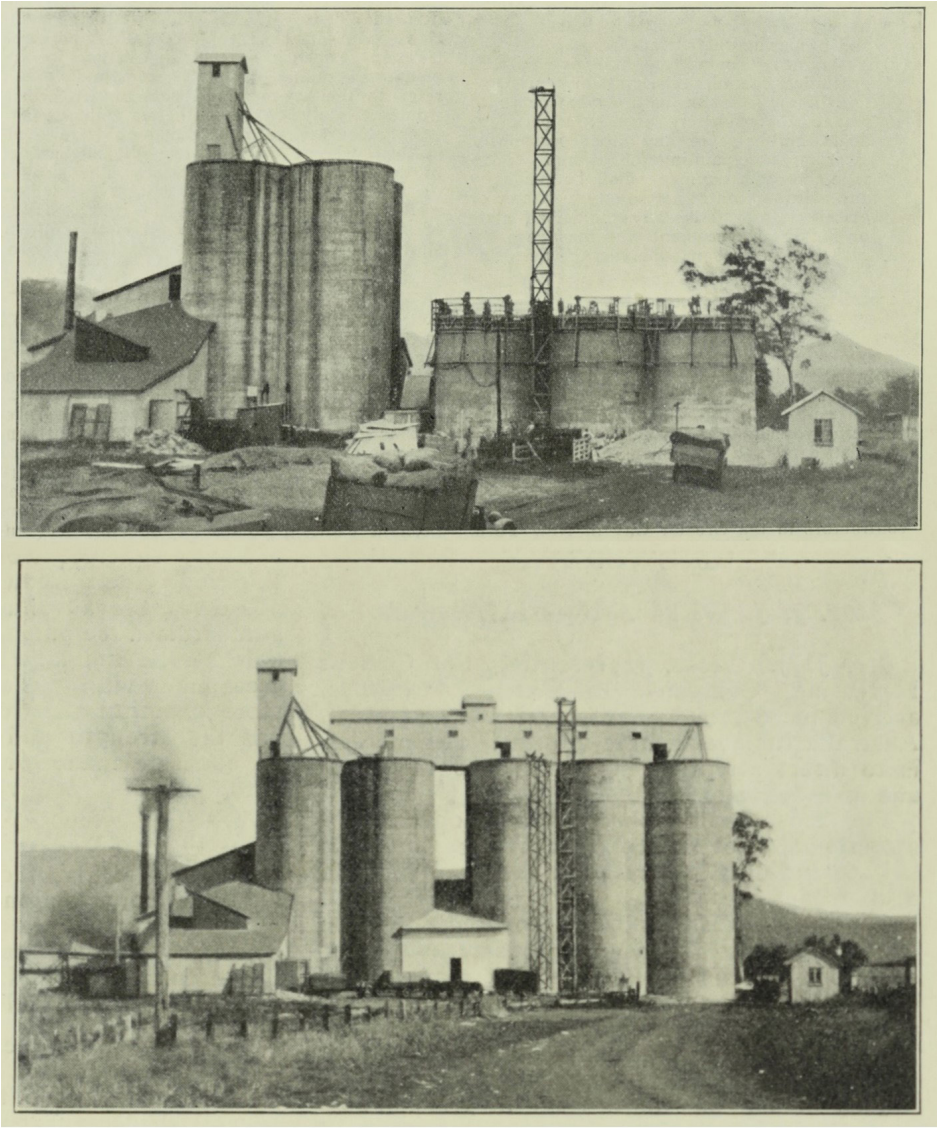

Figure 6: Slip-formed silos under construction, Atherton, Queensland,1933. Reproduced from: *Building*, 12 October 1933, 90-91.

Figure 7: Slip-formed grain elevators, Victoria, Australia,locations unknown. Reproduced from: Public Record Office Victoria, VPRS 12800 / P0007 / C00915-17 / Photographs by State Transport Authority.

Detailed descriptions like the one of the Atherton silos or photographic records of the construction of rural grain elevators in Australia before WWII are not easy to find, but some Victorian photographs available suggest that slip forming was the national standard method of construction used for rural silos in the 1930s. (Figure 7)

Slip forming was not relegated to the relatively simple shapes of rural stations. Australian knowledge and expertise with this technology also allowed the erection of large batteries of bins

in harbour terminals or flour milling complexes in urban settings. Such was the case of Brunton's milling silos erected on the outskirts of Melbourne in 1941 and designed by Henry Simon, an engineer also involved the design of silos in Queensland.[32] Lewis Construction, the building contractor, completed the whole complex in six months of works, slip forming in four weeks an array of fifteen 140-feet-tall silos claimed to be the tallest and one of the 'quickest' concrete construction achievements in Australia.[33]

32. Lewis, "Forms and Systems," 4.

33. "Australia's Tallest Silos," *Building* 67, no. 402 (February 1941): 42–44.

Post-war Tech Transfer

After WWII, the Australian concrete industry entered a new stage of technological change prompted by the advent of motorised construction methods. Progress occurred in several sub-sectors of the industry, with sophisticated methods of vertical construction reflecting trends from the US and Scandinavia, which phased out the hand-operated screw-jack systems of the 1930s with motorised hydraulic jacking systems.
Slip-forming continued as the standard building method for Australian grain elevators well beyond World War II, replacing hand-screw jacking with hydraulic motors. An example of the enduring success of the technology is the impressive Fremantle Bulk Grain Terminal in Western Australia, a facility with 48 circular cells, 36 feet in diameter and 100 feet high that was completed in 1964.[34]

34. K. Kocass, "Off-Form Concrete Related to Fremantle Bulk Grain Terminal Building," *Constructional Review* 38, no. 3 (March 1965): 25–29.

Confidence in concrete technology for speedy structural construction advanced further once moving formwork systems transferred from industrial applications to high-rise buildings. From the early 1950s, in Europe and America, the technology of slip-forming began to be used for multi-storey apartments in Stockholm and Copenhagen,[35] radio and television towers and in a ten storey-high hotel in the USA.[36]

35. "Sliding Formwork: Multistory Concrete Walls Rise 20' a Day Between Continuously Moving Forms," *Architectural Forum* 97, no. 5 (November 1952): 150–52.

36. "Slip Form Construction Speeds Erection of Apartment Hotel," *Architectural Record* 118, no. 4 (October 1955): 248.

In line with these examples from overseas, the technology transfer also took place in Australia, where builders concerned with the challenges of tall concrete structures realised the potential of motorised slip-forming, testing it for the construction of some post-war multi-storey buildings.

One early, possibly the first, slip-formed habitable structure in Australia was in Sydney, at Tatlow Court in Neutral Bay, for a small apartment block designed by Donald Woods Sloane and Gallagher in 1961. The builders, Kell and Rigby, extruded the entire eight-storey-high load-bearing walls with hydraulic jacks and slip-form equipment provided by a specialist contractor named, tellingly, Concrete Silos. The small apartment block was completed in eight days, at the remarkable rate of one storey per day[37] (Figure 8).

37. "'Slipform' Formwork Sets New Pace in Building Erection Times," *Constructional Review* 34, no. 12, (December 1961): 16-18.

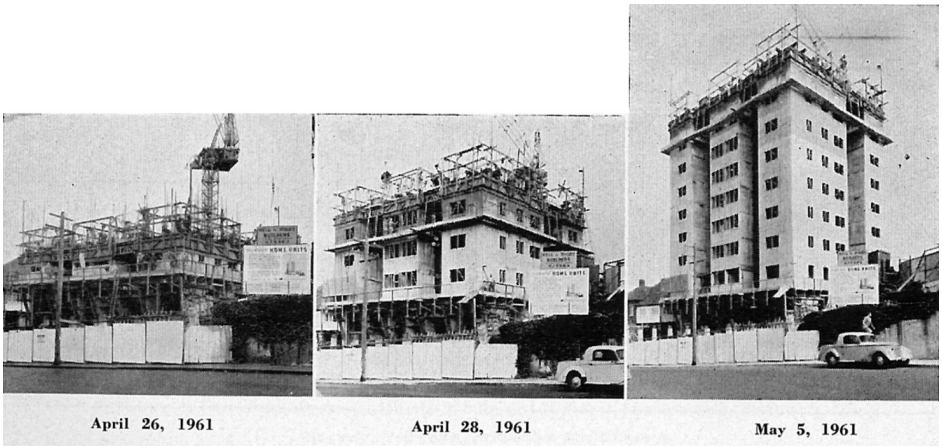

Figure 8: Tatlow Court Apartments, Neutral Bay, Sydney, 1961 (Donald, Woods, Sloane and Gallagher Architects). Photo-sequence of the slip-formed construction used by builder Kell & Rigby and sub-contractor Concrete Silos Pty Ltd. Reproduced from: *Constructional Review*, December 1961, 16.

One year later, Sydney-based structural engineers Taylor Thomson and Whitting and builders Finform applied a similar technique at the Dorian Towers in Double Bay, in another apartment block designed by architects Forsyth Evans and Associates.[38]

38. A. Whitting and D. Pearson, "Innovation in Slip Form Construction," *Constructional Review* 35, no. 12 (December 1962): 14-16.

In the same period, W.M. Newman, a structural engineer from England, was responsible for introducing slip forming in office buildings for the construction of concrete service cores at the Bushell Instant Coffee Factory at Concord (Brewster Murray architects, 1960-61) and Transfield House, in North Sydney (Sabemo architects and builders, 1960-61). The transfer of slip-forming from industrial to commercial construction owed much to the expertise of Concrete Silos, the sub-contractor involved in all these examples. Concrete Silos was the licensee of Scandinavian hydraulic jacking systems, commercialised in Australia under 'Prometeo' and 'Sentab', and the patent holder of a climbing jack system developed by one of its in-house engineers.[39]

39. W. M. Newman, "The Use of Moving Forms in the Construction of Concrete Service Towers for Multi-Storey Buildings," Constructional Review 35, no. 6 (June 1962): 22-27.

Conclusion

The genesis and diffusion of slip-forming as a modern concrete construction method underlines the technical importance of grain elevators in the history of high-rise construction. Acting as a vehicle of international technology transfer and innovation, the legacy of Australian grain elevators has a facet of technological culture that complements arguments that purport the re-use and preservation of the many concrete silos that still survive intact.

Industrial concrete construction processes were essential for the development of new modern architectural ideas. However, industrial architecture influences did not limit to the aesthetic iconography advertised by heroic modernism. Industrial buildings, like grain silos, provided a global terrain of technology transfer bound to have meaningful consequences that went beyond serving the modern aesthetic propaganda that is usually emphasised in architectural historiography.

The rural and urban proliferation of wheat silos contributed to establishing a confident high-rise concrete industry that began thriving with moving formwork construction methods, leading eventually to the transfer of slip-forming from industrial applications to habitable high-rise concrete structures.

In Australia, grain elevators were an instrument of modern nation-building in the hands of public enterprises run by State Governments, similar in the built-form outcomes but very dissimilar in the processes of agency of their American counterparts. The mechanical technique of slip-forming was like a *deus ex machina*, which allowed State Governments to engage, at a fast-tracked pace, in the sudden transformation of the countryside and cities across the nation, scattering hundreds of concrete silos from North to South and East to West, leaving tangible evidence of the far-reaching consequences of modernity. Slip-forming is a fast-track construction process and apparatus that lets the quick building and vertical extrusion of complex architectural forms. In Australia, it was the tool that allowed catching up with the global markets of wheat, filling with concrete a modern infrastructure lag that was perhaps impossible to close otherwise.