

# architecture institutions and change

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## **Dante Bini's "New Architectural Formulae": Construction, Collapse and Demolition of Binishells in Australia 1974-2015<sup>1</sup>**

*The Italian architect Dante Bini began his studies on shell structures during the 1960s. He developed and refined a form-finding and construction technique to erect a finished large-span reinforced concrete (RC) shell structure through the use of an inflatable membrane. This system was patented in 1964 under the name 'Binishell' and, over the following decades, it has been applied to construct hundreds of domes throughout the world.*

*Bini's invention fitted perfectly into the Italian post-war tradition, as he was, at the same time, the architect and builder of his structures. A few experimental tests were initially performed in Italy, and the first binishells that he lifted after the patent was filed were also constructed there. Since 1966, as a result of Mario Salvadori's interest, Bini has been recognised internationally.*

*In 1974 he moved to Australia after the NSW Department of Public Works asked him to realise a set of school facilities using the binishell technology. The construction of concrete shells has always been a difficult and expensive process – the preparation of formworks, as well as the installation of curved reinforcing rods before the concrete is poured, require experience and increase the construction costs. Such problems are particularly relevant in the Australian context, where the use of simple and rapid construction technologies has always been a priority.*

*Dante Bini's life and the binishell technology have been well documented from the historical point of view. However, a detailed report and contextualisation of Dante Bini's Australian experience is still missing. A first attempt to survey the Australian binishells has already been published by the authors.<sup>2</sup> The focus was on placing Bini's early work within the previous research on pneumatic structures which began in the 1920s. The narrative of this paper instead starts in the 1960s, a period of great media success for RC shells. First, the origin of binishells is described as a natural consequence of three preceding inventions/patents. A timeline of the events that defined Bini's emigration to Australia is then provided. A full list of the Australian binishells is also included, with detailed information on the archival sources, major alterations and current conditions.*

## Bini and the media success of reinforced concrete shells in the 1960s

In the early 1960s, the debate on structural form was vibrant, and the dissemination or spectacularisation of architectural forms generated through form-finding and analytical shapes was spreading internationally. However, the application of RC shell construction techniques that did not require scaffolds or timber formworks still appeared to be pure fiction. Only in July 1964 was the architect Dante Bini able to materialise that dream, when a 12m diameter RC shell was successfully erected in less than one day in Crespellano, Italy, through a system that combined a pneumatic formwork with self-shaping reinforcing rods.

Bini's result, on the one hand, was revolutionary; on the other hand, there is no doubt that it can be considered as the natural consequence of the stimulus that was provided by the inspiring context he was living in, namely the incredible media success of RC shells and form-resistant structures in general.

Several authors of the so-called 'structural art', to use a term coined in 1960 by Ada Louise Huxtable<sup>3</sup>, were periodically celebrated throughout the world. For instance, Harvard University conferred the Charles Elliot Norton Professorship of Poetry to Felix Candela, Richard Buckminster Fuller and Pier Luigi Nervi in 1962. They became the poets who represented a new architectural language, which was derived either from classical mathematical principles or basic structural intuitions.<sup>4</sup> Another example is that of the Twentieth Century Engineering exhibition, which was organised by the Museum of Modern Art in New York (MoMA) in 1964, exactly while Bini was erecting his first shell in Crespellano. Works of structural engineers were considered in the international event, and exhibited as true pieces of art.<sup>5</sup> Silos, tanks, cooling towers and industrial/service buildings were all characterised by structural designs of great iconic impact, and were all presented as new monuments of the contemporary age. The most relevant ones were the Lowry Air Force Base in Denver (Colorado), the Sewage treatment plant in Hibbing (Minnesota), the Market hall in Royan (France) and the Little Sport Palace in Rome (Italy). In this panorama, shells that were built through inflation were considered as a separate chapter and, for this reason, exhibition curator Arthur Drexler did not take into account any RC shell based residential architecture (despite the great achievements that Wallace Neff's houses had already had at that time<sup>6</sup>).

1964 is also the year the proceedings of the World Conference on Shell Structures, which was held in San Francisco in October 1962, were published.<sup>7</sup> Papers were presented by the most important architects and engineers engaged in the development and construction of RC shell structures, such as Candela, Anton Tedesko and Nicolas Esquillan, as well as those that dealt with other materials, namely Ildefonso Sánchez del **Río**, Eladio Dieste and Frei Otto. Mario Salvadori, who also attended the conference<sup>8</sup>, was astonished when he discovered Bini's invention, which was the perfect, as well as obvious synthesis of three construction techniques that developed independently. First, the one for in-situ reinforced concrete shells; second, the inflatable and pneumatic membrane technology for air structures; third, the self-shaping steel reinforcement.<sup>9</sup>

The use of pneumatic formworks to pour concrete stemmed from an idea of Normand W. Mohr, dating back to 1927, that had already been developed successfully by Neff during the 1930s and 1940s, as well as by Eliot Noyes, during the 1950s, for his famous houses.<sup>10</sup> However, the revolutionary concept of assembling steel reinforcements on the ground, and subsequently erecting and bending them to reach the desired shapes, was based on another experimental construction system by James H. Marsh, which was presented at a congress held in San Francisco under the name of "Lift-Shape" process.<sup>11</sup> The author underlined that such a method was not "presented as a new concept for the design of shells but rather as a logical construction method that offers comparative speed, safety and economy, with a minimum need for prefabricated components."<sup>12</sup> The steel reinforcement of Marsh's domes was formed by a grid of bars, to which a lightweight mesh was linked. This metallic skeleton was then raised by a crane and temporarily supported in position by wooden poles. Finally, concrete was sprayed to obtain a thin shell, which in principle was similar to Nervi's *ferro-cemento*.<sup>13</sup>

At that time, Dante Bini was a clever young architect and builder who foresaw the potential of an architecture generated through the construction method, which was a synthesis of his studies on the work of architects such as Adalberto Libera and Candela, as well as of engineers such as Heinz Isler, Pier Luigi Nervi, Buckminster Fuller and Frei Otto. Bini claimed to have met these designers during his training, and also to have had the possibility of discussing the building systems they used to construct their most celebrated architectures. Bini also revealed that "instead of simply copying" such already well-known building techniques, he "tried to find faults in these construction methods and improve them" with his own ideas: "even though reinforced concrete domes and thin shell structures" amazed him, he "could not accept that the timber or steel temporary formworks to obtain these sophisticated architectural and artistic engineering expressions, would have cost more than the final structure."<sup>14</sup>

However, the idea of reusable prefabricated formworks is not a novelty in the history of construction: from the early inventions patented by Henri Lossier<sup>15</sup> to the systems employed by Nervi for pouring slabs<sup>16</sup>, these systems have always represented a cost-effective solution that is able to speed up construction site operations. In this context, Bini's innovation was that he invented a prefabricated formwork which could generate form-resistant structures, such as shells.

Hence, Bini's merit not only consists in having developed a construction technique which, as explained by Salvadori "has met with success almost all over the world in the erection of round domes of large diameter (up to 300 feet) for schools, gymnasiums, and halls"<sup>17</sup>, but mainly in having generated "nuove formule architettoniche"<sup>18</sup>, that is new architectural formulae, as Bini himself defined them.

In the previously mentioned 1962 conference, the only presented example of shell-covered residential architecture was the Monsanto House of the Future (Disneyland, California)<sup>19</sup>, which was constructed using a glass-fibre reinforced plastic sandwich. In this field, Bini's

invention started to animate a completely new research area that did not focus on proposing new housing types based on form-resistant structures, but on the large-scale diffusion of stylistic elements derived from the construction technique he patented.

The first two shells that Bini erected in Crespellano and Pegola, Italy, clearly demonstrate how he, as an architect, was sensitive to the expressive potential of his construction method, even when he produced his early prototypes. The structural calculations performed by Bini therefore represented a sophisticated, but also redundant formalism of geometric shapes used to trim dome bases – such shapes were characterised by a purely ornamental role that had little to do with the formal engineering research of that period.

Although, on the one hand, Salvadori immediately revealed his interest in Bini's technique and extolled the new construction system worldwide, on the other hand, Bini rapidly developed his stylistic signature through the exploration of possible ways of puncturing his shells. He started with decorative cuttings at the base and then moved, probably for budget reasons, to other geometrical definitions for openings, windows and intersections between shells. Bini's architecture subconsciously reinterprets the concepts of 'The new sensualism' (or 'stereo-structural sensualism'), which was theorised by Thomas H. Creighton in 1959.<sup>20</sup> The "sensuous plasticity" of the binishells makes them look like nostalgic revivals of the formal attempts which remained pure utopia, with no practical or commercial outcome.

The house that Bini built in 1969 for film director Michelangelo Antonioni in Gallura (Costa Paradiso), Sardinia<sup>21</sup>, was the ideological synthesis of Neff's Bubble House (Falls Church, Virginia, 1941), Friederick J. Kiesler's sculptural prototype of the Endless House (1950)<sup>22</sup> and John M. Johansen's visionary "spray structures" of the mid-1950s.<sup>23</sup> It was also a pragmatic synthesis that only an architect-builder who was capable of inventing and exporting both architectural stylistic features and effective construction methods worldwide could realise. It was a business system which, at that time, had already proved to be successful in Italy, Japan and possibly even in Australia.

### **Dante Bini's Australian experience (1974-80)**

Dante Bini's international recognition coincided with a period of considerable expansion of the "Binishell Spa" company which, in 1971, was already licensing and constructing pneumatically-erected shells in more than 20 countries. At that time, Bini was mainly occupied in promoting his system abroad and, as a consequence, a series of changes in the shares of his company's stock worked against him. Michelagnoli, Cappellini and Torniamenti took command in the board of directors and decided, for instance, to move the head office to Milan.<sup>24</sup> Basically Bini was excluded from the administration, and this in turn led him to explore the potential for investments overseas even more.

In *Building with Air*<sup>25</sup>, Bini reported that he first got it touch with the authorities in Australia in autumn 1971, because the Australian Minister Leon Aston Punch was searching for a rapid system to build multi-purpose centres, schools and libraries to fulfil the promises he had made during the electoral campaign. Bini's contacts were the Agent General based

in London, David Hughes, and, more directly, the Assistant Principal Architect at the NSW Department of Public Works, J. W. Thomson, who also organised, according to Bini, a visit to the Italian structures during the same period.

Reading that book, it seems that Bini's immigration to Australia followed a rather linear process. However, the documents archived at the NSW State Records provide a more articulated version of the story, as well as a different timeline, which shifts it forward by about two years.<sup>26</sup>

A report dated 1 June 1973, and signed by J. W. Thomson, describes the visit to the Italian Binishells as occurring between 21 and 22 May 1973. Details about construction speed and costs of the binishell system seem to confirm that the NSW Department of Public Works was looking for a rapid and cost-effective construction technology. Most of the visited structures served as school gymnasias or small theatres, and this could also lead us to suppose that the department was pondering the pros and cons of similar applications in the Australian context. However, only in a letter dated 11 July 1973, did Thomson discuss the Educational Building Programme budget for the first time with Eric Adams, Senior Industrial Promotion Officer. He wrote in particular about an increase that raised the total amount to \$8,000,000 (to be available on 1 January 1974).

On 10 July 1973, Thomson had already confirmed Bini's first trip to Sydney, with arrival on 6 August 1973.<sup>27</sup> This visit would have helped him to decide about his potential immigration, but also discuss the practical and financial issues involved in using the binishell system overseas.

On 27 August 1973, after Bini had returned to Italy, Thomson sent a report to Adams entitled: "Use of dome structures (Binishells) in the school building programme". At that stage, the intention of applying the binishell system to improve the public school facilities was clear, as the conversation was already focused on potential building contractors, including the Departmental Building Construction and Maintenance Branch (BC&M).

One day later, another letter from Thomson arrived that dealt with the technical aspects of using binishells for the first time in Australia in more detail. He mentioned, for instance, that Bini would have needed at least two Italian technicians for the first construction (later Bini actually asked for three workmen). The budget and equipment were also described in more detail. The inflation tools would have been imported from Italy, for an amount of \$300,000, to be paid as a one-off payment. The cost of a single dome was therefore \$100,000, including finishes, plus \$25,000 related to Bini's fees, his workmen's air tickets, expenses and wages. This letter reported discussions with the contractors and provided information about several companies. First, Sabemo was interested, but required 75 per cent of the shares, leaving 25 per cent to Bini Brothers. Second, Civil & Civil was interested, but only if Bini Brothers could have guaranteed the erection of at least 50 binishells per year. Finally, Concrete Construction was definitely interested, but wanted to clarify several aspects with the department before signing the agreements. Thomson went on to mention that Dante Bini was also interested in

practicing as an architect in Australia, and this would have required him to face the issue of being trained and registered. He also proposed an easy way of eluding the 12-month period of training by providing a contract to Bini, which allowed him to work as an architect for the department.

Bini's immigration to Australia was about to become reality. On Saturday 15 September 1973 he met Eric Adams at London Airport to discuss the matter, as well as his recent visit to New South Wales and Victoria. In a letter that Adams wrote to Thomson later on the same day, Bini's satisfaction regarding his first stay in Australia clearly emerged. However, such enthusiasm did not stop him from looking for other opportunities to export the binishell system abroad. In a letter dated 19 September 1973, Bini frankly confessed to Thomson about a recent meeting he had had with the Atomic Energy Commission (AEC) based in Detroit. It regarded the possibility of being a consultant for the US Department of Defence and of building a Visitor Information Centre in their headquarters in Germantown, Maryland. It is now difficult to say whether that communication was just an honest admission or a reaction to the anxiety generated from having to wait for a final offer from the NSW department. However, the decision to construct a first 32m diameter binishell (later reduced to 18m) reached Bini not long after, on 15 October 1973, by means of a telex signed by Thomson. A further five structures would also have been built, after verifying the success of the first one. Considering that the equipment used for inflation was quoted at about \$300,000, its consistent reuse would have reduced the overall cost per dome. According to the department estimations, building six binishells would have cost \$105,950 each.

During the following week Thomson searched for references about the application of binishells outside Italy, and the final disclaimers regarding Bini's arrival were finally sent on 26 October 1973. J. C. Humphrey, Director of Public Works in NSW, signed the letter that defined the agreement. In a long telex, he stated that the internal Building Construction and Maintenance (BC&M) Branch would have built the first structure, with the help of three Italian technicians. The franchise for using the binishell system would have been non-exclusive and a consultant structural engineer would have been employed. They also expected Bini to arrive in Australia in late November, start ordering the necessary equipment in December and begin the construction in March 1974. The first six domes should have been completed by June 1974.



**Fig. 1** The three binishells at Narrabeen North Public School. Photograph by Alberto Pugnale, May 2014.





**Fig. 2** The three binishells at Narrabeen North Public School. Photograph by Alberto Pugnale, May 2014.

The story that follows is described in a very discursive and readable manner by Bini himself in *Building with Air*<sup>28</sup>, where the text is also complemented with several pictures by the famous Australian photographer Max Dupain.<sup>29</sup> A more inaccessible source is provided by Ross Styles, who wrote his thesis under Bini's supervision at UNSW in 1975.<sup>30</sup> Two promoting brochures that described the binishell system and the early constructions in NSW were also published in 1977-78 by the local Department of Public Works, right after a major governmental change in which Jack Ferguson became the new Deputy Premier and Minister for the aforementioned Department.<sup>31</sup>

The fortune of binishells in Australia did not last long. On 4 January 1975, just after a few constructions, the first 36m diameter structure collapsed at Fairvale High School. The department immediately organised the installation of precautionary support towers in the other 36m domes, as they were also considered at a high risk of failing. The obvious consequence of this measure was a major loss in functionality due to the presence of extra columns in the internal spaces. As the binishells were all intended for use as school facilities, major concerns about their safety were also raised by groups of parents, who did not want to expose their children to danger. The situation calmed down when the reasons for the collapse became official: an exceptional temperature gradient of 25 degrees occurred during the night of 2 January 1975, when the RC shell was still uninsulated and unfinished; this event triggered the failure, but the structure itself was considered safe.

A second collapse at Pittwater School, dated 4 August 1986, definitely marked the destiny of binishells in Australia. Permanent steel structures were installed to support the remaining 36m diameter domes, but most of the schools were already planning their demolition and substitution with more conventional buildings. Structural stability was not the only reason for such a choice – leakage, vandalism and maintenance costs were also major issues in most of the cases.

In 1979, Dante Bini decided to leave Australia for a new professional challenge in the United States. At present, he is living in the Napa Valley, San Francisco, while his business activity is currently managed by his son Nicolò in Los Angeles.<sup>32</sup>

At present, the list provided at the end of this paper, which includes location, typology, construction company, client, dome diameter, major alterations and current status of each structure, is the most complete survey of the Australian binishells.<sup>33</sup> In short, 20 binishells



were built between May 1974 and June 1980 (21 if we consider that the one at Fairvale School was rebuilt). The Narrabeen North Public School is here considered as one single structure, even though it has an intersection between two domes plus a separate one. The Space City Shopping Centre is also counted as one construction, but it was actually an incredible composition of seven binishells, three of which had 18m diameters and four 36m diameter domes.



**Fig. 3** The binishell at Killarney Heights Primary School is presently used as gymnasium but it suffers from major waterproofing issues. Photograph by Alberto Pugnale, May 2014.

Two binishells collapsed in Australia, one was partially demolished in April 1988 and nine others were demolished entirely between November 1988 and May 2014. The dome at Georges River College Peakhurst Campus was the most recent lost, but also the last survival of the four multi-purpose centres realised in NSW by means of the 36m system, scheme no. 1. The latter was the most fascinating, in architectural terms, as the shell was complemented with four kinds of pyramidal frustums to compose a perfectly square plan. Figures 4 and 5 show the Peakhurst binishell just a few days before Australia lost one of the most relevant binishells in the world. In all the cases, except for the Hurstville binishell, major leakage problems have been highlighted by the users since the 1980s, and this has required regular repairs and maintenance works.

Former teachers and employees remember the binishell construction years with nostalgia, as a period of incredible innovation and vision towards the future, whereas some of the current students, and even some of the principals cannot recall the etymology of the term “binishell”.



**Fig. 4** The binishell at Georges River College, Peakhurst Campus, a few days prior to demolition. Photograph by Alberto Pugnale, May 2014.



**Fig. 5** The binishell at Georges River College, Peakhurst Campus, a few days prior to demolition. Photograph by Alberto Pugnale, May 2014.

The Australian experience of Dante Bini becomes even more significant when one compares it is compared with his later achievements. Bini left Australia in 1981 for a new life in the United States, where he founded new construction and consultancy companies. However, his subsequent inventions, based on an inflatable membrane technology, such as the "Pack-Home" system, did not succeed in generating any "new architectural formulae" that would have freed him from the iconic role of being the creative genius of inflated domes.

List of Australian binishells, February 2015.

Date of const.	Name/Typology	Address/Coordinates	State	Const. company/Client	No.	Diam (m)	Current status/alterations
30 May 1974	Narrabeen North Public School	6 Namona St, North Narrabeen, 2101	NSW	NSW Dep of Edu BC&M Branch	2	18	Existing (before and after school care)
Opening June 1974	School library	33°41'56" S 151°17'51" E		NSW Department of Education			Removal of Asbestos, 1983
Mid-1974	Narrabeen North Public School	6 Namona St, North Narrabeen, 2101	NSW	NSW Dep of Edu BC&M Branch	1	18	Existing
	Administration block	33°41'56" S 151°17'51" E		NSW Department of Education			Removal of Asbestos, 1983
Mid-1974	Georges River College, Peakhurst Campus	1 Rona St, Peakhurst, 2210	NSW	NSW Dep of Edu BC&M Branch	1	36	Demolished, May 2014
	Multi-purpose Centre (Scheme 1)	33°58'03" S 151°03'20" E		NSW Department of Education			Removal of Asbestos, 2 January 1985
18 July 1974	Killarney Heights Primary School	10/2 Tralee Avenue, Killarney Heights, 2087	NSW	NSW Dep of Edu BC&M Branch	1	18	Existing (multi-purpose centre)
	School library	33°46'29" S 151°12'56" E		NSW Department of Education			
Mid-1974	Pittwater High School	1668 Pittwater Road, Mona Vale, 2103	NSW	NSW Dep of Edu BC&M Branch	1	36	Collapsed on 4 August 1986
	Multi-purpose Centre (Scheme 1)	33°40'06" S 151°18'12" E		NSW Department of Education			
Oct. 1974	Randwick Girls' High School	Baker St, Randwick, 2031	NSW	NSW Dep of Edu BC&M Branch	1	36	Demolished
	Multi-purpose Centre (Scheme 1)	33°55'20" S 151°14'19" E		NSW Department of Education			Structural loading test, 24 June 1976
Oct. 1974	Fairvale High School	Thorney Road, Fairfield West, 2165	NSW	NSW Dep of Edu BC&M Branch	1	36	Collapsed on 4 January 1975
	Multi-purpose Centre (Scheme 2)	33°52'27" S 150°55'49" E		NSW Department of Education			Precautionary support tower, major leaks and vandalism
Late 1974	Ingleburn High School	Oxford Rd, Ingleburn, 2565	NSW	NSW Dep of Edu BC&M Branch	1	36	Demolition approved, 15 November 1988
	Multi-purpose Centre (Scheme 1)	34°00'19" S 150°52'16" E		NSW Department of Education			Waterproofing, 1981-82; supporting tower after 1986
Mid-1975	Kur-ring-gai Creative Arts High School	Bobbin Head Rd, North Turramurra, 2074	NSW	NSW Dep of Edu BC&M Branch	1	36	Existing
	Multi-purpose Centre (Scheme 2)	33°41'27" S 151°09'10" E		NSW Department of Education			

Date of const.	Name/Typology	Address/Coordinates	State	Const. company/Client	No.	Diam (m)	Current status/alterations
1975 (?)	G.R. College, Hurstville Boys High School	Kenwyn St, Hurstville, 2220	NSW	NSW Dep of Edu BC&M Branch	1	36	Existing
	<i>Multi-purpose Centre</i>	33°57'45" S 151°06'37" E		<i>NSW Department of Education</i>			
Inflated in late 1976	Fairvale High School	Thorney Road, Fairfield West, 2165	NSW	NSW Dep of Edu BC&M Branch	1	36	Existing
Completed in 1977	<i>Multi-purpose Centre (Scheme 2)</i>	33°52'27" S 150°55'49" E		<i>NSW Department of Education</i>			<i>Waterproofing, insulation and façade membrane, early 2010</i>
1977	Ashbury Public School	Trevenar St, Ashbury, 2193	NSW	NSW Dep of Edu BC&M Branch	1	18	Existing
	<i>School library</i>	33°53'54" S 151°07'11" E		<i>NSW Department of Education</i>			
1977	Jesmond Senior C. Callaghan College	Janest St, Jesmond, 2299	NSW	(?)	1	36	Existing
	<i>Multi-purpose Centre</i>	32°54'01" S 151°41'45" E		<i>NSW Department of Education</i>			
1977	Richmond High School	Howes St, Richmond, 2753	NSW	(?)	1	36	Existing (Family-based church)
	<i>Multi-purpose Centre</i>	33°36'01" S 150°44'46" E		<i>NSW Department of Education</i>			<i>Waterproofing, insulation and façade membrane, 2008</i>
1977	Greenwood Recreation Centre	27 Penistone St, Greenwood, 6024	WA	(?)	1	(?)	Demolished, 1989
	<i>Community Centre</i>	31°49'51" S 115°48'39" E		<i>Shire of Wanneroo</i>			
22 April 1978	Whitford Recreation Centre (Padbury)	21 Giles Avenue, Padbury, 6025	WA	(?)	1	(?)	Demolished, 11 October 1993
	<i>Community Centre</i>	31°48'12.8"S 115°45'25.7"E		<i>Shire of Wanneroo</i>			
1978	Hunter Sports High School (Gateshead)	Pacific Highway, Gateshead, 2209	NSW	(?)	1	36	Existing, demolition planned during 2015
	<i>Multi-purpose Centre</i>	32°59'09.0"S 151°41'26.5"E		<i>NSW Department of Education</i>			
1 Dec. 1978	Space City Shopping Centre	1477 Anzac Avenue, Kallangur, 4503	QLD	Jennings Industries Limited	7	3x18 4x36	Demolished, 1991 (abandoned, 1990)
	<i>Major Shopping Complex</i>	27°15'03" S 152°59'57" E		<i>Kallangur Supermarkets</i>			
1978	Phil Renkin Recreation Centre	59 Lisford Avenue, Two Rocks, 6037	WA	Desway Constructions	1	36	Partially demolished, April-December 1988
Opening 24 Feb. 1979	<i>Community Centre</i>	31°29'46" S 115°35'19" E		<i>Shire of Wanneroo</i>			<i>Top of the dome replaced in 1988, building reopened in December 1989</i>
1979	Hunter School of the Performing Arts	109 Lambton Rd, Broadmeadow, 2292	NSW	(?)	1	36	Existing
	<i>Multi-purpose Centre</i>	32°55'26" S 151°43'37" E		<i>NSW Department of Education</i>			
Inflated in 1979	Diamond Creek (Watsonia)	(?)	VIC	(?)	1	(?)	Demolished, late 1990s
	<i>Sports Pavilion</i>	(?)		<i>Shire of Diamond Valley</i>			
March-June 1980	Federation University Australia (Gippsland)	Northways Road, Churchill, 3842	VIC	Jennings Industries Limited	1	36	Demolished, 14 February 2009
Opening 19 July 1980	<i>Multi-purpose Centre</i>	38°18'42" S 146°25'36" E		<i>Gippsland Institute of Advanced Education</i>			<i>Supp. tower, 13 June 1986, Load tests Nov. 1987, tower rem. 1988</i>

- 1 This paper is the result of the combined work of the two authors. Part 1 was written by Alberto Bologna (Laboratoire de Théorie et d'Histoire 3, Ecole Polytechnique Fédérale de Lausanne) and part 2 by Alberto Pugnale (Faculty of Architecture, Building and Planning, University of Melbourne). Both parts have been revised by the authors and the paper structure has been conceived together. This research project has been funded by an Early Career Research Project Grant of the Faculty of Architecture, Building and Planning, University of Melbourne, of which Alberto Pugnale is the Chief Investigator.
- 2 Alberto Pugnale and Alberto Bologna, "Dante Bini's Air Structures (1964-1979): From Early Italian Prototypes to Australian Experience," in *Proceedings of the First Construction History Society Conference, 11-12 April 2014*, ed. James W. P. Campbell et al. (Cambridge: Construction History Society – Short Run Press, 2014), 355-365.
- 3 See Ada Louise Huxtable, *Pier Luigi Nervi* (New York: George Braziller, 1960), 12, 16. The concept of 'structural art' spread during the 1980s because of David Billington. See David P. Billington, *The Tower and the Bridge: The New Art of Structural Engineering* (New York: Basic Books, 1983), 3-8.
- 4 "Fuller, Nervi Candela to Deliver 1961-62 Norton Lecture Series. Three Architects Chosen," *The Harvard Crimson*, November 15, 1960.
- 5 *Twentieth Century Engineering* (New York: Museum of Modern Art, 1964).
- 6 "Balloon Houses Designed for Defense Workers Bloom Under Virginia Trees," *Life*, December 1, 1941, 34-35; "Ballyhooed Balloon," *Architectural Forum* 75 (December 1941): 421; "Airform House is improved for U.S. market, also going overseas," *Architectural Forum* 87 (July 1947): 15; W. Neff, Jr. ed., *No Nails, No Lumber: The Bubble Houses of Wallace Neff* (Santa Barbara: Capra Press, 1986), 177-186; J. F. Muntz, "Bubbles for Defence," in *Wallace Neff 1895-1982: The Romance of Regional Architecture* (San Marino, California: The Huntington Library, 1989), 69-89.
- 7 *Proceedings: World Conference on Shell Structures* (Washington, DC: National Academy of Sciences – National Research Council, 1964).
- 8 *Proceedings: World Conference on Shell Structures*, 688.
- 9 Dante Bini, *Building with Air* (London: Bibliotheque McLean, 2014), 37-41.
- 10 Pugnale and Bologna, "Dante Bini's Air Structures (1964-1979)," 355-365.
- 11 James H. Marsh, "Construction of Thin Shell Structures by the «lift-shape» Process," in *Proceedings: World Conference on Shell Structures*, 447-452.
- 12 *Proceedings: World Conference on Shell Structures*, 447.
- 13 Claudio Greco, "The Ferro-Cemento Experimental Storehouse by Pier Luigi Nervi," in *DOCOMOMO Conference Proceedings*, Third International Conference, 16-19 September, 1994 (Barcelona: Docomomo International, Iberian Docomomo, Fundacio Mies Van Der Rohe), 108-111.
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- 15 Henri Lossier, patent FR 372.499, *Coffrage pour constructions armées*, December 12, 1906.
- 16 Società Nervi & Bartoli (inventor: Aldo Arcangeli), patent IT 455678, *Perfezionamento nella costruzione di solai, volte, cupole, travi-pareti e strutture portanti in genere a due o tre dimensioni, con disposizione delle nervature resistenti lungo le linee isostatiche dei momenti o degli sforzi normali*, July 23, 1949; Pier Luigi Nervi, patent IT 455750, complete to patent IT 406296, July 23, 1949.
- 17 Mario Salvadori, *Why Buildings Stand Up: The Strength of Architecture* (New York and London: W. W. Norton & Company, 1980), 203.
- 18 Dante Bini, *A cavallo di un soffio d'aria. L'Architettura Autoformante* (Milano: Guerini e Associati, 2009), 26. See also Bini, *Building with Air*, 26.
- 19 *Proceedings: World Conference on Shell Structures*, 137-139.
- 20 Thomas H. Creighton, "The New Sensualism," *Progressive Architecture* (September 1959): 141-147; Thomas H. Creighton, "The New Sensualism II," *Progressive Architecture* (October 1959): 180-187.
- 21 Lucio Fontana, "Michelangelo Antonioni's Villa in Sardinia: A Magnificent Leopardian Concrete Moon – abandoned on the step rocks of Costa Paradiso," in Bini, *Building with Air*, 147-159.
- 22 "The Endless House," *Architectural Forum* 93 (November 1950): 124-126.
- 23 "Sculpting with Sprayed Concrete," *Architectural Forum* 111 (October 1959): 167-168.
- 24 Dante Bini, *A cavallo di un soffio d'aria. L'Architettura Autoformante* (Milano: Guerini e Associati, 2009), 26. See also Bini, *Building with Air*, 56.
- 25 Bini, *Building with Air*.
- 26 All the files related to the early conversations between the NSW Department of Public Works and Dante Bini are archived in NRS 4352 30 02 File no. S5000 1462.

- 27 In a letter dated 19 July 1973 and signed by Agent General David Hughes, it emerges that Dante Bini remained in Australia for about four weeks.
- 28 Bini, *Building with Air*, 77-111.
- 29 The same photographs appear in Will McLean, "Domes of Discovery," *Architectural Review* vol. 233, no. 1392 (February 2013): 86-93.
- 30 Ross Styles, "Binishells" (BArch thesis, University of New South Wales, 1975).
- 31 The first brochure was published in 1977: New South Wales. Dept. of Public Works, *Binishells in New South Wales Schools* (Sydney: Dept. of Public Works, 1977). The second one was released in 1978: New South Wales. Dept. of Public Works, *Construction of Binishell Reinforced Concrete Domes* (Sydney: Dept. of Public Works, 1978).
- 32 Two websites are currently active and show the work of Dante Bini and his son Nicolò: [www.binisystems.com](http://www.binisystems.com) and [www.binishells.com](http://www.binishells.com).
- 33 Information about the construction and maintenance of the Binishell at Gippsland Campus, Victoria, can be found in the Monash University Archives, MON 420, A-4-3-4; MON 420, B-4-3-4; MON420, D-4-3-4, MON974, 92-1349. Documents, photos and a video of the demolition, which was planned for November 2008 but took place in January 2009, have been kindly provided by Alan Scarlet, Campus Manager at Federation University Australia, Gippsland Campus.