Pier Luigi Nervi and Harry Seidler's Australia Square Tower: Italian Structure, Australian Design

Paolo Stracchi
School of Architecture, Design and Planning, University of Sydney, Australia

Abstract

The paper explores Pier Luigi Nervi's involvement in the design and construction of Harry Seidler's Australia Square Tower (1962-67) between 1962 and 1964. Far from being a "mere" structural and technical consultancy, Nervi's contribution to Australia Square tells a more significant and complex story. By considering the historical background of the project's evolution, the paper demonstrates how Nervi's participation was instrumental to the introduction of a new design approach to the Australian milieu for building tall structures as a unity of architectural form and structural design. Before the Australia Square Tower, the tall buildings of Australian cities were modelled on the American skyscraper characterized by a conventional steel structure, concealed behind a glass and steel curtain wall. In conceiving his tower, Seidler decided to break with this tradition: following his client's desire to use reinforced concrete as a structural medium, he gave Australia Square Tower a ground-breaking cylindrical form featured by an exposed load-bearing structure. In doing so, Seidler introduced a distinct Italian approach to the skyscraper, which exploited the expression of the load-bearing structure to simultaneously solve and feature the, often unusual, architectural forms. This structural emphasis underlines Seidler's design for Australia Square, which found in Nervi, renowned for the audacious structural design of the Pirelli Tower, the ideal supporter. Although limited by pragmatic and personal reasons, Pier Luigi Nervi thus played a crucial role in pioneering both design and construction of Australia Square, which through Nervi's structural hallmarks – the exterior colonnade and the ribbed floors – marked a paradigm change for the Australian Skyscraper.

Keywords

Pier Luigi Nervi; Harry Seidler; Sydney; Australia; 1960s; skyscraper; precast concrete; ferro-cement.

Introduction

During the 1960s, Sydney, Australia, witnessed the construction of two of the most advanced buildings of the era: the Sydney Opera House (1959-73) and the Australia Square Tower (1961-67). While Jørn Utzon's iconic masterpiece is undoubtedly more familiar today, Harry Seidler's circular tower on George Street is nonetheless a showpiece of record-breaking engineering, novel design and construction techniques, and innovative use of reinforced concrete. In 1958, Lend Lease Corporation and its subsidiary Civil & Civic (C&C) hired Harry Seidler as consultant architect and together they conceived and began planning the project of Australia Square Tower.[1] Following Seidler's recommendation, the building that resulted from this collaboration featured an iconic cylindrical shape designed to limit the 'canyon-like' effect and admit ample sunlight to the plaza below. Upon its completion in 1967, the 50-storey, 688 feet (209.70 m) Australia Square Tower was the tallest building in the southern hemisphere and thanks to C&C's pioneering use of lightweight reinforced concrete it was also the lightest skyscraper in the world.[2]

Seeking to give the tower a dramatic structural aesthetic shaped by the principles of static engineering, in 1962 Seidler sought to engage the Italian engineer Pier Luigi Nervi as a structural consultant for the

Australia Square Tower. However, Seidler wanted more from Nervi than a mere 'structural consultancy'; rather, Seidler championed Nervi's collaboration and sought to create with him a 'design partnership' so as to explore in greater detail the role of "structural expression and design", believing that this would contribute to the 'greatness' he desired for his building:

> Although the shape and the sizes of structural members shown [in the preliminary design] will work, it is felt that perhaps they do not do justice to the concept. We would like to welcome Professor Nervi's frank opinion on the scheme in its present form and any suggestions for its structure, whether basically different of refinements in detail."[iii]

Nervi, one of the leading representatives of European modern structural expressionism, accepted Seidler's offer and his input became essential for giving Australia Square its appearance based on the intimate relationship between structure and architecture.

The design approach of using reinforced concrete load-bearing structure geometrically shaped was already being employed in the Italian skyscrapers of the 1950s. Nervi was a key figure of the Italian model for the tall building, a model that disputed the rampant modernity of the American skyscraper founded on functionalism and industrial aesthetics which fascinated and monopolized the design of the newborn Australian tall buildings constructed throughout the 1950s and 60s. However, Seidler saw the glassy and boxy American skyscraper as a limitation. Encouraged by the client's decision to use reinforced concrete as a structural medium Seidler sought to shape Australian Square Tower with a ground-breaking cylindrical form featured by a daringly expressed load-bearing structure. Therefore what makes Australia Square an important structure in the international history of architectural engineering is its role as an alternative to the dominant American International Style.

Importing into Australia a new architectural model for the tall building challenged the Australian construction industry and its technical know-how. Seidler's creative ambition invested the structure with a primary architectural role which required an unprecedented design attention to the construction process of every single structural part in order to obtain a satisfactory aesthetic look. Nervi, well-known for his glamorous structural expressionism with a masterful use of reinforced concrete, had already proved his ability to resolve his buildings with remarkable construction solutions. Therefore Nervi could provide the needed technical solutions to build the tower, following Seidler's vision and filling those technical gaps naturally present in the dawning era of the Australian skyscraper.

To understand the nature of Nervi's collaboration with Seidler, the paper conducts an in-depth technical study of the design and construction of the column casings and the two famous ribbed floors of the tower – both elements designed by Nervi. The study reveals that these two structural elements, which to date have been viewed as a mere extemporaneous technical contribution to Australia Square, reflect Nervi's usual practice of considering and integrating artistic, technical, structural and economic factors. Furthermore, the paper reveals the structural strategies proposed by Nervi, and it draws out the technical knowledge of the Australian building industry and modern structural engineering at the time, which on the one hand substantially affected Nervi's involvement by limiting his contribution, almost jeopardizing its continuation, but on the other allowed the perfect execution of the column casings and famous ribbed floors. By situating the construction of Australia Square Tower in this historical context it is thus possible not only to reveal the extent of the collaboration between Nervi and Seidler but also to fully understand the tower's role in the evolution of Australian modern architecture and construction. Indeed Australia Square not only challenged the Australian context but made a significant contribution to the international history of the modern skyscraper.

An Italian skyscraper in Sydney

During the 1950s and 60s, Heinz Isler in Switzerland, Felix Candela in Mexico and Pier Luigi Nervi in Italy – among many other engineers – demonstrated the aesthetic beauty and architectural potentials of concrete structures. Echoes of these glamorous yet 'rational' constructions spread across the world influencing the designs of many architects such as Oscar Niemeyer, Kenzo Tange, Marcel Breuer, Eero Saarinen, Gio Ponti and Harry Seidler. In many instances partnerships between architects and engineers were formed to explore structural aesthetics and architecture. Initially, these collaborations were limited to the design of concrete shells or long-span buildings, in which the structural skeleton played a primary role in the architectural form. Translating this novel structural vision of architecture into a different and relatively new building typology, namely the skyscraper, was thus almost inevitable. This natural consequence was particularly evident in Italy, where concrete was essentially the only structural material available for construction of any large-scale building, including the skyscraper.

The beginnings for the use of concrete to create an expressive organic structure in tall buildings can be found in Italy during the mid-'50s. Striking examples of this structural approach are Gio Ponti and Nervi's *Grattacielo Pirelli* (1955-58), the world's tallest building in reinforced concrete (RC) built at the time; the Milan *Torre Velasca* (1950-56), designed by BBPR and Arturo Danusso; and the Montreal Stock Exchange Tower (1961-64), designed by Luigi Moretti and Nervi. Of these, the *Velasca* and the *Pirelli* towers featured distinguished forms: the *Velasca* a mushroom-like shape, recalling the Milanese medieval traditional towers; and the *Pirelli* a diamond-like shape, which belongs to Ponti's original formal vocabulary. (Fig. 1) The formal premises of the two towers required unconventional structural solutions – solutions that were resolved by synergetic collaborations between their architects and engineers, transforming simple structural consultancies into design partnerships. This first form of

Figure 1. Left: Torre Velasca, Milano, c.1960. Architect, BBPR; Engineer, Arturo Danusso. Right: Grattacielo Pirelli, Milano, c.1960. Architect, Gio Ponti; Engineer, Pier Luigi Nervi. (Photo: Paolo Monti. Copyright BEIC foundation and Civico Archivio Fotografico, Milano.)

integrated structural and architectural design approach fostered the advent of the so-called *Italian-style skyscraper*.[4] This *style* owes its identity to two other crucial factors: first, the presence of the ISMES in Bergamo, the world-famous model-testing station founded by Arturo Danusso, which allowed the testing of these original structural systems; and, second, to the extensive use of in-situ concrete, which was convenient for the protoindustrial Italian construction industry.

Like its Italian precedents, Australia Square also was conceived in RC. In the first half of 1963, C&C's engineers draw up a preliminary structural report framing the "background thinking" of the structure and construction of Australia Square.[5] According to the economic study cited in the report, the use of RC as a structural medium was appraised as the "more economical solution".[6] The suggested structural system was then conceived as a coupling of a RC double-continuous core with an array of RC fin-shaped columns running along the façade and avoiding any columns inside the office space so as to optimize the area designed as rentable office space. (Fig.2) Although a continuous core in RC was 23 to 30 per cent more expensive than a portal frame system, in conformity with the Australian Standards in place at the time, it allowed a 20 per cent higher permissible bearing stress, hence it was selected as the load-bearing system. The system – core plus fin-shaped columns – was further girdled by spandrels; thought of as horizontal bracing, the spandrels act as beams contributing to the wind-resistant strength of the structure. The choice of using RC as a structural material was based also on two other reasons that were strictly related to C&C's experience and commercial interests: its direct involvement in the production of lightweight concrete and its advanced construction management system that had been developed and successfully applied in the context of other, albeit smaller, multi-storey buildings built in concrete.[7]

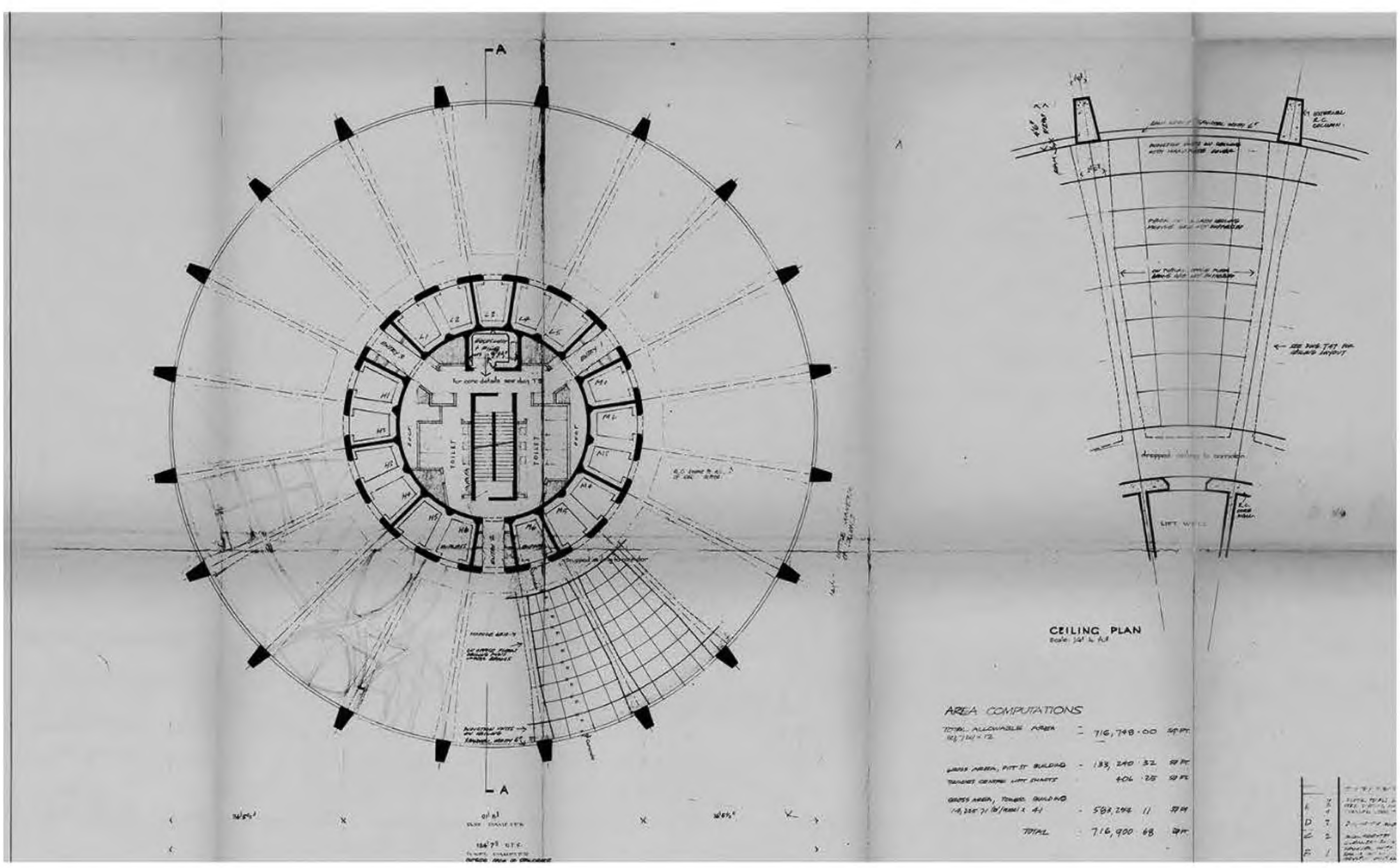

Figure 2. Typical floor plan (detail), Harry Seidler Associates (HSA) Series 59:10, Sydney, 1963. (MAXXI Architettura Collection. Pier Luigi Nervi Archive, Rome.)

The engineer's preliminary structural report was accompanied by an architect's report written by Seidler himself, in which he stated:

> "It is hoped that the entire face of the building will be of structural materials, i.e. concrete without 'infill' materials – for spandrel as well as fins act structurally. It seems likely, however, that this aspect of the design could yield a more imaginative structural answer.
>
> (...) To find a purely organic solution for the column fins, together with the floor and spandrel construction, is the main unresolved element of the scheme – something that will make it possible to clearly see and feel the structure taking stresses, and to understand the simple, direct way in which it was physically achieved."[8]

Therefore, from inside out, Australia Square was from the very beginning to be fashioned entirely in concrete. To the structural solution described in the Preliminary Structural Report, Seidler added his structural vision requesting a 'pure' use of the concrete for all the façade elements and suggesting a clear structural expressionism denoting the load-bearing nature of all the structural elements.

Therefore both the convenient use of RC as a structural medium and Seidler's almost poetical structural vision defined the iconographic premises of the tower. Nevertheless, from a more technical standpoint, coherent construction and engineering solutions needed to be explored. Seidler envisioned his project knowing well modern Italian architecture and engineering, which undoubtedly provided him with a solid example of creative, yet rational, structural design successfully applied to tall buildings. In 1962 the Italian towers the Torre Velasca and the Pirelli were internationally recognized as examplars of a new structural approach to the skyscraper and extensively featured in international magazines. But Seidler's knowledge of the design of these two towers was far more intimate. Eight years before the Australia Square project, during a trip in 1955, Seidler sought first-hand exposure to this new Italian approach to the conception of the contemporary skyscraper. As attested by his diary entry from 15 December, Seidler went to visit the construction site of the Pirelli and sketched the typical diamond-like plan of the tower. In the days that followed, Seidler had the chance to visit the ISMES: "Most interesting. Are doing test on model of Pirelli bldg [building]"[9]; and the BBPR's office, where he saw the plans of the Torre Velasca in Milan. During the same trip, Seidler also had the opportunity of visiting Nervi's office in Rome where he saw some photographs of the latest buildings designed by the firm.

In addition to his experience in Italy, Seidler's "increasing devotion to structural discipline, and to its extension far beyond conventional limits"[10] created the perfect conditions to design a tower featured by its structural expression. So it is easy to conclude from these accounts that the use of RC in the Australia Square Tower and the tower's unusual shape envisioned by Seidler owe a debt to the Italian-style skyscrapers. And it was this style – resulting from integrated collaborations between architects and engineers – which inspired Seidler and led to the involvement of Nervi.

The Australian context

During the 1950 and 60s, Sydney experienced an era of rapid economic growth and saw the construction of a series of multi-storey buildings to accommodate new or growing international and national businesses and the increasing need for space of the public service. This new building development formed what was to become Sydney's central business district. However, apart from the two notable exceptions of the now demolished Unilever House (1957) and the still-standing AMP building (1962), all buildings were simple vertical extrusions of existing rectangular lots. Indeed, as the Duke of Edinburgh quipped during his royal visit in 1966, the changing Sydney skyline reassembled "cigar boxes standing on their ends".[11] (Fig. 3)

Figure 3. Changing Sydney skyline, 1964. On the left side the State Office Block under construction. Architect, Ken Woolley; Engineer, TTW Pty Ltd. (City of Sydney Archives). (Photo: A. Ozolins. National Archives of Australia.)

To break out of this flatness and monotony, Seidler conceived of a new solution for the Australian skyscraper which would challenge the American curtain wall by using the structure itself as a formal tool. This approach also had another important consequence: after a decade of glass and steel façades it was apparent that this crude importation of the American International Style was not well suited to the Australian climate – a new, more environmentally sensitive approach was needed.

The Curtain Wall

By the 1960s, the poor thermal and material performance of the glass curtain wall had Australian architects eager to explore alternatives.[12] This prevailing sentiment was given further impetus by the new – and still experimental – inefficient air conditioning systems which produced exorbitant energy bills due their high running costs. Further, the intense sun and the rapid fluctuation of temperature experienced in Australia caused the glass of many curtain wall systems to fracture. It was evident that other solutions would have to be found.[13] During the preliminary studies of Australia Square, the only precedent in Sydney with analogous dimension and height was the State Office Block (1961-67) designed by Ken Woolley and TTW's engineers. The client, the NSW government, wanted the tower to be an example of a durable and functional building which could better respond to the Australian climate and create a valid alternative to the American prototype.[14] The architectural result was a boxy tower with a bulky colonnade on its perimeter, which provided a shading system and structural support for the building. Certainly, the tower asserted a discontinuity from the glittering international style, but its classic tectonic, rather than stimulating the Australian architectural scene, was almost a nostalgic return to the heavy masonry logic of its pre-war period.

In this phase of critical rethinking "characterised by expediency, shallow shortcut and unimaginative repetition,"[15] Seidler approached the design of his circular tower as an attempt to create a novel and more adaptive model for the Australian context. Seidler's innovation was to reject the full glass wall in favour of a more solid solution but without the nostalgia shown in the State Office Block. An emblematic example of Seidler's functional and modern thinking was the projecting fin-shape of the structural columns which consequently lent themselves to act as a shading system and wind barrier, performing as an integrated and original passive solution for the Australian climate:

> "The fins cut the façade into vertical segment which avoid 'curtain walling'. This is an undesirable element in the local climate being vulnerable not only due the lack of shading, but also being exposed to the full impact of cyclonic rain storms."[16]

So avoiding the "undesirable" and problematic curtain wall, the suggested aerodynamic shape of the fin-columns, recalling the modern epitome where *form follows function*, addressed in one solution static, environmental and formal needs. (Fig. 4)

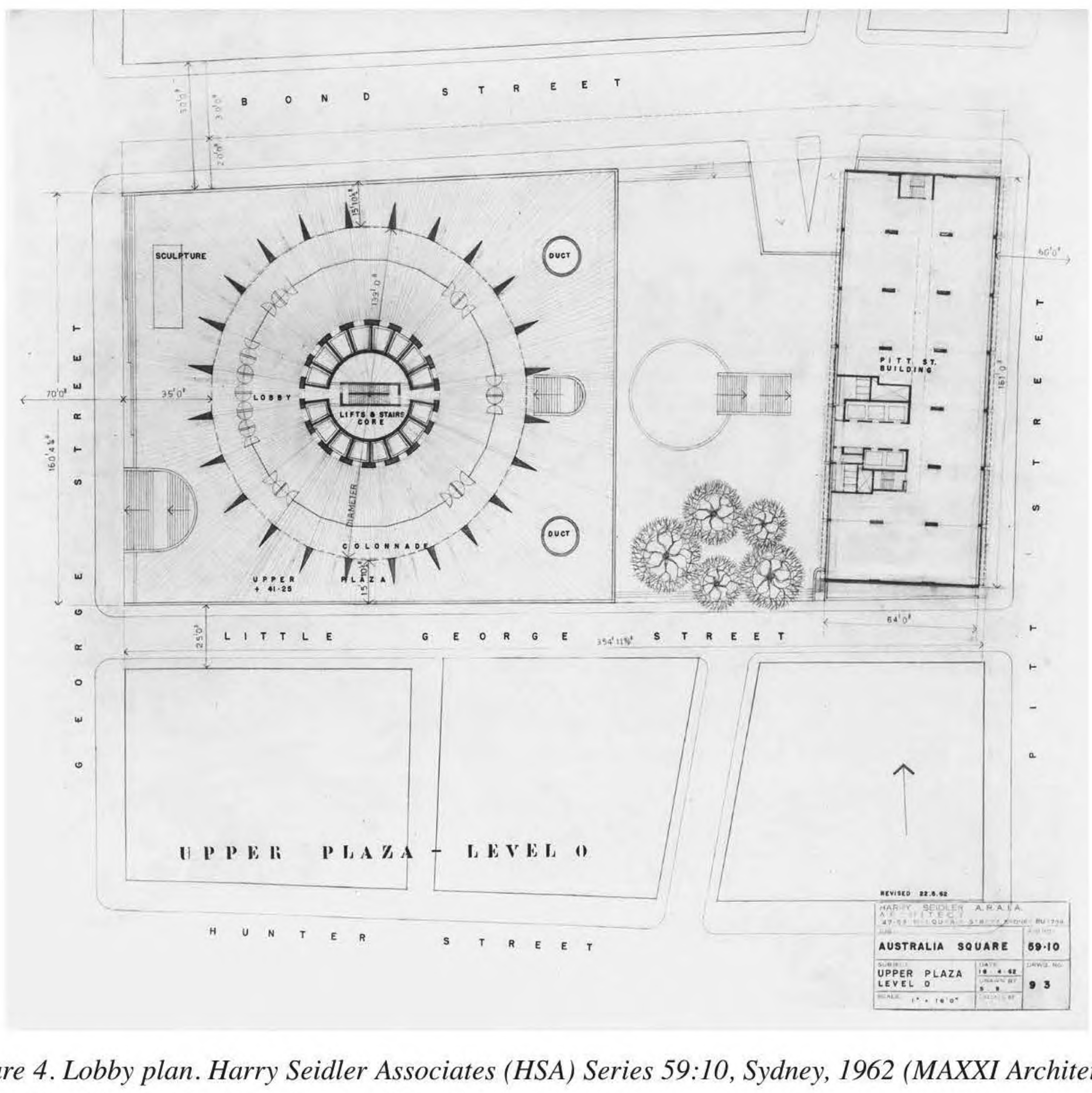

Figure 4. Lobby plan. Harry Seidler Associates (HSA) Series 59:10, Sydney, 1962 (MAXXI Architettura Collection. Pier Luigi Nervi Archive, Rome.)

Structural expression

Breaking with the boxy appearance of the newborn Australia skyscraper was not easy. The unusual shape of the tower was "a difficult one to handle architecturally"[17] and its exposed concrete structure introduced many new technical and structural problems. Like the curtain wall, these problems required a holistic structural and architectural solution. In response, Seidler proposed to bring in Nervi for the design of the tower. After an open and not-so-easy discussion between Seidler and the C&C engineers on whether or not to involve the Italian engineer in the structural and architectural design of Australia Square, the client and founder of Lend Lease, Dick Dusseldorp, agreed to commission Nervi. On the 30th of July 1962, a letter was sent to Rome asking Nervi if he would be willing to collaborate on the project and highlighted the benefit they would obtain from his expert assistance and "world-wide reputation in the design of concrete structures".[18] After a preliminary meeting with the representatives of Lend Lease in Rome, Nervi decided to accept the appointment as Structural Consultant on the 30th of October 1962. Nervi was eager to be involved early on in the preliminary design stages of the project, "in order to set the structural problems together with the architectural ones from the very beginning".[19] Like Seidler, Nervi clearly wanted to explore a solution in which the structure was a primary generator of the architectural form and not vice versa. In August 1963, after obtaining the planning approval from the authorities, the preliminary reports and drawings were dispatched to Studio Nervi. In the meantime, Lend Lease decided to send the entire design team of Australia Square to the United States and Italy in order to gain direct knowledge of the most innovative technical and structural solutions applied to tall buildings. In September and October 1963, Seidler travelled across the US, stopping in all the major cities to visit all the latest high-rise buildings. Among others, Seidler visited One Chase Manhattan Plaza (1961) and Equitable Life Center (today known as UBS Building, 1960), both designed by SOM, and Walter Gropius arranged for him to visit the Pan Am building in New York City. If one tall building could have been taken as a precedent by Seidler, it must have been the CBS building designed by Saarinen. The building was already famous as the antithesis of the American curtain-walled skyscraper. It was also the first reinforced-concrete skyscraper built in Manhattan. (Fig. 5)

However, although the CBS building was still under construction, it was clear that even the maverick Saarinen struggled to break with the rigour and stereometric appearance of the American skyscraper. Saarinen and Seidler both used the structure as a generator of the architectural form, but Saarinen ended up expressing the skeleton as a series of austere heavy masonry columns – fundamentally a reinterpretation of the classical work of the Chicago School. Actually, the only building that the Australian architect claimed in his diary had impressed him during the American trip was the Saint John's Abbey Church (1961), by Marcel Breuer, a clear example of structural expressionism which he could not find in any of the tall buildings he visited. [20]

The strength of the American skyscraper was its industrial nature, but this also became its limitation. Its standardized metallic structure was reduced to a mere scaffold and the seriality of its curtain wall ended up stereotyping—and dulling—its appearance. As Seidler remarked in his short but insightful comment on the just-completed and paramount example of the modern American skyscraper, the Pan Am building, "Pan Am = 0 [zero]." [21] One might read this as a compendium of his thought on the American model as a whole, and suggesting that the only available alternative for Seidler design and construction of his tower could be found in Italy and with Nervi's help.

Not only the concrete technology and its formal use distinguished the Italian model from the American one, but also the relationship between the professions involved in the design. In the US – as in Australia – the structural engineer was a consultant responsible for the structural integrity of the building. In Italy, structural engineers actively participated along the whole design process, influencing and even transforming the final architectural outcome of the buildings. Structural engineers became thus not mere consultants but in fact designers.[22] The same professional model was pursued by Seidler who gave Nervi free rein in the structural design of Australia Square.

Figure 5. CBS building under construction, New York, 1965. Architect, Saarinen; Engineer, Paul Weidlinger. (Saarinen Collection, Manuscripts and Archives, Yale University.)

Nervi's structural study for the tower

While Seidler was travelling in America, on the 6 September 1963 Nervi received C&C's architectural and structural assessment and made his recommendations for the tower's potential improvement and redesign. At this stage, four issues had to be addressed: the general stress analysis of the tower; the structural and technical design of the external fin-columns; the structural spandrel; and both the typical and the special floors. As planned, Seidler arrived in Rome on 29 October 1963, where for the first time he met Nervi; this was the last and the most pressing stop of the trip:

> "it may interest you [Nervi] to know that some years ago I worked with Marcel Breuer in New York and it was really through knowing of your associations with him that I urged the promoters of the Australia Square Project to engage your help."[23]

> "the design submitted is only preliminary and therefore might be modified, even substantially (...) the designers would welcome any suggestion and/or modification from Professor Nervi."[24]

From this encounter, Seidler sought to exploit the famous audaciousness of the Italian engineer not only to structurally support the architectural design of the tallest building in the southern hemisphere but also to find for it an "imaginative structural answer" with the final aim to write a new chapter in the field of Australian architecture.[25] (Fig. 6)

Figure 6. Australia Square, Sydney, circa 1967. (City of Sydney Archives.)

During these first meetings in Rome, Seidler pointed out that the scheme Nervi had received from C&C's engineers "might be modified, even substantially." On 31 October 1963, after two and half days with Nervi, Seidler wrote to his office in Sydney:

"old man [Nervi] has really done things to us for the tower.

1) he did not want to alter the concept basically. He felt in agreement with it, liked the plan.

2) Exterior columns grated on him, obviously + this was his first thing as were the spandrels which are sufficient if only turned down below the floors but obviously thicker for trade floors.

3) We now have a super lobby + trade floor ceiling. Nervi plus.

4) Top beams which he wanted at the first to eliminate + cantilever the top drum (proved difficult) are refined + make good sense now.

[...] He, by the way, is a wonderful, sensitive and energetic man of 72."[26]

Between October and November 1963, Seidler and Stigter (C&C's senior structural engineer) attended four preliminary coordination meetings held at Nervi's office in Rome. From the very beginning, it was evident that Nervi desired to minimize the structural elements of the facade, so as to coherently emphasize the prevailing resistance action of the centre core as a primary structural spine. In doing so, Nervi substantially modified C&C's preliminary structural study. Similar to a core-column structural system, (Fig. 7, left) C&C divided the structural resistance to the lateral loads equally between the core and the peripheric bracing system (columns plus spandrels) while Nervi envisioned a core structural system (Fig. 7, right). To Nervi the exterior bracing formed by the fin-columns and the spandrel performed only a secondary part in the overall structural logic. Instead it was the core that was to act as an elastic beam fixed to the ground that would absorb all the bending stresses due to the horizontal loads. Nervi did not deny the possibility that the external reinforcement could be "instrumental" to strengthen the building on the upper floors, but he was convinced that the elements of the façade could be reduced both from a structural and an architectural point of view, thus underlining the primary role of the central core.

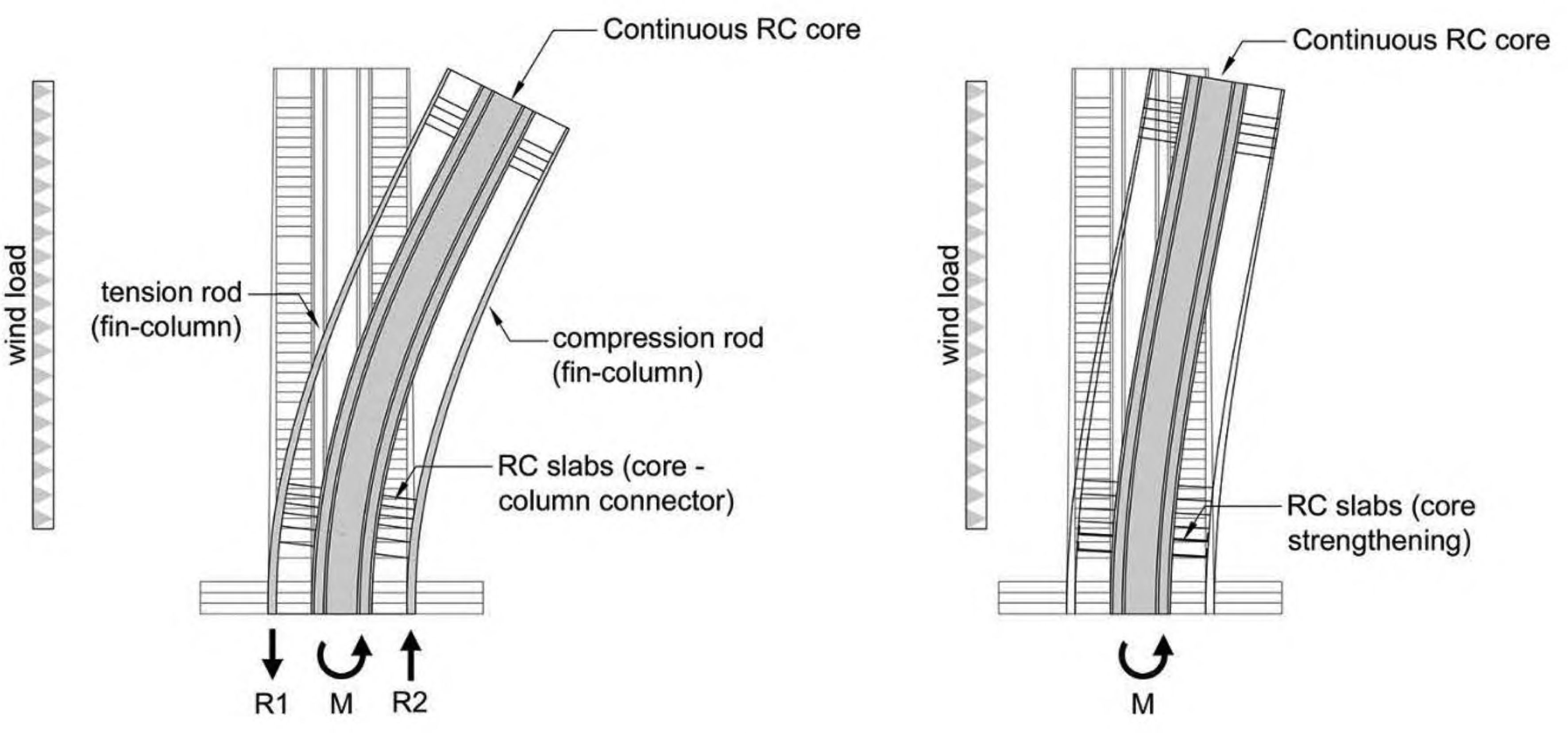

Figure 7. Left: Core-Columns structural system (C&C's option). Right: Core structural system (Studio Nervi's option). (Source: the author.)

To predict the structural behaviour of the tower's structure the only tool available at the time was the stress analysis using scaled-down models. Thus, to verify and further refine his structural idea, Nervi suggested involving a "well-equipped laboratory facility" to build and test a proper scale model, and promoted the appointment of the world-renowned ISMES of Bergamo, with whom the Italian master had designed the structures of the Grattacielo Pirelli and Montreal's Stock Exchange Building. A few months later, despite Nervi's recommendations and a series of initial informal contacts with the ISMES's director, Lend Lease decided to commission the fabrication and testing of the scale model to the structural laboratory of the UNSW. It was also decided to carry on the structural design in Sydney, leaving the role of structural consultants to C&C's engineers. The letter informing Nervi of these changes effectively downgraded the appointment of the Italian engineer to "Associate" Structural Consultant Engineer, reducing the scope of Nervi's collaboration to the design of the ribbed floor and the column casings.[27] Although not specified, it is reasonable to assume that this new arrangement was also dictated by others reasons, such as:

- C&C's proven capacity to carry on the structural analysis autonomously;
- Nervi's reluctance to come to Australia to discuss the project;[28]
- Nervi's lack of experience with lightweight reinforced concrete;[29]
- And the will of Lend Lease to carry out the design without oversetting the preliminary structural concept fixed by C&C's engineers.

Informed of this decision, Nervi decided to step down from the project and asked for his collaboration to remain anonymous or without any official recognition:

> "(…) this decision was made only after considering all the aspects of timing, coordination of the model testing with the theoretical analysis, and the difficulty to splitting the two functions of the design which are closely bound to each other. I know by my personal experience that the exact interpretation of the result established by extensometers is very difficult and that this essential work must be developed with strict cooperation and with a full agreement between the stress analysts and the engineers."[xxx]

Only Seidler's diplomacy, with a personal letter sent to Nervi highlighting the vital contribution which he gave to the scheme during the preliminary discussion, convinced the Italian engineer to accept the credit as Associate Structural Consultant.[31]

The subsequent structural investigations completed in Australia did not take into consideration Nervi's structural idea for the tower and were limited to the verification of the C&C's engineers preliminary structural assumptions. As a result, the final structural design and analysis – completed with the aid of a structural model built at UNSW – divided the horizontal load, due to the wind action, equally between the core and the columns, with the latter behaving as compression or tension rods. Although Nervi's idea of creating a core structural system was abandoned, all his other suggestions were incorporated in the tower, especially those regarding the shape and construction of the ribbed slabs and columns casings. Moreover, the proposed pergola at the top with the exposed roof beams – which never convinced Nervi — was eventually eliminated by Seidler.

Design and construction of Nervi's column casings and ribbed floor

If Nervi's structural solution was not able to cross the Italian borders, the precast column casings and the interweaving ribbed floor certainly gave Australia Square its unique structural look and iconic appearance. Without Nervi's collaboration on the project the structural expressionism envisioned by Seidler would not have become a reality in Australia. In fact, Nervi not only provided the integrated structural and architectural design of the column casings and ribbed floors but he and his office also provided the specifications to erect them. In doing so Nervi gave to Seidler and C&C the solution to build the tower with the construction speed it required in order to obtain a quick return on the client's investment:

"he [Nervi] virtually taught us how to build the building. It was the simplest method of construction for a round building. He said 'It's very logical to have a circular building and the outside of the building is made in the factory and the columns become smaller as the building rises'. The building went up extremely quickly (...)"[xxxii]

Australia Square project thus became an original compromise between the cost-effective standardized production-line logic of the American skyscraper and the proto-industrial in-situ constructed Italian skyscraper – a compromise that greatly benefited from Nervi's experience in creating original buildings with an ingenious prefabrication logic.

Nervi's column casings

By strongly expressing the surface of the cylindrical volume with a pleated series of fin-columns Seidler was able give the entirety a sense of texture in which the primary expression was one of structure. This meant that Seidler had to find a balance between the structure and surface by reducing the initial array of 36 exterior fin-columns to 18 in order to prevent it from having a "drum-like appearance". Eventually the final array was fixed at 20 fin-columns that were bent 90 degrees at the top to form a radial pergola.

Since Seidler's first meetings with Nervi in Rome during 1963, the structural, constructive and formal resolution of the fin-columns was a crucial part of the architectural design of the tower.[33] Already in the preliminary plans (Series 5910, 1962) there is a wedge-like fin-column, which was then refined into a more regular trapezoidal shape (Series 5910, 1963). (Fig8.) In elevation, Nervi's first sketches gave the exterior colonnade a unique profile by tapering the columns from the bottom to the top. In this way, the section of the fin-columns increased as a coherent consequence of the increasing gravitational loads, and univocally expressed their nature of simple compression-bearing elements; as usual in Nervi's work, a ruled surface was used to control the geometrical articulation of the fin-columns. (Fig. 9) Furthermore, the profile section was shaped within the proposed trapezoidal section as shown in the preliminary drawings so as to use the entire specified length of 8 feet (2.5 m). (Fig. 10) The tapered shapes aroused concerns around a possible buckling failure occurring in the tangential direction due to the wind loads, especially at the base where the sections showed a high slenderness ratio. These concerns were promptly rejected by Nervi, who was already considering a more rigid central core, only assisted by a series of bending-stress-free columns which, in any case, would only partially participate to counteract the wind loads; so the sketched profile, with non-eccentric loads, and with a column's volume (measured from the base to the top) equal to the one of the preliminary design, was considered structurally suited and "architecturally valid". Eventually, due to a more conservative structural approach undertaken in Australia, "it was felt that maybe the original shapes were a bit too far out for all the concrete to be effective",[34] along with some objections made by the Building Committee regarding the length of the projecting part of the columns outside the body of the tower, the final section was progressively reduced to 4'11 ft (1.5 m). Nevertheless, the shape sketched in Rome during November 1963 was the one employed in the final design and eventually built.

For the exterior finishing and method of construction, Lend Lease discouraged any use of off-the-form concrete, which, besides all the difficulties related to its execution, was judged as inappropriate for "a prestige office building". Likely as a result of Nervi's involvement, Lend Lease's Preliminary Structural Report proposed few options citing the possibility of adopting "thin facing slabs used as permanent formwork"[35]. This option lent itself well to Nervi's *modus operandi*, in fact he proposed to adopt the technique that he had just used to erect the two colossal trestles for the Cartiera Burgo in Mantova (1962). The two trestles were poured on-site in a precast *scorza* (literally rind), a precast permanent formwork, which assured a controlled finishing without needing any refining job after its implementation. For Australia Square, Nervi suggested casting the tapering fin-columns into a one-

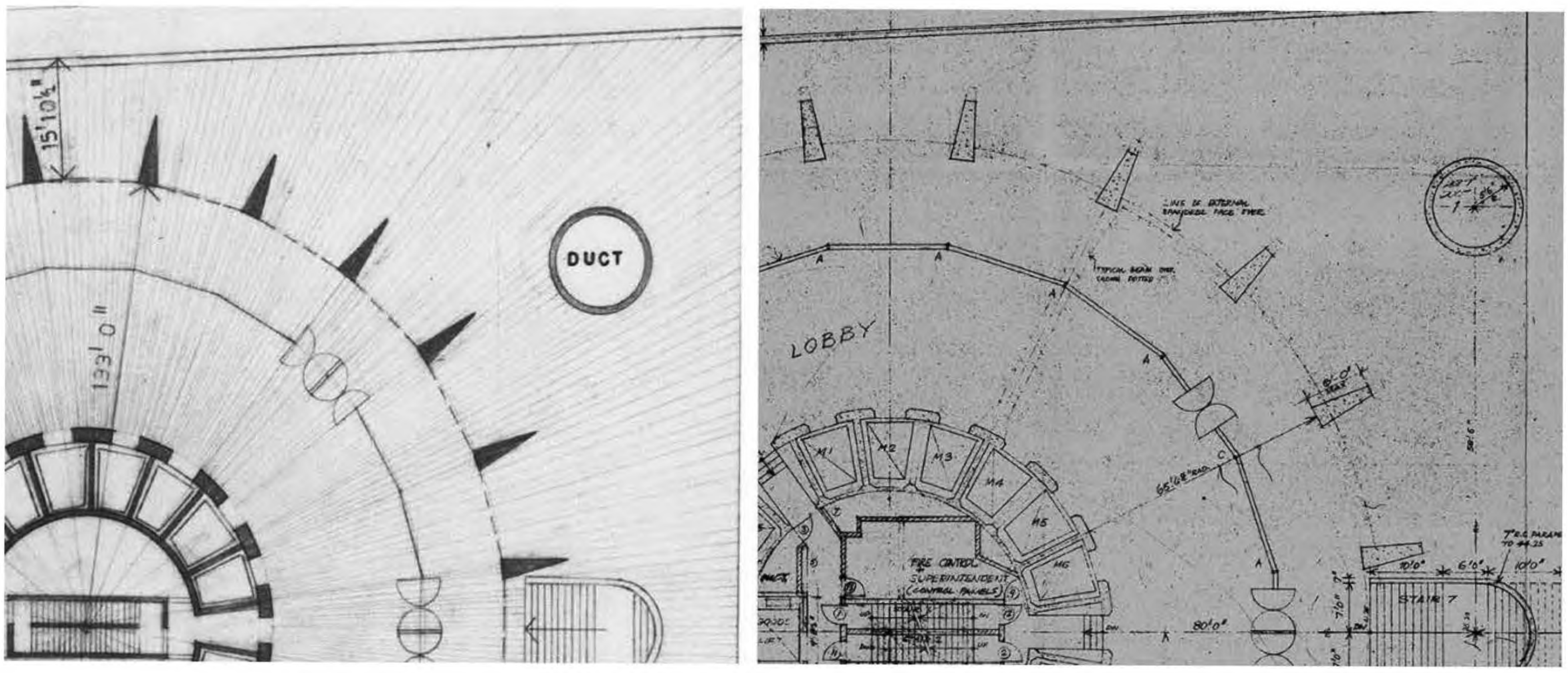

Figure 8. Design development of the column casing. Left: Lobby plan. Harry Seidler Associates (HSA) Series 59:10, Sydney, 1962; Right: Lobby plan, HAS, Series 59:10, Sydney, 1963. (MAXXI Architettura Collection. Pier Luigi Nervi Archive, Rome.)

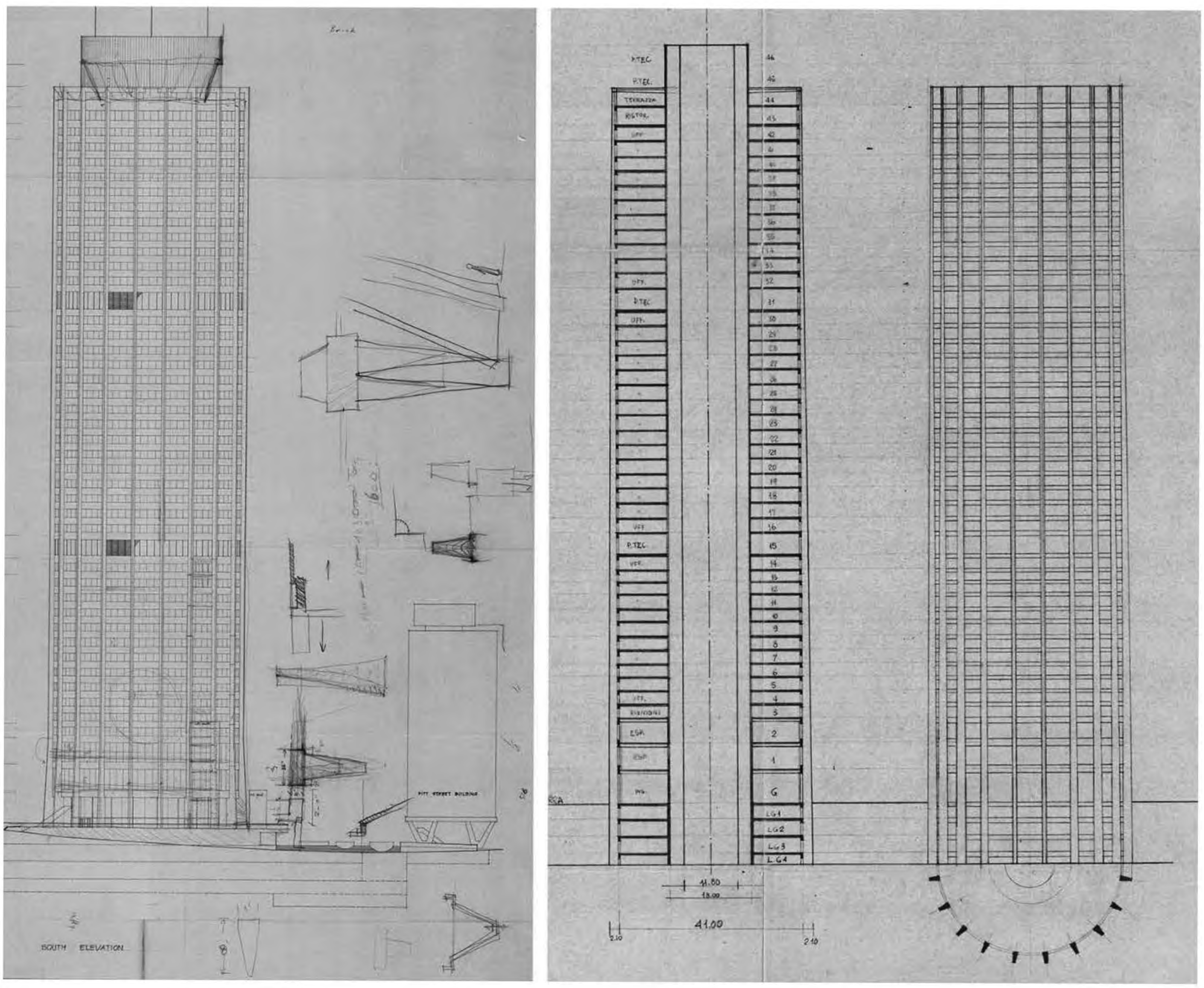

Figure 9. Left: T64 - South Elevation, HAS, Series 59:10 (detail), Sydney, 1963. (MAXXI Architettura Collection. Pier Luigi Nervi Archive, Rome.) Right: SK.4 – Structural Section and Elevation (detail), Studio Nervi, Rome, 1963. (Author Archive.)

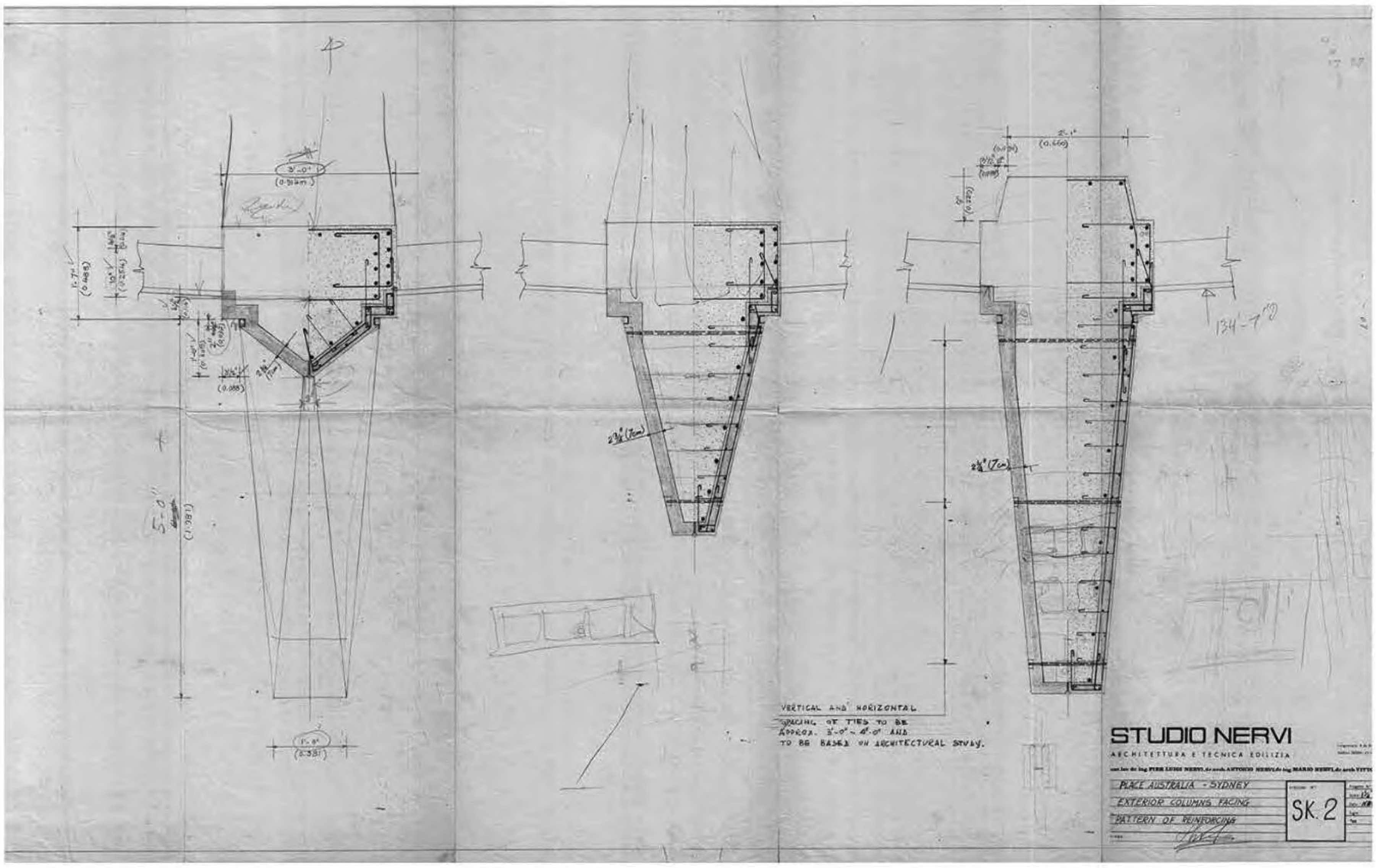

Figure 10. SK.2 - Detail of external facings showing reinforcing, Studio Nervi, Rome, 1963. (John Stigter Archive.)

storey-high permanent casing, which would have to be precast off-site with standard cement, assuring a "very satisfactory visual impact". To complete this task Nervi proposed the use of two symmetric shells connected by ties, bolted from outside or, alternatively, by a fixed wedge system. With their thickness of 7 cm each, the two shells were also designed to participate in the overall load-bearing section of the column. In 1963, two sketches were finalized by Studio Nervi to illustrate the precast casings, and a detailed 1:1 drawing was also provided to show the reinforcement and the connecting system of a couple of shells, demonstrating the high degree of attention given by Studio Nervi to Australia Square. Worth noting is that the word 'casing' often used to describe the permanent column formwork was probably due to a loose translation of the Italian word *cassero* which means formwork.

In 1964, after a second feasibility study, Lend Lease decided to build the entire tower without using any external scaffolding, which meant that the precast column formwork had to be assembled fully-finished since it would have been impossible to work on their exterior surface once in place. To address this problem, a C&C's method engineer was sent to Rome in 1964 to study the construction techniques as well as the equipment available for the production of the precast column casings and the *ferro-cemento* panels. For the fabrication of the precast column casing, one of three solutions proposed by the method engineer was assessed by Studio Nervi as having merit. The premise was that the full section of the column including the casing needed to be load bearing, hence the precast formwork had to be poured off-site with a full thickness of 7 cm and finished, once cured, with a layer of granules of white quartz sprayed on an adhesive film of epoxy resin. Even though the use of epoxy resin to glue the quartz finishing was new to Studio Nervi, the Australian engineer reassured the Italian engineers about the adoption of this solution. As a matter of fact, Australia was well advanced in using epoxy resin as a construction material as it had a long pioneering tradition in the production of epoxy-based granite panels.

The realized precast load-bearing formworks had a triple role: structural, constructive and aesthetic – a three-pronged solution that was also adopted for the precast concrete upright spandrels. Furthermore, the implementation of these ready-made precast elements (columns and spandrels) not only contributed to the economic success of the tower but also provided a physiological benefit for the workmen who could work protected by a prefabricated barrier encircling the entire perimeter of the working floor.[36]

Finally, Studio Nervi was genuinely fascinated by the washed concrete samples for the casings, which were made with white cement and quartz granule. From the moment they saw the effect, they remarked how "the aspect is very beautiful, but the cost is high". Indeed, two years later, Nervi asked Seidler for a full-size mock-up of column casing: "We regret to give you so much trouble, but the matter is of great interest for us at this moment". It is noteworthy that in that period, Nervi was busy exploring different options for the concrete mix for the structure of the Aula per le Udienze in Vatican City (1971) in which he intended to achieve a "purity and beauty" by executing all the precast structural parts in white concrete.[37]

Nervi ribbed floor and its construction system

The second and the most obvious Nervi trademark at Australia Square is the ribbed slab used for the lobby and the trade floor, both visible from the plaza and the street. From the very beginning, Seidler left the lobby ceiling and the trade centre floors (originally two) to Nervi's structural and artistic imagination with the "possibility of studying a special design". Subjected to heavy loads and free from any building services, like three white canvases, these spaces, lent themselves to depict Seidler's idea of structural expression. Nervi, who immediately expressed enthusiasm for this idea, despite the considerable span and loads, suggested the adoption of his famous *ferro-cemento* panels as a permanent formwork to put in place one of his worldwide famous interlacing floors. A month later, after the first meetings in 1963, once back in Sydney, Seidler wrote to Breuer, Gropius, and Olsen to describe the preliminary design done with Nervi in Rome. To Olsen, Seidler wrote:

> "the result of work in Rome has been most gratifying. Nervi has redesigned our exterior column forms into graceful tapered shapes, formed by precast storey-high casings. This has been priced here and, aside from the unresolved finishing problems, has proved to be even cheaper than our previous method. He also designed special ribbed floors for the two lower floors trade centre which, you can imagine, look marvellous going around the circle."[38]

In November 1963, four options were developed at Studio Nervi for the special ribbed slabs to be used at the trade exhibition floors: Type A, B, C and D. Geometrically, A and B (Fig. 11) stylized a rosette pattern following a simple curve, while D (Fig.12) stylized a similar rosette pattern but following a more complex sine-wave curve.

The drawings were refined by Studio Nervi during the first two weeks of November while Nervi was in New York for a work trip. Upon his return (14 November 1963) Nervi stated that "Sketch 10 - Type B" was the one "architecturally resolved", while "Sketch 12 - Type D" was the one "more logic from the construction and structural point of view", and so it was decided to redesign the latter to improve its pattern. What is evident by comparing the two solutions, B and D, is the different resting point of the ribs:

- In B, the ribs rest directly on the external columns;
- in D, the ribs flow – indistinctly – into an annular beam, which, in turn, transfer the loads onto the external columns.

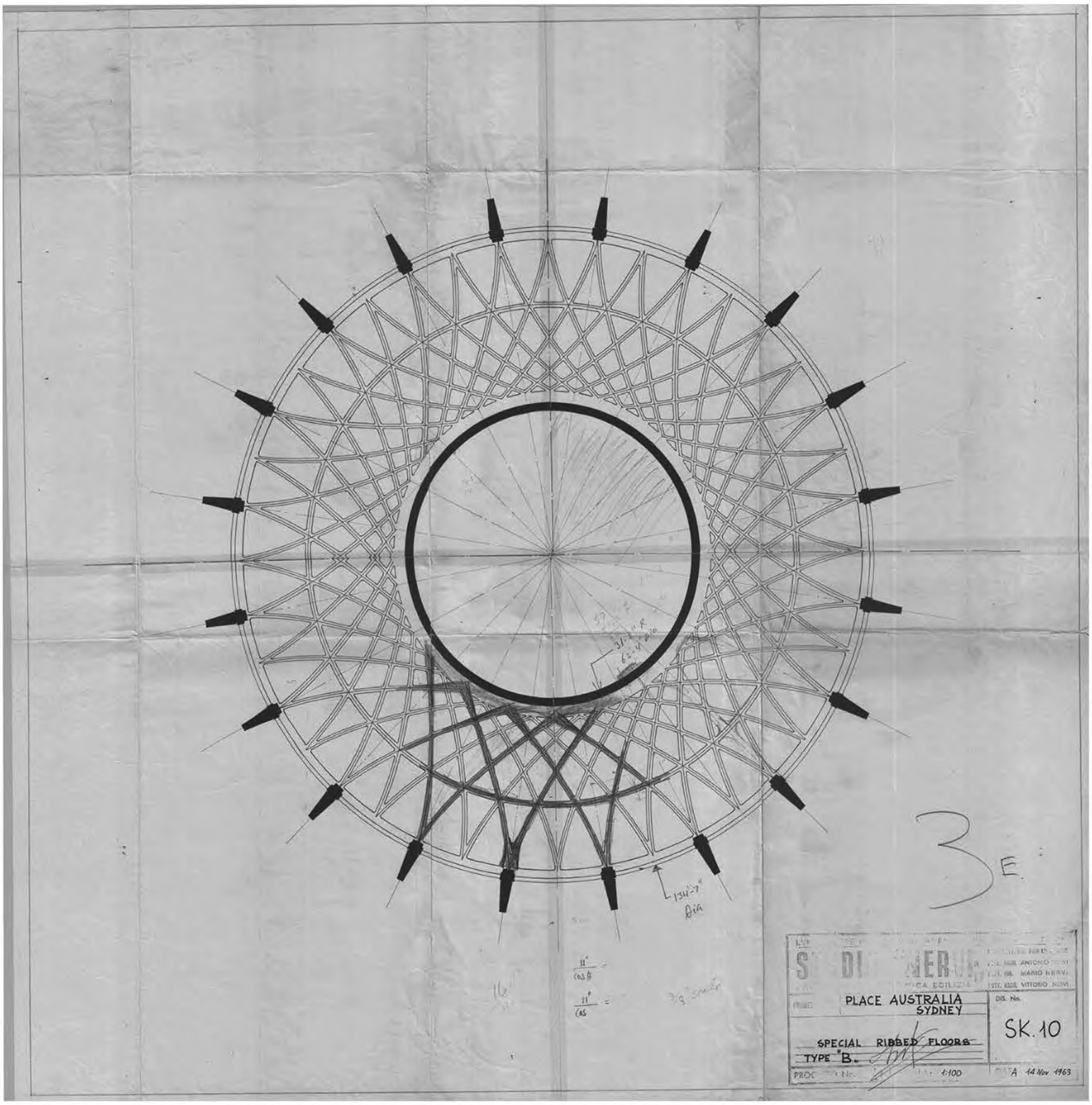

Figure 11. SK.10 – Special Ribbed Floors Type B, Studio Nervi, Rome, 1963. (John Stigter Archive.)

Therefore, structurally speaking, B can be compared, given the formal connection between the ribs and the columns, to a simple radial portal system made of a series of curvilinear portal frames, whereas D is without uncertainties a waffle slab edged by an annular beam.

Formally resembling and structurally working as a waffle slab with diagonally running ribs, solution D was noted as a logical solution because of its fitness to carry concentrated loads – the expected condition for a trade exhibition floor. Further, rendering Type D as a waffle system was the premise on which to assemble the slab by using the precast *ferro-cemento* panels used by Nervi in his many crisscrossing domes and ceilings; an envisioned solution that can explain Nervi's statement regarding its 'more logic construction'. Choosing D, it is also true that Nervi selected the more complex rosette pattern, since D follows an S-like path instead of a gentle curve line, as shown in B. So why did Nervi select D, even if there were no evident practical benefits in using this pattern? This may be due to the "artistic nature"[39] of Nervi's collaboration rather than because of any structural or construction reasons. In fact, while it is

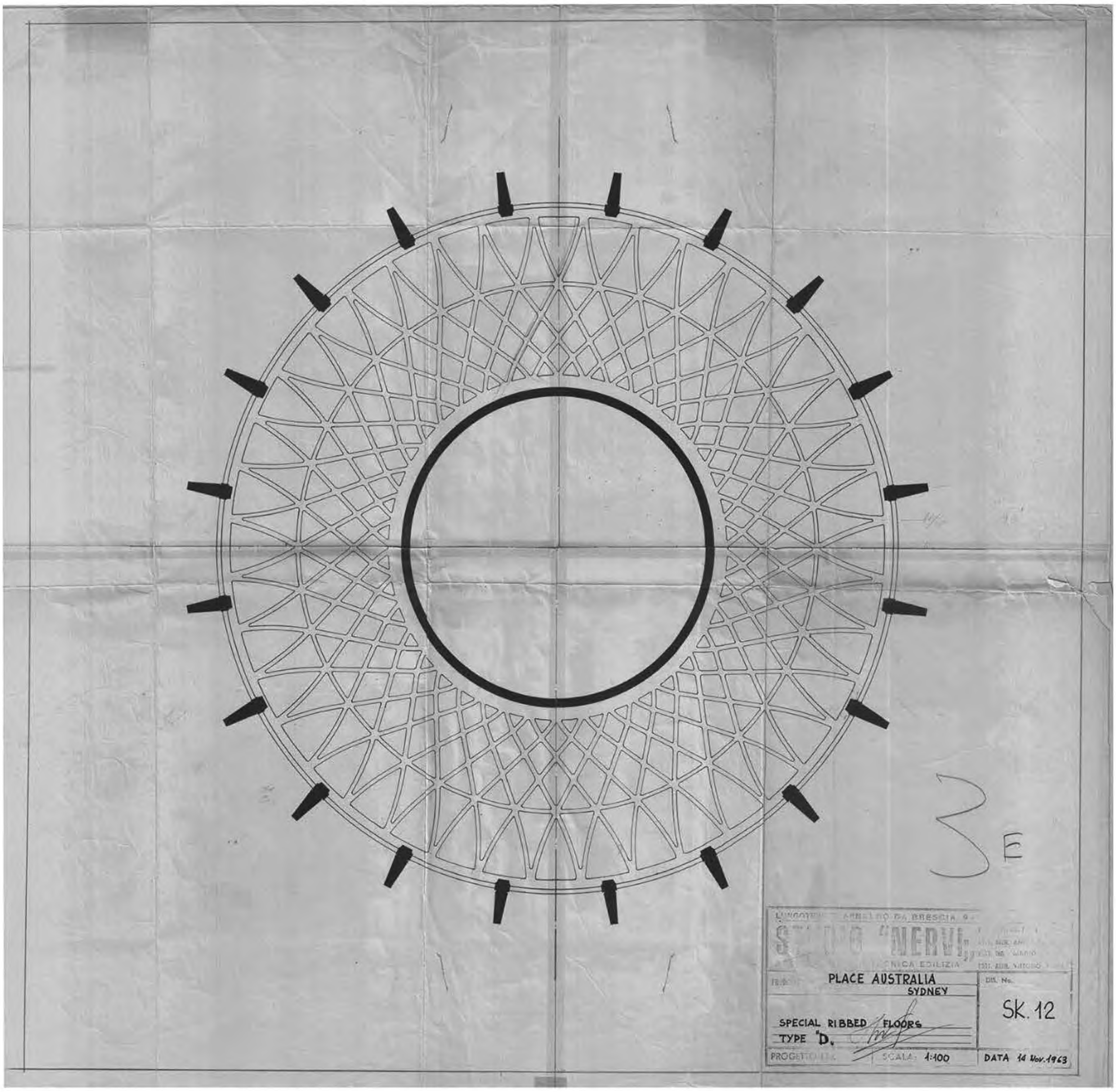

Figure 12. SK.12 - Special Ribbed Floors Type D, Studio Nervi, Rome, 1963. (John Stigter Archive.)

possible to find precedents for the rosette described in B, solution D was a new pattern – an *ad hoc* novel addition into Nervi's vocabulary – highlighting the tireless experimental instinct of the Italian master.

Surprisingly, the constructed floor slab system was a compromise of solutions B and D, where the ribs formed a two-way slab – same as D – but following a simple curve – same as B – successively refined by Studio Nervi in the drawing *Disegno ST1* during July of 1964. That the final design came to this result was probably due to the difficulty of moulding the *ferro-cemento* panels on the S-like path.[40] (Fig.13)

In July 1964, Studio Nervi submitted the final series of preliminary structural drawings for the "special ribbed floor"; the full set illustrated in detail the famous "*Nervi System*" for the off-site production of the *ferro-cemento* diamond-like permanent formworks. The standardized procedure to execute the *ferro-cemento* panels contemplated four phases: first, a *Master Mould* in brick had to be built on the ground to reproduce a whole radial section of the exact dimensions of the ribbed ceiling but turned over; the second phase, on the *Master Mould*, had to be cast a secondary layer to form a *secondary movable*

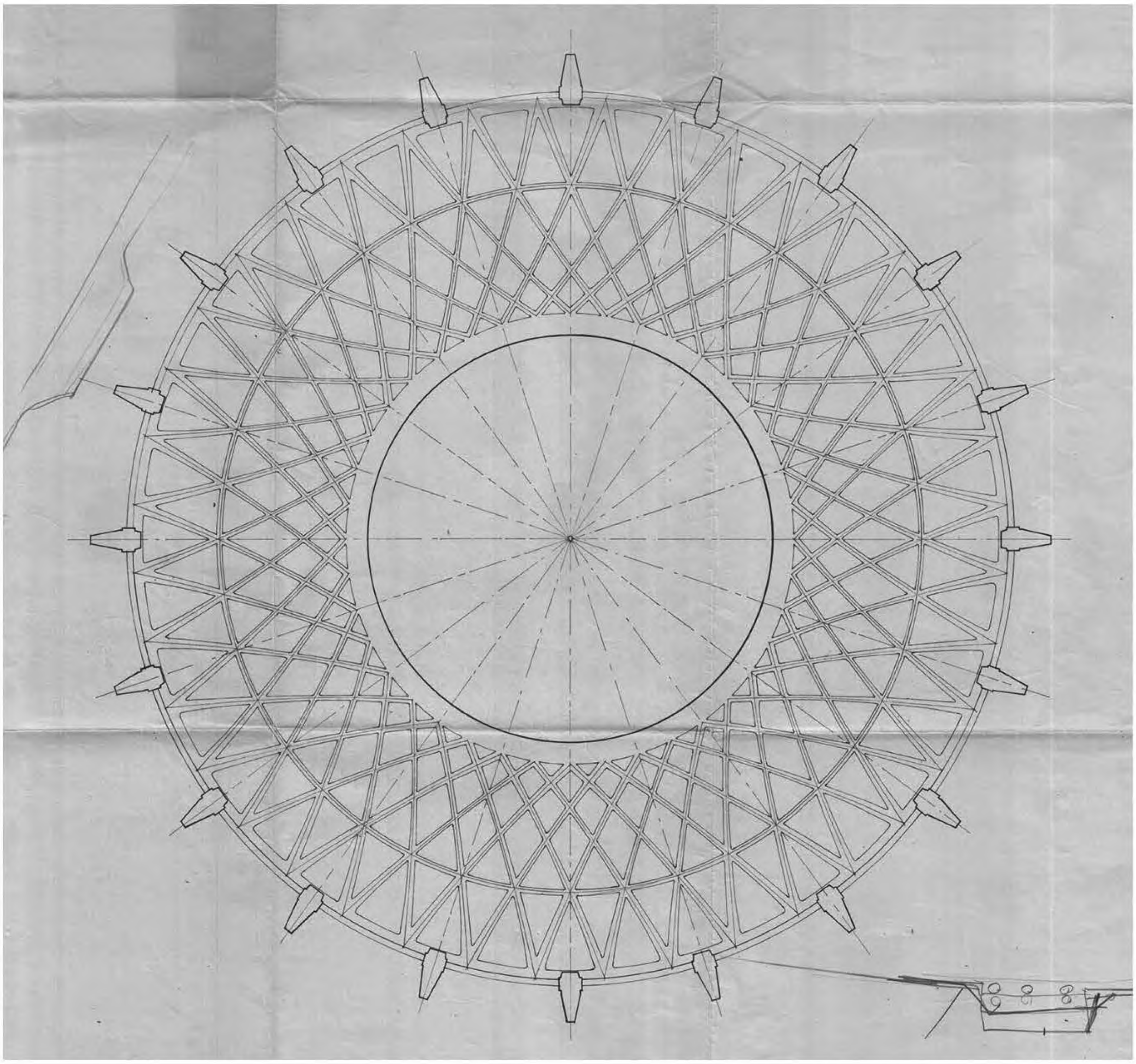

Figure 13. ST1 - Special Ribbed Floor Plan (detail), Studio Nervi, Rome, 1964. (John Stigter Archive.)

mould; third phase, the *secondary mould* – cast from the master – had to be overturned to shape on top of it (fourth phase) the *ferro-cemento panels*. (Fig. 14)

The *Nervi System* was shown to Seidler, in November 1963 during the first meetings, through photographs and drawings of the Cartiera Burgo and the Leverone Field House at the Dartmouth College (US 1961-65) where this technique was extensively used. The latter had an English annotated drawing that clearly illustrated the step-by-step fabrication of the preformed pads. The adoption of an alternative movable formwork in fibreglass was also proposed by Seidler to Nervi. However, it was immediately pointed out that fractioning the slab in several castings would have meant incorporating radial ribs, acting as crosspieces, to structurally connect two adjacent pours; the only way to avoid any joints was then to cover the whole floor area with a continuous formwork to pour the slab as a seamless solution. Covering the whole area of the slab with a formwork in fibreglass was judged "unacceptable" by Seidler as it was considered too expensive, so the *Nervi System* despite its artisanal nature was selected to erect the continuous sweep rib floor.

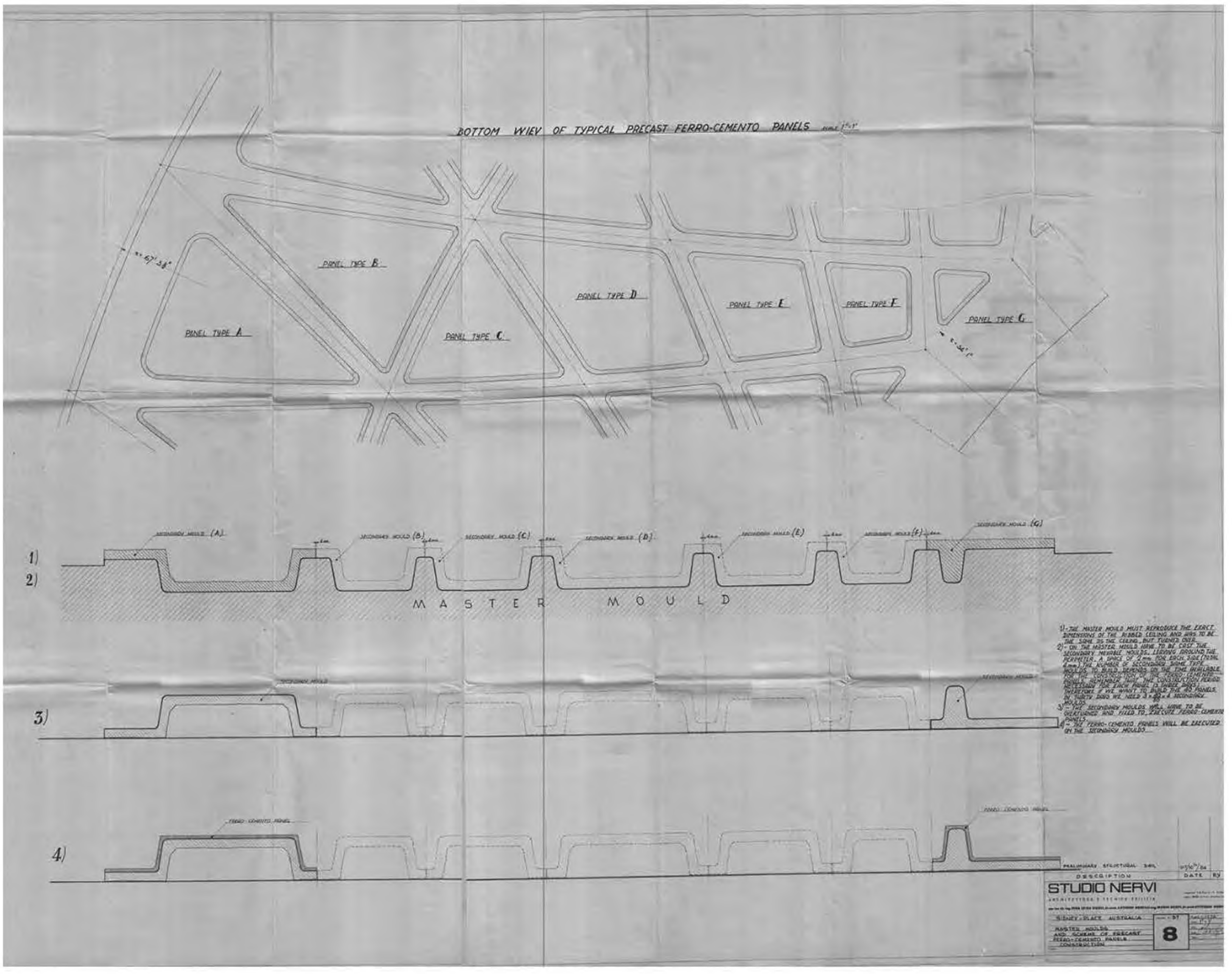

Figure 14. ST8 - Master moulds and scheme of precast ferro-cemento panels' construction, Studio Nervi, Rome, 1964. (John Stigter Archive.)

The artisanal nature of the *ferro-cemento* required high labour skills and on-site experience, so despite all the instructions given to C&C's method engineer in Rome in October 1964, producing the pads was not a straightforward process. The difficulty in achieving the designed radius for the internal edge forced C&C's engineers to vary the reinforcement layout of the slab. Another adjustment due to some on-site and design errors, likely because of some discrepancies between the imperial system used in Australia and the metric one adopted in Italy, led to increasing the depth of the annular beam inside the false floor. A modification that did not affect the final look of the slab and, in the end, the two floors were masterfully executed faithfully reproducing Nervi's design. (Fig. 15)

Today's lobby ceiling is a ribbed plate visually disconnected from the exterior collonade; a visual trick that proffers to Nervi's ceiling its elusive structural liberty and grace. Nervi's structural language in which the static truth is not simply evoked but is plastically described by a physical modelling of the internal tensions is here once again declared. Although, in the case of Australia Square these internal tensions are simply suggested since the slab does not follow a rigorous isostatic pattern, the nature of the structural element – precisely a waffle slab – is pedagogically expressed and artisically refined as typical in all of Nervi's building.[41]

Finally, thanks to Nervi's remarkable construction devices, the structural rosette and the tapering structural exterior skeleton, which together dramatize the bottom-up perspective of the tower, became the architectural and iconographic synthesis of Australia Square.

Figure 15. Top left: rendered bricks master mould; Top right: preparation of secondary mould; Bottom left: ferro-cemento panel; Bottom right: ferro-cemento panels; Sydney, 1965. (Lend Lease Historical Archive.)

Seidler's architectural vision and Nervi's static and constructional know-how combined to create a paramount structural architecture that was equal to the already world-famous Grattacielo Pirelli and the Torre Velasca. The affinity between Australia Square and these Milanese towers is sculpturally demonstrated by the static concept and geometrical complexity featuring the exterior colonnade of Australia Square and so too by the scenographic pillars of the two Milanese towers. Ten years after Seidler's visit to the Pirelli, as a serendipitous fact, it was Ponti who was to visit Seidler's construction site in Sydney – an episode that we might read as a virtual connection between the Italian skyscraper and Australia Square. (Fig. 16)

Conclusion

Thanks to Seidler's international vision and determination, the architectural image of the circular tower brought to Australia a masterful example of modern structural architecture, offering a new model to the theme of tall buildings. However, this was only possible due to Nervi's artistic structural design and ingenious construction system.

Nervi's artistic structural design for tall buildings strongly influenced the newborn Italian skyscraper. Structurally informed, the ground-breaking architectural result of these towers gave life to that significant, though short, parabola of the Italian-style skyscraper. Figuratively and technologically in contrast with the most affirmed American skyscraper, the Italian style was the only available and remarkable alternative for Australia in its quest for a more suitable model. It is, therefore, possible to affirm that Australia Square not only belongs to the masterful Seidler's *oeuvre*, but is a fundamental piece of that little, but historically significant, firmament of Italian structural skyscrapers built between

Figure 16. Gio Ponti visiting Australia Square, in the background the Nervi Ceiling, Sydney, 1965. (Photo: Harry Seidler (?). MAXXI Museo nazionale delle arti del XXI secolo, Rome. MAXXI Architettura Collection. Pier Luigi Nervi Archive.)

the 50s and 70s. Indeed, the structural expression, the extensive use of RC and Nervi's vital involvement all combined to give Australia Square a strong Italian connotation that clearly takes the tower's significance beyond national interest.

Furthermore, looking at the Australian context, Nervi's contribution was essential to Seidler to fashion the iconic presence of the tower. In particular, the paper has shown that it was Nervi who suggested and gave the solution for the implementation of the two structural hallmarks of the tower: the exterior collonade and the ribbed floors. Indeed, before Australia Square, there were only few published details and a small technical discussion of formwork design. In September 1966, Nervi's column casings and the ribbed slab were extensively presented and fully illustrated in *Constructional Review*[42] as "novel techniques" in the flourishing Australian concrete building industry. Fundamentally, the Nervi system and the precast column casings introduced in Australia the concept of 'permanent formwork'. In particular, in 1964, Rinaldo Fabbro[43], who participated at the construction of Nervi's ribbed slab at Australia Square, established the Fabbrostone Pty Ltd, a construction company that based its business core on the production of precast permanent concrete formworks. In Sydney alone, this construction solution was adopted in 18 tall buildings, demonstrating the importance of Nervi's contribution and how the whole Australian concrete industry benefitted from it.

Despite all the technical articles and the wide adoption of the tecniques developed for Australia Square, the novel approach of integrating structural design and architectural expression went largely unheeded in Australia. Indeed, in the design and construction of the Australian skyscrapers that followed Australia Square, the architectural look was characterized by a modular grid pattern aesthetic of load-bearing precast concrete panels with not hint of that structural spirit which strongly animated the design and construction of Australia Square. The structural expressionism needed a synergetic collaboration between architects and engineers, like the one shown by Seidler and Nervi, that was difficult, apparrentely impossible, to emulate in Australia.

On the 14th of December 2012, Australia Square was officially heritage listed by the NSW government to have "established new principles in design and construction through its distinctive efficient cylindrical form, the use of reinforced concrete shaped sculpturally for structural efficiency…".[44] In this respect, given the already proven cultural and technical values of the tower, which has been here extended to a broader international dimension, it is to be hoped that Australia Square will soon be listed in the Australia's National Heritage List, finally recognising the tower as having national significance.

Acknowledgements

The author would like to show his gratitude to Pauline Rose Seidler for her support and kind availability from the earliest start, and throughout the investigation. The author would also like to thank John Stigter for having made available a relevant part of the graphic material here for the first time published.

The Author

Paolo Stracchi is a Lecturer in Architectural Technology at the Sydney School of Architecture, Design and Planning at the Sydney University where he is researching on historical construction methods and speculative developments upon the same. He attained a PhD in Architecture and Construction from the University of Rome Tor Vergata.

Contact details

paolo.stracchi@sydney.edu.au
School of Architecture, Design & Planning, The University of Sydney.
Wilkinson Building, NSW, 2006, Australia.

Notes and References

1. J. Stigter, 'Two fifty-storey buildings in Australia built with lightweight concrete', conference paper presented at the *International Congress on Lightweight Concrete*. London, 1968.
2. For the history and general overview of Australia Square project, see:
   P. Drew & M. Dupain, *Harry Seidler: Australia Square, MLC Centre*. Sydney: Horwitz Grahame Books, 1980.
   K. Frampton, *Harry Seidler: Four Decades of Architecture*. London; New York: Thames and Hudson, 1992.
   J. Stigter, '*Construction and Structural Features of 50 – storey, 600 feet high office tower*', *Sydney, Constructional Review*, Vol.39, no.9, 1963, pp. 10-17.
3. PLN MAXXI, P60/6, 'Australia Square Project, Architect's Report'.
4. G. Capurso,'Il grattacielo "Italian Style". La costruzione dell'edificio alto negli anni cinquanta e sessanta' [The Italian-Style Skyscraper. The Construction of High-Rise Buildings in the Fifties and

Sixties] in T. Iori & S. Poretti (Ed.), *SIXXI Storia dell'ingegneria strutturale italiana, Vol. 1*. Rome: Gangemi Editore, 2014. pp. 90-103.

5. PLN MAXXI, P60/6, 'Australia Square Project, Structural Engineer's Report'.
6. The report also stated that the cost for a steel structure would have been 30 to 40 per cent more expensive of a building made with reinforced concrete.
7. S. Steward & J. Taylor, 'The Building and its Making' in J. Taylor (Ed.), *Tall Buildings: Australian Business Going Up, 1945–1970*. Sydney: Craftsman House, 2001. p. 128.
8. PLN MAXXI, P60/6, … (see Note 3)
9. State Library of New South Wales (SLNSW), Harry Seidler, Subject and Correspondence Files, 1955-1972, Call No.: MLMSS 7078/2, 'World Trip 1955-1956'
10. P. Blake, *Architecture for the New World: The work of Harry Seidler*, GIVE CITY/TOWN: Hortwitz, 1973. pp. 10.
11. *Constructional Review*, Vol.39, 1966. p. 7.
12. P. Tonkin, 'State Office Block, Sydney' in J. Taylor (Ed.) … (see Note 6), pp. 200-07.
13. J. Taylor, 'Australian Architecture, since 1960' Sydney: Law Book, 1986. p. 18
14. Tonkin, 'State Office Block, Sydney' … (see Note 6), pp. 200-07.
15. H. Seidler, *The Link, Journal of the Lend Lease Group of Companies*, Vol.20 (February–March), 1964.
16. PLN MAXXI, P60/6, … (see Note 3)
17. ibid
18. PLN MAXXI, P60/1 2, 'Letter from R. Robinson to PLN, 30th July 1962'.
19. PLN MAXXI, P60/1 2, 'Letter from PLN to R. Robinson, 30th October 1962'.
20. SLNSW, Harry Seidler, Subject and Correspondence Files, 1955-1972, Call No.: MLMSS 7078/2, 'Letter from Seidler to HAS, Rome, 31 October 1963'.
21. ibid
22. G. Capurso,'Il grattacielo "Italian Style"... (see Note 4)
23. SLNSW, Harry Seidler, Subject and Correspondence Files… (see Note 20)
24. PLN MAXXI, P60/1 2, '2nd Meeting – Held at the Studio Nervi, on October 30th,1963'.
25. Unless otherwise indicated, all the information regarding the design development described in this paragraph is taken from the minutes taken during the four meetings held at the Studio Nervi in Rome, attended by H. Seidler, J. Stigter, Pier Luigi Nervi and Studio Nervi's staff. See PLN MAXXI, P60/1 2: '1st Meeting – Held at the Studio Nervi, on October 25th, 1963'; '2nd Meeting – Held at the Studio Nervi, on October 30th,1963'; '3th Meeting – Held at the Studio Nervi, on October 30th,1963'; '4th Meeting – Held at the Studio Nervi, on November 14th, 1963'.
26. SLNSW, Harry Seidler, Subject and Correspondence Files… (see Note 20)
27. PLN MAXXI, P60/1 2, 'Letter from C&C to Nervi, February 25, 1964'.
28. Lend Lease asked Nervi twice to come to Sydney to discuss the project, but Nervi refused because of the long flight.
29. Nervi, as he stated during the meetings, October 1963, didn't have any experience in using lightweight concrete.
30. PLN MAXXI, P60/1 2, 'Letter from Seidler to Nervi, 31 March 1964'.
31. PLN MAXXI, P60/1 2, 'Letter from Seidler to Nervi, 9 April 1964'.
32. SLNSW, H. Seidler, 'Personal History of 50 Years of Architecture', speech by Harry Seidler for the series Library Societies/Friends Talks, Call No.: MLOH T 101.
33. The information regarding the design development described in this paragraph is taken from the minutes of the four meetings held at the Studio Nervi in Rome (see Note 22) and from the minutes of the two meetings held at the Studio Nervi in Rome attended by Adam Cull (C&C) and Studio Nervi's staff; see, PLN. MAXXI, P60/1 2: '1st Meeting – Held at the Studio Nervi, on June 22nd, 1964'; '2nd Meeting – Held at the Studio Nervi, on October 23th, 1964'.

34. PLN MAXXI, P60/1 2, 'Letter from Seidler to Nervi, January 15, 1964'.
35. PLN MAXXI, P60/6, … (see Note 3)
36. PLN MAXXI, P60/1 2, 'Letter from Stigter to Nervi, July 7, 1966'.
37. R. Gargiani & A. Bologna, *The Rhetoric of Pier Luigi Nervi: Concrete and Ferrocement Forms*. Lausanne, Switzerland: EPFL Press, 2016. p. 399.
38. SLNSW, Harry Seidler, Subject and Correspondence Files, 1955-1972, Call No.: MLMSS 7078/2, 'Letter from Seidler to Olsen, Sydney, December 1963'.
39. PLN MAXXI, P60/1 2, 'Letter from Nervi to Hammond, March 11, 1964'
40. The solution eventually adopted was probably drafted in Sketch 9 - Type A; unfortunately, during the research investigation conducted by the author, it was not possible, in any of the consulted archives, to locate SK 9 - Type A; however, this drawing is mentioned by Seidler as the one to be used as a base to study the appearance of the slab, so it is reasonable to believe that Type A had the same look of Disegno ST1.
41. T. Iori & S. Poretti, 'Il linguaggio delle strutture' [The Language of Structures.] in T. Iori & S. Poretti (Eds), *SIXXI Storia dell'ingegneria strutturale italiana, Vol. 2*. Roma: Gangemi Editore, 2015. pp. 9-19.
42. Monthly periodical published by Cement and Concrete Association of Australia.
43. In 1960, Rinaldo Fabbro, an Italian-born architect, introduced in Australia the ferro-cement type of construction erecting a waffle slab with thin precast formworks at the R.S.L. Club Dee Why, NSW.
44. https://environment.nsw.gov.au/heritageapp/ViewHeritageItemDetails.aspx?ID=2423763 (Consulted on 27th August 2018).