The Architecture of Walter Burley Griffin: Concrete Applications

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INTRODUCTION

Concrete technology always attracted Walter Burley Griffin (1876-1937), a fascination that began in his university student days and continued throughout his career in Chicago, 1899-1915, Australia, 1913-1935, and India, 1935-1937. He had a compelling ambition to create a new architecture relevant to modern communities. Building with concrete he believed would aid that goal:

> to utilise scientifically and directly to the utmost the unexplored possibilities of this newest, cheapest, most durable, least limited, most plastic and variable single medium for purity and proportion, harmonies of colour and varieties of texture, unity in scale, appropriate immensities in spans and masses . . .
>
> (Griffin 1913a, p. 68)

A study of his first major architectural work in Australia, the Roman Catholic Newman College at the University of Melbourne, July 1915 to March 1918, has revealed that new French engineering inspired this building's unusual reinforced concrete ribbed dome over a combined dining and meeting hall (Turnbull 2004, pp. 194-200) **(Figs. 1 to 6)**. Also during the college construction period Griffin patented in Melbourne a unique system for constructing walls with interlocking concrete tile blocks, which he called *Knitlock* (Turnbull & Navaretti 1998, p. 151) **(Figs. 7-14)**. Systems for reinforced concrete and reinforced brickwork patented by a Paris engineer, Rémy-Jean-Paul Cottançin (1865-1928) (Dumont 1996, pp. 6-13), informed in part Griffin's advances in these dome and concrete block construction technologies.

A controversial issue is whether Griffin achieved his aesthetic and technical goals working rationally from first principles (Weirick 1995, p. 113), or whether he worked intuitively from insightful analysis of many precedents. The latter is more likely. In his time dependence upon a thorough knowledge of precedents characterized university training in architectural design method, which was being challenged in the design studio however by the precepts of scientific enquiry and pure reasoning.

An architectural analysis of Newman College demonstrates that Griffin was an eclectic architect, that is, he selected compositional pattern ideas from any system that contributed to the design solution for a modern university college (Turnbull 2004, pp. 135-49). The appropriate combination in the abstract of such chosen ideas characterized authentic eclecticism (Collins 1965, pp. 117-27), as distinct from stylistic revival and the mere copying of ornamental details. Griffin's new designs came about from the layering of known patterns. His choice of ideal underlying compositional patterns, adapted from sources Ancient and Modern, Oriental and Occidental, were amalgamated into a new pattern that retained some programmatic and typological characteristics of his original sources. This was a very different procedure from inventing a new pattern from first principles. In this paper certain patterns created in the modern era are discussed, which were relevant sources for Griffin's new constructions in reinforced concrete.

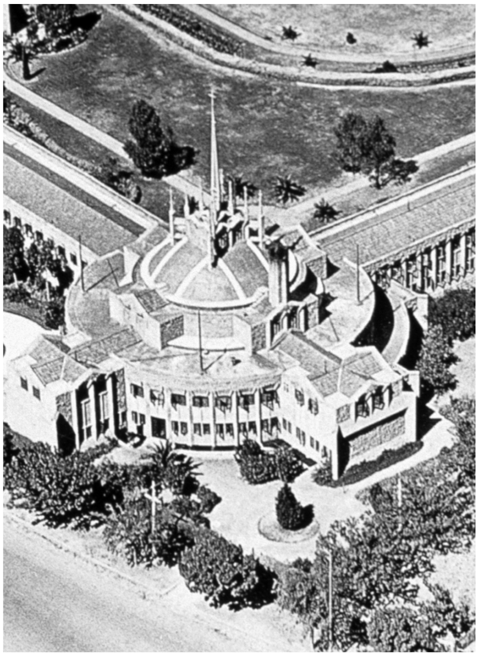

Figure 1. Aerial view of the dining hall rotunda, Newman College,
University of Melbourne, 1915-8 (Turnbull 2004, p. 278)

In addition to Cottançin's engineering forms, compositional patterns found in the late eighteenth century and early nineteenth century buildings of the American architect Thomas Jefferson (1743-1826) were particularly useful to Griffin's personal style. Indeed certain ideas and patterns from Jefferson's dwellings appeared in Griffin's first three *Knitlock* houses in Melbourne, 1919-20 **(Figs. 8-9)**. Jefferson's dwellings were surely models for expressing democratic life, and Griffin evidently wished to express democracy in his own work. Griffin's wife and architectural partner, Marion Mahony Griffin (1871-1961), observed in the very first sentence of her unpublished memoirs (Mahony Griffin 1940-9, Section 1, p. 1) that Jefferson had been the major instrument in establishing institutions of democracy in the modern era. In a number of later sections she described Walter as "Jefferson's successor".

Furthermore, Griffin and Mahony had been raised since childhood in church communities in which transcendentalism and intuition were spiritually of the highest authority. From the 1830s Immanuel Kant's *Critique of Pure Reason* (1781) had a profound affect upon the theology of the American Calvinist churches, the Congregationalists (Griffin) and the Unitarians (Mahony). In addition, Griffin was a Platonist, holding to the view that an original architectural pattern was the Idea that ethereally pre-existed. The Idea was manifested in forms of earthly Being (Jowett 1875, pp. li-iv). In Griffin's architectural philosophy architectural types were realized. In working with a type many varied shapes could be actually generated from just one abstract geometric pattern idea (Emerson 1856, pp. 41-87).

Figure 2. Aerial view of the church of Saint-Jean-Baptiste de Montmartre, 1894-1904 (Turnbull 2004, p. 278)

WALTER BURLEY GRIFFIN'S EDUCATION

From 1895 to 1899 Griffin undertook his tertiary education in the architecture department housed within Engineering Hall at the University of Illinois, where leading theoretical advances in reinforced concrete design were based upon laboratory testing. The civil engineer Professor Arthur Newell Talbot (1857-1942) conducted widely published reinforced concrete design research, which burgeoned after the establishment in 1903 of the university's Engineering Experiment Station. So as to increase his expertise after graduation Griffin needed only to turn to the bulletins on experiments with reinforced concrete construction being constantly issued through his *alma mater* (Marsh & Dunn 1906, pp. 254-64 & appendices). However, his university training obviously enabled the grasp of other developments in reinforced concrete technology, especially in France.

As a student Griffin was also able to watch the progress of new reinforced concrete construction on the University of Illinois campus realized in works by the Professor of Architecture, Nathan Clifford Ricker (1843-1922) (Laing 1973). The new university library building, 1896-7, for example, had walls of stonework, but it had a reinforced concrete floor and roof, a combination chosen for its fireproof attributes (Koeper 1968, pp. 282-3). In 1913 Griffin used a reinforced concrete fabric with a stonework veneer finish for the Stinson Memorial Library in Anna, Illinois (Maldre & Kruty 1996, p. 173). A concrete fabric with a stone veneer was also the technique for the Newman College building, 1915-8, but timber trusses with terracotta tile gable roofs were constructed to two residential wings and two spur pavilions radiating from the central reinforced concrete ribbed dome **(Fig 1)**.

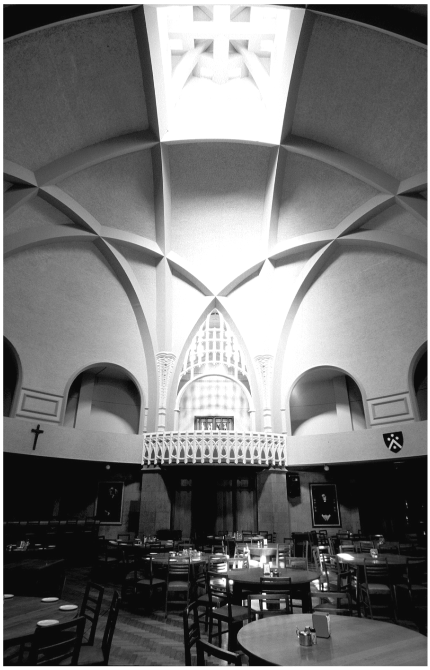

Figure 3. Interior view of the dining hall rotunda, Newman College, University of Melbourne, 1915-8 (Turnbull 2004, p. 178)

In his teaching Ricker imparted to his students an admiration for the nature of structure and materials. He set up workbenches so that students in class could construct models of various structural systems in a range of materials (Woods 1999, pp. 71-2). This model making was preparation for design on the drawing board. In that regard Ricker introduced the new concept and technique of graphic statics to the architecture department at the University of Illinois, preceded only by Yale and Michigan Universities. The forces at work in any particular constructional system were determined graphically. Ricker's textbook on this subject (Ricker 1897) emphasized the analysis and calculation of timber trusses, a type often utilized by Griffin, in the college gable roofs, for example **(Fig. 1)**. (Griffin's own signed copy of this textbook is held in the National Library of Australia, Canberra).

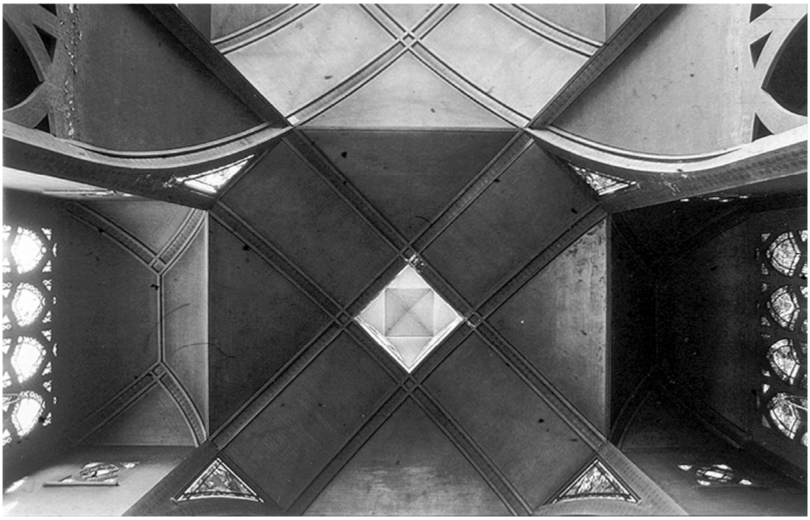

Figure 4. Interior view of a nave bay of the church of Saint-Jean-Baptiste de Montmartre, 1894-1904 (Dumont 1996, p. 49)

Nevertheless Griffin preferred reinforced concrete techniques. As quoted at the beginning of this article, Griffin proclaimed that reinforced concrete was the newest constructional medium that was the least expensive, yet the most plastic, durable and variable. During all of his practice years Griffin confidently acquired further insights and information into reinforced concrete structures. The design of the reinforced concrete fabric for Newman College, including the ribbed dome, appears to have been his own work without the formal aid of an engineering consultant.

In addition to graphic statics Ricker availed Griffin of the discipline of *dessin* (Moore 1977, pp. 145-77). In the architectural design studio classes during the final two years of the four-year course in architecture Ricker relied upon the design methods then prevalent at the Paris Ecole des Beaux-Arts (Griffin 1913b, p. 172). These methods included the trigonometry of *dessin*, in which a building was conceived in terms of horizontal and vertical planes meeting in an additive series of points or lines. In *dessin* the planes could be the envelopes of rectilinear, cylindrical or domical solids, as was the case with the Newman College design (Fig. 1).

Modular dimensioning was essential to *dessin*. The module for Newman College was 7 feet (Griffin 1915, p. 26), apparently derived by Griffin from the first house constructed at Thomas Jefferson's University of Virginia, 1817 (Turnbull 2004, pp. 155-6). Griffin in practice preferred *dessin* rather than freestyle picturesque *composition* prevalent amongst his Chicago peers, as exemplified from 1893 to 1915 in the works of Frank Lloyd Wright. (Griffin in fact was in charge of Wright's Oak Park Studio projects, 1901-6). Griffin's loyalty to *dessin* was opposite in effect to Wright's focus on the building design conceived as a series of picturesque views that flowed together. Wright eschewed any reliance upon Cartesian grids, and described the role of building construction in design as "ephemeral" (Price 1933, p. 4).

The Cartesian grid fundamental to *dessin* formed an underlying structure in Griffin's works that imparted a static rhythmic quality. The accompanying expression of gravity and massiveness in these buildings derived from Griffin's taste for architectonics. Significantly the first book in German that Professor Ricker translated for his students' use was on the subject of architectonics, that is, the aesthetics peculiar to construction (Redtenbacher 1883/Ricker 1884). Either text offered a kind of pattern-book of various ways to detail lintel or arch openings in masonry constructions of walls vaults and domes.

Figure 5. View of stonework veneer details, Newman College, 1915-8

The trace in the mind's eye of the passage of the gravitational forces through the combined pieces of a particular constructional type offered the beholder a peculiar aesthetic delight, its "architectonic". Griffin in practice exercised architectonic expression. For example, the aesthetically massive structural bay in the cloisters at Newman College consisted of a shallow segmental arch between a pair of rotated square-section piers at 7 feet centres, supported by a battered base, and supporting a deep-beam parapet **(Fig. 5)**. Instead of a central projecting keystone the frame of the articulated voussoirs in each segmental arch was punctuated with a pair of lozenge-shaped projecting stones. Apparently Griffin had combined these particular structural motifs having adapted them from various bridge and barrage precedents. The cloister and the roof promenade above give staircase access to the student-sets in each of the two residential wings **(Fig. 1)**. The repetition of these bays symbolically formed a new manifestation of the living-bridge type (Turnbull 2004, pp. 244-7).

NEWMAN COLLEGE, 1915-1918

Construction

The section through the hemispherical reinforced concrete ribbed dome over the combined dining and meeting hall at Newman College reveals yet another unique solution **(Fig. 6)**. Two pairs of main ribs supported upon eight massive piers intersect to form the square base to a lantern. A plan of the hall shows the crossing square patterns of intermediate ribs intersecting with the pairs of main ribs, together with a separate radiating pattern of reinforced concrete ribs within the lantern space.

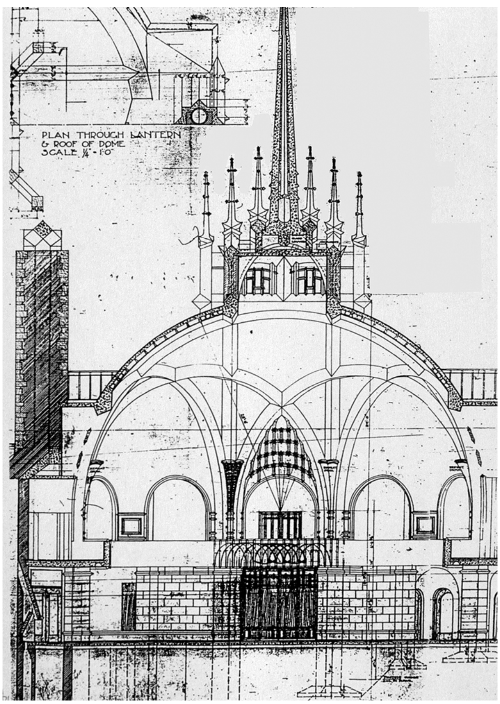

Figure 6. Cross-section drawing through the dome, Newman College, 1915-8 (Turnbull 2004, p. 279)

The lantern in turn supports a perforated fleche element in the centre of the composition (Fig. 6). Intermediate dome ribs spring from every second pier. Four groups of three pinnacles each were aligned on the diagonals through the lantern, making twelve pinnacles in all. The fleche and the twelve pinnacles might remind the viewer of Christ and His twelve Apostles. The vaults supported between the ribs were conceived as two skins of reinforced concrete with a cavity between. In reality the cavity was interspersed with hollow cement blocks and filled with cement grouting.

Planning

For the design of the L-shaped block built at Newman College Griffin adapted in part the functional program and the dome type from the architecture of Thomas Jefferson (Turnbull 2004, pp. 151-5). It can be discerned that in an earlier Newman College plan, August 1915, Griffin drew upon the underlying compositional pattern of Jefferson's first 1772 sketch-plan for his house, *Monticello* (the endearing little hill).

In this earlier College plan Griffin had two L-shaped blocks symmetrically disposed about a central chapel with a domed rotunda to the inside corner of each L-shape block. Only the block with the domed dining hall rotunda was ever built to Griffin's design **(Fig. 1)**, while the other block with a proposed domed library rotunda was never built. Jefferson's first house plan had two L-shaped blocks symmetrically disposed about the central cross-axial house, with a domed rotunda to the inside corner of each L-shape block. Jefferson was to omit these two original domed rotundas to the inside corners of his two L-shapes in his later 1793 house plan, but he retained the idea of roof walkways from the house out to two end-pavilion office buildings. Griffin adapted that circulation idea with the building of cloisters and overhead roof promenades at Newman College **(Fig. 5)**. One of Jefferson's two office buildings, the South Pavilion, was built initially in 1770 as the first dwelling on the site. Here Jefferson wrote key documents for American independence and democratic rights. Thus in adapting Jefferson's functions and forms Griffin invested his College design in Melbourne with his interpretation of architectural symbols of democracy.

The laminated timber dome over Jefferson's dining room at *Monticello* was a generating idea for Griffin and his dome over the dining and meeting hall at Newman College. The library dome at the centre of Jefferson's design for the University of Virginia also provided a precedent for Griffin and his dome over the proposed library at Newman College. In addition Jefferson's university library building form referred to the Pantheon of Ancient Rome that was indeed constructed in concrete. Thus Griffin's proposed college library dome and its dining hall dome pair were two more manifestations of the concrete dome type first established in ancient times.

Furthermore, each wing of Jefferson's university building complex had a colonnade with a roof walkway above giving access to each house, and to the library with a gymnasium beneath it. The role of the cloisters and roof promenades in Griffin's college building was functionally and symbolically similar. Pavilion VII was the first dwelling built on this University of Virginia site, the only one to have an arcade as its contribution to the sheltered colonnade up to the library. As already noted the module for this house and its arcade was 7 feet, the same module that Griffin employed in the Newman College design.

Cottançin's constructional systems

As previously noted Griffin always remained a student of reinforced concrete design developments. The works of Paul Cottançin, a Paris engineer, who patented in 1889 new reinforced concrete building techniques, also a reinforced brickwork system, apparently impressed Griffin. Cottançin was the engineer for the architect Anatole de Baudot (1834-1915), Church of Saint-Jean-Baptiste de Montmartre, Paris, 1894-1904 (Figs. 2 & 4) (Dumont 1996, pp. 46-9). Cottançin provided the engineering design for the reinforced concrete columns, roof ribs and vaulting for this church, and also for the reinforced cavity brickwork for the walls of the church.

Clearly Griffin adapted Cottançin's system for constructing ribbed reinforced concrete vaults for the dining hall dome at Newman College **(Figs. 1-4)**. Aerial views show that the same type of major rib pairs cross to form the square base to a lantern in both the Melbourne college and the Montmartre church. However Griffin did not replicate de Baudot and Cottançin's church details. Griffin's dome is a single hemispherical shape aligned to the cardinal directions and the orientation of the L-shaped block **(Figs. 1 and 3)**. In contrast the church has three shallow vaulted bays with the pairs of ribs crossing on the diagonals to form the three lanterns **(Figs. 2 and 4)**. The comparative interior views of firstly the dining hall domed ceiling and its square lantern and secondly one bay of the church vaulted ceiling and its square lantern demonstrate a contrast in architectural quality due to the different orientations of the main ribs **(Figs. 3 and 4)**. Griffin's dome appears foursquare and somewhat Baroque, while de Baudot's vault is reminiscent of the emphasis on rib diagonals seen in the French Gothic.

There were two likely sources for Griffin on Cottançin's constructional systems. One source was in two articles in Griffin's favourite magazine *Architectural Record* (Price 1933, p. 3). In these two articles de Baudot's church design and Cottançin's reinforced concrete and reinforced brickwork construction were described. The second source was in a textbook on 50 patent systems of reinforced concrete construction. This book was reviewed, and highly recommended, in *Architectural Record*.

The French-Swiss architectural critic, Jean Schopfer (1868-1931) wrote the two articles on de Baudot's church and Cottançin's systems of *ciment armé* and *brique armée* (1902, pp. 271-8 & 375-91), that is, reinforced concrete and reinforced cavity brickwork respectively. The textbook source was English (Marsh & Dunn 1906), originally written in 1904 by Charles Marsh. Only two of the 50 systems in this textbook enabled dome shapes to be formed. Cottançin's system rivalled that of the French Monier system.

Various aspects of Cottançin's system of *ciment armé* were covered in different subject sections of Marsh & Dunn. The exact patterns of rib placement and the double skin vaulting and cavity that

Griffin used in the Newman College dome **(Fig. 6)** can be recognized in an early chapter that has a written description of Cottançin's dome roofing system (pp. 42-8). Further, two key illustrations of de Baudot & Cottançin's Montmartre church appear in a later chapter devoted to examples of new structures erected in reinforced concrete (pp. 471-2).

The church columns and vault ribs have thin and attenuated rectilinear shapes **(Fig. 4)**. These members in section consisted mostly of a woven mesh of mild steel bars with the barest minimum covering of cement. Due to his university experience Griffin knew to bulk up the section of the ribs at Newman College and to use much less reinforcement **(Fig. 6)**. Griffin's rib sections have only three bars toward the bottom to resist tension forces. Where each rib is revealed it appears to have a half-square section given a 45º rotation. Each rib profile whether revealed outside **(Fig. 1)**, or inside **(Fig. 3)**, is presented as a rotated half square with a 90º arris. In reality the thickness of the double skins and the cavity of the dome vaulting is taken up with a hidden rectilinear block **(Fig. 6)**.

In the college design the square section idea for the concrete ribs was thematically linked to the form of the stone piers of the structural bays through the 45º rotation shared by both elements **(Figs. 5 & 6)**. In addition the 45º rotations are to be seen in the half-square triangular sections to all the timber railings planted onto the room and cupboard doors at Newman College. The pattern of the 45º rotations Griffin thus transposed from one material element to another, between concrete, stone and timber. A 45º rotation may have been a functionally better shape in one material than in the others. For Griffin the truth lay in the integrity of the pattern, not necessarily in the optimum shape in relation to the properties of the material. Thus in Griffin's personal architectural style a pattern that may have been the rational solution for an element in a particular material might be expressed in another material altogether. In the detailing of the Newman College building the underlying compositional pattern of 45º rotations was for Griffin a singular Platonic idea that had its being in multiple material manifestations. A pattern for him was the architectural idea of significance.

The description of Cottançin's dome roofing system in Marsh & Dunn stated that prefabrication and dry installation of the ribs and vaults was feasible, and was also a constructional advantage. The construction of the dining hall dome at Newman College began during April 1916. An item in June in the local Roman Catholic newspaper, *The Advocate*, commented that the dome was already complete, which suggests that some degree of prefabrication may have occurred in Melbourne during the dome roofing construction period of less than eight weeks.

GRIFFIN'S *KNITLOCK* PATENT, MELBOURNE, 1917

Knitlock was patented six years before the appearance of Frank Lloyd Wright's more widely known hollow concrete tile construction in the Alice Millard *La Miniatura* house, Pasadena, California, 1923 (Frampton 1995, pp 93-120. Frampton does not discuss Griffin's earlier *Knitlock*). In 1917, during the construction period for Newman College, Walter Burley Griffin, together with a builder

David Charles Jenkins, patented a concrete building block system marketed under the name of *Knitlock* **(Fig. 7)** (Turnbull & Navaretti 1995, p. 124). Mahony Griffin claimed in her memoirs (Section 3, p. 76) that Griffin had substantially worked out the *Knitlock* system in America before they settled in Australia in May 1914. Indeed Cottançin's reinforcing bar patterns were adapted in concrete work that Griffin constructed in America. The invention of *Knitlock* was in part an outcome of Griffin's admiration for Cottançin's construction systems, but there are no actual examples of *Knitlock* construction in Griffin's American works.

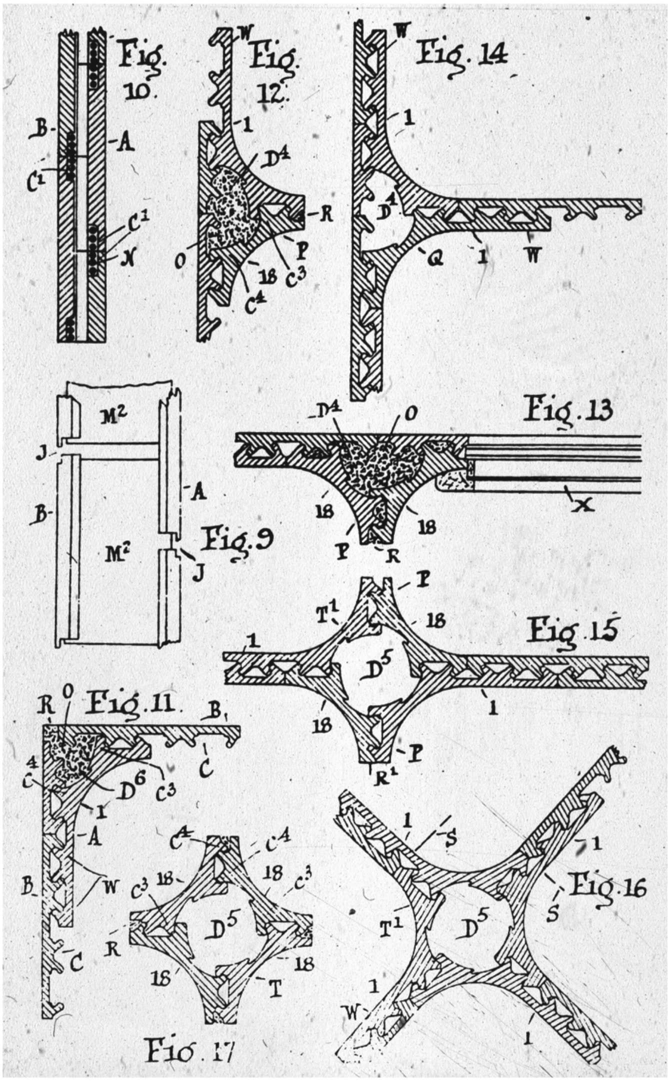

Figure 7. *Knitlock* patent drawings (Turnbull & Navaretti 1995, p. 124)

Figure 8. *Gumnuts*, Frankston, 1919

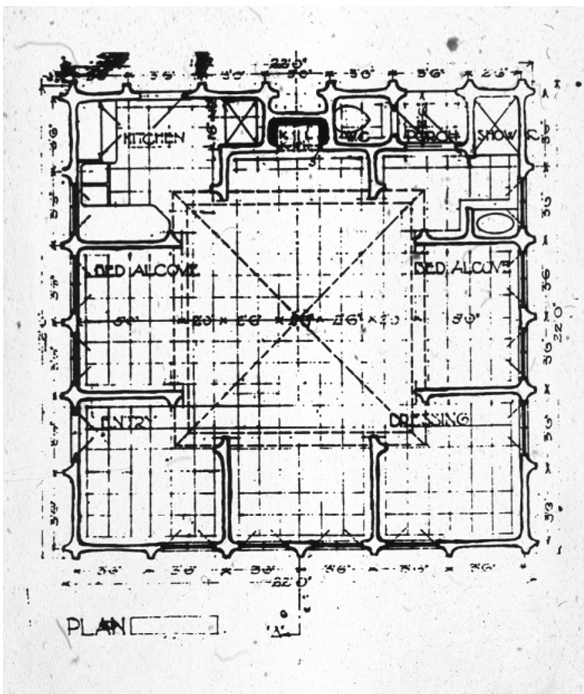

Figure 9. *Pholiota* working drawing plan, 1920 (Turnbull & Navaretti 1995, p. 126)

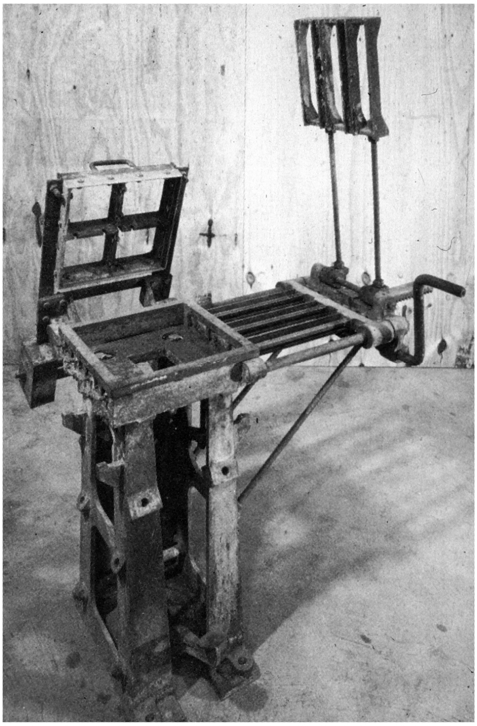

Figure 10. *Knitlock* concrete block machine (Weirick 1995, p. 104)

Griffin and Jenkins evidently shared an interest in the social and economic views of the American political activist, Henry George (1839-97), as well as being participants in the local building industry. They were both active in Melbourne's association of Henry George followers. At this time in Melbourne issues of *Progress*, the local newspaper of the Free Trade and Land Values League (followers of George) published notices of in-house public lectures by Griffin and by Jenkins. Significantly, during 1897, George formed the Thomas Jefferson Party (so as to contest the New York mayoral election). Mahony Griffin in her memoirs (1940-9) frequently extolled the virtues of equity in accord with George's views. Hence *Knitlock* construction was evidently a vision for enabling ordinary citizens to manufacture their own building materials on site and construct a simple concrete house **(Figs. 7 to 9)**.

Machines that would manufacture *Knitlock* blocks were essential to this enterprise, and were developed in conjunction with a Melbourne engineer, Malcolm Stewart Moore **(Fig. 10)** (Weirick 1995, p. 104). The *Knitlock* machine appears to be a similar shape, size and scale as a model-making workbench that Griffin would have used during Ricker's classes, as previously described. This machine would not look out of place in an engineering laboratory that tested reinforced concrete elements.

The Griffins and their friends began building with *Knitlock* during 1919 with the construction of a pair of holiday houses at Frankston on the southern outskirts of metropolitan Melbourne, of which only *Gumnuts* is extant **(Fig. 8)**. The construction soon followed in 1920 of the Griffins' own house, *Pholiota* (named after a fungus species found growing on their site) **(Fig. 9)**. (Griffin scholar, Simon Reeves, recently proved that 1920 was the starting year for *Pholiota*, not the usually cited 1922). The plans of these three houses were similar. Each house was 21 feet square, a *mandala* of nine 7 feet modular squares, with vertical columnar elements at 3 feet 6 inches centres. The square space in the centre of the plan was the living room that could be curtained off as desired from the perimeter of alcove spaces and the small utility rooms in each corner.

The spur walls of *Knitlock* construction that partitioned the square area of the house strengthened the thin double skin outer walls of 2 1/2 inches thickness **(Fig. 9).** Quarter-round "Vertebral Blocks" were stacked and reinforced to create a hollow column **(Figs. 7 to 9)**. Griffin's "vertebral block" term was rather like Cottançin's "spinal-stiffener" term, which the latter used to describe the bunching of reinforcing bars to form ribs, or to form cross-bracing elements within floor slabs or vaults (Marsh & Dunn 1906, p. 472). In Griffin's *Knitlock* system vertically stacked "Tessaral Blocks", 12 inches square, provided the fabric of the two panel skins between the column spines. There is an ideational link between the term "tessaral" and the Ecole des Beaux-Arts term "mosaique" for the design treatment of the wall. (Tessera are the small square ceramic pieces used in mosaics). The raised tongue projections and recessed grooves cast into each *Knitlock* concrete building block enabled them to be slid into each other for greater stiffness and strength, in what became a monolithic two-ply wall in the construction process **(Fig. 7)**. Reinforcing bars grouted with cement into the cavity between the two skins further strengthened the construction.

Initially Griffin's solution for waterproofing the wall was the application of bituminous paint to the surfaces of the concrete blocks that were to interlock within the cavity. These surface seals were often damaged in the act of sliding and locking the blocks together. As well the inlets and outlets for electric conduit and water pipes housed within the cavity could breach what were intended to be impervious layers. Water capillary action through the concrete blocks themselves exaggerated these flaws. Notwithstanding these inadequacies Griffin soon successfully changed the details for waterproofing *Knitlock* buildings (Weirick 1995, pp. 106-8).

Door and window jambs and the casement windows were of timber, with nail pivot hinges and metal latches devised by Griffin. The patterns for the timber sashes were usually varied from one *Knitlock* house to another using rectangular and square fenestration crossed with diagonal members. Griffin patented a concrete pan tile system for cladding the shallow hip roofs to the three earliest *Knitlock* houses in Melbourne **(Fig. 8)** (Turnbull & Navaretti 1995, p.125). In the case of *Pholiota* however the local municipal council successfully demanded that the roof be finished in conventional terracotta roof tiles.

THE *KNITLOCK* ARCHITECTONIC

A view often expressed (Johnson 1970, p. 189) is that Griffin quickly conceived and designed the *Knitlock* construction system during 1916 in answer to the problem of expedient and inexpensive building of dwellings for Canberra, the new Federal Capital of Australia, the city planning and building works for which were under the direction of Griffin, 1913-20. As already noted Mahony Griffin understood that her husband had earlier conceived the *Knitlock* construction system while still living in Chicago.

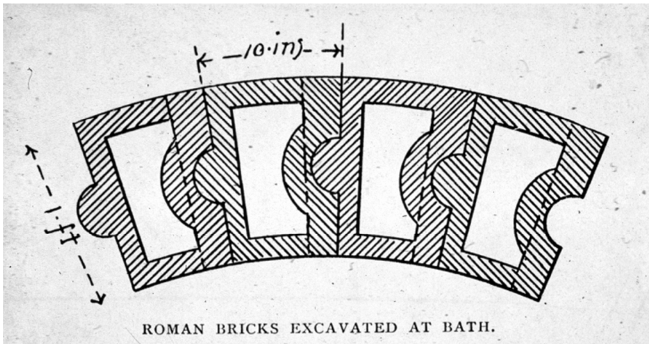

Figure 11. Ancient Roman terracotta block arch diagram published in Chicago, July 1899 (Turnbull 2004, p. 322)

An architectonic idea for *Knitlock* in fact appeared on page 134 in a Chicago magazine, *The Brickbuilder*, as early as July 1899 **(Fig. 11)**. Perhaps Griffin had seen and appreciated this diagram during his last year at the University of Illinois. Marion recalled in her memoirs that Walter was an avid reader, especially of magazines. She further related that Griffin had cultivated a talent for memorizing diagrams, indispensable for the recognition of plant species in landscape architecture design, and a most useful skill for an eclectic architect (Mahony Griffin 1940-9, Section 1, p. 335). This diagram may have been part of Griffin's phenomenal memory bank, later recalled as part of a solution to problems of block construction. Hollow terracotta voussoir blocks from ancient Roman times were depicted, from arches discovered at Bath, England **(Fig. 11)**. These arches are the same shape as the segmental arches at Newman College **(Fig. 5)**. Tongue and groove moldings on the sides of the Roman blocks allowed them to be slid into each other and lock together. Indeed Griffin also referred to *Knitlock* as "Segmental Architecture" (Griffin 1927, p. 13).

Another diagram that Griffin may have memorized during student days was a precedent for the architectonic of the overlapping pan roof tiles in the *Knitlock* system laid in a diamond pattern. Diagrams recorded patterns of sheet metal roof tiles **(Fig. 12)** in an 1881 book on medieval architecture written by Redtenbacher, the same author of the book on architectonics that Ricker translated for his students. The diagram labeled “Fig 241” on the left shows sheets laid in a diamond pattern with two upturned edges on top and two turned down at the bottom, the same detail as seen in Griffin’s square-diamond concrete pan tiles **(Fig. 8)**.

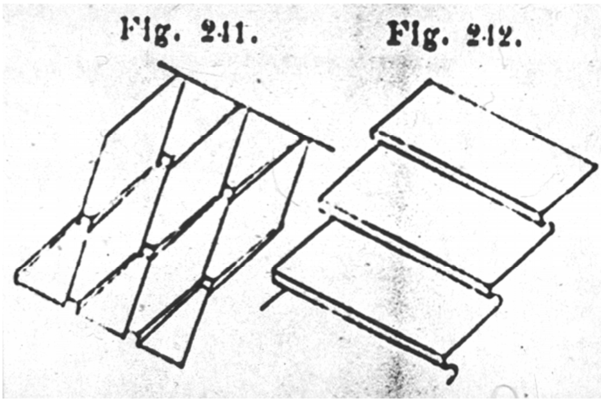

Figure 12. Medieval pan roof tiles diagrams (Redtenbacher 1881, Figs. 241-2)

Two houses that Griffin designed in America before settling in Australia are of particular interest in relation to precedence for his *Knitlock* construction system. Both of the Rule and Blythe houses were parts of an estate development at Rock Crest/Rock Glen, Mason City, Iowa, 1912-3 (Maldre & Kruty 1996, pp. 172-5). The Arthur Rule House, 1912, was constructed from hollow terracotta blocks (White 1924, pp. 68-9). The James E Blythe House, 1913, was constructed with reinforced concrete slabs for the floors and roof, and a reinforced concrete frame with infill panels of hollow terracotta blocks for the walls (Weirick 1995, pp. 111-2). Reinforced concrete and terracotta block technologies were juxtaposed in this building. Griffin was able to manipulate in his mind’s eye the architectonics for reinforced concrete and for terracotta blocks, which he integrated into the *Knitlock* system.

The contract documentation for the Blythe house shows Griffin’s reinforcing bar patterns for the reinforced concrete floor and roof slabs have some resemblance to the reinforcing patterns in Cottançin’s system, as illustrated in the English textbook on reinforced concrete (Marsh & Dunn 1906, p. 44). The pattern of Griffin’s reinforcing mesh however was prefabricated and rigorously modular, whereas Cottançin’s dense yet irregular reinforcing mesh was laid out by hand. Spinal-stiffeners are a feature of the photograph in the book and also of Griffin’s contract drawings. Thus Griffin was apparently familiar with Cottançin’s system for reinforced concrete work. Both Marsh & Dunn’s textbook and Schopfer’s *Architectural Record* articles on new concrete methods in France show and discuss *brique armée* in wall construction **(Fig. 13)**. Griffin used in the walls of the Rule and Blythe houses Denison Fire Proofing company hollow terracotta blocks, actually manufactured in Mason City **(Fig. 14)**.

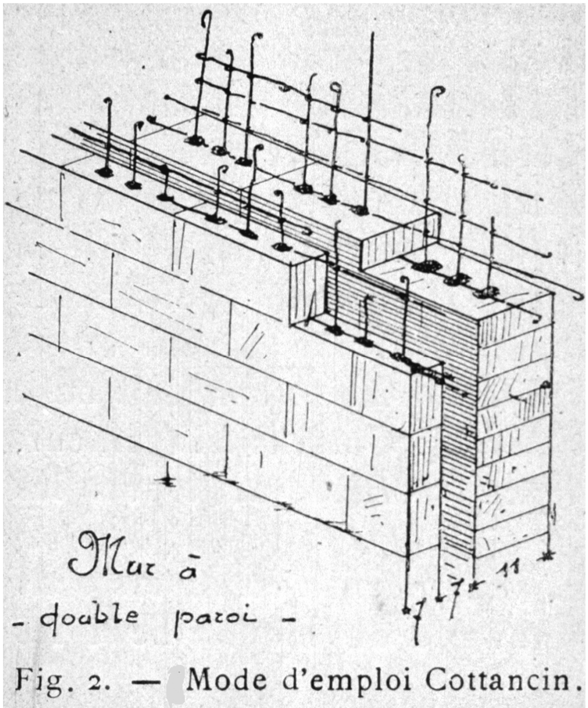

Figure 13. Patent brick cavity-wall system, 1889 (Turnbull 2004, p. 323)

These terracotta blocks have extrusions rather like the cast linear projections to the concrete *Knitlock* blocks **(Figure 7)**. (Colleague Professor Miles Lewis kindly lent a copy of White's *Hollow Tile Construction*, 1924, from his building construction rare book collection in his newly established Osbert Lancaster Memorial Bibliographic Institute). Griffin imaginatively amalgamated underlying compositional patterns from these brick and terracotta technologies in conceiving the new *Knitlock* concrete building block system. For example, the ideas of the cavity and the reinforcement were adapted from the brick technology, and the terracotta block technology suggests another example of sliding together blocks with a tongue and groove cast. Further, a wood template with timber moldings planted on was placed on the *Knitlock* machine to create the pattern of tongue and groove indentations (Weirick 1995, p. 106).

KNITLOCK HOUSE PLANS

Precedence mattered in the planning, constructional and formal aspects of the first *Knitlock* houses in Melbourne - the pair of houses at Frankston, which included *Gumnuts*, 1919 **(Fig. 8)**, and *Pholiota*, 1920 **(Fig. 9)**. As with the conception of Newman College, patterns adapted from the works of Thomas Jefferson figured in Griffin's new house typology (Turnbull 2004, pp 200-2). The plan for each of the first *Knitlock* houses was 21 feet square, the approximate dimensions for Jefferson’s upper floor study/dwelling in the South Pavilion at *Monticello,* 1770, where Jefferson penned the Declaration of Independence and the Virginia Constitution. Furthermore, the Griffins’ holiday houses at Frankston were a pair on the same site, just as Jefferson’s south and north pavilions at *Monticello* became a pair after the extensive additions there from 1793.

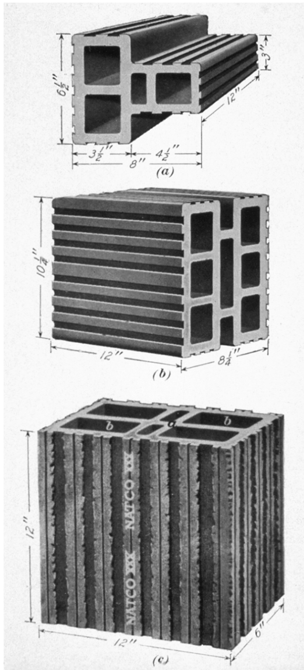

Figure 14. Denison terracotta blocks (White 1924, p. 5)

Knitlock construction allowed a builder or householder to be self-reliant, to make the building materials on the site, and then to construct the small yet sufficient dwelling **(Figs. 7 to 9)**. Griffin in using concrete blocks and portable machines had developed a modern equivalent to the earlier processes of brick making at work for Jefferson’s south pavilion, where bricks for that building were manufactured on the site. Further, the concrete block fireplaces in the Griffins’ houses were of a similar shape and occupied a similar position as the brickwork fireplace in Jefferson’s pavilion.

Partitioned service areas were placed in every corner of the plan of the Griffins’ three houses **(Fig. 9)** whereas there were only two such areas of about the same size in two corners of Jefferson’s south pavilion plan. The central square living area, remote from the outside walls, was a pattern Griffin adapted from Jefferson’s holiday house, *Poplar Forest*, built about 1820. The Griffins’ beds were in the alcoves formed by spur walls **(Fig. 9)**. In Jefferson’s central *Monticello* house, built between 1793 and 1809, all of the beds were built into wall alcoves.

In building *Pholiota* Griffin had designed with his usual convincing integration of the plan construction and form. Until they moved permanently to Sydney in 1925, the Griffins dwelt with great simplicity in their humble abode on the eastern fringe of metropolitan Melbourne. As one together they lived as "Jefferson's successor", fired with the democratic spirit (Turnbull & Navaretti 1995, pp. 121-3).

CONCLUSION

For Griffin the overall design involved more than just the technical questions that arose in the utilization of concrete technology. He was also driven by the social significance of the functional program, and the integrity of the architectural work of art. The building design in all its aspects was the problem he intuitively solved through an imaginative adaptation of precedents.

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