

The use and significance of proportional composition in Sir Edwin Lutyens' later work is explored through detailed analysis of the Leicester Arch of Remembrance.

Unlocking Lutyens: a gateway to the hidden legacy of John Pell and Sir Christopher Wren

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The work and the life of the English architect Sir Edwin Landseer Lutyens (1869–1944) have been extensively documented over the past hundred years and clearly show a career with at least two phases. The first is characterised by the design of private country houses in the Arts and Crafts style and, in collaboration with the horticulturalist Gertrude Jekyll, the development of their gardens. The second begins around 1900 and reflects a shift towards Neo-Classicism, initially in country houses and later in a wider range of larger public buildings and monuments both in England and abroad. Lutyens developed his use of the Neo-Classical idiom throughout the latter part of his career into a unique style of design which Arthur Stanley George Butler has termed his 'elemental mode'.¹ This was characterised by a highly controlled use of form and mass, apparent adherence to rules of Classical proportioning and the sparing use of symbolic Classical motifs. However, very little is known with any certainty about how Lutyens actually achieved this style, in particular what role was attributable to intuition and good taste, as is often assumed, and how much may have been attributable to quantitative and formalised methods of design. Circumstantial evidence exists that strongly suggests that quantitative analytical methods may have been used in a method which drew upon his interest in puzzles and mathematics, his interests in architectural history (particularly English Neo-Classicism), his leanings towards mysticism and his exposure to Theosophy.

Around 1919 Lutyens was invited to design the war memorial in Victoria Park in Leicester, known, at that time, as the 'Arch of Remembrance' to commemorate the men of the city, and the county of Leicestershire, who had died in the First World War. It is one of a number of memorials he designed for sites in England, France and Belgium, India and South Africa. As a monument it has a purely symbolic function and is not burdened with the functional demands of inhabited buildings and as such can be viewed as an exercise in purely architectural composition and a particularly clear exemplar of Lutyens' 'elemental mode' of design. It

would appear from this to be a useful candidate for analysis to reveal what, if any, formalised or quantitative design methods Lutyens may have employed. Before embarking upon such an enquiry it is helpful to examine in more detail the background, work and personality of Lutyens to assess circumstantial evidence and potential motives for his use of such design methods.

The architect

Of Lutyens it was said that he was 'part schoolboy, part great artist, part mystic'.² The first attribute expressed via an endless stream of puns as well as his 'vivreations' (cartoons) is perhaps the best known aspect of his personality and one which would have been constantly invigorated by the cartoons and visual humour found in the London newspapers and magazines which were ubiquitous in upper middle class London households of the time. However, as many have observed, this behaviour covered up a deeply serious creative mind.³

His shyness and loathing of committee work is well-documented, but there is also a distrust of words especially when applied to architecture. An example of this is the following sentence, to be found in his 'Foreword' to A. S. G. Butler's book, *The Substance of Architecture*: 'Mr. Butler's essay gives indispensable help to all those earnest in the desire to reach beyond the clouds of words to the real substance of architecture'.⁴ This distrust of words, even of his own, led him to ask his wife, Emily, with whom he had a voluminous correspondence, to burn any letters in which he wrote of his architecture.⁵

Butler, his co-biographer (with Christopher Hussey) and author of *The Substance of Architecture*, called him 'the greatest artist in building that this country has produced'. The significance here is in the term 'artist', used instead of 'architect', as might have been expected, for Lutyens had a deep distrust of the more 'professional' side of the architectural profession, as exemplified by the RIBA, with which he had little association.⁶ As an artist, he identified more with the Royal Academy, of which he became an Associate (ARA) in 1920, and then President in 1938. It is likely that this desire to be considered an artist

rather than an architect dates back to the schism of 1891, when the artists/architects led by Richard Norman Shaw, whom Lutyens knew and admired, left the RIBA.⁷

Of Lutyens the mystic there is little hard evidence except for his well known pantheistic approach to the design of the war memorials and the close association of his wife Emily with Theosophy, a belief system established in the 1870s professing deterministic natural laws operating within a universal paradigm. He was regarded as a great Humanist by Hussey, but this, as we shall see, is to understate the rather specific potential that such an acute and deep a mind as Lutyens' might develop towards matters of spiritual belief and its relationship to his architecture. Perhaps the most important aspect of his character though is that he was naturally an autodidact, gifted with an extraordinary visual memory, who believed that little could be taught but much could be self learnt.⁸

His work

Lutyens is probably best known internationally for his work at New Delhi, which started in 1912 and occupied him right up until 1931. His earlier, mainly domestic work, was often carried out in association with Gertrude Jekyll and Lutyens' later discovery of and conversion to Classicism during the early years of the twentieth century is well-documented.⁹ Perhaps less well known is his magnum opus, the design for the Roman Catholic cathedral of Liverpool. This was started in 1929, but only the crypt was built before it was abandoned because of mounting expense.¹⁰ Frederick Gibberd's later design (1967) sits upon this plinth. If completed, the Lutyens cathedral would have been twice as large as St. Paul's, and with a bigger dome than that of St. Peter's.¹¹

Between New Delhi and Liverpool are a number of other buildings, of which his work as one of the principal architects of the Imperial War Graves Commission (1917) has begun to receive more critical attention.¹² These structures, perhaps more than any others of his realised work, exemplify what Christopher Hussey called his 'elemental' style, effectively a reinvention of the Classical canon, being both extremely personal but also very abstract, with a sheering away of what many might regard as the very essence of Classicism, 'the Orders'.¹³

With the War Graves work came a number of similar commissions in the United Kingdom, of which the Cenotaph in Whitehall is the best-known and loved. The war memorial at Leicester is very obviously in this group, and a fine demonstration of the elemental style. This, then, is the prime reason for an extensive examination of its design.

Leicester, like so many other Midland cities, lost heavily in the Great War: the Monument proclaims the loss of twelve thousand men. The city council, again like those of so many other villages and towns throughout the country, formed a Memorial Committee, in this case under the patronage of the Duke of Rutland and chaired by Alderman Sir Jonathan North. This committee, which also included representatives from the country, was

charged with the overseeing of the development of some appropriate memorial to the fallen of the region. The committee first met in 1917 and built what was known as a temporary war memorial in that year in the Town Hall Square. Lutyens, already well known for his other memorials, was appointed architect in early 1919.¹⁴

Initially he planned a cathedral-like structure housing a Great War Stone, an altar-like block used at a number of his memorials, surrounded by formal landscaping.¹⁵ This structure was almost certainly intended to be situated in the city centre, probably in the Town Hall Square. However, for reasons not yet known, this proposal was abandoned in September 1919, and no trace of the design has been found. There also seems to have been other subsequent and also unknown designs before the Arch itself was settled upon. This must have occurred somewhere near the end of 1922, but the final design itself was only formally accepted at a public meeting of the citizens of the town held on 18 May 1923.¹⁶ The working drawings are dated February 1923.¹⁷

By this time a new site outside the city centre had been chosen. The Arch took almost two years to build, and was finally unveiled on 3 July 1925 by two mothers who had lost seven sons between them. The Bishop of Peterborough officiated at the ceremony, and a crowd of 30,000 was present, as was Sir Edwin.¹⁸ Newspaper accounts of the time referred to it as the White Arch and spoke of its marked visibility – Portland stone had been chosen for its cladding, and it was conspicuously sited above the city. The cost of the Monument was £27,000, and the contractors were a London firm, Trollope and Collis of Wandsworth.¹⁹

The problem

Virtually every serious writer on Lutyens' work intuits that he was using some form of geometrical system.²⁰ In commenting on his drawings, Margaret Richardson asserts that, when his assistants 'had to draw up his sketches to scale, they did so by applying a system of ratios and proportions which Lutyens had evolved and which gave the distinctive character to all his work'.²¹ Unfortunately, if this is true, none of them ever recorded this system in any detail at all. Richardson also explains that the working drawings for memorials in Lutyens' own hand give a good idea of the geometric forms and setbacks used.²² Gavin Stamp also writes of a 'geometrical hierarchy' in his recent study of the Thiepval Arch.²³

Further evidence of Lutyens' preoccupation with mathematics is given by his daughter, Mary, who makes reference to his 'gift' for mathematics,²⁴ and his concern that his children be instructed in 'the meaning, view, and invention of conic sections, the differential calculus, etc. etc., without the necessity of any sums or figures, and without the puzzle-world comprised within the numerals'.²⁵ One might reasonably argue that Lutyens was here advocating the intuitive visual quality of geometry above the more abstract numerical difficulties of calculation and algebra, with which he, as an adult, might be comfortable but which might easily dissuade a young mind from further interest in the subject.



1 The Arch of Remembrance, Victoria Park, Leicester, viewed from 'Peace Walk' along its 'main' axis

2 Side arch of the Arch of Remembrance



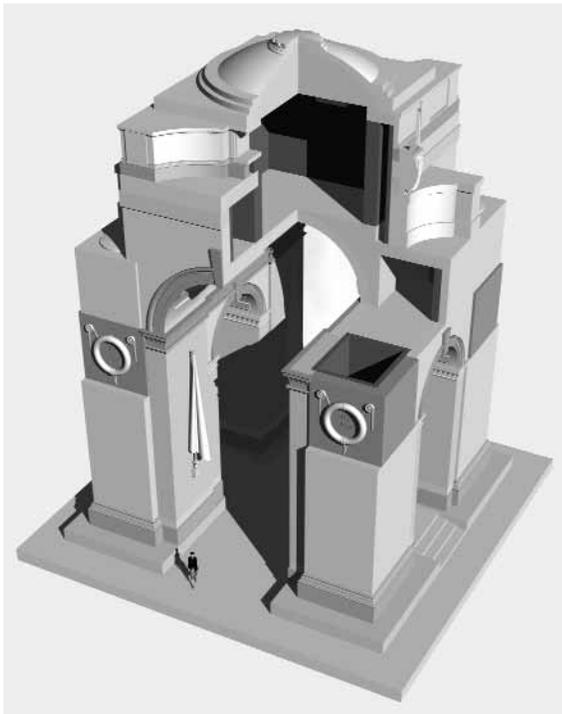
His other daughter, Elizabeth, wrote that in 1927 he became fascinated by the realisation that music was built on structural principles stemming, as those of architecture did, from the Greeks.²⁶ Significantly when contemplating the education of his son Robert, he wanted him to learn geometry and 'sciography' (the science of shadows).²⁷ It is in fact to Robert that we owe one of the few surviving contemporary interpretations of Lutyens' use of geometry in his 1942 biography of his father, in the chapter entitled 'The Armature of Planes'.²⁸ However, as a description of a conceptual method of understanding his father's compositional process it is perhaps of limited use (see below) and Mary Lutyens says that her father told her, not uncharacteristically, that he could not understand a word of it.²⁹ Despite this, the circumstantial evidence noted above surrounding Lutyens and his work gives us good grounds for suspecting a predisposition towards using some formalised system of proportioning and design composition in his architectural work, especially in the design of his war memorials. Although there is no explicit, first-hand description by him of any such design method, it is possible to speculate with a degree of precision on the nature such a system may have had. For the correct interpretation of Lutyens' built and unbuilt designs, particularly from the latter part of his career, a detailed knowledge of the principles and methods underlying their composition would be of considerable use not least in comparative studies with the more widely understood proportional and

compositional theories of his contemporaries and of other architects engaged in this field.

The purpose of the investigation described here has therefore been to propose a probable method for Lutyens' design of the memorial at Leicester based upon the available factual and circumstantial evidence. It has not been our intention here to exclude other possible candidate methods, nor to propose that any method used at Leicester is applicable without modification to other of his works.

The Leicester Arch of Remembrance

The Arch of Remembrance [1, 2] is situated in Victoria Park, just south of the city centre, off the London Road, which is historically one of the major routes out of the city. There is no record of who chose this site for the memorial, possibly it was Lutyens



3

himself. If so, he made full use of its potential. The monument is placed at the northern edge of the park at its highest point, overlooking the railway line, the river valley and the town beyond. Originally the section of the site now occupied by the University of Leicester would have been far more open, and the monument would have been more visible from a distance than it is at present.

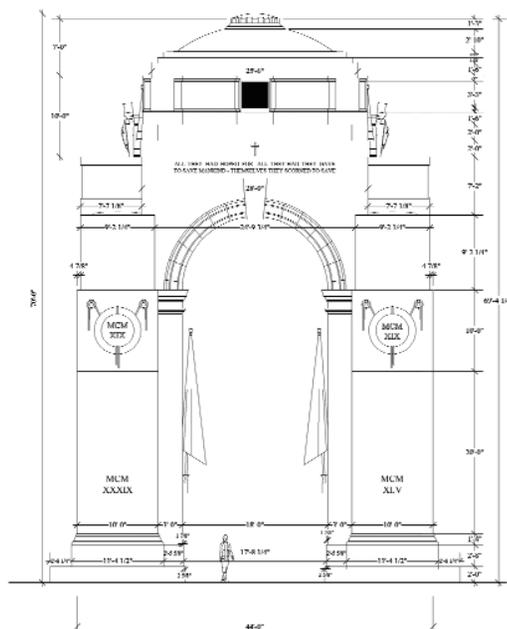
It is situated on the centre-line of Lancaster Road, which follows the west wall of the 1824 prison below. This means that there is a commanding vista, from both up and down the street, the monument coming into view both as you move along the railway line and along Welford Road which is another major route out of the city. The last part of the vista is a

pedestrian approach now called Peace Avenue, leading from the end of Lancaster Road to the monument itself. This is given prominence by a set of gates at the bottom of the avenue, donated by Sir Jonathan North in memory of his wife, and built in 1931 to Lutyens' design. The Arch is fenced in by a circular screen of railings and stone piers almost certainly built at the same time as the gates. However, early photographs show the site as completely open, without any railings.³⁰

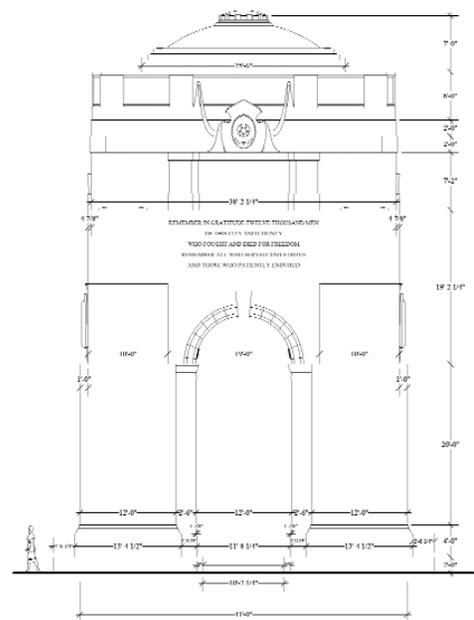
To the north-east, at what is now the formal entrance to the park from London Road, is a pair of lodges framing a similar set of gates to those on Peace Avenue. These were also donated by Sir Jonathan and built in 1931 to Lutyens' design.³¹ The centre-line of the gates is virtually on the line of the cross-axis of the monument. Thus the Arch is locked (in both directions) to its immediate context in a cross-axial relationship.

A study of the proportions of a building like the Leicester Arch necessarily focuses attention on its dimensions and on first inspection one may consider the study and measurement of the proportions of the real building to be the most immediate method of understanding the design rationale of its architect. However, beyond issues of ensuring acceptable accuracy of measurement and detection and quantification of errors, an issue which Philip Steadman correctly notes in relation to previous work on Lutyens,³² there may be a number of possible interpretations of the relationships between the resultant dimensions. This kind of field evidence is therefore only of value when it is substantially supported by evidence from other sources which limit the number of possible interpretations.

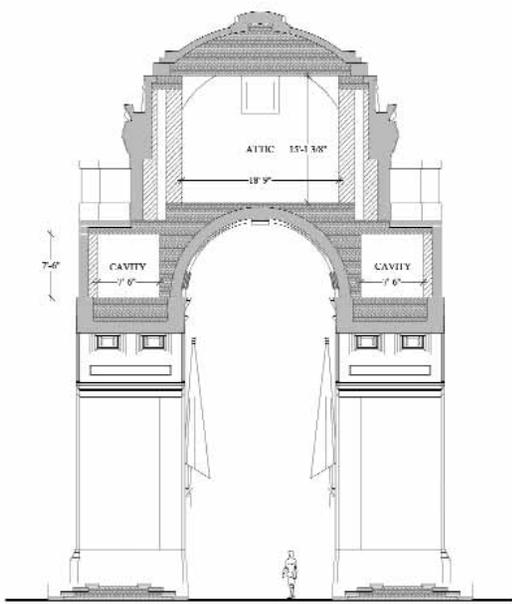
Three types of evidence have been employed to support the present study: first, direct literary evidence, supported by drawings, showing how the architect intended the building to be; second, indirect literary evidence, the literature that provides



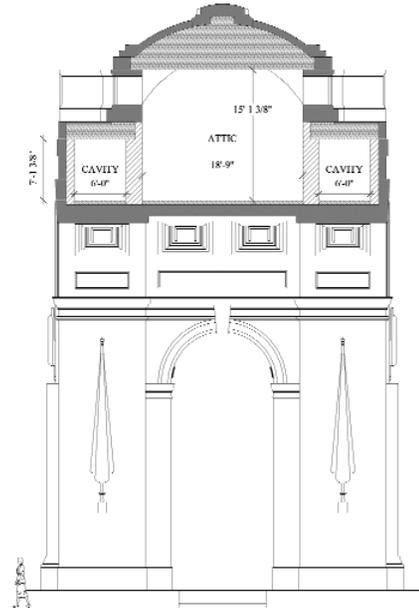
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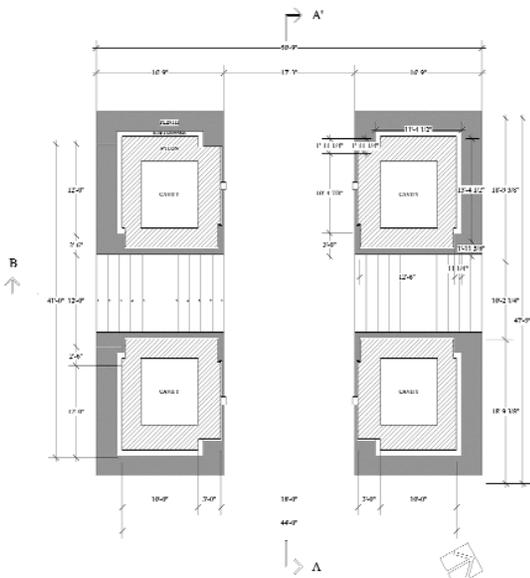
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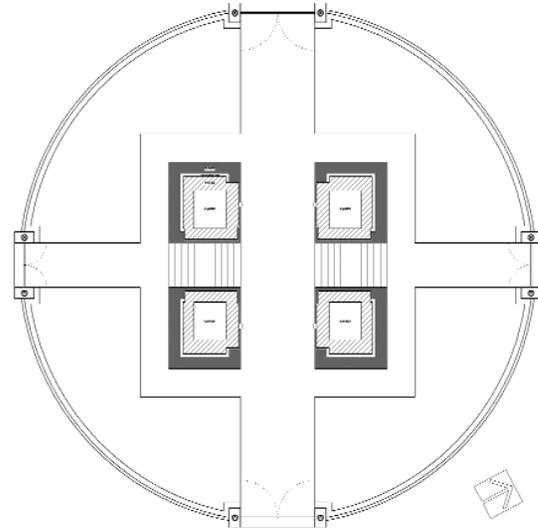
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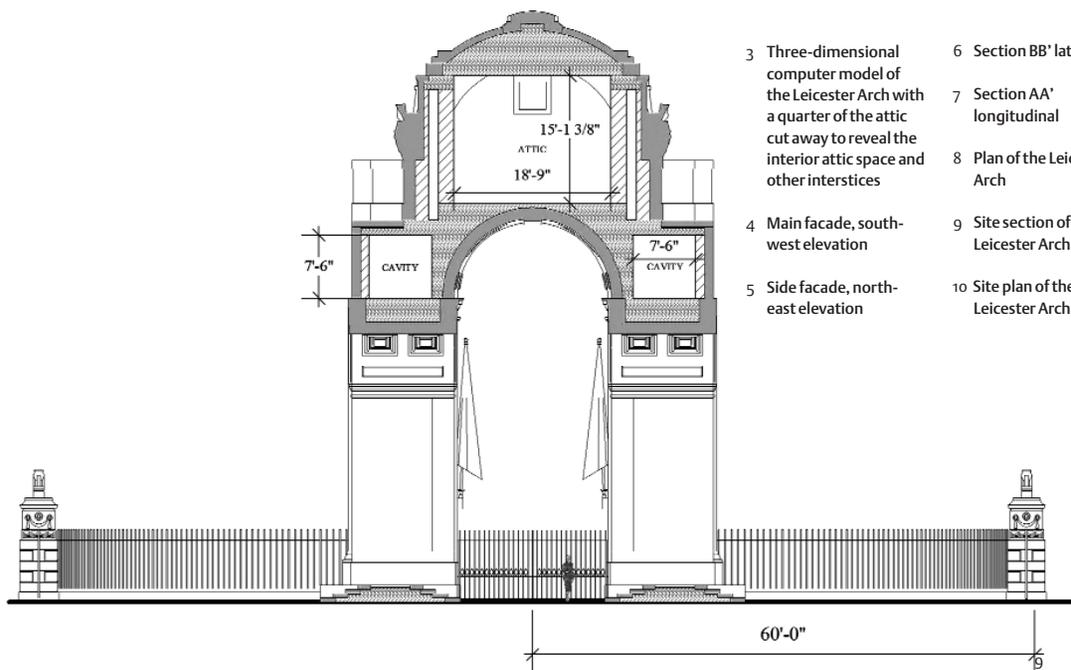
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3 Three-dimensional computer model of the Leicester Arch with a quarter of the attic cut away to reveal the interior attic space and other interstices

4 Main facade, southwest elevation

5 Side facade, northeast elevation

6 Section BB' lateral

7 Section AA' longitudinal

8 Plan of the Leicester Arch

9 Site section of the Leicester Arch

10 Site plan of the Leicester Arch

clues as to the ideas current in the period under consideration and their pedigree and precedents; and third, physical evidence, the building itself and the remains of other surviving works.

The first and second evidence types serve to control the interpretation of the third evidence type. The drawings prepared by Lutyens' office for the construction of the Leicester war memorial exist and these provide highly coherent, annotated dimensions for the monument. These dimensions have been used to generate a three-dimensional computer model of the building (accurate to within $\frac{1}{64}$ of an inch over 70ft) which has subsequently been used in the proportional analysis [3]. One of the advantages of using a CAD model is that you can achieve consistent dimensional accuracy using both graphical or numerical input, in other words you can illustrate reliably and exactly with graphical geometry the numerical/analytical methods. The building itself was constructed almost entirely as shown in Lutyens' working drawings apart from a minor variation in the build of the concrete roof of the attic which fills the underside of the saucer dome. This is in fact crudely vaulted internally using in-situ concrete to a point a quarter of the way down the internal brick walls of the attic instead of being of flat, reinforced concrete with small corner pendentives as shown in the figures presented here and in Lutyens' original drawings. This variation does not affect the external appearance of the building and in the interests of consistency we have adhered to Lutyens' drawings in constructing the model.

The annotated dimensions from Lutyens' drawings have been compared with surveyed check dimensions of the lower half of the monument [11]. As may be expected using conventional tape measures, smaller dimensions yield higher percentage errors of their overall length, but these remain in our view within acceptable limits for the purpose of verifying that the memorial was constructed as per the dimensions given in Lutyens' drawings. The generally high degree of fit of the check dimensions to the dimensions Lutyens gives on his drawings gives confidence that the unsurveyed (but visually inspected) upper half of the monument can be reasonably represented by the dimensions given for it in the same office drawings.

In the few cases where the drawings from Lutyens' office do not give dimensions for significant parts of the monument (for example for the impostes and archivolt mouldings), these have been measured to an estimated accuracy of $\pm \frac{1}{16}$ ". The dimensioned drawings from this study are presented in this paper

	Measured	Drawings	Error
Long side	44' $\frac{3}{4}$ "	44'	0.05%
Short side	40' 11 $\frac{3}{8}$ "	41'	0.13%
Large arch width	18' $\frac{3}{8}$ "	18'	0.17%
Large arch 'column' width	2' 11"	3'	2.78%
Small arch width	12' $\frac{3}{8}$ "	12'	0.61%
Small arch 'column' width	2' 5 $\frac{3}{8}$ "	2' 6"	2.92%
Height of base & plinth	6' $\frac{1}{8}$ "	6'	1.22%

11 Table of check dimensions for lower half of the Leicester Arch

to facilitate detailed discussion of the proportions of the memorial and all the dimensions illustrated on these drawings apart from those noted above are those given by Lutyens on his originals [4–10]. Preference in this analysis is given to the data from the drawings.

British architectural theory circa 1920

In considering the design of the memorial it is of interest whether Lutyens may have had a commonly acknowledged body of enabling theory to work from which allowed him to re-express the genre. It is worth mentioning here two works which Lutyens would have known about. The first was Lethaby's *Architecture, Mysticism and Myth* published in 1891 and the second was Geoffrey Scott's *The Architecture of Humanism* published in 1924. Both these works attempted to move past the mere question of style into a deeper enquiry as to the essence and purpose of architecture.

However, a review of the books left in Lutyens' office in 1951 does not include any of these, but does include a 1707 treatise on perspective and a copy of Gromort's *Choix d'éléments empruntés à l'architecture classique*.³³ The rest are mostly monographs on aspects of English architectural history. This was an area that had received a great deal of scholarly attention at the time. For example, Reginald Blomfield, Lutyens' colleague on the War Graves Commission, had produced a number of studies of both English and French Classicism.³⁴

Perhaps the best way to sum up the major concerns of the traditionalists is to attempt a summary of the book by Butler to which Lutyens provided the foreword, part of which has been previously quoted.³⁵ For Butler architecture was essentially the adjustment of two elements, the aesthetic and the practical.³⁶ Beauty was the product of a harmonious unity while the proper consideration of weight and movement would lend a building the quality of 'vital stability'.³⁷ Butler also claimed the following:

*'Proportion relies on the maintenance of scale and affects the whole disposition of the parts of the building in all their relations; it is less a rule for relative lengths and areas than a general instinct which propels the machinery of beauty.'*³⁸

A further very interesting point is the observation by Butler that by adding an element of mystery, great architecture avoids the obvious.³⁹

Lutyens, we suggest, shared this view of avoiding the obvious in architectural design, and saw the building as a compositional puzzle with proportion, on which he comments:

*'Tradition, to me, consists in our inherited sense of structural fitness, the evolution of rhythmic forms by a synthesis of needs and materials, and the avoidance of arbitrary faults by the exercise of common sense coupled with sensibility. The best old work was composed. Few modern buildings seem to have a feeling of growth; in them the forms and the details appear to meet as strangers, and their phrasing to consist in little more than an initial and a mark of new and complete interrogation.'*⁴⁰

Proportioning systems

Beyond any mystical attributes with which they may be imbued, the main functional objective of the use of proportions in architectural composition is the repetition of a limited number of similar shapes which have additive properties of dimension such that their assembly has an order and economy of form which simultaneously achieves unity and variety.

The practical generation of these similar shapes within a coherent proportional system in architectural design can be achieved by the use of compass and set-square. This is a *geometrical system* and provides the architect with direct visual control over the shapes without necessarily requiring the numerical definition of their dimensions. This is a useful attribute where there is no knowledge of mathematics or arithmetical calculation or the presence of a consistent system of measurement is absent. However, the additive properties of the geometrical figures can become highly complex in two or three dimensions and the architect in most cases eventually prefers and indeed requires numerical output for the building construction, which if derived from manually drawn plain geometry alone almost always introduces dimensional inaccuracies.

If you accept a loss of the immediate visual appreciation of the shapes that the geometrical system provides and reduce the problem of proportional relationships to the manipulation of linear dimensions, it is possible to arrive at an *analytical system* in which the terms of the system are linked by a pre-arranged, numerical pattern of proportional relationships. This avoids both the additive complexity inherent in three- or two-dimensional geometrical figures and the errors of manual drawing and measurement.⁴¹

Square root geometric progressions tend to have more extensive additive properties than whole number progressions, and allow more complex and varied architectural compositions to be based upon them. The simplest square root progression is that of the $\sqrt{2}$ rectangle, sometimes designated by the neologism ‘diagon’ and when geometrically employed to govern aspects of architectural design known as the process called *ad quadratum*, a method used in the design of medieval and early Renaissance religious buildings.⁴²

There are two commonly used square root progressions. First, the widely used progression based upon $\frac{1+\sqrt{5}}{2}$, which is equal to 1.618 ..., designated as ϕ , and known in the form $\phi:1$ as the Golden Section, or ‘extreme and mean’ proportion. Lutyens is supposed to have used the ϕ rectangle in the early part of his career, for example at Hampstead Garden City Institute. Second, the progression based on the number θ , which is equal to $1+\sqrt{2}$, or 2.414 ...:

$$1 \quad \theta^2 \quad \theta^3 \quad \theta^4 \dots$$

and known in the form of $\theta:1$ as the silver ratio. Lutyens is supposed to have used this progression in

the later part of his career including the design of the Arch of Remembrance at Leicester.

These square root progressions or ratios have two significant characteristics. Firstly they are incommensurable (you cannot add the smaller terms of the progression to yield the larger terms). Lastly they rely upon the irrational numbers θ and ϕ which make their manipulation by manual calculation time-consuming and error prone, factors which were significant disadvantages before the advent of digital computation in architectural design and would have been so in the first half of the twentieth century.

Within the technological context of Lutyens’ architectural career, realistically useful, analytical proportional systems would have had to allow flexible repetition of a limited number of shapes, have a high degree of numerically communicable accuracy and be easily used without recourse to complicated mathematical calculation.

Pell’s series

Fortunately this can be achieved, avoiding the limitations of the irrationality of the ϕ and θ progressions while preserving their advantages, by their substitution with integer sequences which approximate the ϕ and θ progressions. The ϕ progression can be approximated by the well-known Fibonacci series, where each term is the sum of the two previous terms thus:

$$1 \quad 2 \quad 3 \quad 5 \quad 8 \quad 13 \quad 21 \quad 34 \quad 55 \quad 89 \quad 144 \dots$$

The θ progression can be approximated by the use of a particular form of Diophantine equation (an indeterminate polynomial equation that allows the variables to be integers only) called Pell’s equation, expressed as $x^2 - ny^2 = 1$ (where n is a non-square integer), and as a special case where $n=2$ where Pell numbers are defined recursively:

$$P_n = \begin{cases} 0 & \text{If } n = 0; \\ 2 & \text{If } n = 1; \\ 2P_{n-1} + P_{n-2} & \text{otherwise} \end{cases}$$

In other words the next factor (or Pell number) of the Pell series is obtained if a factor is multiplied by 2 and the preceding factor added, thus:

0	1	2	5	12	29	70 ...
1	1	3	7	17	41	99 ...
2	1	4	9	22	53	128 ...
3	1	5	11	27	65	157 ...
4	1	6	13	32	77	186 ...

The ratio of successive terms of the sequences approaches θ as $n \rightarrow \infty$.

Pell numbers and their series have been known to have arisen in the approximation of the square root of 2 since ancient times. Pythagoras (500BC) was aware of the properties of Pell numbers and the Indian mathematician Brahmagupta (628AD) studied them in detail, his work being translated into Arabic



¹² John Pell, mathematician (1611–1685), portrait by Sir Godfrey Kneller

in 773AD and into Latin in 1126AD. While it seems that Brahmagupta's work on the Pell equation was unknown to European mathematicians in the sixteenth century, it is clear that Pell numbers were known to a few Renaissance architects including Leon Battista Alberti (1404–1472) who used Pell numbers in the dimensioning of his designs for San Sebastiano in Mantua and which are shown (in a modified form) on a near contemporary plan drawing of the building by Antonio Labacco.⁴³ It was only Pierre de Fermat's rediscovery of Pell's equation in the seventeenth century and his challenge to contemporary mathematicians to find solutions to it which brought about the equation's wider understanding in the west.

The name of the Pell numbers stems from Leonhard Euler's (1707–1783) attribution of the equation and the numbers derived from it to the English mathematician John Pell (1610–1685) [12]. Pell has been characterised as a proselytiser of the works of others, his own work forming a supportive backdrop and facilitator to their ideas. He was obsessively devoted to the demanding tasks of tabularisation and algebra, particularly to the calculation and use of logarithmic, trigonometric, Pythagorean triples, squares, sums of squares, primes and constant differences tables, mathematical tools essential at the time to the practical and accurate application of mathematical techniques in other fields such as astronomy, navigation, construction and surveying. He was closely associated with many of the leading scientists and philosophers of the day and of particular interest to this discussion is his association with the co-founder of the Royal Society, Sir Christopher Wren.

Sir Christopher Wren and John Pell

Wren was Pell's junior by 21 years. Pell himself recalls that he first met the young Christopher Wren in '1652 or 1653' when Pell was about 41 years of age and Wren was 20.⁴⁴ Pell frequently participated in the discussion of mathematics with other contemporary specialists in the field including Wren and he was actively involved in the Royal Society from its inception (he was its 19th member and served as its vice-president in 1675). There is also specific evidence that Wren and Pell were working together in January 1669 when with other specialist members of the Royal Society they examined papers on motion from Christiaan Huygens.⁴⁵ Wren it has to be remembered was an eminent mathematician in his own right. Sir Isaac Newton (rarely noted for his praise of others) states in his treatise *Philosophiæ Naturalis Principia Mathematica*, that he held Wren to be one of the finest mathematicians in England.

It is suggested here that between two such eminent mathematicians Pell's known interest in tabularised integer approximations of $\sqrt{2}$ (which were published) would have been discussed with Wren, and that given their close association for many years and had he not done so already, Wren had both the means and the opportunity of learning about Pell numbers. The question remains as to what motive Wren may have had for doing so.

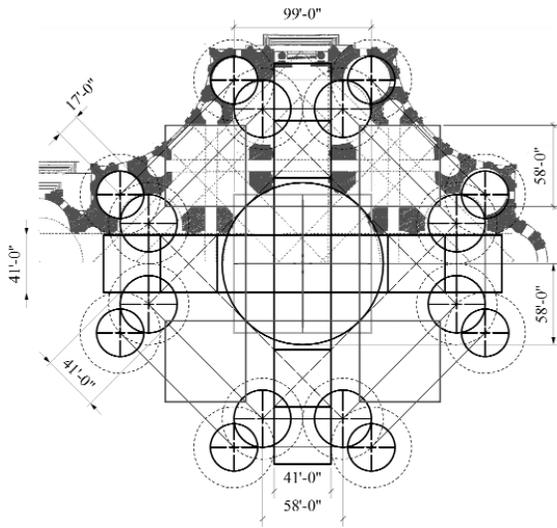
Wren's interests included the use of mathematics for informing a theory of beauty which, in turn, formed a basis for his architectural designs.⁴⁶ For Wren natural beauty was the first criterion of architectural design but was less of an intrinsic structural quality than an optical effect, an appearance of geometric purity which engaged the observer. This he believed could be achieved through the use of mathematical science to produce strong, clear geometric forms of which he held the square to be fundamental. In relation to the example of the Temple of Mars Ultor in Rome, Wren states:

*'Squares in the Wall of the Cella opposite to the inter-columnations, tell us how extremely the Ancients were addicted to the square and geometrical Figures, the only natural Foundation of Beauty.'*⁴⁷

At a secondary level, and as a geometrician, for Wren the natural guarantors of firmness or structural integrity were Euclidean principles.⁴⁸

The square's role in natural beauty within architectural design was for Wren a rational one based, after Fréart's *Parallèle* of 1650, on empirical judgements of human perception and man's supposed inherent preference for visually balanced, regular geometric forms rather than on those of an abstract Vitruvian cosmology. For him the problem of relating architecture to nature was more an exercise in deploying the new science of optics than metaphysics to embody nature's beauty made visible with that science and by doing so express the hidden truths of God's natural world.⁴⁹

Evidence of Wren's practical implementation of this philosophical approach as a motive idea in architecture is amply evidenced by the plan composition of the Great Model design of (1673–74) for St. Paul's Cathedral which is based upon a



13 Plan of Sir Christopher Wren's 'Great Model' design for St. Paul's Cathedral showing its Pell number dimensions and $\sqrt{2}$ geometry. Although not built in this form the 'Great Model' was Wren's favoured design for the cathedral

superimposition of squares. It was just prior to this design, 20 years after first meeting Wren, that in the spring of 1672 Pell published a 32 page volume of mathematical tables, *Tabula numerorum quadratorum decies millium ... (A Table of Ten Thousand Square Numbers ...)*. In one of his private memoranda, Pell discloses that he undertook this work because of the errors he found in Paul Guldin's *De centris gravitas inventione* (Vienna, 1635). Wren's long association with Pell would suggest that Wren was probably aware of Pell numbers and their properties long before the publication of the tables and before he embarked upon the protracted series of designs for St. Paul's Cathedral. Wren it should also be remembered had studied Alberti, and was familiar with his design for the centrally planned church of San Sebastiano in Mantua, in which Pell numbers are used to derive the plan form.⁵⁰ Of interest here is that Pell's published table of square numbers would have been available to Wren while he was draughting the Great Model design and in fact the main parts of the plan layout of the Great Model can be entirely reproduced using Pell numbers [13].

Sir Edwin Lutyens and Sir Christopher Wren

'Wrenaissance' was a term used humorously by Lutyens to describe the Neo-Georgian style which he began seriously developing in 1901–1902. This drew heavily upon the English Baroque architecture of the late seventeenth and early eighteenth centuries and in particular upon the architecture of Sir Christopher Wren. From 1906 and his design for Heathcote at Ilkley in Yorkshire (his first fully-formed Classical villa), Lutyens became increasingly interested in controlling the sense of proportion and

the organisational principles possible in architectural design which led him towards a more extensive exploration of harmony, strength and repose and the incorporation of a highly developed sense of symmetry, balance and order. In this he regarded the manipulation of the Classical vocabulary as an intellectual game, and one which he makes clear in a letter to Herbert Baker dated 15 February 1903 he believed had been well played by Wren in what Lutyens famously called the 'the High Game' of architecture.

*'In architecture Palladio is the game!! It is so big – few appreciate it now, and it requires training to value and realise it. The way Wren handled it was marvellous [...] It is a game that never deceives, dodges never disguise [...] There is no fluke that helps it – the very what one might call the machinery of it makes it impossible except in the hands of a Jones or a Wren. So it is a big game, a high game, a game that Stevens played well as an artist should – tho' he never touched Wren.'*⁵¹

In the same letter, after emphasising the discipline required to work within the Orders, Lutyens goes on to enunciate his conviction of the universal relevance of the Classical ideal again referring to Wren and also making an oblique reference to the rejection by the Clergy ('Deans' and 'Chapters') of Wren's 'Great Model' design.

Lutyens had studied and clearly admired Wren's work, was familiar with the designs for St. Paul's Cathedral including the 'Great Model' and like Wren believed that architecture arrived at through geometry and empiricism had a special significance. Referring to a letter from Lutyens to his wife Emily written in 1914 Hussey notes:

*'Apart from the recognition of Wren's mathematical rather than aesthetic mind, the most notable passage is the testimony to his [Lutyens'] belief in the possibility of ultimate revelation, relating the very nature of God to aesthetic ideals and achievements. [...] It was this conviction that he at last sought to embody in his elemental designs.'*⁵²

Lutyens appears to have shared with Wren similar beliefs in the relevance of geometry to architecture as a revelation of what they saw as the hidden truths of the fundamental laws of nature and consequently of aspects of divinity. This should not be surprising since Lutyens' wife Emily was for many years devoted to Theosophy, a belief system with which he became familiar if far from a devotee. None the less, while being attracted to the philosophical implications of geometry he was clear that geometry should be implemented analytically. Lutyens was greatly in favour of analytical methods, to the extent that he advised his students in the latter part of his career to dictate design in figures from memory: 'It entails much thought and accurate statement of fact and there is no danger of being run away with cross-country by a soft-nosed pencil'.⁵³

The anecdotal evidence of the rapidity with which Lutyens could compose a design on squared paper is well documented,⁵⁴ which suggests in the absence of drawing instruments for geometrically arriving at ratios and dimensions, that he had preferred ones which he could call to mind very quickly. In this regard and beyond the philosophical and aesthetic

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attraction of enabling the production of architectural designs that have related integer dimensions (and a consequent sense of unity and inevitability), the advantage of Pell's series as a practical design tool is that it is simple to use and the methods of the derivation of its elements can be easily memorised, as can, if necessary, the elements of the sequence themselves. It yields shapes which are proportionally very similar (it is suggested here indistinguishably so to the naked eye) and it allows repetition of those shapes to give a sense of unity and harmony of the individual parts to the whole. Of greatest use is that it provides a system of $\sqrt{2}$ proportional dimensioning which is computationally tractable by manual means.

The concept of using an integer series to asymptotically approximate with negligible error a series of irrational numbers in proportional series as we have seen has had a long history and at the beginning of the twentieth century was reasonably well documented. One interesting route that has been little explored by which Pell's equation, Pell's series and Pell numbers would have been available to the reading public, including Lutyens, in the early twentieth century was puzzle games.

Henry Ernest Dudeney and square puzzles

Lutyens was attracted to puzzles, his daughter Mary notes his fondness for crosswords⁵⁵ and as already noted his 'gift' for mathematics.⁵⁶ Recreational puzzle books and publications were widely available in the late nineteenth and early twentieth centuries and were popular not only with the readers of London newspapers and magazines but with teachers of mathematics as educational tools for children. They often contained mathematical, geometric, logic and alpha-numeric puzzles involving square and cubic numbers, magic squares, chess-board and grid problems.

The foremost author and proponent of recreational puzzles in the late nineteenth and early twentieth centuries was the English puzzelist Henry Ernest Dudeney (1857–1930) whose house appeared in a loose-leaf article in *Country Life* (21 May 1910) 'Lesser Country Houses of Today: Littlewick Meadow' and who published puzzles in various London magazines and newspapers including: *Tit-Bits*, *Strand Magazine*, *London Magazine* and *The Daily Mail*. He also published a number of puzzle books including the very popular *Amusements in Mathematics* in 1917 which has been continuously in print ever since.

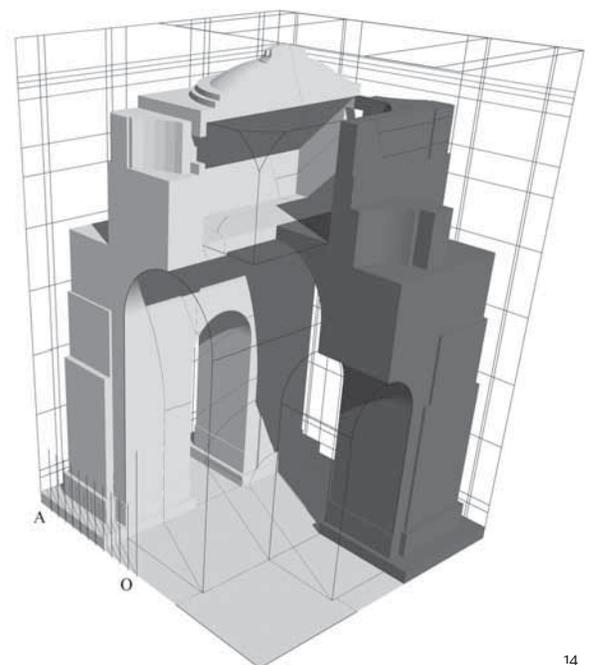
About the time Lutyens embarked upon his change in architectural style from the Arts and Crafts to the Neo-Classical, the 1 June 1900 edition of *The Weekly Dispatch* published in its puzzles and prizes columns 'Puzzle 333: The Battle of Hastings Problem' by Dudeney, which required the reader specifically to solve a Pell equation. This puzzle was reprinted in Dudeney's *Amusements in Mathematics* in 1917 as 'Puzzle 129: The Battle of Hastings'. Mathematically, the problem requires the reader to find a perfect square that, when multiplied by 61 and increased by 1, yields another perfect square. That is, to yield an integer solution to the equation $y^2 = 61x^2 + 1$. In order

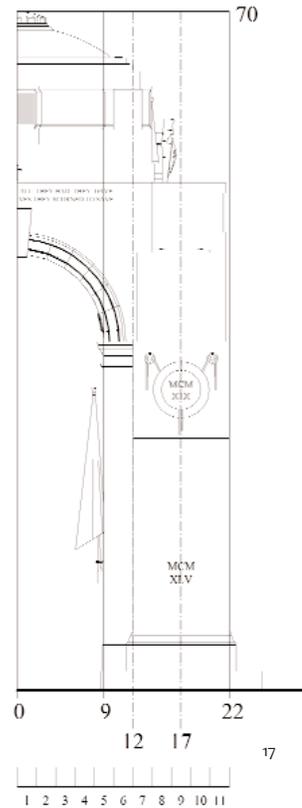
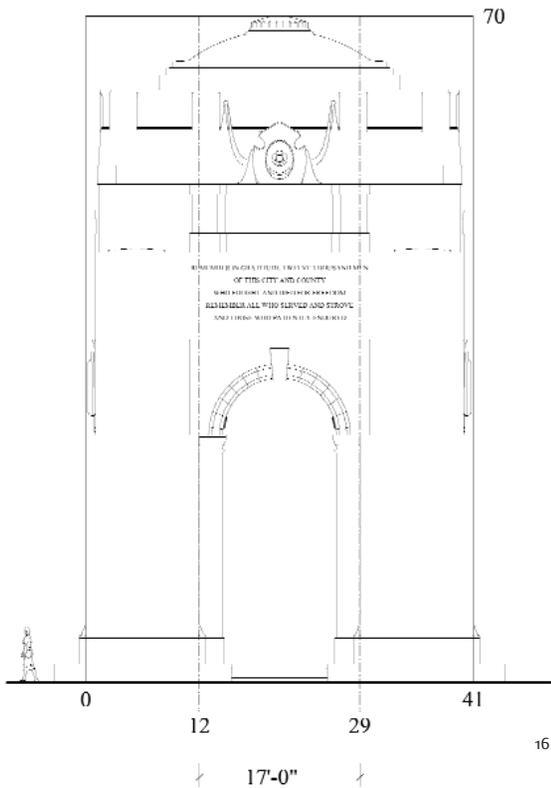
to do so one inevitably comes across Pell's series, the significance of which would not be lost on someone who was both mathematically literate and interested in the application of $\sqrt{2}$ geometry. Dudeney created a number of similar root 2 problems which were also published and show that the mathematics of Pell's equation was in the public domain at the time Lutyens was developing and refining his 'elemental mode' of design.⁵⁷

We suggest here that it is highly probable that Lutyens was aware of Pell's series principally through his knowledge of the work of Sir Christopher Wren or through his fascination with number puzzles and perhaps most likely through a combination of the two. We also suggest here that aspects of Lutyens' character and the context within which he worked would have imbued these kinds of mathematical games as applied to architectural design with a deeply philosophical or almost spiritual significance. For this reason it is not unreasonable to examine how Lutyens may have used Pell's series in the 'elemental mode' that characterises the work of the second half of his career. In the remainder of this article we do so by considering the design of the Leicester Arch of Remembrance and suggest that just as it is correct to view the designs for St. Paul's Cathedral as Wren's attempts to embody in stone a conception of natural beauty and the laws of nature as they were then being revealed by the new science in the early eighteenth century, Lutyens' use of Pell numbers in his 'elemental mode' was a similar attempt to express universal truths as he saw them in the early twentieth century.

The analysis

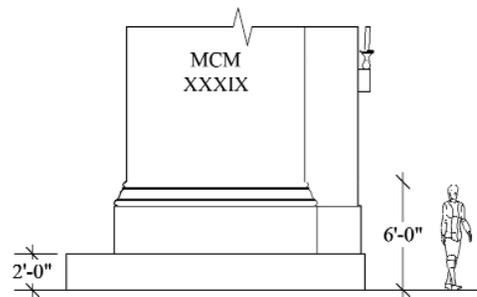
In his book *Sir Edwin Lutyens: An Appreciation in Perspective*, his son Robert Lutyens describes a conceptual geometric framework he calls an 'Armature of Planes' which by using a fictional example he illustrates as a formal means of





- 14 The Leicester Arch of Remembrance within an Armature of Planes (after Robert Lutyens, *Sir Edwin Lutyens: An Appreciation in Perspective*, p. 62). Dimension OA is divided into 11 equal units. In the Leicester Arch of Remembrance OA = 22ft and each equal unit is $\sqrt{2}$ ft
- 15 Table of Pell's series showing the diagonal of successively descending bases, with the Pell number 22 at its centre. It is germane that the principal dimensions of the memorial can be contained within a diagonal of a specifically 5 x 5 (square) matrix
- 16 Side facade showing the principal horizontal dimensions conforming to Pell's series
- 17 Main facade (half only) showing Pell's series dimensions
- 18 The base, plinth and moulding of the memorial, main facade

Base	Unit	Terms				
		01	02	03	04	05
0	1	2	5	12	29	70
1	1	3	7	17	41	99
2	1	4	9	22	53	128
3	1	5	11	27	65	157
4	1	6	13	32	77	186



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understanding the architectural composition of his father's later work. The Armature of Planes is essentially a simple three-dimensional matrix of planes arranged horizontally in arithmetical sequence and vertically in geometric sequences related to the horizontal sequences, which define three-dimensional 'cells' of space. These 'cells' may be empty space or contain a solid portion of the building. The solid cells taken together define the building, those that are empty, the space within and around the building.

Several commentators have cast doubt upon whether Sir Edwin Lutyens himself conceived of his work in this way, and it has been dismissed as a somewhat over-elaborate attempt to formalise what is claimed to be a much more pragmatic process of design development. However there are several aspects of Robert Lutyens' description of the Armature of Planes which bear a close similarity to the dimensioning and composition of the Leicester Arch of Remembrance. We do not suggest here that Sir Edwin Lutyens therefore used the Armature as described by his son in his conception and

development of the design, rather we will suggest that the Armature is one way of partially describing, geometrically, the use of Pell's series as an analytical framework for coordinating the dimensioning of the design which Sir Edwin did use.

In his book Robert Lutyens begins his description of the Armature of Planes with the statement, 'There are twenty-two equal units in each of the three dimensions [...]'.⁵⁸ The overall dimension of the main facade of the Leicester Arch of Remembrance is 44ft which can be divided into 22 units of 2ft each and so conforms to his description of an arithmetic sequence based on the number 22 being used to initiate the horizontal layout of a facade [14]. However, the main side dimension is 41ft and the height is 70ft, neither of which is commensurable by integers with the 'twenty two equal units'.

The apparent difficulty of reconciling the design of the Arch with the Armature is overcome if we accept that Robert Lutyens' description of the Armature was a generic one intended to illustrate a basic concept but one capable of extensive adaptation and evolution, and that beyond the basic concept of

form-making in a cellular manner all he is really telling us is that the number 22 is important in starting off a design (he does not mention any other dimensions apart from 11 as a half of 22 and the 12 vertical planes separating the 11 equal units). The question arises as to why the choice of the number 22. If we look at its position within Pell's series, a pattern emerges [15].

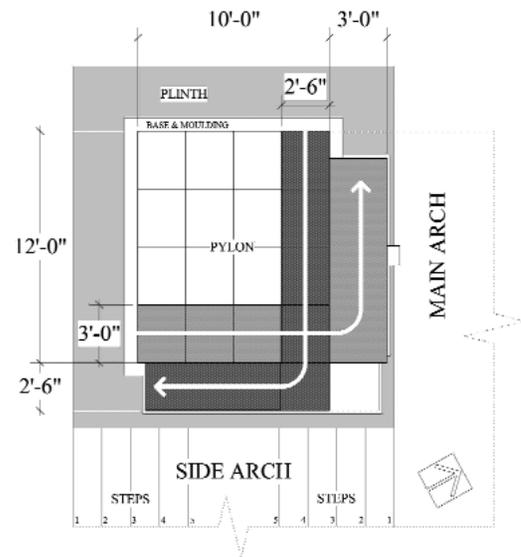
The number 22 is base 2 and term 3 of the Pell series and forms the first of a diagonal sequence of three successive terms from successively descending bases. The overall dimension of the side of the memorial is 41ft (base 1 term 4) and the overall height of the memorial is 70ft (base 0, term 5) [16]. The fit between the terms and the design of the memorial appears to be good if we accept a doubling of the 22 to yield 44 for the dimension of the main facade. This is more reasonable than might at first appear.

After describing the 'twenty two equal units' Robert Lutyens goes on to state that on his diagram and the one presented here [14], [...] at the bottom, on the left, are indicated eleven equal units [...] in other words half the facade. He goes on to explain, 'As the building is symmetrical the series repeats in the reverse order, but is not shown'.⁵⁹ If you accept that, in a symmetrical building you may design only half the facade and that the other half will be its

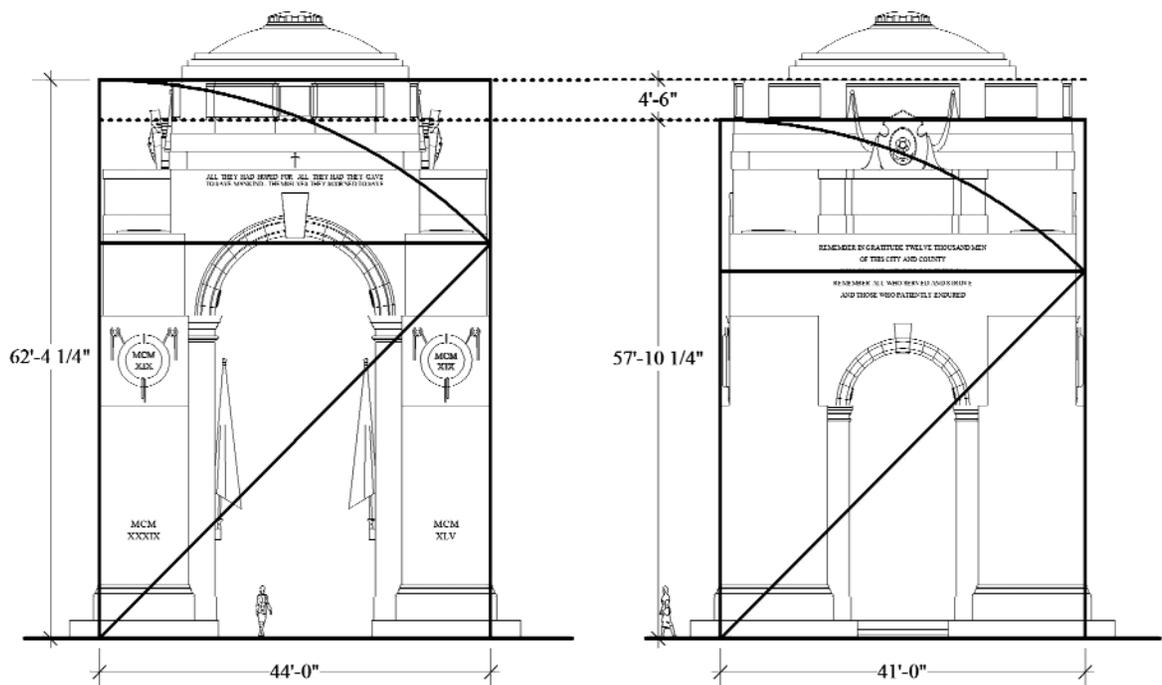
horizontal reflection (we will return to the notion of reflection later), then you can arguably apply the Pell series to one half of the elevation rather than the whole. This in fact appears to have been the case on the main facade of the memorial where terms 2 and 3 of base 2 (Pell numbers 9 & 22) require the start of the dimensioning to be at the centre-line of the main arch [17]. Lutyens may have seen this as a practical expedient to overcome the rapid increase in the value of terms in the θ series which only yields a maximum of 5 Pell numbers to any base within 0 and 44ft as opposed to say the ϕ series which yields a maximum of 8 Fibonacci numbers to any base within same range. By applying the 5 Pell numbers to half the facade and doubling it, Lutyens in effect increases the number of terms available for use as preferred dimensions. The alternative is true of the

19 The principal horizontal dimensions of the pylons when divided by 4 are translated by reflection through 90° into the widths of the columns of the arches on the perpendicular facades

20 The main and side elevations conform to $\sqrt{2}$ rectangles, the difference in height generated by the difference in length of sides being the height of the attic entablature which contains the only aperture (or window) into the memorial



19



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side facade where the dimensioning appears to begin at one end. In both cases the outer edges of what may be termed the 'columns' of the arches are defined by a second series of Pell numbers of a different base. In the main facade the outer edge of the column is at 12ft (base 0, term 3) and in the side facade the outer edges occur at 12ft (again base 0, term 3) and 29ft (base 0, term 4).

It now becomes apparent why the horizontal dimension of the side and the vertical height of the monument do not conform to Robert Lutyens' proscription of 'twenty-two equal units in each of the three dimensions'. They are in fact conforming to the geometric $\sqrt{2}$ progression of Pell's series in each of the three dimensions, one of which (the main facade) is also in simple arithmetic progression of 11 x 2ft units in the manner of 22 equal units he describes. One could consider this a more subtle evolution of the basic concepts of the armature of planes, or that the armature was a rather incomplete and/or generic description.

To return to the Pell series it will be seen [15] that the number 11 (the number of equal units in half an elevation as Robert Lutyens describes) lies upon the same diagonal but in the ascending base value and is followed by the number 6. Coincidentally, if one adds the base number to the term number +1 for each of these terms on the diagonal, the answer is always 6 (e.g. [base] 5 + [Term+1] 1 = 6, [base] 4 + [Term+1] 2 = 6, [base] 3 + [Term+1] 3 = 6, etc.). If you omit the +1 to the term the answer is always 5. The number 22 at the centre of this 5 x 5 matrix of Pell numbers has an inevitability of arithmetic and graphical logic which may well have had an aesthetic appeal to an architect seeking a starting point for the coordination of the dimensioning of a building.

Of further symbolic interest is the fact that the combined height of the plinth, the pylon base and its moulding is 6ft, not only the starting point (base 4, term 1) of the diagonal sequence of Pell numbers already noted but also a common approximation for the height of a person, an approximation which has been used by architects in the past, particularly those working with proportional theory [18]. Also, if $\theta = 1 + \sqrt{2} = 2.414$ then $\theta^2 = 5.827$, which if we call numbers, feet, places θ^2 within 2.9% of 6ft, thus reasonably closely relating the human dimension directly to the θ series. You may speculate that Lutyens was in fact grounding the design in the Humanist tradition by imbuing the part of the monument in closest proximity to the observer with a well-known dimension related to human scale while with the same number simultaneously signalling the first term in the diagonal of the Pell series to be used in the generation of the principal dimensions of the memorial. It should also be noted that the first term of Pell's series (base 1, term 1) is the number 2. As the smallest of the Pell numbers it is embodied not only as the fundamental unit of horizontal dimensioning on the main facade ($(2 \times 11 = 22) \times 2 = 44$), but is also in the vertical direction the height of the plinth at the base of the monument upon which the bases of the pylons and indeed the rest of the memorial rests.

Having established a means by which the

individual facades could have been laid out in the horizontal plane, the question arises as to how the two different elevations relate to one another. If we examine the plan form of one of the pylons [19] we see that the main pylon is 10ft x 12ft. If we divide each of these sides by 4 we may show a grid of 16 cells each of 3ft by 2ft 6in. By a process of translation through 90° the dimension of the side of any one of these cells produces the horizontal width of what may be termed the 'column' of the arch on the perpendicular facade, specifically a 'column' width of 3ft on the main facade and 2ft 6in on the side facade.

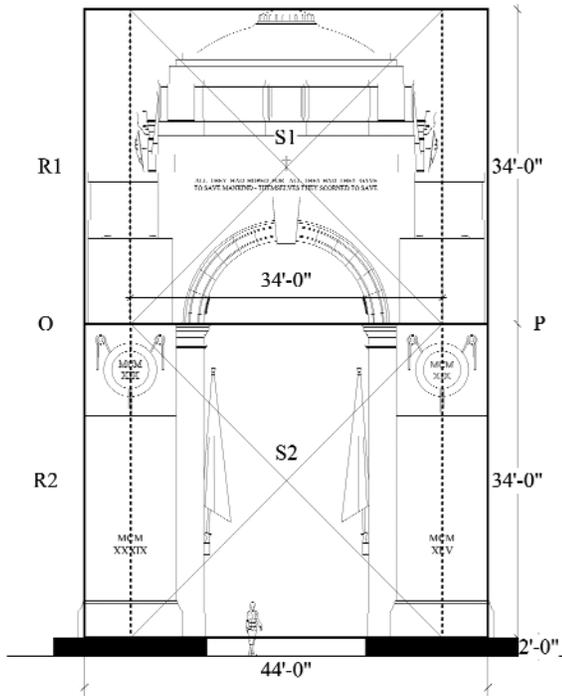
This divisional device is a significant generator of the design in that not only is the 'column' width determined by $\frac{1}{4}$ of the width of the perpendicular face of the pylon but the height of the imposts is determined by $\frac{1}{4}$ of the radii of the arches with which they are associated. Specifically the radius of the main arch is 9ft which is divided by 4 to yield the impost height of 2ft 3in, and the same $\frac{1}{4}$ division is carried out on the side arch of radius 6ft yielding an impost height of 1ft 6in.

The dimensioning of the memorial in the vertical direction follows Robert Lutyens' rubric that, 'In a vertical direction, however, the major planes are usually at intervals in geometrical progression, forming a closed sequence, incapable of extension'.⁶⁰ If we consider the two facades we may see that the overall proportioning of both is based on $\sqrt{2}$ rectangles of the length of their sides [20]. The difference in the height of the $\sqrt{2}$ rectangles defines the height of the entablature of the attic.

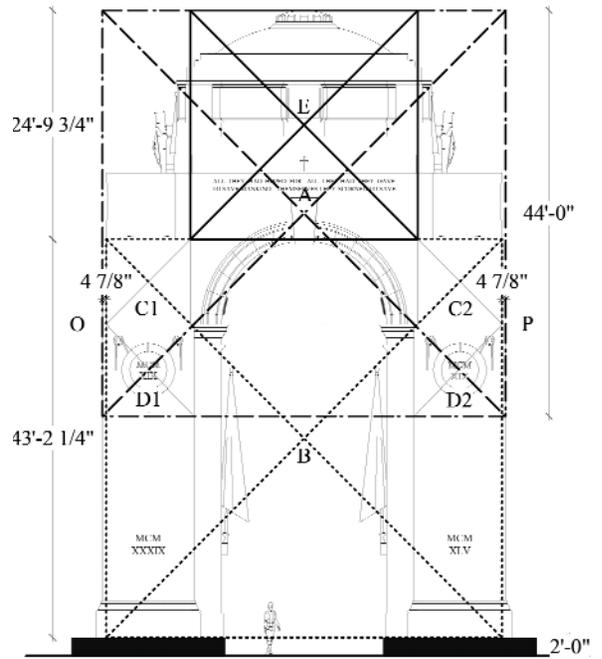
Beyond this the composition becomes more complex and is predicated upon achieving a degree of vertical symmetry, an issue which has traditionally been viewed as problematic. Straightforward reflection in a horizontal plane of a composition from the lower half of an elevation to the upper half creates an overall elevation that appears top heavy and unstable. Visual concepts of repose require a diminishment of width, a batter (slope to a wall), scarcements (offsets in width to a wall) or steps as the elevation increases in height so as to give an impression of stability. If the width of an elevation decreases with height and proportional relationships are applied that vary the heights with the widths, then overall vertical symmetry in the elevation becomes impossible. Such issues of architectural composition were widely known at the time. John Beverley Robinson had explicitly described them in some detail in a series of articles in the *Architectural Record* in 1898–99 and advocated dissimilar proportions (usually increasing with height) for reasons of 'continual variety, which is essential to grace'.⁶¹

Butler, writing in *The Substance of Architecture* notes that:

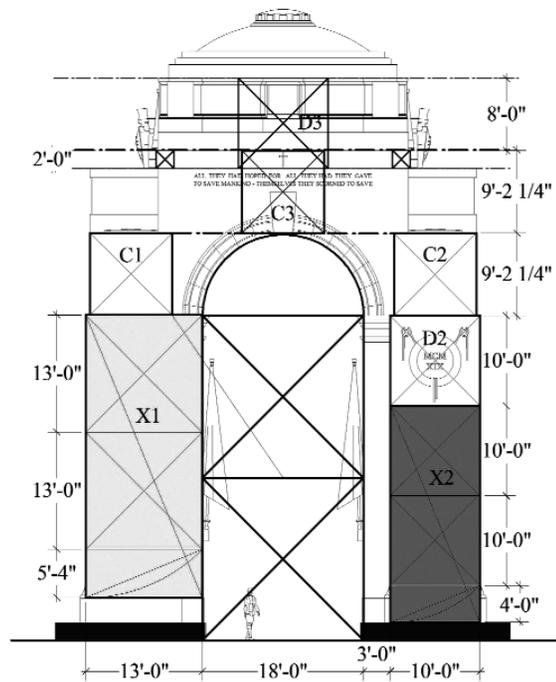
*'good proportion in architecture [is] that happy adjustment of apparent weights and apparent movements in the arrangements of lines of a composition which gives the required effect of vital stability. It is the nice allotment of emphasis on groups of lines to make comfortable masses and enjoyable rhythm.'*⁶²



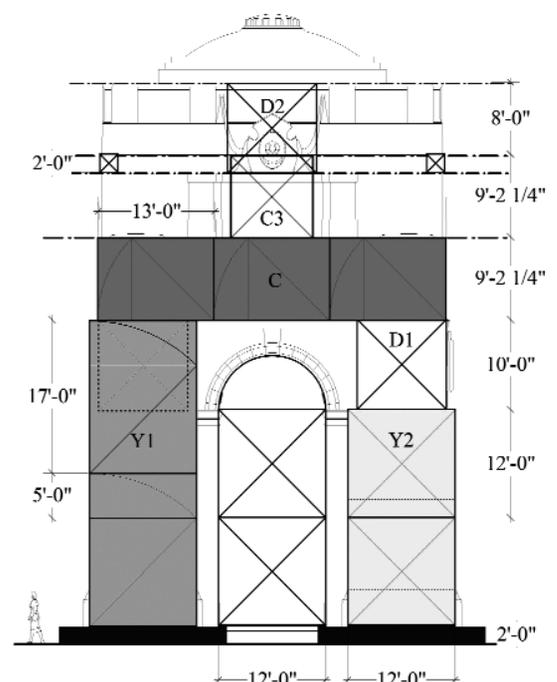
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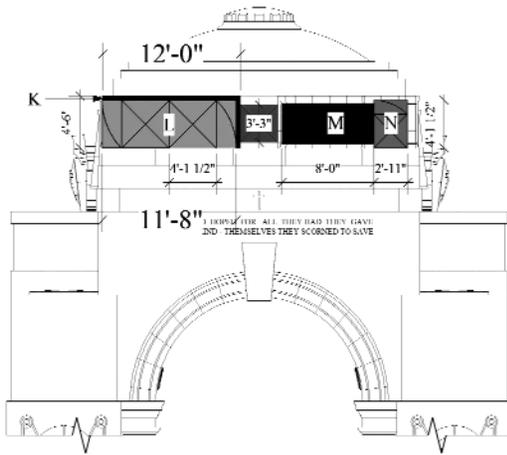


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He reminds us that repose or 'vital stability' is the appearance of harmonious unity in a building and it is achieved through an intuitive sense of proportion. Lutyens' achievement in the memorial is to establish a sense of repose in the design but by using similar $\sqrt{2}$ and θ shapes, similar proportions and by employing a form of staged or sequenced vertical symmetry by reflection and displacement about horizontal planes, rather than Robinson's compromise of dissimilar proportions.

The technique of vertical reflection in the facades begins with the horizontal bisection of the main facade at the top of the impost along line OP [21], creating two similar rectangles (R1 and R2). The

centre-lines of the pylons in this elevation define the vertical sides of two squares (S1 and S2) which are adjacent at line OP. The lower half of the memorial (below line OP) conforms on both facades to simple, adjacent square and θ rectangle geometry [22, 23] while the upper half comprising the archivolt and attic is more complex. The line OP marks a boundary and a change in horizontal dimension where the sides of the monument are displaced inwards by $4\frac{7}{8}$ " on each side. It will be noted that this dimension is $\frac{1}{32}$ of 13ft, the latter dimension being the combined widths of the main pylon (10ft) plus the width of its associated order or 'column' (3ft) on the main facade. This change in dimension is expressed



25

- 21 The main facade divided in two vertically equal halves at line OP
- 22 The main facade showing the formation of the pylons using θ rectangles and the formation of the attic height by reflecting and translating pylon squares and governing their overlap by a key dimension
- 23 The side facade showing formation of the pylons and 'lintel' using squares and $\sqrt{2}$ rectangles. Also the formation of the attic heights by the overlapping of the squares by the smallest Pell number
- 24 Main facade showing the height of the memorial defined by the setback of $4 \frac{7}{8}$ "
- 25 The main compositional components of the attic entablature
- 26 Table showing the proximity of the actual dimensions of the compositional rectangles shown in the facade to those calculated from their short sides

in the dimension of squares C1 and C2 [24] which are $9' 2 \frac{1}{4}"$ on a side. The height from the top of the base to the top square C1 is $43' 2 \frac{1}{4}"$, the same as the distance between the two outside edges of squares C1 and C2 [24] forming a square B. The height of the memorial from the base of square D1 is 44' which is the width of the monument at the main pylons and forms square A. These squares overlap by the combined heights of squares C1 and D1. Lutyens has effectively used squares C1 and D1 to control the amount of overlap of squares A and B such that the width of the lower part of the monument defines the height of its upper part and the width of the upper part defines the width of its lower part, to yield an overall height of the Pell number 70 (feet).

The same technique of using a controlling dimension to govern the distance of overlap of two squares is again used to determine the principal vertical dimensions of the attic. Squares C2 and D2 may be translated and reflected about the line connecting the upper corners of C1 and C2 to the positions of similar squares C3 and D3 [22]. Here they are overlapped by the distance of 2ft, the smallest Pell number which is expressed visually by the

height of the prominent string-course which defines a horizontal mid-band of the attic facade.

Within the overall horizontal and vertical dimensioning of the facades the pylons can be composed of geometrically related rectangles and squares. In the main facade [22] similar θ rectangles X1 and X2 may be used to define the dimensions of the main pylons. In the side facade the pylons can be alternatively defined by $\sqrt{2}$ rectangles Y1 or by squares Y2 and D1. The attic entablature on the main facade serves to demonstrate Lutyens' compositional use of similar rectangles at a smaller scale [25].

It will be noted that in both facades the dimensions of the rectangles are very close integer approximations (in whole feet and whole inches) to what should be irrational dimensions were they to be constructed entirely geometrically. The degree to which they approximate a numerically accurate solution is given in figure [26].

In most cases the differences are small enough to be visually undetectable, however further analysis at a detailed level is required to examine the degree of conformity of smaller parts of the design to $\sqrt{2}$ and θ rectangle geometry, particularly those of the entablature of the attic facades.

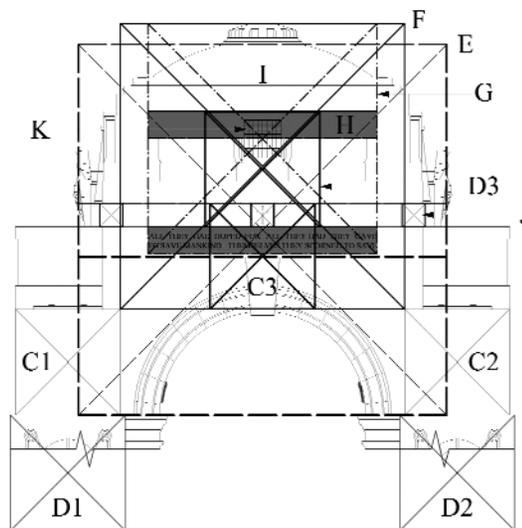
The detailed evolution of the vertical dimensions of the attic shows that the composition is made up of squares E, F and G [27]. The line OP provides the base line for square E which is a multiple of square C1 ($9' 2 \frac{1}{4}"$ on a side) [28]. Line OP displaced upwards by the height of square C1 provides the baseline for square F whose side is the horizontal distance between squares C1 and C2. The difference between the top of squares E and F defines the height of the cap on the saucer dome. The horizontal mid-band of square E contains the prominent string-course and a dedicatory inscription. The overlapped squares C3 and D3 are overlapped by the distance defined by square J and serve to define the height of the uppermost extent of the attic entablature. The top of square G is coincident with that of square F and its centre defines the centre of the attic window K which is $3' 3"$ square, a dimension which can be divided by 8 to yield the initial offset dimension of $4 \frac{7}{8}"$. Square G has further vertical similarity as shown by the use of square D3 to define the height of a rectangle H1 within rectangle I which is then repeated in the lower half of square G, the H2 rectangle which contains the dedicatory inscription on this facade. Square J centrally located in the facade of the attic and defining the distance of overlap of squares C3 and D3 contains a simple inscribed crucifix on the SE facade and an inscribed figure of a 13-pointed crown on the NW facade.

Rectangle Identifier	Short Side			Calculated Long (Root 2) Side	Actual Long (Root 2) Side	Difference	Difference
	Ft	In	Ft (decimal)	(Ft, decimal)	(Ft, decimal)	(Ft, decimal)	%
x1	13	0	13	18.384776	18.333333	0.051442978	0.40
y1	12	0	12	16.970563	17	-0.029437252	-0.25
x2	10	0	10	14.142136	14	0.142135624	1.42
c	9	2.25	9.1875	12.993087	12.6875	0.305587104	3.40

26

For the purposes of demonstrating a coherent set of techniques which Lutyens may have used as a method in the design of the Leicester Arch we believe the foregoing form adequate examples at this stage. The principles of this method may be summarised as: overall dimensioning using Pell numbers; the square as the prime generative figure both geometrically and analytically; reflection; overlap and translation.

Clearly the analysis could be extended to further levels of detail within this building and we believe that there are sound reasons for doing so. First, the degree to which the design conforms to these principal methods at a smaller scale is not known but would have been important to Lutyens both at an intellectual and a practical level. Second, the coherence between the dimensions Lutyens gives for the memorial and the geometric figures we have derived from them, specifically the small differences between the irrational dimensions one would expect from an analytical application of $\sqrt{2}$ geometry and the apparent rounding to rational feet, inches and fractional inches (generally to $\frac{1}{8}$ th) which Lutyens appears to have adopted, requires further explanation, possibly within the context of Pell's series.



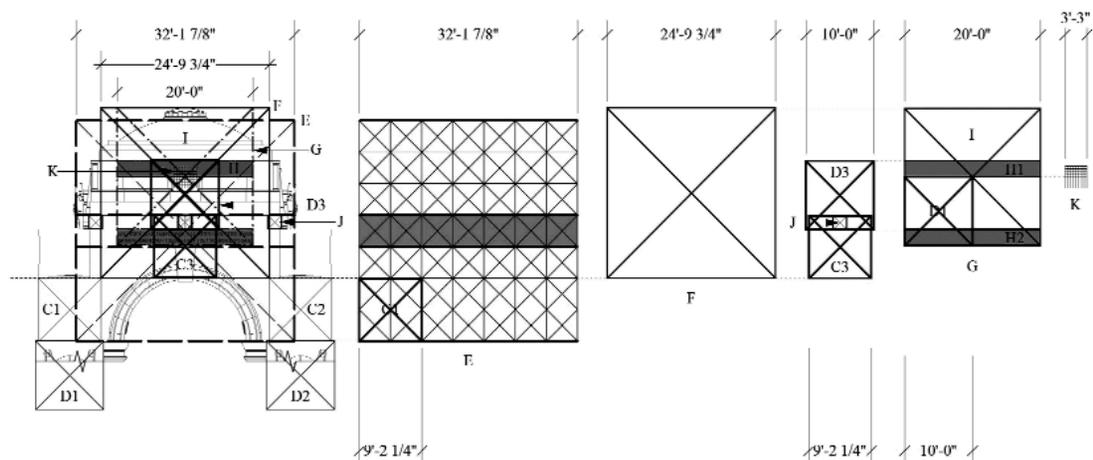
27

Conclusion

Our purpose in undertaking this study was first and foremost to bring the geometry and dimensions of the Leicester Arch more fully into the public realm in order to encourage informed debate about, and analysis of its design as we believe it is a particularly unadulterated example of Lutyens designing in his 'elemental mode'. In doing so we have presented historical evidence which demonstrates a social and a personal context which would predispose Lutyens towards the use of an analytical design method. We have presented evidence which supports our hypothesis that he was aware of and used Pell's series as part of an analytical method of dimensioning and we have presented a series of related principles of architectural composition which plausibly explain how Lutyens may have 'grown' his design for the Leicester Arch towards closed dimensional goals in a way which fits with what we know of his personal beliefs and his predispositions towards mathematics. We suggest here that it is very probable that he may have discovered the value of Pell numbers for architectural design through a study of Wren's Great Model and that he may have to some extent been predisposed to do so by his interest in number puzzles and exposure to them in the popular press. We also suggest that Lutyens' character may have led him to imbue number games in architecture with a particular philosophical, almost religious significance and that in total the appeal to him of Pell numbers as an attractive and useful aid to architectural design is hard to ignore. All this is in the nature of a key towards further study of his work and provides a demonstration of what Lutyens termed the 'high game' of architecture.

27 Main facade of the attic showing the principal compositional components

28 The sequence of assembly of squares to achieve the configuration of the attic



28

Notes

1. Christopher Hussey, *The Life of Sir Edwin Lutyens (Special Edition)* (London: Country Life, 1953; repr. by Woodbridge, Suffolk: Antique Collectors Club, 1989), p. 462.
2. *Ibid.*, p. xi.
3. Colin Amery, 'Introduction', in *Lutyens: The Work of the English Architect Sir Edwin Lutyens (1869–1944)*, catalogue of exhibition held at Hayward Gallery London SE1, 18 November 1981 – 31 January 1982 (London: Arts Council of Great Britain, 1981), pp. 8–10 (p. 9).
4. Edwin Lutyens, 'Foreword', in Arthur S. G. Butler, *The Substance of Architecture* (London: Constable, 1926), p. vii.
5. Mary Lutyens, *Edwin Lutyens: By his Daughter*, rev. edn. (London: Black Swan, 1991), p. 80.
6. Hussey, p. 586.
7. Andrew Saint, *Richard Norman Shaw* (New Haven: Yale University Press for the Paul Mellon Centre for Studies in British Art, 1976), p. 315.
8. Hussey, p. 166.
9. Jane Brown, 'Gertrude Jekyll and the Pattern of Partnership', in *Lutyens: The Work of the English Architect*, pp. 17–24.
10. Hussey, p. 531.
11. *Ibid.*, p. 53.
12. See for example Sissi Castellano, 'Sir Edwin Lutyens e i cimiteri della grande guerra nel nord della francia: the silent cities' (Sir Edwin Lutyens and the Great War Cemeteries in the North of France: The Silent Cities), *Casabella*, 64.675 (2000), 6–27.
13. Hussey, p. 462.
14. Unknown, *Illustrated Leicester Chronicle*, 1919.
15. Helen Boynton, *The History of Victoria Park, Leicester and its Surrounding Areas* (Leicester: Helen Boynton, 2000), p. 20.
16. Unknown, *Illustrated Leicester Chronicle*, 19 May 1923.
17. Sir Edwin Lutyens (Leicestershire County Records Office, Leicester, 1923).
18. Unknown, *Leicester Advertiser*, 24 June 1925.
19. Boynton, p. 20.
20. Hussey, p. 475.
21. Margaret Richardson, *Sketches by Edwin Lutyens*, RIBA Drawings Monographs, no. 1 (London; New York: Academy Editions in collaboration with the Royal Institute of British Architects, 1994), p. 17.
22. *Ibid.*, p. 18.
23. Gavin Stamp, *The Memorial to the Missing of the Somme* (London: Profile, 2006), p. 132.
24. Mary Lutyens, *Edwin Lutyens: By his Daughter*, p. 16.
25. *Ibid.*, p. 138.
26. *Ibid.*, p. 288.
27. *Ibid.*, p. 109.
28. Robert Lutyens, *Sir Edwin Lutyens: An Appreciation in Perspective: By his Son* (London: Country Life, 1942), p. 58.
29. Mary Lutyens, *Edwin Lutyens: By his Daughter*, p. 281.
30. Unknown, *Leicester Advertiser*, 24 June 1925.
31. *Lutyens: The Work of the English Architect*, p. 196.
32. Philip Steadman, 'Lutyens's Proportional System: An Analysis Analyzed', *arq*, 3/4 (1999), 295–296.
33. *Lutyens: The Work of the English Architect*, p. 198.
34. Richard A. Fellows, *Sir Reginald Blomfield: An Edwardian Architect* (London: Zwemmer, 1985), p. 175.
35. Lutyens, in Butler, p. vii.
36. Butler, p. 309.
37. *Ibid.*, p. 310.
38. *Ibid.*; and see pp. 82–91.
39. *Ibid.*, p. 312.
40. Quoted in Hussey, p. 557.
41. Peter H. Scholfield, *The Theory of Proportion in Architecture* (Cambridge: Cambridge University Press, 1958), p. 12.
42. James S. Ackerman, "'Ars Sine Scientia Nihil Est": Gothic Theory of Architecture at the Cathedral of Milan', in *Distance Points: Essays in Theory and Renaissance Art and Architecture* (Cambridge, MA: MIT Press, 1991), pp. 211–268.
43. Robert Tavernor, *On Alberti and the Art of Building* (New Haven: Yale University Press, 1998), pp. 127–146.
44. Noel Malcolm and Jacqueline Stedall, *John Pell (1611–1685) and his Correspondence with Sir Charles Cavendish: The Mental World of an Early Modern Mathematician* (Oxford: Oxford University Press, 2005), p. 141.
45. *Ibid.*, p. 211.
46. James A. Bennett, *The Mathematical Science of Christopher Wren*, 1st edn. (Cambridge: Cambridge University Press, 1982), p. 120.
47. Christopher Wren Jr. and Stephen Wren, *Parentalia: Or Memoirs of the Family of the Wrens ... Chiefly of Sir C. Wren ...* (London: 1750), reprinted in condensed form as *Life and Works of Sir Christopher Wren from the Parentalia, or Memoires of his Son Christopher*, ed. by Ernest J. Enthoven (London, 1903).
48. *Ibid.*
49. Vaughan Hart, *St. Paul's Cathedral: Sir Christopher Wren* (London: Phaidon, 1995), p. 13.
50. Tavernor, pp. 127–146.
51. Quoted in Hussey, pp. 121–122.
52. Hussey, p. 141.
53. Mary Lutyens, *Edwin Lutyens: By his Daughter*, p. 80.
54. John Rollo, 'Metiando Vivendum: "by measure we must live"', *arq*, 3/2 (1999), 147–163 (p. 159); Jane Ridley, *Edwin Lutyens: His Life, his Wife, his Work* (London: Pimlico, 2003), p. 51; Hussey, pp. 163–164.
55. Mary Lutyens, 'Sir Edwin Lutyens', in *Lutyens: The Work of the English Architect*, pp. 11–16.
56. Mary Lutyens, *Edwin Lutyens: By his Daughter*, p. 16.
57. Henry E. Dudeney, *Amusements in Mathematics* (London: Thomas Nelson and Sons, 1917), p. 258.
58. Robert Lutyens, p. 63.
59. *Ibid.*
60. *Ibid.*
61. John Beverley Robinson, *Architectural Record*, VIII (1898–9) 1–25; 181–223; 297–331; 434–465.
62. Butler, p. 91. See also pp. 82–91.

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