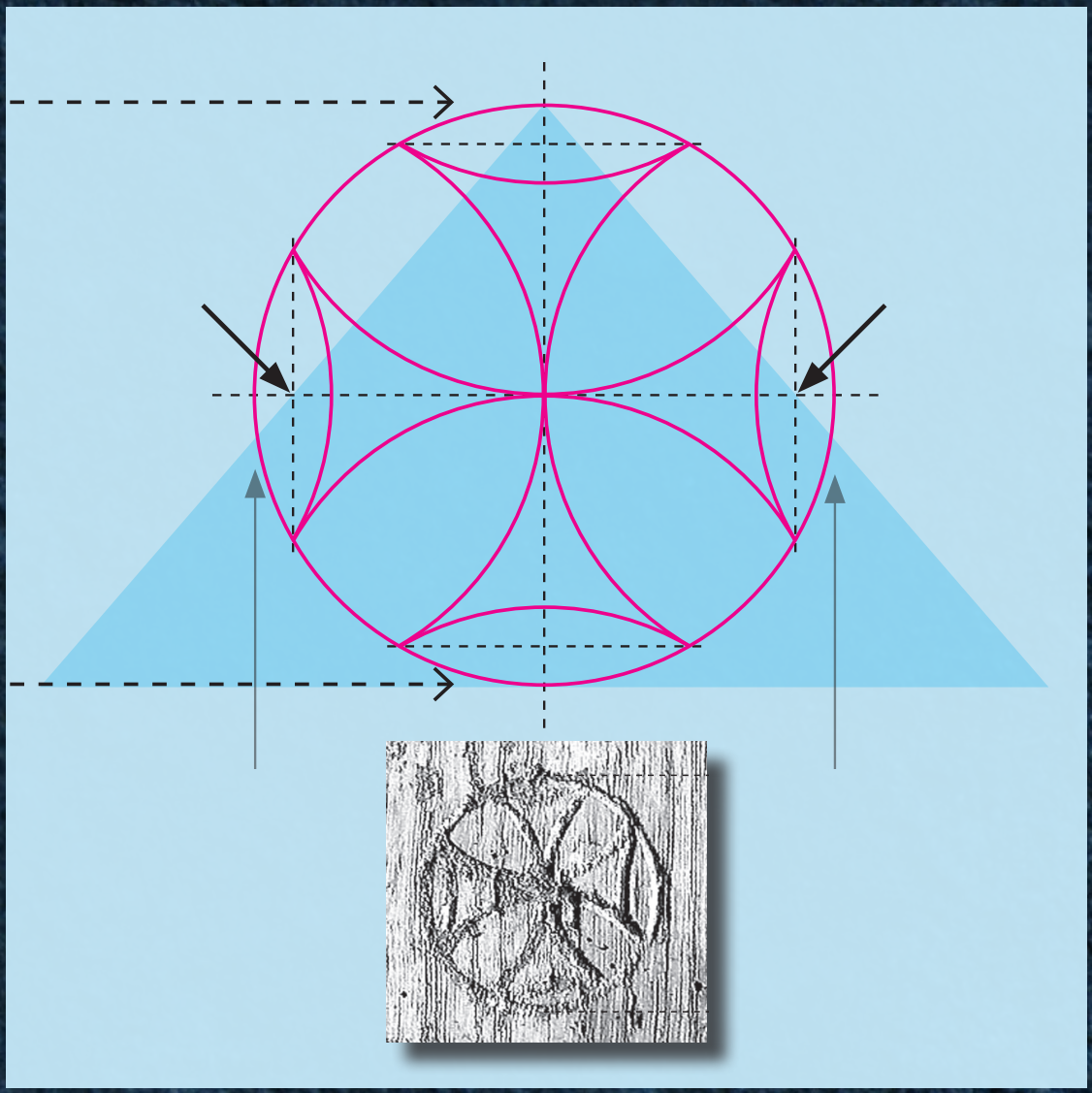
An Anglo-American Geometrical Design Dialogue



Laurie SMITH

HISTORICBUILDINGGEOMETRY

The text* was written jointly by
Rick and Nicole Collins
and Laurie Smith
who were fed and watered
during their dialogue
by Hilary Smith.

Laurie Smith is an independent early-building design researcher, specialising in geometrical design systems. Because geometry was part of the medieval educational curriculum he uses geometrical analysis to excavate and recover the design methodologies of the past, a process he thinks of as design archaeology. He lectures, writes and runs practical workshops on geometrical design and publishes his work through his website HISTORIC BUILDING GEOMETRY.

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A Geometrical Design Dialogue

The text records four days of drawing and dialogue under each speaker's name in turn

Laurie

Before flying to the UK for Frame 2013 at Cressing Temple in Essex, Rick and Nicole Collins requested a period of geometrical study and revision with me so after Frame we shared the return car journey back to my home in Devon.

Rick's introduction

I first heard the term "daisy wheel" through a Carpenters Fellowship offering in 2008. For years I had been fascinated by the buildings I'd been working on in rural Illinois. Timber framing began in Illinois with the French settlers around 1680 and continued almost uninterrupted until the early 20th century. The vast forests of the Midwest had supplied Europeans and Americans with what had appeared to be an inexhaustible supply of building materials. In these timber frame structures the outward appearance and frame construction always followed some basic design rules. Whether early French buildings, early 19th century German fachwerk frames or late American timber frames It became easy for me to date structures, by observing these rules and the materials used. Part of what I had unknowingly discovered revolved around proportional changes. Changes not only in materials but sizes of framing materials, locations of windows and roof pitches. There was something there, and I couldn't put my finger on it. One of the main things I noticed was how many structures were based on an agricultural unit of measure called the Rod. Often a wall height might be 16' 6" tall and a building might be 33' wide for example.

Laurie

33' is the first whole number in a series of fractions: 33' - 16^{1}/2 - 8^{1}/4 - 4^{1}/8 - 2^{1}/16 - 1^{1}/32. Each fraction is half its greater and double its smaller neighbouring fractions. This makes the sequence perfect for compass geometry where the radius and diameter of a circle are in the same half and double relationship. 33' divided into half gives the 16'6" medieval Rod which, divided into thirds, also gives 11' and 5'6". These dimensions feature strongly in medieval buildings. Ely Cathedral's nave is 77' across internally, 88' across externally with walls 5'6" thick and foundations 5' 6" deep. Salisbury Cathedral is 99' across its western facade.

Rick's introduction continued

I had heard someone speak years ago about something called regulatory lines. What the presenter didn't know, and I what I came to learn later from Laurie was that this was a very simple explanation for a much deeper and much more interesting topic. The term regulatory lines is a simple way to explain how windows and doors need to line up with diagonal line across a particular elevation. (see picture). What Laurie has brought forward is so much more; a system that calls out building specifications down to detailing the timber dimensions themselves. My time working on the Gardener's Shelter taught me the beginnings of this new language, and I feel that the time we spent with Laurie, immediately following August 2013 Frame, tied up some loose ends and has set me on the path of learning more. It was interesting and timely to attend a presentation at Cressing by Mathieu Peeters, a Danish carpenter who had been studying Japanese carpentry at a shop in California. His presentation introduced the origins and applications of Japanese layout methods. Most interesting in all of this was the concept of Kiwari - or the study of proportion. As he spoke of timber sizing, he explained that what had drawn him to Japanese carpentry was the level of detail, especially how timber sizes were ratios and related to the entire structure. He suggested – but did not say - that this intricate level of thought did not exist in Europe. I, however, disagree – I think we have forgotten it. Laurie is helping carpenters today to remember it - helping us learn this forgotten universal language again, the language of all craft, of design, of method . . . . .

Laurie

A perfect example of timber sizing from the daisy wheel can be found in the design of the aisled hall, Tŷ Mawr at Castle Caereinion, Montgomeryshire. A daisy wheel 1 Rod in diameter determines the width of the building's nave. A hexagon drawn between the wheel's six petal tips generates six spaces between the hexagon and the wheel's circumference. The building's two spere posts stand precisely in two of these spaces at opposite ends of the wheel's diameter. The spere posts are octagonal from ground to the capital and cruciform above that level, figure 1.

Nicole's diary Day 1

Travel from Cressing Temple to Sutcombe in Devon. Our training began at Saint Andrews Church at Greensted juxta Ongar in Essex. This is the oldest wooden church in the world built from vertical, originally earth fast, oak staves in about 1060. The staves are half tree trunks with their diameters forming the flat interior walls, each stave rebated and joined to its neighbouring timbers by slips fixed into the rebates. Measured the surface mounted rim lock on the front door and later confirmed it conformed to daisy wheel ratios. A nice road trip across England including past Stonehenge on the A303, with a few stops along the way. Arrival at the Church Lodge. Dinner by Hilary: Homemade Pizza!!! We start our discussion of the daisy wheel that night over dinner.

Laurie

Before leaving Frame Rick and Nicole had asked to visit Greensted Church, in the maze of Essex lanes where I cycled as a youth. Inside the church we discussed the structure and proportions. Because we had no tape with us Rick paced out the nave length and width heel to toe. I measured his boot sole (13 inches) and worked out the dimensions later ~

Length 28½ Rick feet = 370½ inches = 30 feet 9 inches (to nearest whole number)
Width 16 Rick feet = 208 inches = 17 feet 4 inches (to nearest whole number)
The resulting floor rectangle can be defined by arcs using one rod swung from A and B or by triangulation from A and B using two equal rods, figure 2. The exterior and interior of the north wall are shown in figure 3.

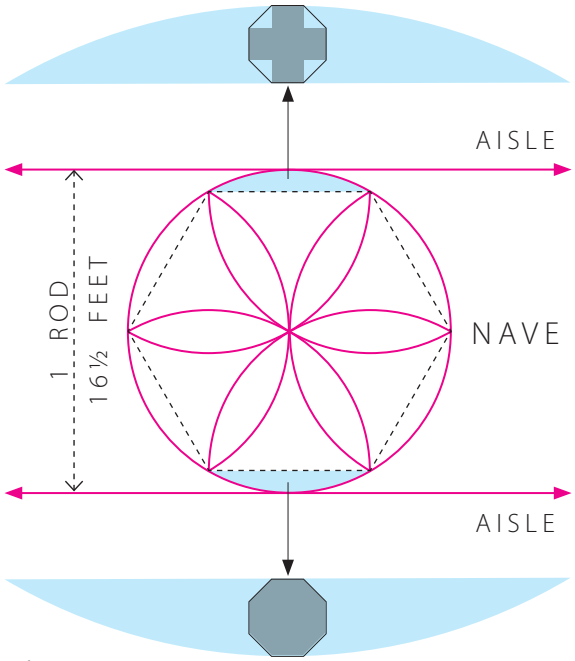


Figure 1

Timber dimensioning at Tŷ Mawr. The nave is 1 Rod wide. The daisy wheel sectors between the upper and lower petals and the full circle define the footprint of the spere posts. The upper cruciform section and lower octagonal section and are shown enlarged. The outer walls of the aisles are not shown.

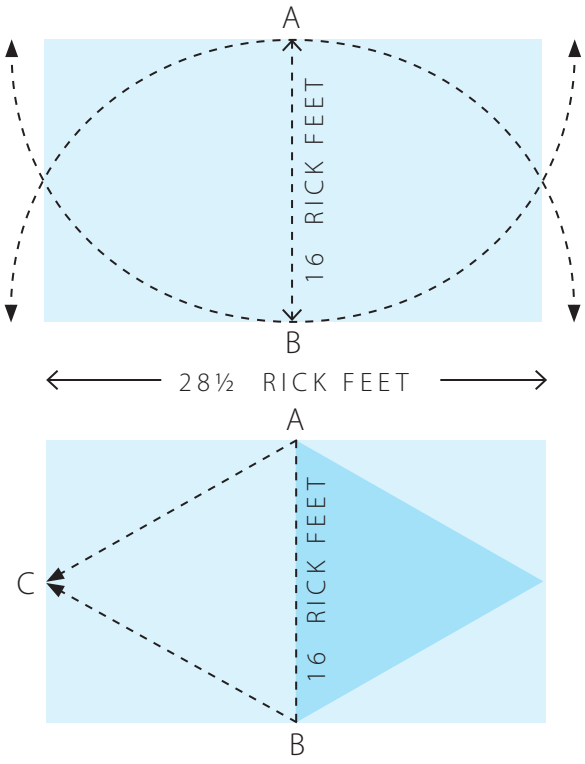


Figure 2

Laying out the proportions of Greensted Church floor using a single rod, upper drawing, and two identical rods, lower drawing. The rod length is a matter of choice.

Figure 3 Saint Andrew's Church, Greensted juxta Ongar, Essex

UPPER PICTURE The north wall of the Saxon stave church, probably originally earth-fast. In the Victorian period the presumeably rotten feet of the timbers were cut and underpinned with a brick plinth.

LOWER PICTURE The flat diameters of the halved logs line the interior of the north wall with the tiny *leper's squint* cut through the solid timber. The axe (or adze) work is clearly visible on the timbers.

Nicole's diary Day 2

Anxious to begin training, but instead, Laurie suggests we start the day with a walk down an ancient road that skirts the perimeter of the village. Laurie identifed many plants, most notably a morning glory whose flower is a perfect hexagon. I can't wait to launch into geometric design stuff . . . but as we return to Church Lodge for a phenomenal lunch by Hilary… We begin to catch on - and realize our training was already deeply under way. Laurie had been teaching us all morning about one of the things in our universe that regulate the forms of everything in it . . . geometry! More on the many ways forms are expressed or manifested, through circularity, angularity, harmonies achieved in opposites, similars, colors . . . More on the motivations of humankind to acquire knowledge, observe the visual and structural language of our world . . . and then to develop these observations in order to communicate and create deep meaning in what we construct. Laurie also speaks of the well-documented Greek and Roman ideas of symmetry and structure in building. Our discussion continues through dinner and suddenly it's 10pm.

Laurie

Circularity and angularity are the two opposing yet inter-related aspects of geometry in natural forms. We find circularity in the spheres of the Earth, sun and moon, in the section of trees and, of course, in the spheres and circular irises of our own eyes. We find angularity in the mineral world, in the triangular, square and hexagonal sections of crystals. In medieval architecture this harmony of opposites is expressed in the alternating circular and angular piers of cathedral and church arcading. The supreme example is Durham Cathedral where the circumference of the cylindrical piers is equal to their height, thus making their surface area a square. The square is set out with diagonal lines that are either chevroned, cross hatched to form a diagonal pattern of squares, figure 4, or spiralled with every line rising diagonally from the cylinder's base.

In his *Ten Books on Architecture* the Roman architect Vitruvius, who lived around the time of Christ, states that the design of a temple depends on symmetry, the principles of which are due to proportion. Proportion is a correspondence among the measures of the

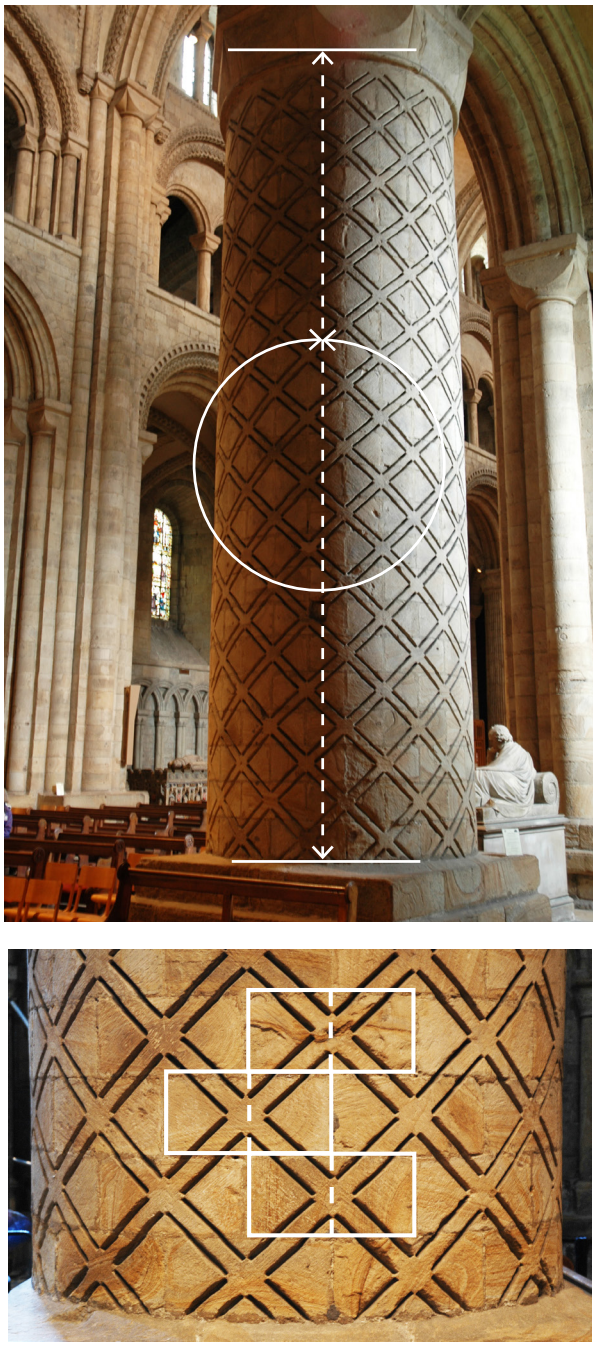


Figure 4

Durham Cathedral cylindrical pier proportions with the pier's height equal to its circumference. A simple experiment proves the point ~ cut a circle of card the same size as the circle on the pier and mark a point on the circumferece, stick a needle (axle) through the centre of the circle, start with the mark at the base of the column and wheel the circle up the arrowed line to the mark at the top. Note that in the photograph the column tapers towards the top. This is visual perspective and the real column is a true cylinder. The individual stones are double squares cut to a predetermined pattern using templates.

individual members of an entire work, and of the whole, to a certain part selected as standard. This is a similar concept to Kiwari so the intricate level of thought that Rick mentioned above was alive in Europe 2000 years ago. Leonardo da Vinci's *Vitruvian Man* shows how the human body relates to both circle and square, figure 5.

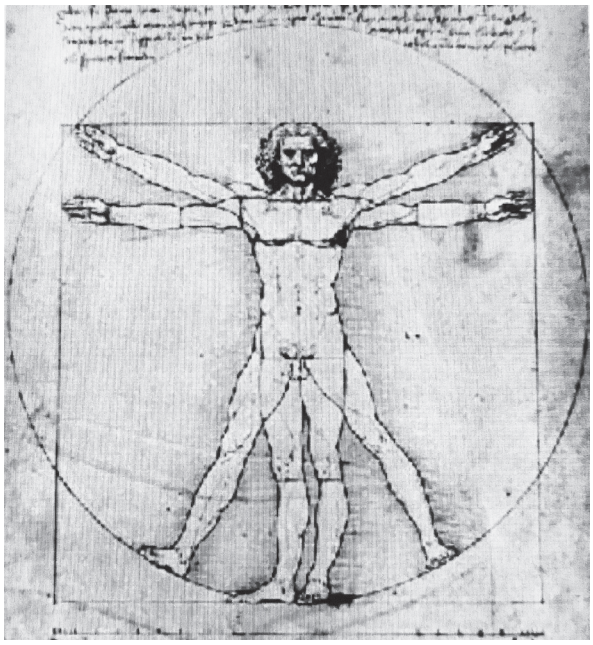


Figure 5

Leonardo da Vinci's famous drawing.

Nicole's diary Day 3

We visit Saint Andrew's church through the lych gate beside Church Lodge. We see quatrafoils in the carved oak pews; geometrical design in the windows, column capitals, placement of doors, arches…

Laurie

Saint Andrew's Church has a nave and two aisles, the Soldon and Thuborough aisles, built as chapels by wealthy local families. The Thuborough aisle, has a date stone **IB 1630 RB** set into the gable wall. There is a daisy wheel carved inside the O of 163O, figure 6. The date stone is also a design icon, a visual clue to the design method applied in the chapel's construction: the Thuborough aisle is set out to daisy wheel geometry and has a 33 feet x 19 feet footprint, exactly the same as Shackleton's NImrod Hut, a knock down kit building made in London for assembly in the Antarctic 270 years later for the 1900 expedition.

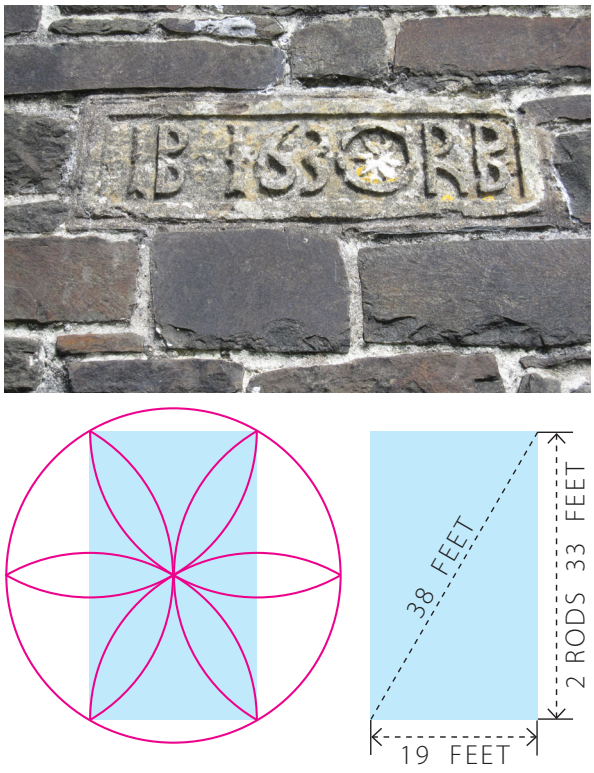


Figure 6

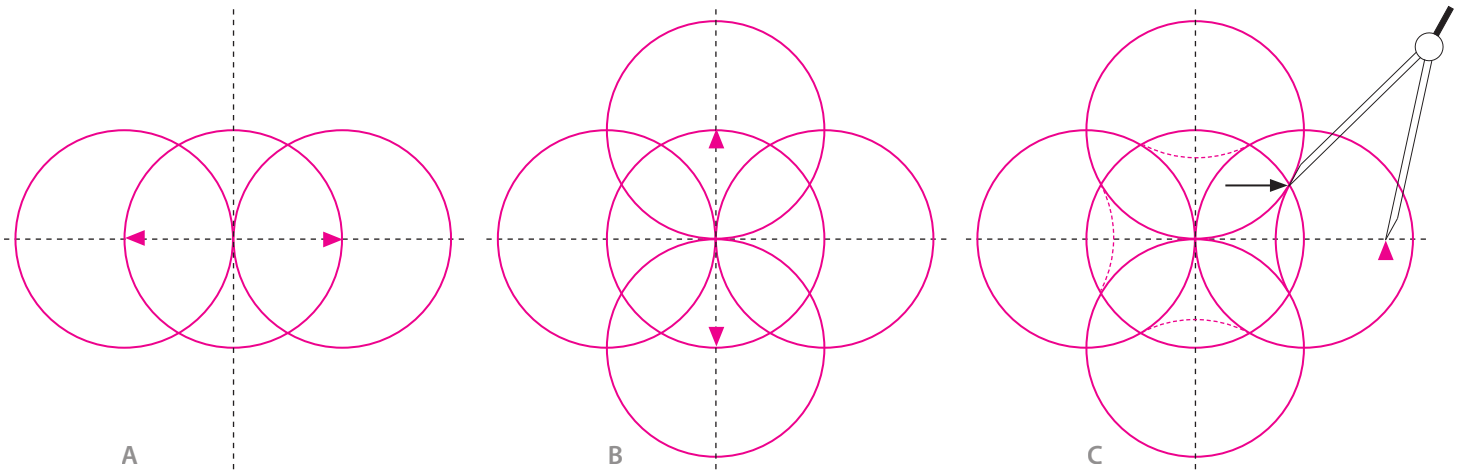
IB 1630 RB datestone and design icon set into the gable wall of the Thuburough chapel at Sutcombe Church, Devon. The chapel is laid out in daisy wheel proportions with the rectangle's long side at 33 feet (a double Rod) and short side at 19 feet. The short side equals the circle's radius so the rectangle's diagonal and circle's diameter are 19 x 2 = 38 feet.

Nicole's diary Day 3 continued

We learn about 5 circle geometry, and look at the beautiful design of a 1460s Welsh aisled hall Tŷ Mawr at Castle Caereinion in Montgomeryshire. This one clearly has its post and truss dimensions and positions called out through five-circle geo.

Laurie

The design of Tŷ Mawr evolves from a single geometrical symbol that was carved into the inner face of the eastern aisle post at the northern end of the house, a symbol that was recorded in a scale drawing and on a video clip but lost during the "restoration" of the building. Like the Thuborough chapel date stone in Sutcombe, the geometrical symbol at Tŷ Mawr is a design icon that provides the fundamental geometry from which the building's floor and section, including roof pitch, can be designed, figure 7.



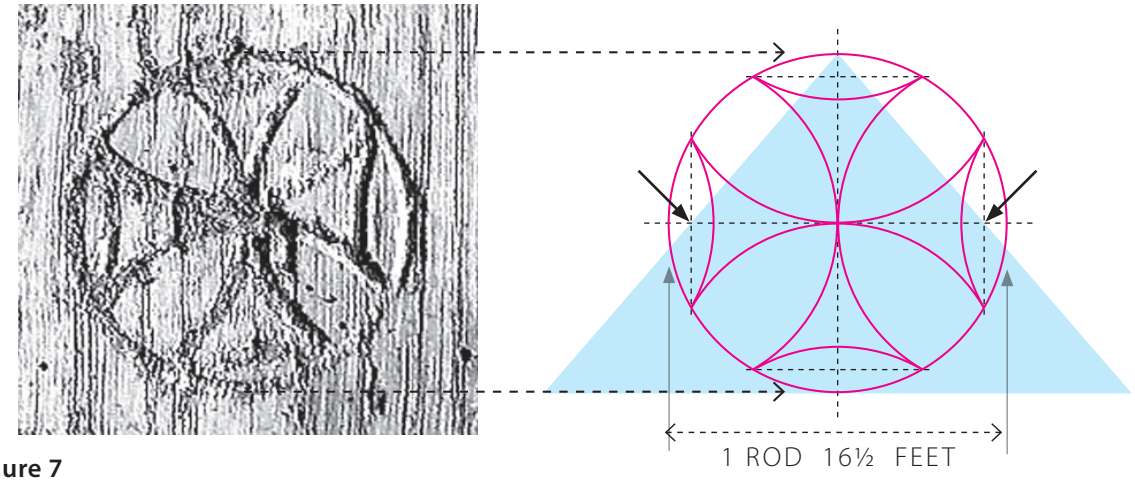


Figure 7

UPPER DRAWING Setting out the 5 circle geometry that defines Tŷ Mawr's nave and section. **A** The perpendiculars are drawn first and the central circle is drawn from their intersection. The east and west circles are drawn to the same radius from the central circle's poles. **B** The north and south circles are drawn to the same radius from the central circle's poles. **C** The radius of the small arcs are drawn to the same radius as the full circles. The compass *pen* is placed at the intersection marked by the black arrow and the *pin* on the perpendicular. This is repeated for the remaining arcs.

LOWER DRAWING The video clip of the carved symbol at Tŷ Mawr, left (© Clwyd-Powys Archaeological Trust), and its function as a design tool to establish the roof pitch, right. It can be seen that the roof height from tie to ridge is equal to the full circle height and that the pitch runs precisely through the small arc intersections marked by black arrows. It is also clear that the carving is a shorthand of the full 5 circle geometry but utilising only the necessary central core.

Nicole's diary Day 3 continued

We move on to explore the layout of Ely Cathedral (1181) by drawing the crossing and transepts using 5 circle geometry using an old school chalk compass on an 7 x 3½ feet blackboard on the dining table, figures 8 and 9. We go on a 5-circle diversion finding related proportions: drawing methodology for a perfect square, diamond, whirling squares, ocatagon and maltese cross, etc. Then back to Ely, developing a triple daisy wheel sequence along the nave followed by an angular sub-geometry of diamonds, with both defining the locations of the cylindrical and angular piers, figure 10.

Figure 8

Setting out Ely Cathedral 5 circle crossing.

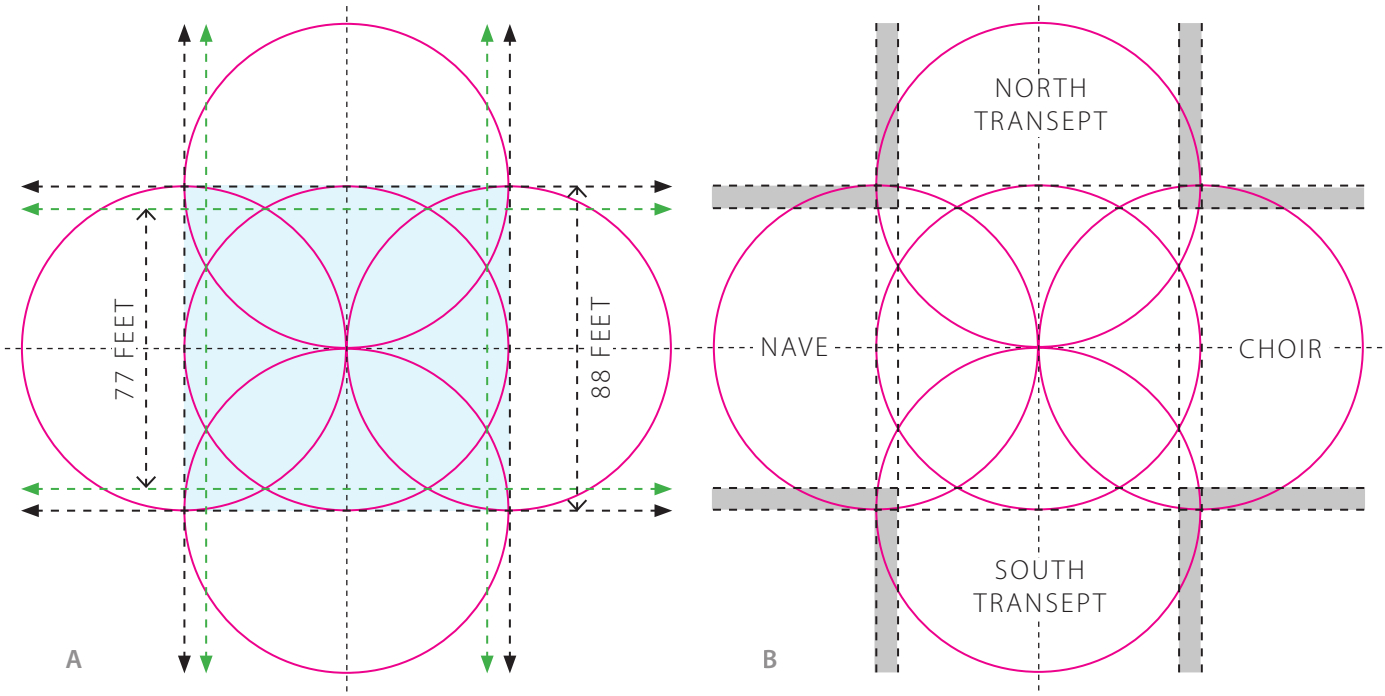


Figure 9

Setting out Ely Cathedral crossing using 5 circle geometry.

A The basic 5 circle geometry, left, allows tangents to be drawn across the circles to generate the perfect square, shown in blue tone, between the intersections of the four outer circles. Within the square there are eight further intersections, in pairs adjacent to each side of the square. Parallels, shown in green line, are drawn through these intersections. **B** The parallels, right, define the wall thickness, shown in grey tone. The geometry of the ends of the transepts and choir are not shown.

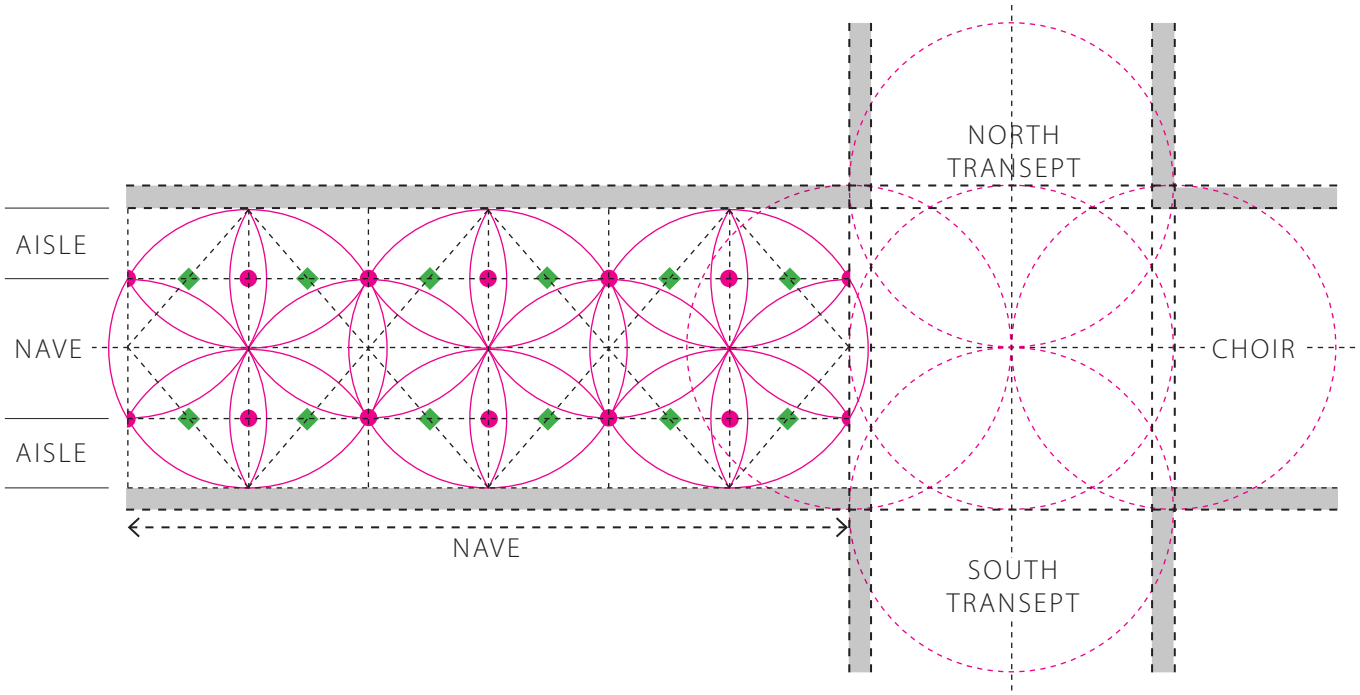


Figure 10

Setting out Ely Cathedral nave using daisy wheel geometry.

The centre line and wall alignments established by 5 circle geometry can be extended to allow for the development of the nave geometry. Three inter-linked daisy wheels are drawn to fit the internal dimensions of the nave (77 feet) and an angular sub-geometry is drawn between the wheels vertical petal tips and the centre line, in dashed black line. The intersections define the alternating locations of the cylindrical and angular piers in their perfect harmonic interchange of circularity and angularity.

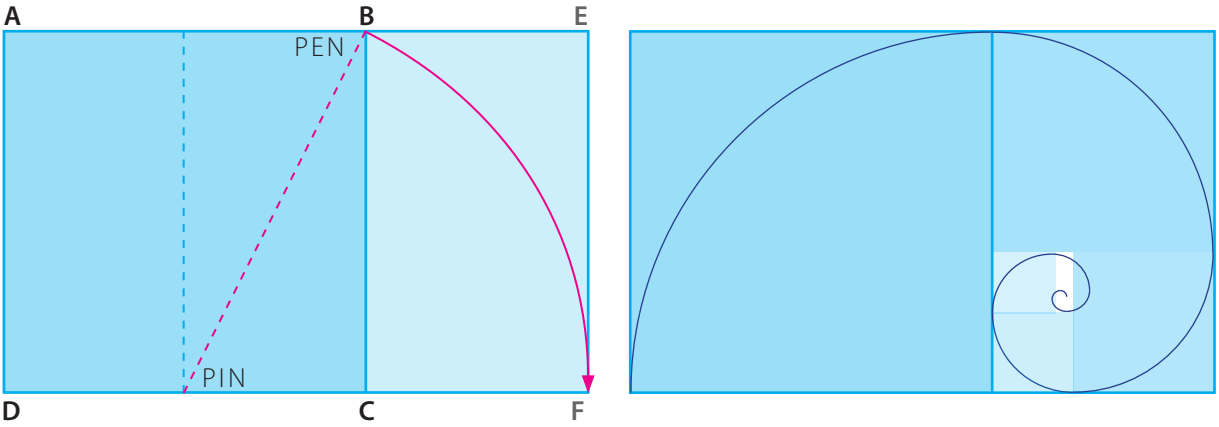


Figure 11

Drawing the golden rectangle and logarithmic spiral.

LEFT DRAWING The drawing starts with a square ABCD which is halved. The diagonal of one half is used as a radius to draw the magenta arc down to the square's base line at F. The square is extended to E and F. The large rectangle AEFD and small rectangle BEFC are both golden rectangles. The side EF is simultaneously the short side of the large rectangle and long side of the small rectangle and it is this that gives the two rectangles a harmonic relationship.

RIGHT DRAWING Starting with the original square, a series of diminishing squares, shown in blue tones, are drawn within the two rectangles. A series of diminishing quarter circle arcs, drawn in each square, link to form the logarithmic spiral. At the axis of the spiral the accuracy of the drawing fails and this small area is shown in Greek volutes by a plain disc that was known as the eye of the spiral.

Nicole's diary Day 3 continued

Then, with Ely behind us, we take a look at Islamic traditions. All design begins with a circle - symbolic of eternity or god. We discuss the harmonies of similars and opposites, the color relationships of patterns and their balance within the environment. The psychology of how space separates as we experience a structure and move through it. Now on to drawing the golden rectangle and logarithmic spiral! Patterns of natural growth, figure 11. A lunchtime trip to the beach. Hilary said that we are working ourselves too hard and we need a break! We drive to Morwenstow and walk out along the cliff top to eat Cornish pasties in the cliffside hut constructed from shipwreck driftwood by Reverend Hawker, around 1840.

Laurie

Hawker was a renowned eccentric who dressed up as a mermaid, excommunicated his cat for mousing on Sunday, built his vicarage chimneys to match his favourite church towers, smoked opium and wrote sermons and poems in the cliff top hut.

Through the open stable door we face the Earth's curvature on the Atlantic horizon, part of a 24,900 mile circumference drawn from a 3,959 mile radius, circularity on a grand scale seen through the human eye's circular iris.

Nicole's diary Day 4 continued

Further down the coast at Sandymouth we walk along the sand and listen to the roar of stones as each wave drags them back down the beach. Laurie points out Devon Rag roof slates – roofing tiles that are locally quarried and distinctly wide. But mostly, we see geometry everywhere. In Saint Morwenna's church we find daisy wheels around the capital of one of the Norman arcade piers and 5 circle geometry on a carved oak pew end, figures 12 and 13, and the star of David and pentangle of Solomon in the Victorian stained glass. Outside we find geometrically patterned cut slates used to protect the bargeboards on the weatherbeaten gable end of the church, Celtic spirals in the cemetery, symmetry in the foliage around us.

Back at Church Lodge, it's another phenomenal dinner and then some time in Laurie and Hilary's impressive library to look at books and revisit Tŷ Mawr. Our meals were fantastic and our lodging very comfortable. We spent many hours asking questions about all manner of things. Laurie and Hilary were fantastic hosts and indulged our every need. This is truly a once in a lifetime experience and an incredible offering by two of the most talented people I have met. Then it is time to wrap-up. A last look at the delicately carved geometrical

Figures 12 and 13

Saint Morwenna's Church, Morwenstow

UPPER PHOTOGRAPH A daisy wheel, half circle interlace and spiral capital in the Norman arcade.

LOWER PHOTOGRAPH 5 circle geometry in a pew end. The left side of the panel has been lost.

church tracery panels hanging on Laurie's wall and then, at 10am, we all head out to Drewsteignton on the edge of Dartmoor where we meet up with Oscar, Joel and Samantha for lunch in the sunlit pub garden (*Google Emmanuel Hendry to see examples of their carpentry*). After a great lunch we say our farewells and go our different ways.

Laurie

Nicole's comments are very generous. The truth is that Hilary and I learned as much from Rick and Nicole as they did from us. We enjoyed their visit immensely and, as always, it was a great opportunity to expand our knowledge of each others' cultures.

An email from Rick

Hi Laurie

This sounds fine, I am also writing an article today for Scantlings about the pavilion, I will send it to you as soon as I complete it.

I miss the picture of Nicole and I at the pub.

Laurie's reply

The Mortice and Tenon cut the picture due to their space limitations but I can do as I please on my website so here it is ~

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