Chartres Royal Portal with the three lower lintels shaded.

Part 6 of the Royal Portal Series

September 2020

Chartres Royal Portal - lower lintels and plinth geometry

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There are five lintels in the west portals, one under the *Maiesta Domini* tympanum over the central door, and two over each of the lateral doors [above]. Only one lintel was installed as carved, while the others were mutilated, on the south more than once. In the years before the second crusade these are the only double lintels anywhere in northern France, an unusual decision that requires a separate analysis in Part 2. Here we will concentrate on the changes to the three lower lintels and what that might tell us about the placement of the plinths and the first, second and third proposals for the portal.

The measurements for the first layout show two sets of ratios, one sacred and the other mundane. As in the rebuilding sixty years later, fundamental phrases of Christianity are written into the dimensions, including the dedication of the cathedral.

We also describe the attempts by later masters to unravel a tangled web of changes and mistakes they inevitably made in order to complete the portal. And consequentially, the ever-present question in medieval studies on the master's comprehensive inability to share either their designs or their measurements in a way that would enable a successor to complete the work as begun. It was not a matter of confidence, of which there was little

Links to the Series

In italics those that have been completed.

shortage, but of an institutional disintegration that followed the fall of the Roman Empire. This will be discussed in Part 9.

This is Part 6 in a series that will describe the history of the Royal Portal in the detailed way that it deserves. Being aware that historians beyond number have had opinions about the inconsistencies and discrepancies in this wonderful work without the benefits of toichology[1] that has enabled me to unravel the story in a different way. I wish you joy in this attempt.

The central lintel

Three types of materials have been identified in the portal. *Biodetric* limestone,[2] came from quarries near the town of Maule (within the former diocese of Chartres), *miliole* limestone from quarries near Conflans Sainte-Honorine, Pontoise or Saint-Leu-d'Esserent, and *liais* from Saint-Maximin south of Créteil.[3]

The lintel under the central tympanum displays figures arranged in four groups of three separated by shafts, and the central twelve are flanked by additional figures, to make fourteen. From the measurements from Andrew Tallon's laser image of the portal,[4] the visible face of the lintel between the archivolts is the same width as the tympanum, at 3,89cm, the height is 1.17cm and the depth 54cm.[5] This enormous block of about 2.5 cubic metres would have weighed more than six tons.[6]

How did they get this monster onto the site, let alone in place? Transport would have been by barge along the Seine to the Eure, a waterway that was navigable until blocked by flour mills in later times. Jean Villette showed me where the small church of Saint Nicholas used to be, a little upstream from Saint-Andre and just before the Pont des Minimes. He believed this was as far as the barges could have travelled in those days. Suitably, Saint-Nicolas is the patron saint of sailors.

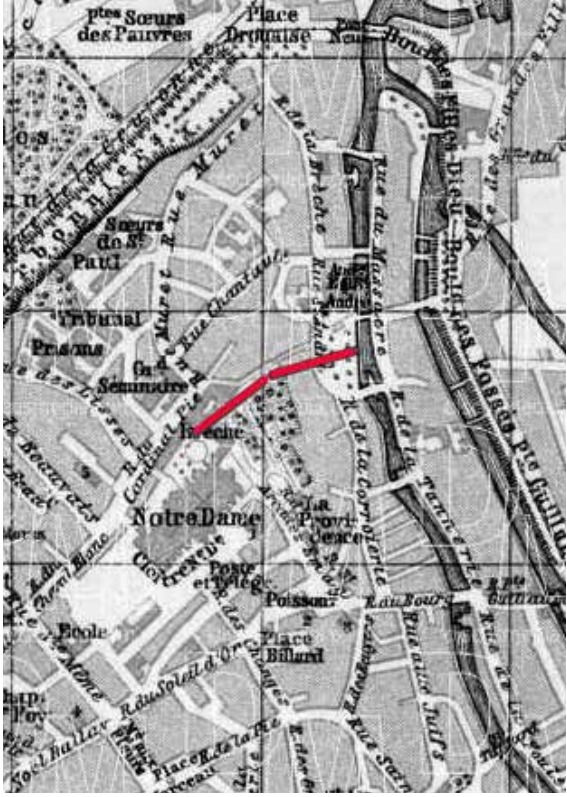
From the loading platform by the Tertre Saint-Nicolas there could have been an inclined structure to slide materials uphill on rails, as still exists today in Mont-Saint-Michel. The rails would rise up the steep slope, through the Bishop's garden to the east end of the cathedral. The lift would be 75 metres above the surface of the river, and across a horizontal distance of 200 metres. The slope of about 20^{O} would not be too difficult, and could have been in two stages with between them enough level area for a winch or for horses and pulleys, and space to re-hitch a second team for the upper haul [top, right]. The same arrangement could then have been used for the 1194 church in which many of the stones weighed as much as this lintel, such as the bosses.[7]

Medieval lifting gear was sophisticated, and if properly supported over its length the lintel could have been raised and placed with safety. But let us not forget the difficulties with scaffolding that would have encumbered the space, and the delicate pieces underneath that would have been placed earlier.

The lintel is supported on the capitals and their imposts. We cannot measure the amount that is hidden behind the archivolts, though the lintel would be longer than what can be seen as the ends continue behind the stones that butt against its face [right].

Under the canopies at each end the figures are framed with stones that extend the full height from the base of the lintel to the underside of the canopies [in yellow]. Their lithic characteristics are different to the rest of the lintel, being grainier in texture and slightly yellower in colour. They look like they were added onto the ends of the lintel.

On the left end, where the lintel meets the archivolt, the arched canopy over the figure extends behind the archivolt so that the edges of the archivolt



1908 plan of Chartres, possible route from the Eure

Central door, lintel with inserted frame on the right

Central door, lintel, figure on the left

Central door, lintel, figure on the right

project into the recess for the figure [arrow, above right]. One would expect that the decoration of the canopy was meant to be exposed to view, not covered.

On the right end, more of the canopy is exposed, the yellowed block is set back from the outer edge of the canopy and the inner face is angled differently to the intrados of the canopy and therefore does not comfortably align with the curved surface above it [arrow, above right]. As the junction between the yellow block and the canopy would have been obvious it has been shaved back. These two yellowed stones were therefore inserted into the lintel after it had been finished.

It is unusual to have shafts between each group of apostles and none at the ends. At Bourges, Saint-Loup-de-Naud and Le Mans, all *Maiestas Domini* portals, the lintel figures are framed between shafts that support every arch of the arcade, including the ends [right].

Lintels at Bourges, Saint-Loup-de-Naud and Le Mans

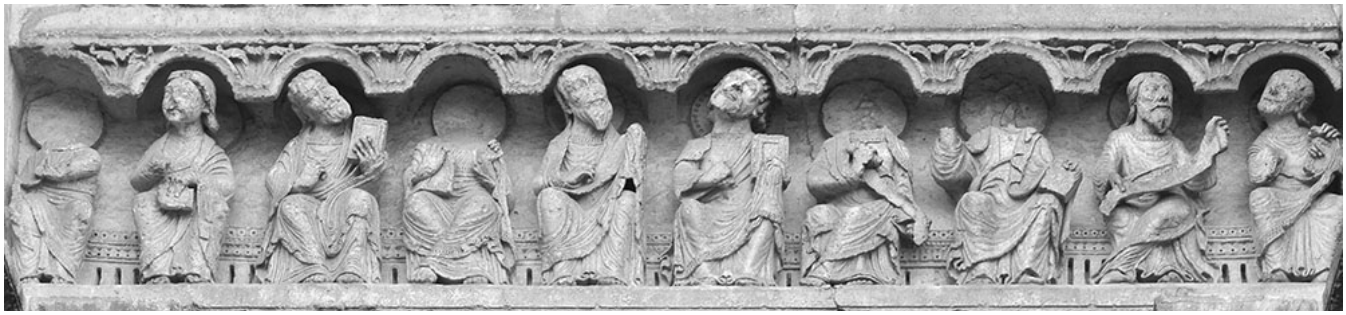
At Chartres, it looks like the inserts replaced shafts and their capitals that would have flanked the end figures. Therefore, the lintel would originally have been significantly longer when carved, and was cut down in size. As discussed in Part 2, the lintel was carved in campaign-F and as the width of the tympanum above it was designed to suit the shorter lintel, the tympanum was carved and the lintel shortened in a later campaign.

To estimate the original length, I have simply added copies of the intermediate shafts to each end of the lintel [below]. By measurement this increased the lintel by about 23cm.

On the assumption that nothing else had been changed, the width of the doorway, measured at the plinths, would have been about the same 23cm more than it is now. Today it measures 3,02cm at the plinths, which means that the width of the opening for the doorway that was intended when the lintel was carved would have been about 3,25cm. I will shortly use this to see if we can determine the first plan for the portal.

Central door, lintel, as it may have been carved in campaign-F

North door, lower lintel, as it may have been with twelve figures

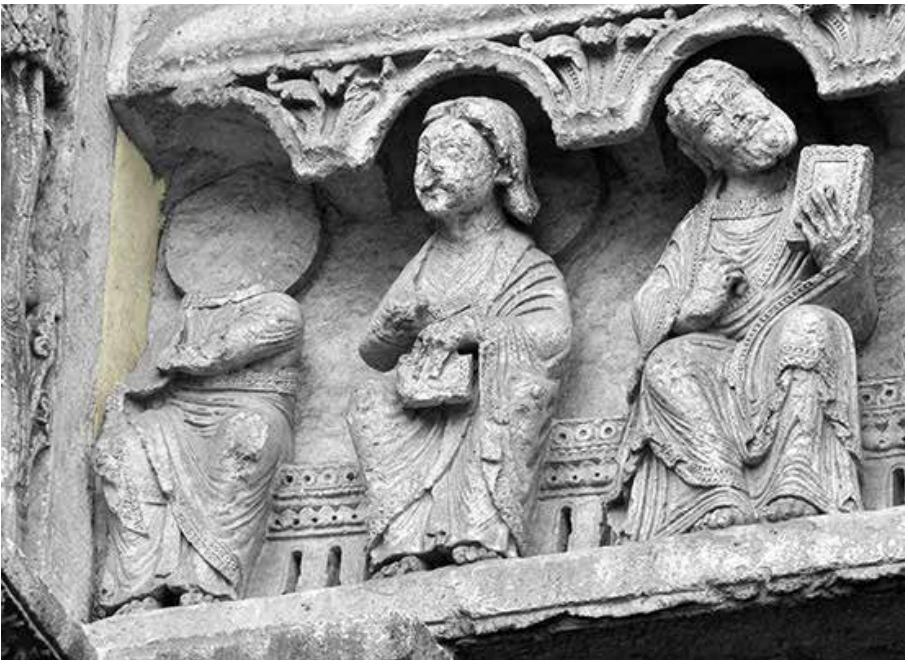


North door, lower lintel, as it is today

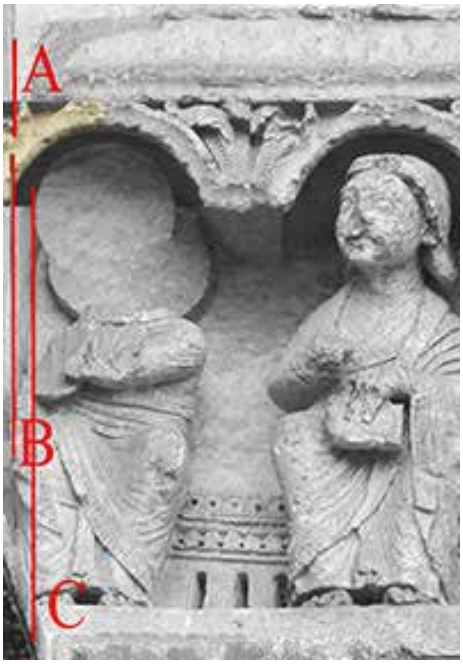
The north lintel

The lower lintel on the north contains ten figures of apostles under continuous canopies without the shafts between them, and like the central lintel the ends have been mutilated.[8] On the left, the canopy is broken, and the frame that should enclose the lintel has been removed and replaced with the edge of the archivolt that continues into the figure above, and behind it a roughly finished infill block [yellow, below left].

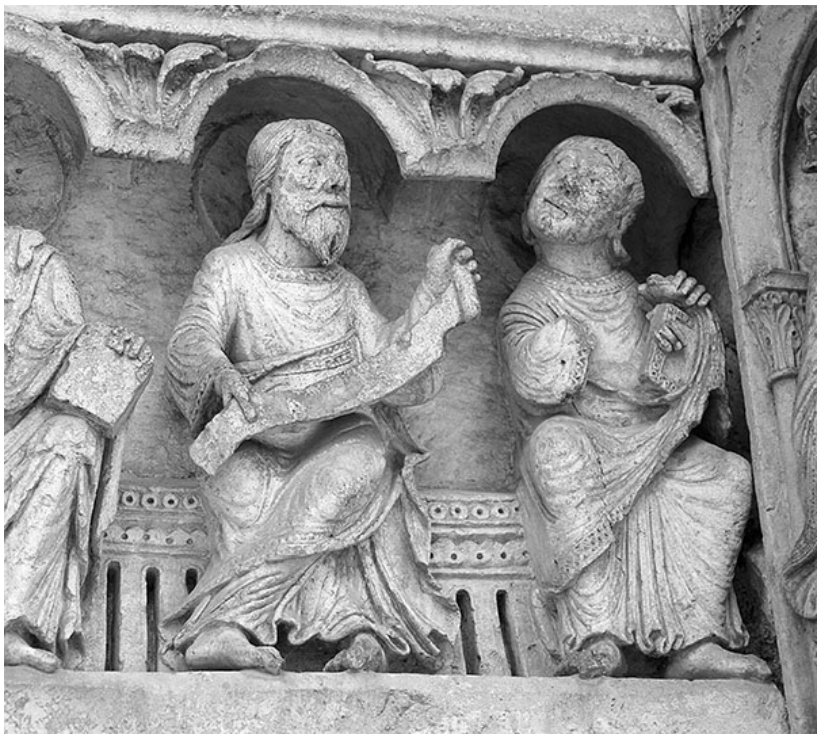
When the full curve of the arch is added to match its neighbour [orange, below right], the left edge extends into the space of the archivolt A. The edge of the clothing B and the feet C are squashed against the side of the archivolt. The compression of the figure against the archivolt with no space



North door, lower lintel, left edge with infill block of roughly -finished yellowish stone.



North door, lower lintel, left misalignments



North door, lower lintel, right end

Detail with matching extension to arch

to the left shows that some of the lintel was removed, including the return that would have framed the lintel.

The situation is worse on the right where the lintel disappears behind the figure of Janus [above]. It looks as if part had been removed, leaving the arch without a horizontal return at the bottom and the short tip of foliage without a branch. When replaced [above, right] the red line shows the minimal width of the original. As on the left, nothing remains of the frame to the right of the figure - that is, if it had been the end figure.

These discrepancies show that the lintel had been reduced in width and therefore had originally been carved for a wider space. Either the doorway underneath would have been wider or more space should have been left above the imposts.

The reason for ten figures has been questioned and discussed without finality. At Saint-Loup-de-Naud and in the Etampes south portal, ten figures were carved in the lintel. The layout as well as many details suggest intimate connections between these buildings.[9] As ten figures may have been deliberate, only a little extra at each end would have been needed to complete the arches and the frame. This door would then have been more than 11cm wider than today, at about 2,06cm.

On the other hand, if the lintel was meant to include all the apostles, then two additional panels were needed to increase the number [top, previous page]. If this were the case, the door width would have been about 3,44cm, not much larger than the central door today. If there had been 14 figures, as in the present middle lintel, the width would have been even greater. The small height of the lintel would not have spanned that distance, and would have needed a trumeau to provide a central support,

This suggests that the lintel had been carved in an earlier campaign for a different design with a wider doorway, perhaps not unlike Moissac [right]. In which case there may have been panels on each side with sculpture to enhance the entry. The curious pieces of sculpture now under the northern embrasure figures may have come from this earlier proposal.

Moissac, tympanum south portal

South door, lower lintel as it is today.

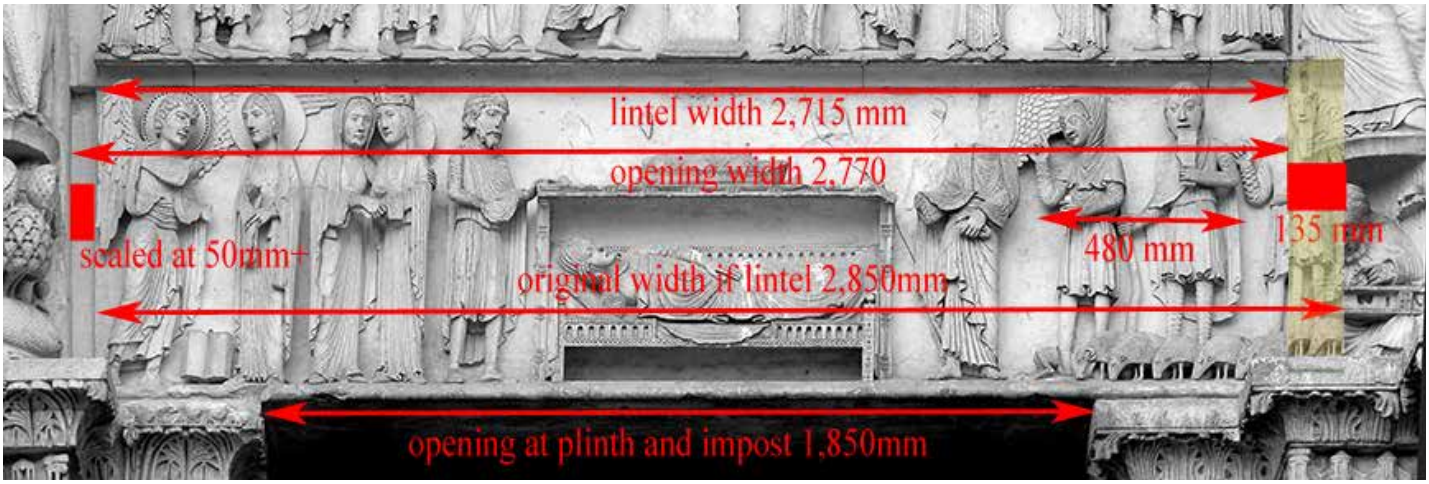
The south lintel

When the deeply excavated foundations for the south tower were begun the designers would have presumably wanted the widths of the lateral doors to be equal. As the four portal plinths appear to have been carved together [discussed in Part 2], and as three masters were involved in their placement each with their own method for determining dimensions, some differences were inevitable. This is apparent in the widths of the side doors, for the north is 1,95cm wide and the south 1,86cm. The south would have been even smaller at 1,75cm if work on this campaign had not stopped just under the threshold, indicated by the nib below the right plinth. These are significant issues, and will be addressed in a moment.

In the lower lintel of the Nativity, the figure of the shepherd on the far right was cut through the middle [above]. The reduction is so beautifully executed it would ideally have been cut back in the workshop before being placed, and was delivered to the erecting gang this length. But, the gap on the left of about 5cm shows that something else had gone amiss, see Part 8.

The measurements are summarised below, derived from Tallon's laser scan. The topmost is the width of the lintel as it is today, 2,71cm. The second is the width of the space between the archivolts of 2,77cm. On the left there is a gap that is a tiny bit more than 5cm, and there is a slight gap on the right side of the lintel of less than 4mm. The width of the present doorway is noted at the bottom at 1,85cm, which is 10cm less than the north door.

Moving to the right end of the lintel, I measured the existing shepherds to calculate the part that has been lost, shown in yellow (slightly transparent to



South door, lower lintel with dimensions in millimetres.

retain the outline of the archivolts). I was not sure where to measure from, the arm, the skirt, the edge of the hand or the elbow. But the dimension of 48cm across two figures looked about right. Completing the truncated figure as shown added 14cm to the total width, leading to the next dimension (second arrow from the bottom) that is the estimated width of the lintel at the time it was carved, 2,85cm.

This is the same as the space provided for the lintel over the north door, determined in campaign-F. As the Nativity lintel's original dimensions suit Master-F's geometry for the portal, the lintel could have been carved in campaign-F at the same time as the lintel in the centre. Clearly not by the same carvers, but dimensions suggest it could have been in the same campaign. Because the lower lintels for the south and central doors were reduced after being carved, I conclude they were both carved before the width of either door was established, and therefore before the two southern piers were placed or the south tower raised above the ground.

South door plinths sit the tower and the small nib that marks the junction between campaigns G and H.

Today the lintel no longer suits the width of the south door, from a complex history that is disclosed in the nib in the course immediately under the portal plinths [arrow, above]. This nib projects into the space of the doorway and if the plinths had been placed to suit it, the doorway would have been 12cm smaller than it is today. The smaller opening would have been perfect for the reduced lintel. Therefore, it looks like the lintel was cut down by G to suit his smaller door. But after the door had been enlarged in campaign-H to what we have today, the earlier reduction in the width of the Nativity was not recognised until they came to erect it. Then it was found to be too small and was set hard against the southern archivolt, leaving that oft-noticed space on the left, discussed more fully in Part 8.

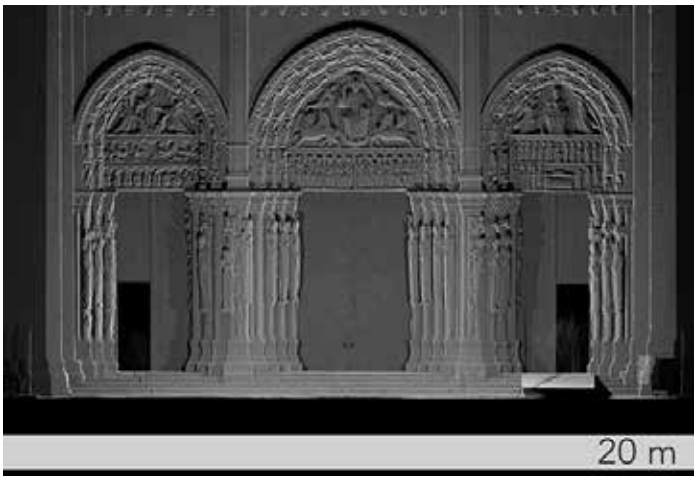
The geometry that Master-F used to dimension the portal will be discussed next. As suggested in Part 2, he may have worked on the footings for the south tower, but above the footings the walls of the tower were by his successor, Master-G, who increased the size of the tower and reduced the space for the portal by about 29cm. This reduced the space available for the lower lintel. The upper lintels of both lateral doorways were affected by other very different circumstances, presented in Part 8.[10]

Measurements and method

Before discussing Master-F's layout, it may be valuable to repeat the ground rules in this analysis. To investigate geometric methods with as few errors as possible, three actions are needed: our own measurements need to be more precise than those used by the builder, every ratio needs to be calculated to four decimal places, and then the maths compared with reality. This creates theoretical "ideal" dimensions, even though too accurate for the "real" world. The differences between the ideal and the as-built will be our tolerances and will provide truer results than trying to cope with the endless combination of on-site and computational errors.

For calculations to be more accurate than the builder's, we need to measure and calculate in millimetres, otherwise cumulative discrepancies soon produce unacceptable figures. The most solid method is to create the "ideal" geometric system calculable to the millimetre, and revert to centimetres after completing the maths.

Over the years I have made many attempts to measure the complex outline of the portal, both in long lengths and increments, with tapes long and small and with a hand-held laser, but none were satisfactory. I realised that small changes to the angle of the plinths, inaccurate sizes and varying thickness of mortar were making precision impossible. Andrew Tallon's full-size scan came to the rescue [right], and all that follows is based on his scan.[11]

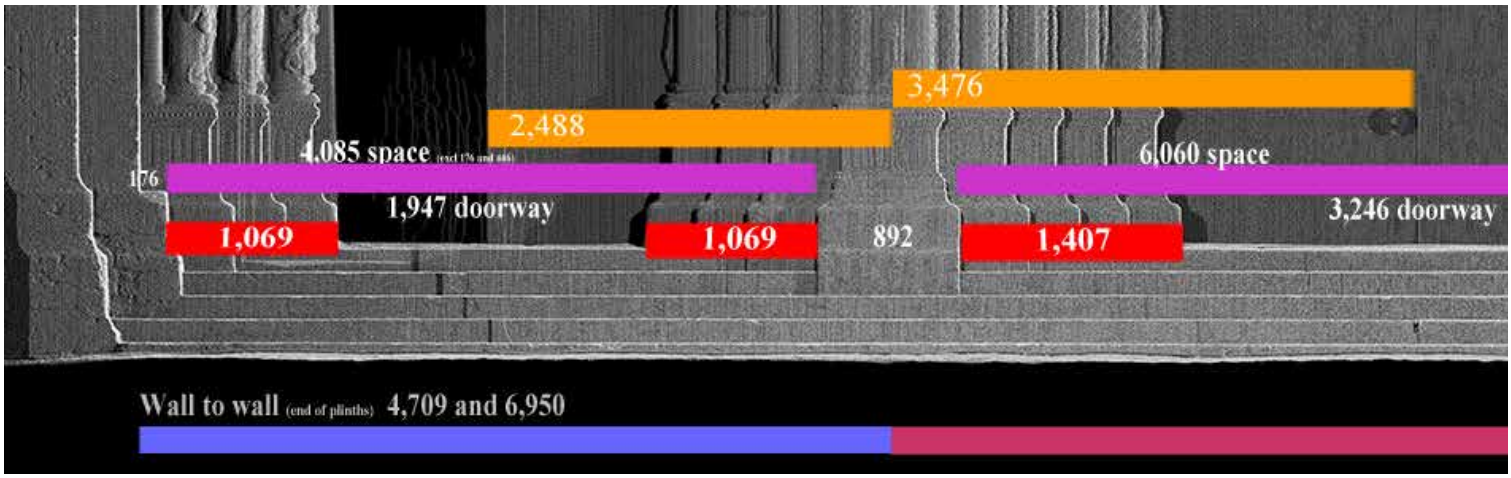


Andrew Tallon's laser survey of the Royal Portal.

In calculations I check the measurements against the building by adding the lengths and dividing it by the sum of the ratios. For example, when comparing the width of the plinths, the one against the north tower measures 1,245mm, and that between the doors measures 3,368mm. The slide rule shows they relate as 10-27. To confirm, add the two measurements and divide that by the sum of 10 and 27. Then, multiply that by, say, 27 for the theoretical "ideal" dimension, which in this case is 3,366.24mm. The ideal differs from the actual by 1.76mm, which is the tolerance.[12] You then decide whether that is an acceptable tolerance, or not.

Ratio of 10-27 between the solids of the piers

Working in centimetres is mathematically too inaccurate. Though findings may be presented in centimetres, calculations will always lean to greater degrees of accuracy, in millimetres. All measurements have been derived from the laser scan, with adjustments already discussed for the lintels. Having applied the same procedure to every ratio, I expect the ones in this study to represent the "ideal" portal as designed by Master-F.[13]



Major dimensions measured from Andrew Tallon's scan

Setting out

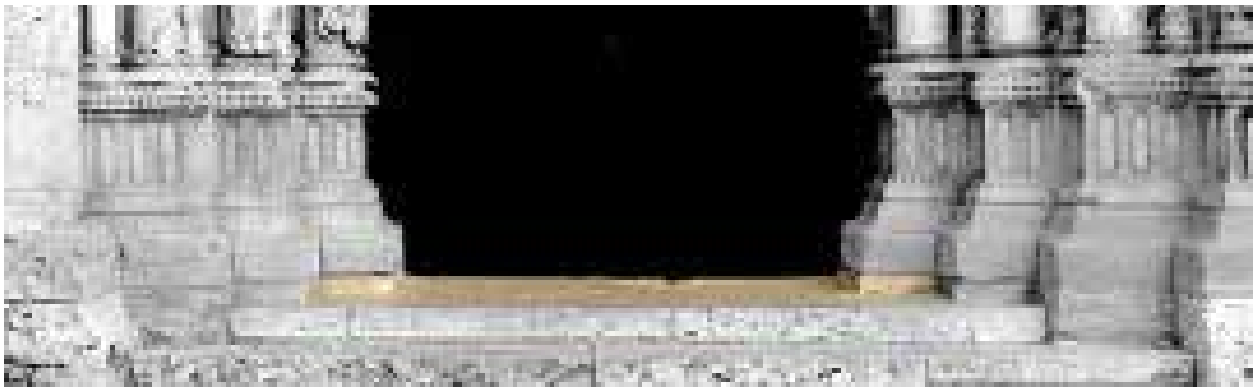
The master's first step in setting out depended on site conditions, and these can be extremely difficult from mud and wind and squalls and the many people who tend to get in the way. It is easy to set up stringlines, but more difficult to keep them in place over long periods of time. Nowadays we fix the strings to nails hammered into hurdles, and they may have done the same. The hurdles are not set on the corners, as they would be moved during excavation, but are driven into the ground some distance away and the corners located where the strings cross. Even so, hurdles are easily disturbed.

Where was the first measurement made for the portal? Logically it would have been between the towers, but from where? The wall face of the tower, or the plinths that project beyond the wall, or maybe some more secret place? We are looking for a process that could be easily used on a dirty wet site encumbered by equipment and scaffolding, where the lower courses of the north tower were in place but with a large hole to the south in which the foundations were only now being packed in, as discussed in Part 2.

An accurate setout depends on the careful placement of the lowest courses, especially important where there is sculpture. At Chartres the first course is in stone from the local quarry at Berchère rather than the finer *calcaire* from distant quarries, as used in the rest of the portal. Local stone meant that the builder's tradesmen could start the footings before the arrival of the more expensive *imagiers,* who may have come from distant venues.

To maintain this accuracy the threshold under the north door was carved from a single block with upstands at each end that mark where the plinths were to be placed [orange, below]. This most unusual decision was probably made because they realised that only with the accurate placement of the bases would the complex sculpture fit together as intended, and that on this site under these conditions a high degree of accuracy was going to be hard to maintain. As this is the sole surviving threshold from campaign-F, I presume that similar thresholds had been carved for the other two doors, but not used as the dimensions were changed in later campaigns.

South side north door with upstand.



North door with upstands marked at each end of the threshold to locate the plinths.

This study concentrates on the original design for the portal, not the one we see today with altered lintels and smaller doors. To understand the first plan, we need to recreate the dimension for the original. The threshold shows we have accurate dimensions for the north doorway and its two flanking piers. We also have the two piers that, from the evidence in Part 2, were carved at the same time from enormous blocks to a uniform design. The lintels show we should enlarge the centre door by 23cm and the south by 10cm. With these we can estimate the measurements for Master-F's first plan for three

doorways and four plinths, which were intended as above, in centimetres. They were calculated from the Tallon scan. Together this indicates that the overall length of the portal would have been 16,37cm. This is wider than today by about 29cm. I will be using these "ideal" dimensions in the following analysis, but in millimetres with tolerances.

The mundane and the spiritual

The four strips shown pink in previous sketch [and right] were not defined through geometry, but were left-overs from the previous process. The middle two form the pilasters that continue into upper levels, and the two at each end are infills that complete the towers. They measure 892mm and 176mm.[18]

In the centre it passed though the portal from the pilaster on the outside to the narthex shaft on the inside. As the towers flank the portals, the strips flank the embrasures. They may have been conceived 'structure', like frames that 'hold' the three assemblies of doors-plus-embrasures. They may have represented solid rather than void, mass rather than decoration, and symbolically, even the distinction between the mundane and the spiritual.

It seems relevant that the bases under the pilasters were carved from the same Berchère limestone used in the towers, and not *calcaire*. Also, that they are the **only stones** without setback profiles on the sides [arrow, right]. Were these vertical cuts a visual device to emphasise that the pink strips through the pilasters were separate from the space of the doorways? A unique detail to subtly demonstrate the designer's intent that the pilaster represented a segment that bounded, but was not one with, The Way displayed in the doorways.

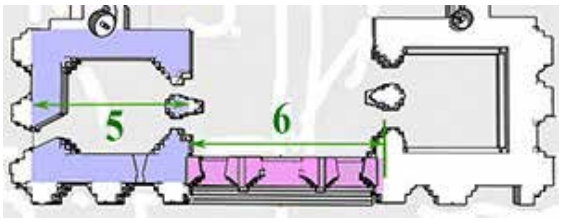
With the discovery of these ratios, a new realm of investigation was opened. We might have the ratios for the embrasures, but how did they get there? What decisions and arguments had to be in place to arrive at the embrasures? Surely, these ratios would have been the outcome of earlier larger-scale decisions, rather than just turning up on their own? I sensed the parts, but needed the whole.

In the foray that follows we will stray a long way from academic rigour, yet let us continue. To extend the search into the broader elements in the towers and narthex, a larger unit is needed, one closer to the size of a foot. Foot units invariably lie within the range of 25-33cm, usually divided into inches or digits. .

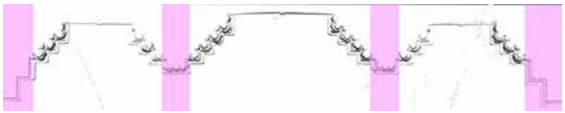
It was intriguing to find that 60 of these 'feet' would fit into the space between the towers, which is also the width of the portal. Extending the 'foot' across the west front, the ratio between the portal and the mass of the towers, excluding the buttresses, is 50-60-50 [right].

More is needed on the procedures of their rituals, and the meaning that were ascribed to them. More is needed on any relevant descriptions by the great scholars in residence at that time. More is needed on their use and knowledge of gematria, their use of Arabic notation, and so on. I leave that for another time, and meanwhile trust that the consistency of the phrases, their appropriateness, and the mathematical coherence of the dimensions will permit me to leave these thoughts with you.

The westwork was a singular design derived from these four ratios. There was no common denominator, yet they are accurate by calculation as well as measurement to millimetres, to centimetres at most. The masters were more likely to use whole numbers in setting-out rather than complex figures, if only to make it easier in the mud and rain on an open site. Greater complexity could be included in the more detailed work above the bases, and in the shed, but could be dangerous on site.



Plan of tower and portal in campaign-F, with the bulk of tower framing the space for the portal.


'Structural' panels separating the passages


Vertical sides to lowest course under pilasters

You may ask how large numbers were set out with no more than rudimentary measures marked on the rod or square, A length of 360 feet can be laid out with a ten or twenty-unit rod, and then take off six for one proportion and 240 less 1 for the other. This is the system described by Villard de Honnecourt.[22] Once the numbers were worked out in gematria the setting out needed only patience and care.

There may have been an earlier design that left remnants in the north lintel and the little figures inserted under the first statue-columns [see Part 2]. I presume the clergy thought it was not as integrated as this enticing arrangement, and readily scrapped it in favour of the profound spiritual concepts written into the design we have today.

Changes by Master G

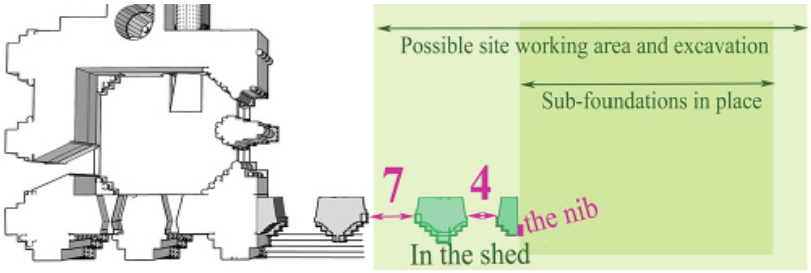
Master-F placed the two plinths of the north door. In the south tower he had laid the footings but nothing was yet visible above ground. He did lay the lowest courses in the crypt and the start of the passage thereto, and may have built formwork for the barrel vault in the crypt.

When the next master arrived on site, he would have seen two plinths in the north and only a hole to the south. He would have examined the two plinths waiting in the shed, and once he had absorbed that information he would start planning the completion of the portal and the location of the north wall of the tower. There were no working drawings and there were no techniques available whereby he could have understood the intentions of his predecessor. Therefore the width of the central and southern doorways would be his choice, and with them the adjacent face of the tower.

Just in front of the portal against the south tower there is a small damaged projection or nib that serves no purpose today, but as discussed in Part 2, the top marks the junction between two campaigns, G and H [arrow, above]. The joint can be followed from inside the tunnel into the crypt, around the walls of the room and out both sets of doors to the exterior. It looks like the projection would have located the south end of the portal.

He measured the gap between the piers-in-place and the footings in the south, subtracted the width of the two plinths in the shed, and divided that by eleven. Four of these he assigned to the south door, and seven to the centre to an error of less than two millimetres.[28] This made both doorways smaller than planned, and the nib was added to enlarge the tower a little to the north to fit against the side of the plinth. It was a clever answer, and easy to achieve on site, while still retaining some of the meaning in the original.[29].

South door plinths against the tower and the small nib that marks the junction between campaigns G and H.



Relationship between the unfinished work to the south and Master-G's decisions.

This raises a most important question, why did Master-G not take the easy approach, to measure the north door and simply replicate it in the south? This goes to the lack of post-Empire industry norms. As the Roman jurisdiction declined the accepted rules of measurement faded from use until there were no legal constraints on units of measure. The centuries-old dominance of the Roman foot unit dissolved in the regionalism that followed. Yet masons still had to issue precise directions if stones from the quarry were to fit snugly on site. This is where geometry took the place of measure. By 1100 foot units were not required. Using a practical man's geometry he and his men would know exactly what to do. Simple? Maybe not, but more on this in Part 9.

G set the height for all the openings by carving the uppermost jamb figure in the north door [see Part 3]. The height actually works geometrically to the width of the central door and uses the same 4-7 proportion as he had set between the doors.[30] The use of the same proportion across three spaces seems enough circumstantial evidence to suggest that Master-G could have been responsible for all three decisions.

While he was at it he placed the third plinth, thereby fixing the width of the central opening and determining where the left jamb of the south door was to be, but not the right - his bequest to the next master.

Alternative ratios

Here is a sample of some of the other ratios that are accurate to millimetres:

The lateral doorways are related to the central as 3-5-3 to an error of 0.6mm, the north door of 1,947mm to central as 3,246mm [red],

I doubt that the pier widths would have been determined first, but having established the door widths the piers next to the towers and those between the doors "turn out to be" in the ratio of 10-27 to less than 2mm. This divided the solids between the towers into 74 parts [orange].

There is also a one-unit difference between the adjacent pier and the central doorway as 25-24. The 'ideal' pier as 3,368mm and door 3,246mm,

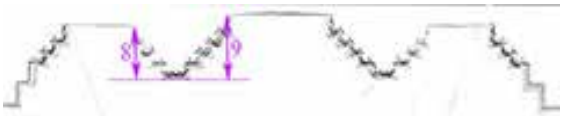
The ratio between the width of the central door 3,246mm and the centres of the pilasters 6,952mm is 7-15 with a larger error of three millimetres [blue].

The depth of the embrasures relate to each other as 8-9 [purple], and the central embrasures to the depth as 3-11 [green].

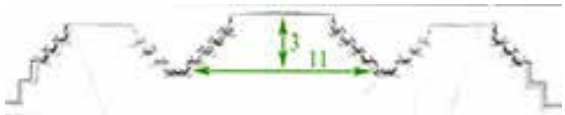
Ratios between doorways ADD 55 RF

Ratios between piers

Ratios between door centres



Vertical sides to lowest course under pilasters



Vertical sides to lowest course under pilasters

Changes by Master H

Master-H placed the next nine courses from the portal plinths to the elbows of the column-statues. Each course of Berchère in the tower is exactly aligned with the courses of *calcaire* in the embrasure.[31] The continuity shows both were built together. As with Master-G, the extent of the campaign is recorded in the mason marks on the internal walls and within the tower stairs.[32] Nine courses was a fairly average rate for walling at that time.[33]

When he arrived on site the width of the central doorway had been fixed and without slide-rulers or calculators he had no way to determine Master-G's geometry. Yet he still needed a ratio to enable him to issues instruction to the men. The central door opening had been established, and what fitted the available space was to ignore the nib and widen the door for a golden-mean approximation of 18-11 to the central door. Such a ratio may have been inscribed on his square or dividers, and there was no reason to recalculate it.[34]

This is as far as I have taken the geometric analysis. It could be continued to include every minor element or setback, but this is enough to show that there were practical reasons for the use of geometry in setting out and, in this case, when later masters made changes they needed to apply their own geometric system, one that they and their men were used to.

Consequences

By enlarging the size of the tower and reducing the space available for the portal, Master-G set in motion a train of unforeseen consequences. The storage of work that was prepared but not erected in the one campaign meant that essential information was lost, and errors accumulated from here on. With four, maybe five builders involved in the erection of the portal, each with different ideas about design and geometry, and with no documented master plan, is it any wonder the outcome became confused. Worse, masters did not have universal rulers of length with subdivisions by the inch or digit, a decisive lack that is mentioned in Part 7 and will be addressed more fully in Part 9. We can see that discontinuous contracting has had a significant impact on architecture for as long as there were no agreed rules of measure nor trained supervisors on these jobs.[35]

Endnotes

1. The techniques of toichology were first established during my study of Chartres between 1969 and 1974, described in John James, *The Contractors of Chartres,* Wyong, ii vols. 1979-81. Some have struggled with the implications, John James, "In defence of Toichology", *Avista Forum*, vii 1994, 9. Also in https://creationofgothic.org/COGA/articles/Site_organisation.
2. Reine du Colombier, *Les chantiers cathédrale, matériaux et transports*, Paris, 1973
3. Blanc *op cit*; Philippe Dubaud, *Les Maitres Tailleurs de pierre de la Cathédrale de Chartres, leurs marques identitaires dans les chantiers du XIIème siècle*, Chartres, 2020, 72.
4. Andrew Tallon, kindly shared with the author, not published.
5. Annie Blanc, Lore Holmes, Garman Harbottle, "Lutetian Limestones in the Paris Region: Petrographic and Compositional Examination", BNL-66036; Chantal Hardy, David Booth, Dominique Bouleric, “The stones of the royal portal of Chartres”, International colloquium of stone. European Heritage 2005, *Edition of the Committee for Historical and Scientific Works*, 2006.
6. Limestone weighs approximately 2,700 kg per cubic meter, *Wikipedia.*
7. The roofing stone could have weighed twice as much, James, *The Contractors*, 260-61. The high vault bosses were as large, as were the lintels in the transept porches.
8. For the upper lintel see Part 8, and John James, "An examination of some anomalies in the ascension and incarnation portals of Chartres Cathedral", *Gesta,* xxv 1986, 101-108. There is a copy online at https://www.creationofgothic.org/COGA/articles/portals.
9. For Etampes, /COGA/files/articles/Were-Etampes-capitals-raised.pdf.
10. John James, "La construction du narthex de la cathédrale de Chartres", *Bulletin de la Société Archéologique d’Eure-et-Loir,* lxxxvii 2006, 3-20. Also COGA/articles/Chartres.
11. This is the “ideal” difference. The Tallon measurements in millimetres for the existing pier-north-pier-centre-pier-south-pier are 1245-1945-3375-3020-3390-1845-1335 for total 16,155, and in this analysis they are 1245-1947-3368-3246-3368-1947-1245 for total 16,366.
12. Ideal are 1,246.8mm and 3,366.2mm with an error of less than 2mm, if that is acceptable.
13. See discussion in James, *The Contractors,* 27 on tolerances,
14. James, *The Contractors,* chapter 8.
15. See also John James, *The master masons of Chartres*, London, NY, Chartres and Sydney, 1990, 105-110. Gematria depends on which alphabet was chosen, though the first 19 letters from A-T excluding J was the most common sequence. Differences were principally found in conflating U and V to 20, and scattering the remaining four letters as convenient.
16. 6,060mm and 4085mm from a unit of 17.1mm. The north embrasure in fact adds to 238 units, and it is acceptable to add or subtract unity to a sacred measure without changing its meaning. This is one unit less than the length used in the 1194 reconstruction. John James, *The traveller’s key to medieval France; a guide to the sacred architecture*, Alfred Knopf, New York, 1986, 68-74.
17. The basic truth of Christianity is that Christ was born of a Virgin and after death was physically resurrected. This is the proof on which the entire intellectual structure of the church rests, and they verify Mary's position, Adolf Katzenellenbogen, *The sculptural program of Chartres Cathedral*, New York, 1959.
18. Incidentally they are almost 5-1 ratio, when the ideal would have been 890mm and 178mm.
19. I had first thought the Roman Foot was used in the initial setout, marking a distance of 55 feet. But it did not coincide with the masonry. Though 11 feet may have made the central door, it too was inaccurate. The 274mm foot has an ancient lineage that harks back to Sumerian times. Remaining wills show that the master's foot unit was his property, handed down over the generations.
20. 43,822 by measurement, where 160 feet of 273.8 has a discrepancy of 14mm. 13,735-16,366 = 5-6 and the sum is 43,836.
21. For an imaginary initial discussion between the clergy and the master mason, see James, *Master Masons,* 83-85.
22. Though they had no need for roman numerals, I would not think it was easy for them to layout some of these proportions on the ground. However, 360 feet less six provide one proportion and 240 less 1 the other. Then simply use the system described in François Bucher, *Architector. The lodge books and sketchbooks of medieval architects*, New York, 1979, V39.
23. The centre of the door to the face of the pilaster is 6,060mm. Half the door of 1,623mm is added to the √3 *ad triangulum* for a distance across the embrasures of 6,063.4mm, error 3mm, not much more than the width of a piece of string. And remember that this error is skewed as our estimate for the original width of the door is itself based on an uncertain estimate for the original width of the lintel.
24. Half door = 1,947/2 multiplied by √2 for the embrasure width of 1,069 with an even smaller error. Against the north tower this does not include the plain colonnette, which was included to adjust the design to fit more than one geometric sequence.
25. See the 250 geometric studies in James, *Contractors,* and note 27. The portal could have been setout more simply by adding many small units, such as column bases, but that would have accumulated errors. It would have been more accurate to start with the largest length and divide it into parts.
26. Chartres stair windows in John James, *In Search of the unknown in medieval architecture,* 2007, Pindar Press, London, 394-398. Reprinted in COGA/articles/Geometric. See also *ibid.* 413-433. Also John James, "Discrepancies in medieval architecture: careless or deliberate?" *Architectural Association Quarterly*, xiii 1982, 41-48.
27. John James, "The tools of Hues Libergier, Master Mason of the Thirteenth Century", *Architectural Theory Review*, ii 1997, 142-149. Also pdf in COGA/articles/Geometric_methods
28. In numerology 7 is the more spiritual number, and 4 the more earthly. One implication is that the ratios used by Master-F were not passed on, and may not even have been known to the client. As one should presume that the client was a clergyman, it suggests they did not understand the original geometry and therefore it had been created by the master on his own - likely?
29. South door width is present width less the nib, (1,845-118)=1,727mm, which relates to the central door 3,022 as 4-7. The ideal is accurate to less than one millimetres.
30. Height of north door 5,270mm to current width of centre 3,022mm is 1.744, which is close to 7-4.
31. James, *Contractors*, 220.
32. James, "Narthex".
33. See discussion on construction timetables in “Boundaries that delineate periods in art-history between 1090 and 1180”, *Avista Forum Journal*, 2014, xxii 23-46. Also /COGA/Articles/Boundaries.pdf 3rd item.
34. James, "Libergier". The centre measured 3,022mm and the south door 1,945mm. The ratio between them is 1.638 which is 18-11 within a millimetre.
35. Discueed in chapter 22 of *The Contractors* and considerably updated in "Master Masons as Contractors" in James *In Search of the unknown*, 295-311.