

# Flying buttresses before 1180

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The origin of the flying buttress is crucial to our understanding of the evolution of Gothic architecture. Without it, tall, glass encased buildings like the cathedral of Beauvais would not have been possible. Prior to its invention, the side thrusts from the stone high vaults had to be absorbed by the thickness of the encasing walls and their attached buttresses. While great height increased the loads on the walls, the wide windows decreased their capacity to withstand these loads, only by transferring the load to the outer walls, where big buttresses could be built without limiting the window sizes, could the upper vaults be stabilized [b1]

Besides the structural function of flyers, there was an important aesthetic purpose. The arches and the buttresses that support them form a lofty cage around the perimeter of the building that screens the clerestory wall [b2]. Like weightless fins, flyers hide the upper walling so that the precise outline of the symbolically most spiritual part of the building cannot be defined.<sup>1</sup> From both the structural and the artistic points of view, flying buttresses were a major aspect of the style.



Sens cathedral, flyers from the east,



Saint-Denis-en-France, flyers from the east,

Ever since Lefèvre-Pontalis's categorically stated in 1919 that the first flyers were intended for the nave of Notre-Dame in Paris sometime around 1180 and asserted that "all apses built before the thirteenth century were devoid of flyers," historians have found it difficult to free themselves from his opinions.<sup>2</sup> Lefèvre-Pontalis's reputation was so great that this assertion could be made without any evidence whatsoever,<sup>3</sup> and his authority so unquestioned that his opinions were repeated by nearly every historian for the next fifty years. And this in spite of Viollet le Duc's belief that the flyers in the choir of Saint Remi were "parmi les plus anciens."<sup>4</sup>

In 1976 Prache reopened the question when she wrote, "It would be interesting to know if examples still exist of external flyers before 1180. It seems we should rehabilitate those of Saint Germain-des-Près. One readily admits that its choir flyers are amongst the oldest, but no one appears to contradict Lefèvre-Pontalis's belief that they were additions. However, his only argument was that there were no external flyers before those of the Notre-Dame in Paris nave. Though these flyers have been almost completely rebuilt in the nineteenth century, one pleads in favour of an early date, perhaps in the 1160s."<sup>5</sup>

The question having been opened, Henriët argued in 1978 that the massiveness of the southern buttresses at Saint Martin-d'Etampes indicated that flyers had been intended from around the middle of the twelfth century.<sup>6</sup> Four years later he suggested that the tiny pilasters on the clerestory walls of Sens cathedral could not have held

the great vaults without the support of flyers.<sup>7</sup> The contrary view that the Paris nave had to be first was repeated in 1983 by Bony, who argued that other twelfth-century flyers found at sites not far from Paris “confirm that the first structure ever conceived and built with exterior flying buttresses was the nave of Notre Dame.”<sup>8</sup> In the next year Clark and Mark wrote in a similar vein with arguments that were more sophisticated than Lefèvre Pontalis’s.<sup>9</sup> Bruzelius and others questioned their conclusions a few years later without finally settling the issue.<sup>10</sup>

In this controversy too many of the conclusions and the dates that support them are based on simple assertions of principle with arguments that are more theoretical and art historical than toichological.<sup>11</sup> Few writers have subjected stonework to the depth of scrutiny that would allow their conclusions to be checked and either verified or rejected. The result has been history by fiat and argument rather than by evidence: as Henriët has pointed out, “There are two types of arguments: the first is a simple statement of principle that external flyers appeared first in the nave of Notre Dame in Paris, around 1175-1180; then, comments on the irregularities and imperfections in the bonding of flyers that were supposedly added later are often made without valid preliminary analysis of the buildings concerned.”<sup>12</sup>

To attempt a resolution, I will address the archaeological and chronological evidence in the six cathedrals and eight churches where flyers may have been built or intended before the 1180s. This will be done in five sections. In the first, six buildings with documented dates will be set forth. In the second, the lithic evidence in five buildings (three of which have documented dates) will be presented to show that their flyers, or parts of them, were definitely built with the walls they restrain. These five are the choir clerestory levels of Sens cathedral, Saint Germain-des-Prés, Voulton, and Saint Lomer in Blois and the nave clerestory of Saint Remi in Reims, all probably under construction in the 1160s.<sup>13</sup>

In the third section (following the demonstration that flyers were being constructed in the 1160s), nine contemporary buildings, which lack conclusive evidence but where there is reason to believe that flyers may have been planned, will be considered. In the fourth, the many similarities in the capitals and associated profiles in some of these churches will be shown to suggest a common attitude to design. In the fifth, dates will be proposed for the flyers in undocumented buildings based on the style of their foliate capitals. These dates are noted under the heading for each building and should be accurate to within five years either way. Finally, some consequences of the invention of flying buttresses will be discussed.

### ***Chronology (first part)***

Documents help determine the approximate dates of the footings at Senlis and Laon cathedrals and Saint Remi in Reims and of the completion of the choir clerestory of Notre-Dame in Paris.<sup>14</sup> From them one could reasonably presume that the choir galleries of Senlis and Laon were probably under construction within a decade of their documented beginnings in 1151/1155 and 1155, respectively; the Saint Remi westernmost bay and choir, fairly soon after Pierre de Celles became abbot in 1162; and the choir gallery of Notre Dame, some five years before the completion of the walls in 1177. Though the consecration of Saint Germain des Près and Sens were probably timed to suit the presence of the pope rather than the building campaigns,<sup>15</sup> it is possible (if with less certainty than in the first four buildings) that their clerestory walls and roofs, if not the vaults, were completed by the time of their consecrations in 1163 and 1164, respectively.

A relative chronology for these buildings, based on the documents, is suggested in Table 1. The importance of these dates is that preparation was being made for flyers in all of these buildings more than a decade before the nave of Notre-Dame, begun around 1180. Later, after we have examined the lithic evidence for all fourteen churches, we will augment this list with the relative chronology of the undocumented buildings through an assessment of their foliate capitals.

TABLE 1 - Relative chronology of those churches mentioned in the documents. The < and > refer to the works being under construction before or after the dates mentioned in the documents. The third column lists the date suggested in the article.

	Documented Date	Probable Date
Sens, choir clerestory	< 1164?	1160
Saint-Germain-des-Prés, clerestory	< 1163?	1160
Senlis, choir gallery	> 1153	1160
Laon, choir gallery	> 1155	1160
Saint-Remi, south nave clerestory and choir footings	>1162	1165
Notre-Dame, Paris, choir gallery and clerestory	< 1177	1170

## Restoration

Though most flying buttresses in French churches have been restored to some extent, if not entirely rebuilt, over the past eight hundred years, only recently have adequate records been maintained. The records of most of the buildings to be discussed here, which are held by the Monuments Historiques, at the Bibliothèque Nationale, or in the archives of the departmental architects, are either minimal or imprecise. In most cases one has to rely on the visual evidence of surface weathering, methods of stone working, and colour, texture, and type of mortar to determine whether a stone is original or replaced. Studies of restoration will be quoted where they exist; otherwise, wherever it is noted that a stone is “original” without substantiating documentation, I have arrived at this opinion only after comparing each stone in the closest way with indubitably twelfth century stones in nearby courses of the same building.

### *Sens cathedral, choir clerestory, 1160*<sup>16</sup>

Having rigorously examined the authenticity of the existing flyers at Sens, Henriot believed they “would not be later than the end of the twelfth century.”<sup>17</sup> He gives the following three reasons: there being no cross walls or internal arches at gallery level, the vaults would not have been structurally stable without flyers on unbuttressed walls 9 meters high, that prior to restoration the flyers had a quarter circle intrados like others of the twelfth century,<sup>18</sup> and there were no stormwater channels on the cornice, a device that did not appear before 1220.<sup>19</sup>

Henriot’s argument about the structural inadequacy of the gallery and clerestory walls is impeccable. These walls, from the gallery floor upward, have buttresses that measure only 960 mm wide by 530 mm deep. Not only is it doubtful, from a modern structural point of view, that they could have supported stone rib vaults over the widest space covered up to that time (over 15 meters), but it is also hard to imagine that any twelfth century builder would have considered carrying such loads on virtually unbuttressed walls. This is not proof that flyers were intended, however, as the master may have planned to build cross walls or arches within the gallery at a later date when erecting the vaults. Therefore, more cogent evidence is needed to eliminate this and other alternatives, and to show without doubt that the flyers were constructed with the walls.

The evidence exists in the choir clerestory level, though it is not readily visible [b].<sup>20</sup> The octagonal pilasters are bedded into what is left of the twelfth century walls after the windows were enlarged in the thirteenth century. The original earlier masonry is whiter in colour, and its weathering is more irregular than that of later masonry.



Sens cathedral, junction between choir flyers and clerestory wall



Sens cathedral, detail of junction



Above the pilaster capitals, large seating blocks support the flyer arches. They are nearly always bonded into the walls with their bed joints matching those of the adjacent wall masonry. In the flyer to the south of the axial chapel, four courses of twelfth century stonework are still in place.

All twelfth century stones are outlined separately [r1]. The two seating blocks 5 are large stones, resting on top of the impost and extending back into the wall. The adjacent wall block 1 is exactly the same height and made from the same material. The outer faces of the seating blocks 5 are inclined at about 7° to the vertical and slope backward.<sup>21</sup> Where capitals were placed over pilasters, it was normal to cap them with a small glacis sloping at about 50°, as in the adjoining sketch 3. This could not have been the purpose of seating blocks 5 for three reasons: there is not enough space at 4 between the seating block and the edge of the impost to accommodate the outer block that would have finished off the glacis; the upper edge of stone 5 would have had to have been cut back to fit within the slope of a normal glacis; and if the glacis were to be steeper, and if the present inclination of the seating blocks were extended upward along the dashed line 7, it would have met the pilaster near the top of the windows an arrangement not used elsewhere over capitals. Also, as 6 is narrower than 5, there would have been a step in the glacis. We can therefore say that these seating blocks were not meant to form part of a glacis.

In the ambulatory pilasters, the sides of the seating blocks 1 [r2] are not set at 90° to the wall, nor are they parallel to the existing flyer arches 2. The difference is quite noticeable. The reason is to be found under the roof of the chapels. On the south side of the axial chapel, the bottom course of the existing buttress 3 that supports the flyer arch rests on the top of the aisle wall. But next to it, and some 400 mm to the north, is a rectangular mass of whiter masonry, 4. The material is similar to that used in the seating blocks. It is a large mass and is roughly finished on top. As it is placed precisely in line with the inclined sides of the seating block 5, it is probably all that is left of the twelfth century buttress that would have supported this flyer arch.

In [r1] the seating blocks 5 are some 60 mm wider than the existing flyer arch 2. The pilaster above the flyer arch 6 is a little narrower than the seating blocks, and, unlike them, its sides are set at 90° to the wall. If the flyer arch or its coping 8 had not been intended, the differences in width and orientation between the seating blocks and the pilaster could not have been disguised. Such a noticeable change in width and orientation is only explicable if an element was to have been inserted between the two.

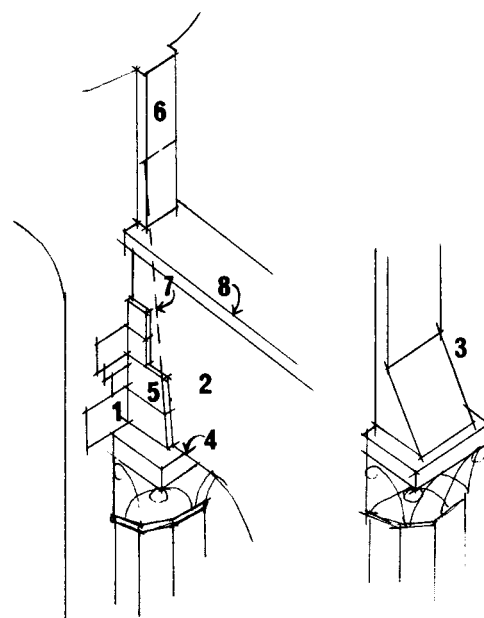
One of the twelfth century arches may still remain, in the first straight bay on the north. The arch is the same width and aligned in the same direction as the seating blocks, but has roll moulds along the lower edges instead of the chamfers found in the other arches. The roll moulds of the uppermost voussoir continue over the top of the impost and stop only a few centimetres before the backwardly inclined face of the seating blocks.

These observations show that flying buttresses were intended when the apse clerestory walls were being built in the 1160s, and that at least one of the flyer arches was erected at that time.

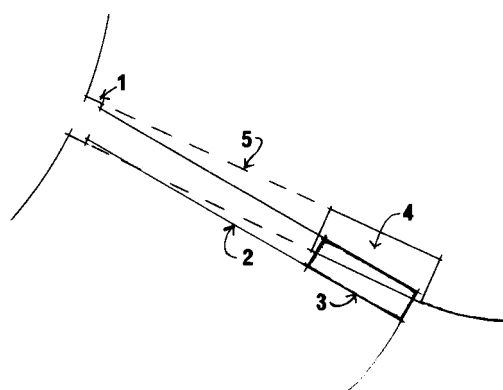
### ***Saint Germain des Prés, choir clerestory, 1160***<sup>22</sup>

As quoted above, Anne Prache believes that the flyers of Saint Germain-des-Prés, though almost completely rebuilt in the nineteenth century, could be dated to the 1160s.<sup>23</sup> Godde's monthly reports on his restorations at Saint Germain between 1819 and 1825 have little to show whether there was or was not any twelfth century stonework in the flying buttresses.<sup>24</sup>

The pilasters at Saint Germain are like those at Sens, being octagonal in plan and supported on square plinths and imposts. In the second flyer on the north, some of the masonry may be original. Where the arch meets the



Sens cathedral, flyers junction with wall



Sens cathedral, plan of flyers

wall, the third and fifth courses of projecting seating blocks are well-worn stones, with the same colour and texture found in unrestored portions of the church. These seating blocks are bedded into the wall; and the adjacent wall masonry, which is also original stonework, butts up against the blocks with very small mortar joints. Though the coursing in the blocks and that in the wall do not coincide, the fact that the wall perpendiculates lie close to and are flush with the sides of the blocks suggests that the two could have been built together.

These seating blocks provide crucial information for an understanding of the early history of the building. If the flyer arches had not been intended, we would expect to find a glacis over the impost, as in Sens. From other examples in the Paris Basin, we would expect this glacis to have been at the most three courses high with a slope of around 5°. Yet there are seating blocks in the fifth course that were built with the wall, showing that such a glacis was not considered. Further, as at Sens, the blocks project so far that they could not have formed the upper part of a glacis; and if they were to have been part of a rectangular pilaster, its corners would have projected over the edges of the octagonal shaft underneath in an ungainly and exceptional manner. See also the small original stone in the third course on the eastern side of the first apse buttress that suggests, as at Sens, that flyers were built with the upper clerestory walls.

In spite of inconclusive evidence in the masonry and extensive restorations, the many similarities with the Sens clerestory and the few original stones that remain suggest that if flyer arches were not actually built at Saint Germain, they were nevertheless intended and their supports were already in place when the clerestory walls were built. Their erection would have attended only on the completion of the high vaults.



Paris, St-Germain-des-Prés, use flyers against the clerestory wall

### ***Voulton, choir clerestory, 1160***<sup>25</sup>

Salet showed that the decision to build flyers at Voulton occurred after the aisles had been completed, because the arches sit uncomfortably on the aisle buttresses; but he gives no reason for the date of 1190 other than agreeing with Lefèvre Pontalis that in such a small church the flyers would have to have been built after those at Paris. We will examine the crucial matter of dating in a moment but will first discuss the evidence in the stonework that shows that the Voulton flyers were erected at the same time as the clerestory walls.

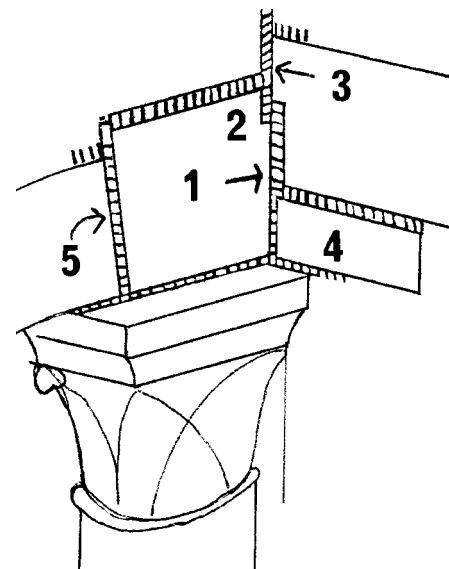
The eastern clerestory wall was completed at the same time as the western bays of the aisles. In the apse, the external

clerestory pilasters are rectangular and are finished with sloping glacis. Except for those against the stair tower on the south side, all the other clerestory pilasters are round, with Plinths, tori, and capitals. They were built with the walls they support, as some original blocks have lateral projections that extend into the adjacent walling [r2].

Most stonework in the flyer arches was replaced during the restorations of the architect Nodent in 1896-1897. In June 1984 I mounted the scaffolding to examine closely the stones of the northern choir flyer and to peer behind the downpipe that obscures some of their junctions. In the sketch the three original stones (marked 1, 3, and 4) are separately outlined.



Voulton from the east



Voulton, detail EN1 flyer junction

The arrow on the seating block 1 shows where the lower part has been let into the wall. The upper part has been checked at 2 to allow the wall course 3 to pass over the top of it. Such checking is normally done before placing the stone, as hammering once in place would damage the mortar and could dislodge stones already laid underneath. The arrow shows where 3 passes over and behind 1, locking the two courses together. The lower wall stone 4 butts hard against the seating block 1, leaving no space and showing that neither stone could have been inserted later. Like the pilaster, block 1 was built with the wall.

The outer face 5 of the seating block is angled in the opposite way to the seating blocks at Sens, to support steeply inclined flyer arches.<sup>26</sup> Being this shape, and having been erected with the wall, these seating blocks could not have been part of a glacis. Therefore, the eastern clerestory walls, were constructed with stones designed to receive flying buttresses.

### ***Saint Lomer in Blois, choir clerestory, 1165<sup>27</sup>***

In the hemicycle the external pilasters are rectangular. In their lower courses, both the face and the sides of these pilasters have been aligned true to the wall, but above the windows the pilasters have been realigned. The location of the twist can be clearly seen on the pilaster to the left of the flyer arch. The original stones show that both upper and lower sections of these six pilasters were built with the clerestory walls.

Flyer arches were erected against only two of the pilasters, leaving the other four pilasters without support. These two arches meet their pilasters three courses above the springing of the windows, which is also in the same course as the realignment of the buttresses. As the radiating chapels are not equally spaced around the ambulatory, the buttresses supporting the flyers are not on the same radials from the centre of the apse as are the vault shafts. In the two pilasters that support flyers, the twists have turned their sides so they are parallel with the sides of the flyer arches. Presumably the pilasters were realigned to support the flyer arches securely.

Though there are no flyers against the other four pilasters, the inclination of the upper courses was changed, in the same way as it was in the pilaster that did support a flyer arch. This demonstrates that the twists were incorporated into the pilasters so that flyers could be set against all of them, and that this was done as the upper wall of the clerestory was being built and before the arches were laid up.

The vertical outer faces of the flyer buttresses are decorated with shafts, bases, and capitals that are not unlike those found in the Voulton pilasters. The style of these capitals, as will be seen, is decidedly earlier than that of the capitals of the Paris nave.

It may be that after work on the walls reached the top of the clerestory windows, the builders became concerned at the size of the vault and reconsidered the supports for the project. At this point it seems to have been decided to install six flyers, and the inclination of the pilasters was altered to support them. The rest of the wall was presumably erected next, to and possibly including the roof; and later, when the vault was being erected, the two flyers were erected. Whatever the subsequent history, we can see that flyers were planned for the choir from the time the upper section of the clerestory wall was being built.



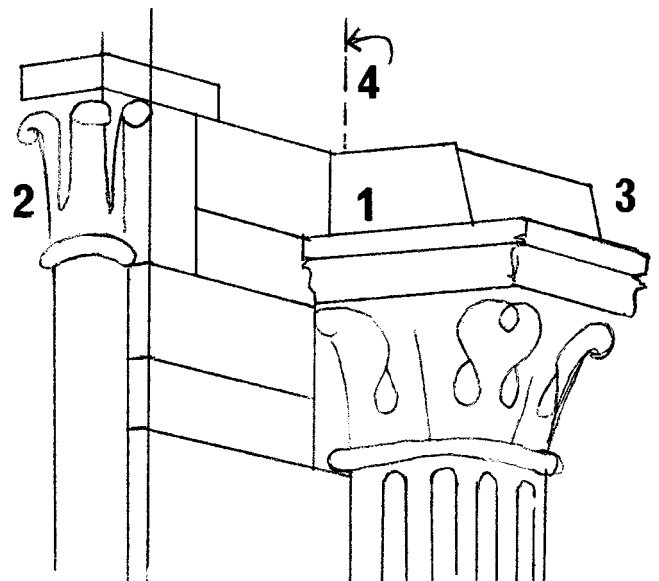
### *Saint Remi in Reims, nave clerestory, 1165*<sup>28</sup>

The addition of the two westernmost bays onto the eleventh century nave of Saint Remi may have been the first building work undertaken by Pierre de Celles after he was appointed abbot in 1162.<sup>29</sup> The capitals in all four stories are similar enough to suggest a short building campaign, though it seems there was a pause once work had reached the top of the older adjacent wall just below the small clerestory roses. The change in stonework between the clerestory windows and the roses above them shows where this joint occurred. At the western end of the southern clerestory wall, hidden behind the mass of the tower, the flyer pilasters are circular and fluted like those on the lower stages of the west front.<sup>30</sup> The pilasters have plinths, tori, and capitals, and they lie entirely below the roses and therefore below the level of the pause in the construction. These pilasters were constructed course by course with the adjacent walls. In the westernmost pilaster on the south [b2], the height of the single seating block 1 matches the adjacent courses including the small capital 2, next to the window. The outer face of the seating block is inclined inward at about 7° just like those at Sens. The flyer arch 4 is narrower than the seating block 1, showing that it was carved from different templates, probably with the high vaults later in the century.

There are also circular pilasters to each of the southern nave bays between the tower and the transept. The capitals over these pilasters and those alongside the windows suggest that all were completed with, or shortly after, the work in the western bay.<sup>31</sup> Only alternate pilasters have flyers, as the vaults are six part. The employment of pilasters with capitals in each bay suggests that four part vaults were intended at this stage and were changed to six part later on, especially as the unused pilasters have the same seating blocks with inclined outer faces as do those with flyers.<sup>32</sup> Flyers in all the southern bays of the nave were therefore intended at the time these walls were built.



Saint Remi, west nave flyer junction



Saint Remi, detail stone over capital

### *Contemporary buildings with less certain evidence*

Now that we have shown from the lithic evidence that flyers were intended in five buildings, most of which would be unhesitatingly dated to the 1160s or early 1170s, we can consider a number of others where there is no specific evidence for flyers in the stonework, but where the wish to install flyers may be the most likely explanation for certain unusual features.

### *Domont, choir clerestory, 1160*

Domont is a small church, smaller than either Sens or Saint Germain-des-Prés. Its flyers are not twelfth century, for two are fifteenth-century and two were rebuilt in the nineteenth century.<sup>33</sup> The gallery and the clerestory pilasters that support them, however, are identical to those at Sens and Saint Germain des Prés. The pilasters are octagonal in plan with square plinths and capitals. Instead of impostes and seating blocks, however, the capitals have been topped with glacis, and there are no pilasters above the glacis to interrupt the curve of the hemicycle.

Both Kimpel and Plagnieux believe that Domont was designed for flyers.<sup>34</sup> A photograph that Plagnieux

unearthed, taken before the nineteenth century restorations, shows that the two flyer arches that were rebuilt in the last century may have been erected at the same time as the high vaults, because their copings had the diamond decoration typical of twelfth century Ile de France cornices. Like their replacements, they emerged from the roof and met the pilasters below the capitals [b1].

The profiles and capitals suggest that the entire inner wall of the choir, from the aisle arcades to the clerestory windows, was built in one operation. The outer ambulatory walls and their vaults were constructed some time later. The high vault was also erected later, probably some fifty years after the walls, for the foliage in the central boss is like the Chartres cathedral aisle bosses from ca.1200.<sup>35</sup> It is the pilasters, however, that interest us here.

Though much of the stonework is new, there is enough original material, especially around the first southern choir pilaster, to show that the capitals and the glacis over them were built with the adjoining stonework. As similar pilasters, capitals, and galleries are found in two other buildings with flyers, Sens and Saint Germain, it may be reasonable to presume that whoever built these walls had intended to add flyers here, too, though at some later date after the outer ambulatory walls had been built to support them.

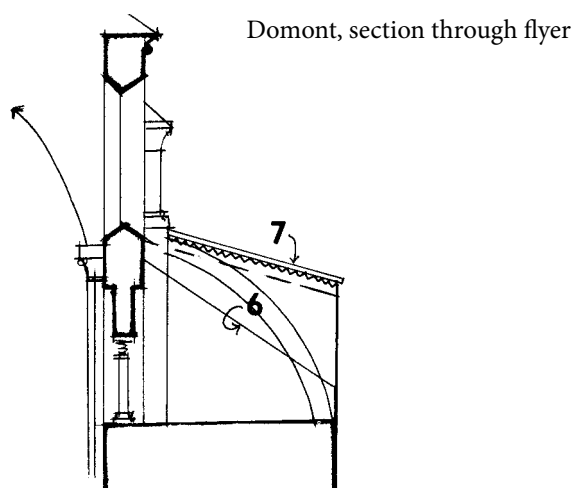
Considering this construction sequence, it is possible that the pilasters were intended to support flyers, though the outer walls that were to support them and the vaults themselves were not erected for a couple of generations. This suggestion is reinforced by two design elements that recur in the buildings we have been discussing: the shape of the clerestory pilaster and the plan form of the gallery.

In Sens, Saint Germain, and Domont the pilasters are octagonal, and in Saint Remi and Voulton they are circular. They all have capitals and bases with full plinths and tori. This arrangement is not found in any other contemporary buildings from the Paris Basin.<sup>36</sup>

In the first three buildings, the galleries consist of twin openings framed under a common arch that is supported on shafts. The arches over the twin openings are supported on one circular shaft in the middle but (and this is the unique feature) on rectangular jambs at each side. In the whole of the Paris Basin there are only five galleries like this: the choirs of Sens, Domont and Saint Germain-des-Prés,<sup>37</sup> and the naves of Grez-sur-Loing and Ennery.<sup>38</sup> Though the Voulton choir gallery has a single opening, it too has rectangular jambs and a circular central shaft. Also, there are small rectangular pilasters behind all these galleries, that turn into octagons and circles at the clerestory window sills. None has other buttressing or cross walls under the roof. These buildings also share similar foliate capitals.<sup>39</sup>

Vaulting profiles have been omitted as vaults could be constructed in so many ways that it would be futile to draw comparisons: the arches and ribs could have been begun with the capitals (Senlis gallery), they could have been left out altogether until the roof was complete (Domont clerestory), or the surrounding arches may have been started with the upper walls without the ribs (Saint Germer-de-Fly aisles). In some there are so many campaigns in the vaults that profiles change from bay to bay (Orbais chapels, Noyon aisles, and Notre-Dame gallery).

As both gallery and clerestory levels of these buildings have features that are not found elsewhere in the Paris Basin, they were probably constructed in the same campaign and under the same direction. Their imposts may also indicate a common designer. The simple ones over most of the pilaster capitals seem to have been for exterior use only [b2]. Internally the imposts are more complex. The one used at Saint Germain is also used in the Domont clerestory and gallery string course. The little groove marked with an arrow is present in some of the Saint Germain profiles and absent at Sens. Where the roll is at the bottom, as in Voulton and Saint Remi, the fillet may be at the top or alongside the roll.



SENS	●	●			
VOULTON	●		●		
DOMONT	●	●	●	●	
SAINT-GERMAIN		●			
SAINT-REMI	●		●	●	
NOTRE-DAME		●			●

Schedule of profiles in flyer arches



### ***Saint Remi in Reims, choir ambulatory, 1165***

Compared to those of any contemporary apse, the buttresses between the chapels of Saint Remi project abnormally far [r]. The buttress 1 supports the chapel vaults and is aligned along the radials from the centre of the chapel. The inclined faces 2 are also placed square to the radials and therefore represent the same function as 1, which is to buttress the chapel vaults. If the main buttress 3 had not been built, the smaller ones marked 2 would still have been needed. It is 3 which is aligned on the centre of the hemicycle vault and supports the upper parts of the building.

The massive stonework of buttress 3 was not added later. In spite of restorations, the remaining original stones show that it was built with the adjoining walls: where coursing is not continuous, the taller stones are housed over the smaller with equal care on both sides of the corners; and the toothing, or penetration of the stones from one side into the mass of the other, is equal all the way up.

The arrangement of buttresses between the chapels shows one of the most characteristic modalities in medieval design: the clear separation of different functional parts. Each buttress expresses its separate purpose from the ground up, without being consolidated into one simpler or larger shape.<sup>40</sup> Thus, the external expression of each function remains distinct, and any buttress could be finished off at the top of the chapel walls, or at the roof, or wherever else its purpose ended, without affecting the others. This allowed the central buttress to continue upward, freed from its lateral adjuncts, into the clerestory.<sup>41</sup>

Because of their size, placement, and orientation, the huge buttresses 3 could well have been designed to support flyers. As these buttresses are carried up to the chapel roofs with only very small glacis, it is hard to believe they were not meant to support flyers in the next story.<sup>42</sup>

In the invention of any great idea there are experiments. Some preparation is needed, some trials deliberately undertaken to examine feasibility or usefulness. This is particularly important with a large building. Sens and Voulton show that the earliest examples of flyers were in buildings that were already well into the second story at the time the concept was first conceived. Therefore, before the foundations for the radiating buttresses in the Saint Remi choir were set out, the master may have already experimented with the idea in the nave clerestory to make sure it would work.<sup>43</sup> Both in elevation and in structure, the western nave bay seems to have been a prototype for the choir. The master may have been able to create such a light construction in the choir because the structural problems had already been resolved in the west.

### ***Orbais, choir ambulatory, 1160***<sup>44</sup>

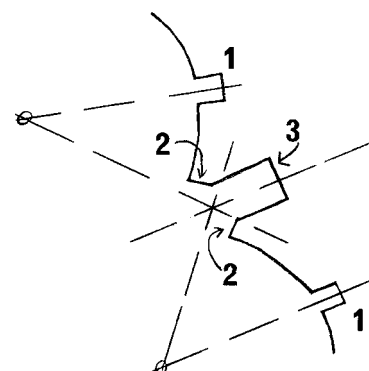
The chapel walls were built first, and some twenty years later the ambulatory piers and vaults were added.<sup>45</sup> Orbais is susceptible to many of the arguments just used at Saint Remi. As at Saint Remi, the buttresses between the chapels are substantial and are aligned directly toward the centre of the apse. The glacis at the springing level of the chapel window arches are shallow, and fully half the buttress projects above the roof cornice of the chapel wall. It is unlikely that these buttresses would have been carried up to the level of the roof if they had not been intended to support flyers.

### ***Saint Germer de Fly, upper walls of choir ambulatory, 1160***<sup>46</sup>

Though the buttresses between the ambulatory chapels are not exceptionally large, and though they have small glacis at sill and vault springing levels, the bulk of each buttress continues above the roof of the chapels and is not reduced in size until some courses above the cornice. Cross walls may have been placed under the roof, but the stability of such walls rests within themselves, and these large projecting buttresses would have served no useful structural purpose at the level of the cornice. It is therefore likely that these buttresses were to support flyer arches in the next level.

It looks as if there was a changed intention at the time the gallery was started, as the buttresses that could have been carried past the gallery to support flyers were greatly reduced in depth. The gallery windows, which are so much smaller than those in the chapels or in the clerestory, suggest that a more conservative design was being pursued at this level.

In the clerestory the pilasters are circular, with bases and tori; but instead of the capitals found at Voulton, the tops of the pilasters are finished with small cones. This is such an unusual termination that one suspects,



Sens cathedral, flyers from the east,

especially as the ambulatory buttresses are so big, that the pilasters were to have had capitals for the support of flyers but were finished with cones when it was decided to leave the flyers out.

### *Notre Dame in Paris, choir gallery, 1170*<sup>47</sup>

The restorations in the gallery are extensive. Nearly every stone in the walls and vaults is of the nineteenth century. Yet the restorers may have followed the original masonry with some care: within the choir gallery the three different profiles that were used for the formerets have been preserved, as were the two for the ribs. Instead of simplifying these profiles and making them the same, which has happened in so many insensitive restorations, the restorers retained individuality and even some of the unfortunate junctions.<sup>48</sup>

If we can trust the internal profiles, we may also be able to trust some of the external details. As at Saint Remi, there are two rows of flying buttresses: one supports the high vaults, and the other supports the vaults of the gallery.<sup>49</sup> The gallery flyer rests on a narrow square pilaster that has an impost moulding but no capital, like Blois. The pilaster above the flyer is smaller, and if there had been no flyer arch this reduction would have looked ungainly. Both the size of the lower pilaster and the reduction in the upper pilaster suggest, as at Sens, that the gallery vaults were to have been supported by flyers.<sup>50</sup>

The decision to include flyers would have been made at the gallery level, for this is where Notre-Dame's great height was imposed. The aisles are quite squat compared to contemporary Sens, and the original clerestory was much smaller than would be expected in a building of this height. Tallness was established by the long gallery shafts, the steeply pitched arches over them, and the domical vaults that pushed the interior roses upward and created the huge expanse of wall between the two. It is no wonder that flyers were considered essential at this level.

As in the gallery, the clerestory pilaster is minuscule compared to the height of the wall it has to buttress [r1]. Only with flyers could the thin clerestory wall have supported the high vaults.<sup>51</sup> The flyers themselves were not installed until the high vaults were built more than thirty years later, as can be seen in the style of the bosses: the one in the third bay, for example, has foliage like that in the Chartres bosses from 1205 to 1215.<sup>52</sup> They were possibly erected at the same time as the eastern nave high vaults, for the first two nave bosses also have foliage similar to Chartres from the early 1220s. From this it can be argued that the Notre-Dame vaults were erected around 1215, and that the refined flyer arches with their trefoil openings were probably set up at the same time to support these vaults.<sup>53</sup>

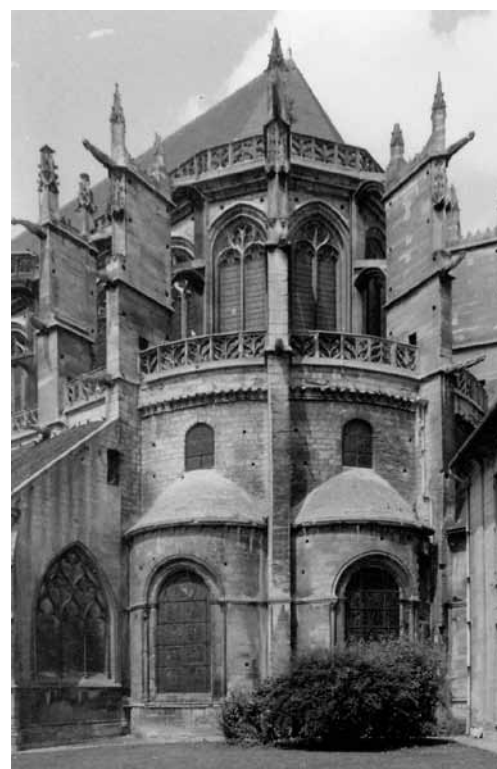
Following the evidence already presented that flyers had been in use for fifteen years or more at the time that the Notre-Dame gallery and clerestory were being built, we can conclude that the gallery and clerestory levels of the choir were also designed for flying buttresses.

### *Senlis cathedral, choir gallery, 1160*<sup>54</sup>

As in the previous buildings, the buttresses between the chapels are quite deep and have been placed radially to the centre of the high vault. They continue without setbacks from the ground to the top of the gallery wall [r2]. If the purpose of these buttresses had been to support only the vaults of the gallery, they would have been terminated before they reached the level of the roof. The continuation of the buttresses into the clerestory level, however, indicates an intention to support lateral buttressing to the high vault.



Paris, Notre-Dame, choir clerestory buttresses



Senlis cathedral, flyers from the east,

### ***Laon cathedral, choir gallery, 1165***<sup>55</sup>

In the third northern bay of the choir gallery, one buttress remains from the first construction stage before the hemicycle was pulled down and replaced with the present square ended choir in the 1180s.<sup>56</sup> Its projection is much greater than would be needed for the gallery vaults on their own. Also, as at Senlis, it continues to the top of the gallery roof without glacis. The coursing is continuous from the buttress to the top of the adjacent windows, and though some of the stonework is new, there are enough original stones to show that it was built with the adjacent wall and window. As at Senlis, it seems to have had only one purpose: to support flyers in the next story.

### ***Noyon cathedral, upper ambulatory walls, 1165 + outer gallery walls, 1170***<sup>57</sup>

As in Orbais and Senlis, the buttresses between the chapels are larger than were needed for the aisle vaults, and they have been carried up to the cornice over the chapels with only a token glacis. This suggests that at this level the buttresses were intended to support arches to hold the six part vaults in the gallery.

The capitals in the gallery show that, unlike Saint Remi, the outer walls were constructed before the inner arcade, rather than the other way around. On the outer wall only a thin circular shaft supports the central rib of the vaults, while a small rectangular pilaster supports the doubleau and diagonal ribs. Although most of the stonework in the present flyer arches and the gallery wall has been replaced, there is evidence in the masonry that while the lower courses of the gallery pilasters were added onto the wall, the upper courses were erected with it. There are also small, though not conclusive, indications in some stones that suggest that the gallery flyer arches may have been built with the pilasters that support them. It is therefore reasonable to conclude that the buttresses between the chapels may have been designed to support flyers.

### ***Mantes la Jolie, ambulatory walls, 1170 + choir gallery walls, 1175***<sup>58</sup>

Jean Bony observed that the large, unaccented buttresses between the gallery windows, which, as at Senlis and Laon, continue up to the clerestory level without setback, were contemporary with the walls.<sup>59</sup> Bony argued that this shows that from the moment the building “had reached the level of the gallery floor” it was the master’s intention, at that level if not before, to continue the buttresses into the clerestory to support flyers to the high vaults. Bony goes on to argue that the reduction in wall thickness from 1,800 mm in the aisles to 420 mm in the gallery was part of the Parisian thin wall technique that implied flyers.

The size of these buttresses at ground level, however, suggests that flyers may have been intended from the beginning. In spite of their encasement in later chapels, the buttresses project even farther than they do above, with only a minimal setback at gallery floor level. As at Saint Remi, they are radial to the centre of the high vaults, which would be unlikely if they were meant to support only the aisle vaults. It is more probable, considering the other examples discussed here, that the master of Mantes had intended to use flyers from the foundations, ca.1170.

### ***Champeaux***

As the buttresses in the aisle walls occur only on alternate bays, and as they continue without setback from the ground to the aisle roof, it can be reasonably argued that these buttresses were meant to support the six part high vaults. From here, it is all a matter of dating. Some of the nave arcade capitals are like those at Canterbury,<sup>60</sup> and an analysis of the capitals suggests a date in the 80s.<sup>61</sup>

### ***Saint Denis choir, 1140***

As the buttresses at crypt level are quite large for their time, it has been argued that they were meant to support flyers [r].<sup>62</sup> But they are not all directed toward the centre of the high vault, and they were reduced in size at the main floor level. On the other hand, they were not reduced at the ambulatory cornice but finish in capitals, as at Langres and other central French buildings. Whether flyers were intended may have to remain an open question; but as the earliest provable flyers were started at Senlis, Sens, Saint Remi, and Voulton some fifteen years later, I doubt they were intended at Saint Denis.

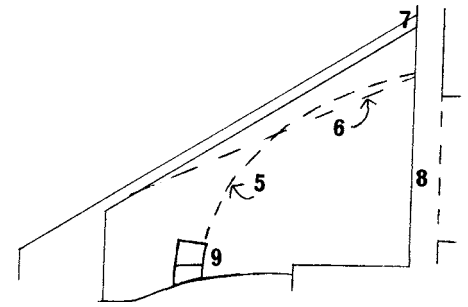


St Denis, crypt buttresses



## Langres

Schlink has suggested that the two rows of voussoirs under the roof behind the gallery show that flying buttresses had been intended around 1160.<sup>63</sup> But Schlink's figure 7 on page 41 is drawn incorrectly. The putative flyer 9 does not sit where he has shown it, but rests over the middle of the aisle vault, at a distance of 3,005 mm from the pilaster inside the gallery wall, 8 [r]. At this point the height from the springing of arch 9 to the string course just below 7 is 3,640 mm. From the proportions of his drawing, one would have the impression that this height was less than 2,900 mm, with a roof at 6. As only two voussoirs remain, the actual radius of the arch cannot be measured accurately, but it would seem to have followed the curve 5. It is not so steeply pitched that the top of the arch could have reached above the clerestory sills. Langres seems to have had a sub roof arched buttressing system similar to Laon. Prache asks, however, why the external buttress capitals were raised above the aisle roof cornice if they were not for flyers, as "it was not usual to top a buttress with a capital because a capital was meant to carry something so there must have been something projecting."<sup>64</sup>



Langres, section through choir roof.

## Saint Martin in Etampes

It has been argued that the size of the buttresses, particularly those on the south, could only have supported flyers.<sup>65</sup> The widths of the buttresses vary so greatly, from 646 mm through 730, 850, and 1,015 to 1,645 mm, and in a random arrangement, that the sizes of the buttresses cannot be used as evidence that flyers were intended. The two biggest buttresses on the south side of the choir have the mass to support flyers, but they could equally have been intended to support a tower. Also, the largest buttress is the only one not supporting a flyer arch today. In the clerestory the pilasters are set square to the wall and finish in glacié, which can still be seen behind the later flyers, and there are no seating blocks as at Sens, nor any realignment of the outer faces of the pilasters as at Blois. The construction history is complex, and the coursing shows that the western bay with the largest buttresses was built before the apse. I do not believe that the evidence is firm enough to prove that flyers were either intended in the plan or built with the clerestory wall.

## Chronology (second part)

In Table 1 was listed the approximate dates for the six buildings with flyers that have some documentary substantiation. For the remaining buildings we need some other indicator of relative chronology. The most accurate indicator lies in the way the foliage was cut and arranged on the capitals.

Between 1140 and 1240, only parts of fourteen buildings from the Paris Basin can be dated with any certainty from the documents fewer than 1 percent of the surviving churches.<sup>66</sup> Many other buildings have documents that mention construction work without referring clearly to any definable part of the building. Many more have documents that refer to consecration but consecrations could be held at the start or the finish of the works, or at almost any time in between.

By comparing the capitals in these fourteen datable parts, it can be shown that after the 1170s there was a stylistically regular evolution of foliate carving from the almost two dimensional delicacy of the 1170s and the bold simplicity of the 1190s, to the vigorous, naturalism of the 1220s foliage was being transformed in graduated stages that can be succinctly defined.

What is most useful for our purposes is that there was a definite divide during the 1170s when foliate carving was altered radically. Before 1168± all foliage is stylized, while after 1180± every capital is based on natural models. This decade was a watershed. There had been a sudden transformation in design attitudes that seems to have affected all carvers equally: within the work of any one building campaign in nearly all the churches in the Paris Basin, almost every capital will be either stylized or naturalistic. The parts of buildings with a significant proportion of both types of capitals can be counted on one person's fingers for example, the choir gallery of Notre-Dame in Paris datable to the early 1170s, the external wall of the Noyon choir gallery, and the Veully-la-Poterie aisles.<sup>67</sup>

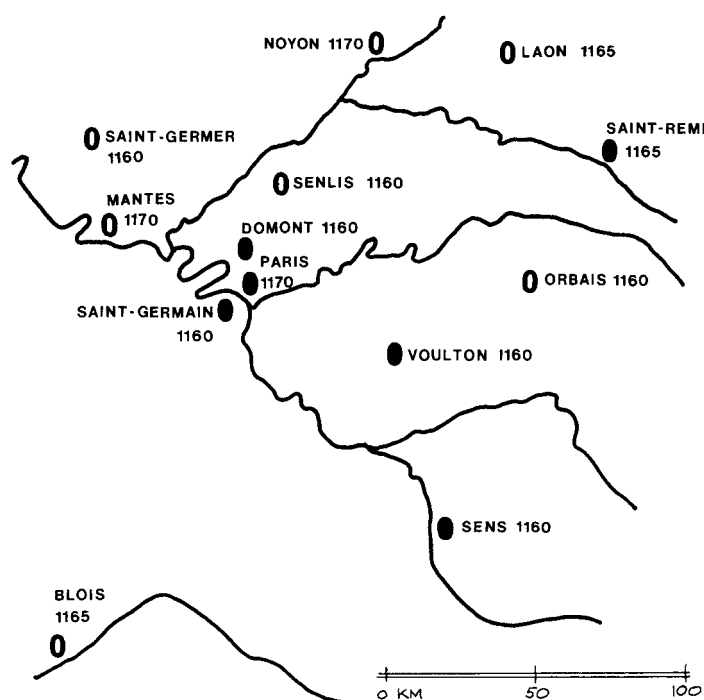
This shows that in thirteen of these churches, all of which have nothing but formal capitals and no naturalistic ones, the capitals under the flyers were carved before 1170. The relative chronology suggested in Table 2 comes from this ongoing analysis of the capitals, and includes all the buildings discussed here.

Depending on interpretation, three documents - being the dedications at Sens and Saint Germain and the

starting date at Senlis – tend to throw the earliest dates back into the 1150s; or, alternatively, Torrigny’s account of Notre-Dame could bring the earlier dates forward a bit. Whichever way we examine the chronology, however, we still have to conclude that the invention of the flying buttress occurred much earlier than 1180, and definitely sometime before 1165. The map shows that most of these early flyers were built around the periphery of the Paris Basin. There is no definite geographic concentration that might give a clue to any one centre of operation, and without a more secure chronology we can neither prove nor disprove that flyers were invented in the Ile de France (Saint Germain or Domont), or anywhere else (Voulton or Sens).

TABLE 2 Relative chronology of the flying buttresses or their pilasters in churches discussed in this article. The churches are listed in approximate order of construction. Dates are  $\pm 5$  years. The second column lists the dates before or after which the work was built, as suggested by the documents. The third column lists the probable dates calculated from the second column and from the foliate style of the capitals in *The Ark of God* and individual churches in <https://www.creationofgothic.org/COGA/capitalphases.php?id=DOMONT>

	Documented Date	Estimated Date
Domont, clerestory		1156
Saint-Gemer-de-Fly, upper ambulatory walls		1156
Saint-Germain-des-Prés, clerestory	< 1163?	1158
Sens, choir clerestory	< 1164?	1159
Senlis, choir gallery	> 1153	1159
Orbais, upper ambulatory walls		1161
Laon, choir gallery	>1155	1162
Provins, Saint-Quirace, choir clerestory		1164
Voulton. clerestory		1165
Saint-Remi, south nave clerestory	> 1162	1165
Saint-Lomer, Blois, choir clerestory		1165 $\pm$
Saint-Remi, ambulatory walls	> 1162	1168
Noyon, upper ambulatory walls		1169
Mantes-la-Jolie, ambulatory walls		1170+
Notre-Dame, Paris, choir gallery and clerestory	< 1177	1170
Noyon, outer choir gallery walls		1170+
Notre-Dames, Paris, choir clerestory	<1177	1174
Mantes-la-Jolie, choir gallery		1175 $\pm$
Notre-Dame, Paris, nave aisles		1190 $\pm$



Map with location flyers before 1170

### *Flyers as the embodiment of a new geometric paradigm*

Inevitably the invention of the flying buttress revolutionized the way buildings were evolved. Aligned on the radials from the center of the main vault, it encouraged architects to design out of the axis rather than from the thickness of the wall. An axis is a theoretical line, without density or mass, which passes through structural elements and readily represents the direction of the forces within them. This is illustrated in Villard de Honnecourt's ideal plan for a Cistercian church in which the walls are drawn as intersecting lines.<sup>68</sup> Only the weight-carrying members, the piers and the buttresses, are drawn with thickness. The walls between the buttresses, which carry no significant load, are represented only by thin lines. Everything has been concentrated on the intersections.

By comparison, the ninth century plan of Saint Gall is also drawn in lines, but there is no distinction between what is loadbearing and what is infill.<sup>69</sup>

We know from some of the geometric methods used to set out Romanesque buildings that the thickness of the walls was determined by the span between them. One way was to draw a square with a circle around it and to place the internal faces of the walls along the sides of the square and the external faces tangential to the circle, while another was to set a modular grid across the site to determine both the spaces and the thickness of the walls.<sup>70</sup> Either way, the wall was defined by its faces rather than by any axes running through it, and its thickness was related to the spaces it enclosed, as matter defines void.

But as buildings became more complex, with shafts and buttresses, the masters were offered new choices: was the outside to be defined by the external face of the wall or by the buttress, and was the inside to be determined from the inner face, as before, or by some part of the shafts now attached to it? In the apsidal towers at Chartres, this choice was still being hammered out. In the south tower, the geometry defines the inner wall face and the shafts are, as it were, stuck onto it; in the north, the geometry defines the axes through the rib shafts and the wall is defined separately.<sup>71</sup> In structural terms the difference has almost no effect at all: the difference is entirely in attitude. As buildings came to be designed around one or more theoretical axes lying within the masonry rather than to the bulk of the masonry itself, the masters would have begun to approach their craft in a new way.

The first outer manifestation of this new inner design paradigm may have been to transfer the vault thrusts, which had been absorbed by the wall, to buttresses at a distance. Around 1100 this was being done within the middle story with arches hidden under the gallery roof.<sup>72</sup> But once moved up into the open in buildings that were already well advanced when the decision was made, such as Sens and Voulton, their inclusion in new buildings encouraged the masters to think through how the flying buttresses could be logically extended down to the ground. This is why we find in Saint Remi an utterly new type of building: one that was to have light and elegant walls and arcades that just filled the spaces between heavy buttresses, which lay along the axes that radiated from the central boss and were dedicated to the support of flyers.

An axis has only one dimension and exists only in the imagination of the architect. Yet conceptually, as he drew an axis onto the plan, he could visualize around it the actual mass of masonry that it represented. As an abstract line rather than mass came to illuminate the design process, masonry was created from and around these lines rather than from the faces of the solids. This could be seen in nearly every geometric system used at Chartres from 1194 onward,<sup>73</sup> and is not evident a century earlier.<sup>74</sup> When thrusts are represented as lines, the separation of the different functions can be readily maintained, as in chapel buttresses at Saint-Denis, Saint Remi, and in the intersecting flyers at Chartres. Chartres illustrates the flowering of this idea: the thrusts from the choir and transept vaults pass independently through each other to their respective supports without affecting one another.

The buttress was seen no longer as part of the wall, but as an independent unit that stabilized the vaults. It was then but a small step to see that if the buttress is large enough, the wall has little structural purpose and can be replaced with glass. The building became a cage-like skeleton, in which thin piers and clusters of shafts on the inside, and thin buttresses and arches on the outside, supported the arches and ribs of the vaults. This began a process that in time dispensed with the masonry wall as the primary structural unit a concept that has set medieval designers apart from all previous masons. The full maturity of Gothic architecture revealed the power of this idea.

The concept of the skeletal frame did not die with the Middle Ages but was reborn in the architecture of our own day. It may be significant that it was in the later decades of the eighteenth century, when people were becoming interested in the Gothic Revival, that the first multi-storey skeletal cast iron factories were being constructed in the north of England.



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2. Eugène Lefèvre-Pontalis, "Etude historique et Archéologique sur l'église de Saint-Germain-des-Prés", *Congrès Archéologique*, lxxxii 1919, 363. His opinion was repeated by Marcel Aubert, *Notre-Dame de Paris, sa place dans l'histoire de l'architecture du XIIe au XIVe siècle*, Paris, 1920, 44 and 88-106; and Robert Branner, "Gothic architecture", *Journal of the Society of Architectural Historians*, xxxii 1973, 327-333.
3. "Malgré certaines apparences trompeuses, il est certain que l'apside de Saint Germain des Prés était caractérisée par l'absence d'arcs boutants." Eugène Lefèvre-Pontalis, "L'origine des arcs-boutants", *Congrès Archéologique*, lxxxii 1919, 378.
4. Eugène Emmanuel Viollet-le-Duc, *Dictionnaire raisonné de l'architecture du XIe au XVIe siècle*, 1868, i, 62.
5. Anne Prache, "Les arcs-boutants au douzième siècle", *Gesta*, xxv 1976, 37.
6. Jacques Henriët, "Recherches sur les premiers arcs-boutants un jalon: Saint-Martin-d'Etampes", *Bulletin Monumental*, cxxxvi 1978, 309-323.
7. Jacques Henriët, "La cathédrale Saint-Etienne de Sens: le parti du premier maître et ses campagnes du XIIe siècle", *Bulletin Monumental*, cxl 1982, 152-212.
8. Jean Bony, *French gothic architecture of the 12th and 13th centuries*, Berkeley, 1983, 180. These buildings were Saint Leu-d'Esserent, Gonesse, Champeaux, and Mantes la Jolie. Except for the last, the relevant sections of all three lie closer to 1200 than to 1180. Bony's methodology assumes that innovations had to originate at major work sites; John James, "03 Memes and assumptions", *In Search of the unknown in medieval architecture*, 2007, Pindar Press, London.
9. William Clark and Robert Mark, "First flying buttresses: a new reconstruction of the nave of Notre Dame de Paris", *The Art Bulletin*, lxvi 1984, 47-64.
10. Caroline Bruzelius, "The construction of Notre-Dame in Paris", *The Art Bulletin*, lxix 1987, 550-53. Grodecki and others have also supported an earlier date for flyers; John Fitchen, *The construction of Gothic cathedrals. A study of medieval vault erection*, Oxford, 1961, 290-92; Louis Grodecki, *Gothic Architecture*, New York, 1977, 48; Louis Grodecki, "Les arcs-boutants de la cathédrale de Strasbourg et leur origine", *Gesta*, xv 1976, 43-51; Dieter Kimpel and R. Sukale, *Die gotische architektur in Frankreich 1130-1270*, Munich, 1985, 150; and Christopher Wilson, *The gothic cathedral, The Architecture of the Great Church 1130 1530*, London, 1990, 41-43.
11. John James, "In defence of Toichology", *Avista Forum*, vii 1994, 9 and also James, "05 Toichology", *In search*.
12. "Les arguments ... sont de deux ordres, d'abord une simple pétition de principe ... ; ensuite tin certain nombre de remarques, faites le plus souvent sans critique d'authenticité préalable des édifices concernés et mettant en évidence, clans les arcs-boutants soi-disant ajoutés ultérieurement, un certain nombre d'irrégularités ou d'imperfections dans la liaison de leurs éléments." Henriët, "Sens", 137-38.
13. Bruzelius, "Notre Dame", 555, suggests that the one remaining flyer in the nave of the Cistercian abbey of Ourscamp should be dated to 1175. Dominique Vermand, "La voûte d'ogives et l'architecture de 'transition' dans l'Oise: les premières expériences (1100-1150)", *L'art roman dans l'Oise et ses environs*, GEMOB 1995, Beauvais 1997, 123-168.
14. All relevant documents listed in John James, *The Creation of Gothic Architecture - an Illustrated Thesaurus: The Ark of God*, vols 1-2, Part A: "The Evolution of Foliate Capitals in the Paris Basin 1170 to 1250", London and Hartley Vale, 2002, appendix v.ii. Saint Germain: *Archives nationale*, L753, no. 7. Sens: "La chronique de Clarius," *Archives de l'Yonne*, Dept. de Sens, G.124. These are all set out in James, *COGA/Documents.php*.
15. Henriët, "Sens"; and Kenneth Severens, *The cathedral of Sens and its influence in the twelfth century*, Dissertation John Hopkins Uni, 1968.
16. Henriët, "Sens", 137.
17. Henriët, "Sens", 134.
18. Henriët, "Sens", 133 and 137.
19. "Whether we look at the choir or the nave, the [flyers] do not appear to be joined into the clerestory walls." Henriët, "Sens", 136.
20. All replaced stones have retained the same inclination on the outer face. Henriët's, Fig. 60 in "Sens", 134, shows the same situation in a drawing of 1809, before the flyers were renovated.
21. Lefèvre-Pontalis, "Saint-Germain"; and J. P. Nortel, *Saint-Germain-des-Prés*, Paris, 1976; James, *COGA/Documents.php*.
22. Prache, "Arcs boutants", 37.S
23. Philippe Plagnieux kindly allowed me to read this part of his not-yet-submitted doctoral thesis on the building. I am convinced by his evidence, which follows a close examination of the masonry, that these flyers were built with the clerestory walls. Concerning Godde's reports, he writes, "Il n'est plus possible nie de nier l'authenticité des arcs-boutants du chœur ni de contester leur intérêt archéologique."
24. Francis Salet, "Voulton", *Bulletin Monumental*, cii 1944, 91-115; and Prache, "Arcs boutants", 33-34.
25. Prache, "Arcs boutants", 34-35 refers to the idea that early flyer arches were formed from quarter circles. Voulton shows that this is not a universal truth. It is more likely that the width of the aisle was not large enough to support quadrant flyers for a vault of this height, and the master took this practical solution.
26. G. E. Everett, *The role of the abbey church of Saint-Lomer-de-Blois in the evolution of Early Gothic architecture*, dissertation Harvard, 1975.
27. Anne Prache, *Saint-Remi de Reims: l'œuvre de Pierre de Celle et sa place dans l'architecture gothique*, Geneva, 1978, 56; and Anne Prache, "Les arcs-boutants du chevet de Saint-Rémi de Reims", *Bulletin de la Société nationale des Antiquaires de France*, 1973, 41-3.
28. Prache, *Saint-Remi*, 56.
29. The bombardment in 1918 destroyed the nave vaults. Photos taken just afterwards show that the flyer and its supports predate the restorations. My thanks to Anne Prache for sending me copies of these photos.
30. On the north, the flyers at gallery level lie underneath the roof of the cloister. Their capitals are later in style than those on the south, being similar to those in the Orbais ambulatory piers, the Braine triforium, and the Soissons south transept, which suggests a date in the mid 1180s; James, *Ark of God*, 241; and Prache, *Saint Remi*, 83.
31. After World War I the outer faces of these seating blocks were turned into glacis with mortar; Prache, *Saint-Remi*, Fig. 25.
32. Lefevre-Pontalis, "Arc-boutants", 379.
33. Philippe Plagnieux, "Arc boutants", n. 24; Kimpel and Sukale, *Gotische architektur*, 517.
34. John James, *The contractors of Chartres*, Wyong, ii vols. 1979-81, 230.
35. The authority for this and similar statements comes from the survey reported in John James, "An investigation into the uneven distribution of churches in the Paris Basin, 1140-1240", *The Art Bulletin*, lxvi 1984, 13-46.
36. The windows were lowered in 1645-46; Dom Bouillant, *Histoire de l'abbaye royale de Saint-Germain-des-Près*, Paris, 1724, 238.
37. The nave of Grez sur Loing may not be relevant, as it dates from the first half of the twelfth century. Ennery is to the northwest of Paris, and though the capitals to the gallery are from the 1190s, the capitals to the arcade underneath and the bases to the gallery shafts seem contemporary with the Sens choir gallery; thus the lower courses to the gallery were built with the aisle arcades.

38. Fully illustrated in Vols. 4 and 5, James, *Ark of God*. Also in James, *COGA/capitalphases.php?id=ENNERY*.
39. Separation discussed in James, *Contractors*, 267 and 312. Consolidated buttresses, like those between the Chartres chapels, are exceptional in the Paris Basin; *ibid.*, 179.
40. Two of the buttresses flanking the axial chapel are not radial to the choir. There is a staircase inside one of them which would have forced the encasing walls outward. The other was possibly squared off to balance the stair buttress, a preference that is discussed in James, *Contractors*, 267. This staircase would not have accessed the roof over the aisles, for the roof is at its lowest point just here. Did the builders intend to construct a second chapel over the first, as at Saint Leu d'Esserent? This stair would then have led to the upper chapel.
41. Prache, *Saint Remi*, 72, dated the inner wall of the eastern gallery arcade to the 1170s. The outer wall was built more than a decade later and therefore after the Paris nave, Dom Bouillant, *Histoire de l'abbaye royale de Saint-Germain-des-Près*, Paris, 1724, 48-50, and it is generally agreed that flyers were intended at this level; Prache, *Arcs boutants*, 39. The surviving original window capitals of the gallery and clerestory levels are identical and are 1175/1185, James, *Ark of God*, 240 et seq.
42. Prache, *Saint Remi*, ch. 3.
43. Alain Villes, "L'ancienne abbatiale St-Pierre d'Orbais", *Congrès archéologique*, cxxxv 1980, 549-589.
44. The "add a chapel" strategy, John James, *The Template-makers of the Paris Basin*, Leura, 1989; Bouillant, *Saint-Germain*, 50-53.
45. Jacques Henriot, "Un édifice de la première génération gothique: l'abbatiale de Saint-Germer-de-Fly", *Bulletin Monumental*, cxliii 1985, 93-142; and Mark Pessin, "Twelfth century abbey church of Saint-Germer-de-Fly and its position in the development of the first Gothic architecture", *Gesta*, xvii 1978, 71..
46. Bruzelius, *Notre Dame*; James, *Ark of God*, 81 et seq.
47. The five sets of templates in the capitals, imposts, and windows may indicate some five campaigns in this zone, as in the Chartres and the Essômes triforiums. This may best be studied in the three southeast bays, and especially in the corner wall pier; Bruzelius, *Notre-Dame*, 550.
48. I suggest that the master who built the Saint-Remi gallery also built the Paris choir gallery and clerestory. There are so many architectural, proportional, and foliate connections that it is hard to believe otherwise.
49. "From the late 1160s or early 1170", Bruzelius, *Notre Dame*, 530.
50. Lefèvre Pontalis, "Saint Germain", 342, believed that the under-buttressed walls of Notre Dame were capable of supporting the vaults; this is an error.
51. James, *Ark of God*, 86-87.
52. Prache, "Arcs boutants", 32. Trefoils in flyers used in Chartres choir at this date; James, *In search*, 84-85; James, *Contractors*, fig. 446.
53. Dominique Vermand, *La cathédrale Notre-Dame de Senlis au XIe siècle: étude historique et monumentale*, Paris 1987.
54. William Clark and Richard King, *Laon Cathedral. (I) architecture*, London, 1983.
55. James, *Ark of God*, 401 et seq.
56. Héliot, "Architecture gothique"; Tom Folk, *Saint Denis, Noyon, and the Early Gothic Choir*, Frankfurt am Main, 1982; and James, *Ark of God*, 215-.
57. Jean Bony, "La collégiale de Mantes", *Congrès archéologique*, civ 1946, 163-220; and James, *Ark of God*, 191 et seq.
58. Bony, "Mantes", 196-97.
59. Roslin Mair, "The choir capitals of Canterbury cathedral", *Medieval Art and Archeology at Canterbury*, Transactions of the British Archeological Association, 1982, 56-67.
60. James, *Ark of God*, 360 and 837 and COGA [Champaux] Phase5.
61. Fitchen, *Gothic cathedrals*, 290-92; and comments in Prache, "Arcs boutants", 38-39; and Wilson, *Gothic cathedral*, 41-43.
62. Wilhelm Schlink, *Zwischen Cluny und Clairvaux: die Kathedrale von Langres und die burgundische Architektur des 12 Jh.*, Berlin, 1970, 40-43.
63. Prache in a letter to the author; also Prache, "Arcs boutants", 39-40.
64. Henriot, "Saint-Martin".
65. James, *Ark of God*, ch. 2.
66. Set out in detail in James, *Ark of God*, including the argument for dating of the Paris Notre-Dame nave to the 1190s.
67. François Bucher, *Architector. The lodge books and sketchbooks of medieval architects*, New York, 1979.
68. Walter Horn and E. Born, *The plan of St. Gall, a study of the architecture and economy and life in a paradigmatic Carolingian monastery*, Berkeley, iii vols, 1979.
69. Kenneth Conant, "Medieval Academy excavations at Cluny IX: systematic dimensions in the building", *Speculum*, xxxviii 1963, 1-43; James, *Contractors*, 39 and 204; James, *Traveller's key*, 105-106; John James, "Discrepancies in medieval architecture: careless or deliberate?" *Architectural Association Quarterly*, xiii 1982, 41-48; and Elizabeth R. Sunderland, "Symbolic numbers and Romanesque church plans", *Journal of the Society of Architectural Historians*, xviii 1959, 93-103.
70. James, *Contractors*, 330 for the north tower and 333 for the south.
71. Stephen Gardner, "The nave galleries of Durham cathedral", *The Art Bulletin*, lxiv 1982, 564-579; James, "17 Rib vaults of durham," in James, *In Search*, 222-240; and Lefèvre-Pontalis, "Arcs boutants".
72. James, *Contractors*.
73. James, "32 Discrepancies"; Conant, *Cluny*; and Sunderland, "Symbolic numbers".