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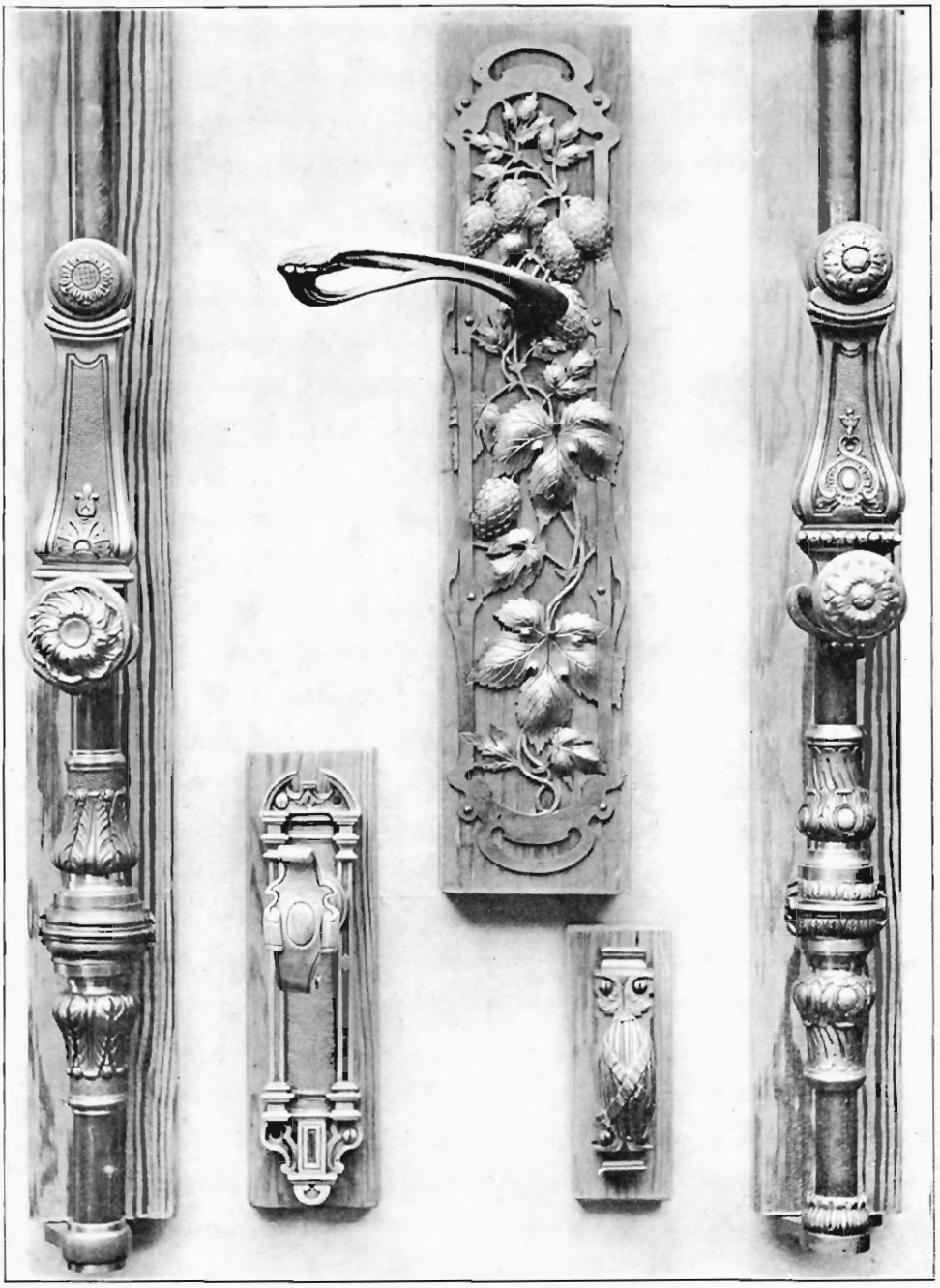

EXAMPLES OF MODERN FRENCH HARDWARE.

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ARCHITECTURAL REFINEMENTS IN FRENCH CATHEDRALS.

Second Paper.*

The Cathedrals of Paris and Amiens.

A GLANCE at the illustrations of my August paper, as connected with the dimensions of the original buildings which are mentioned in the text, will show that these illustrations were selected, with one exception, from churches of small dimensions, and in several instances from side aisles of these churches, which are of smaller dimensions than the naves. The apse of the Balaban Aga Mesjid (Fig. 1 of the August Number) is only 12 ft. in height. The height of the piers in St. Mary Diaconissa, at Constantinople, is 33 ft. In St. Jean at Caen this height is 35 1-2 ft. In St. Loup at Chalons it is 32 ft. In the side aisles of St. Alpin and Notre-Dame at Chalons, the heights of the pilasters illustrated were respectively 14 ft. and 15 ft.

The Widening in Notre-Dame.

These remarks bear on the possibly inadequate impression which the photographs of the outward divergence in Notre-Dame at Paris and in Amiens Cathedral (Figs. 1 and 4) may make upon the reader, as compared with the pictures of churches of smaller size, in the preceding paper. It must be borne in mind that in cuts of these small dimensions we are now representing naves which are 147 ft. in height at Amiens and 110 ft. in height at Paris. Consequently the divergence of the piers at Amiens, which is nearly 3 ft., is not very clearly seen in Fig. 4.

The divergence at Paris in the piers at the crossing of nave and transept is more easily seen in Fig. 1, although it is of less amount (about 21 inches in the piers on the choir side of the transept), because the church is not as high as at Amiens and the picture is consequently of larger size, as compared with the original. For one who is familiar with the large photographs of Notre-Dame in the Brooklyn Museum, Fig. 1 is, however, somewhat disappointing, as compared with the enlargement from the same negative.

In this exhibit of photographs of French cathedrals, which was installed early in June, there are twenty-eight photographs of Notre-Dame which are 25x35 inches (inside photograph measure)

*In continuation of the paper which appeared in the August Number, on "Architectural Refinements in early Byzantine Churches and French Cathedrals." The illustrations of these papers are from photographs of the Brooklyn Museum surveys, of the series of 1903. The purpose and effects of the refinements described in these papers have been discussed at considerable length in previous publications, relating to other churches. See, for instance, Brooklyn Museum Memoir No. 2, "The Architectural Refinements of St. Mark's at Venice," published by the Macmillan Company.

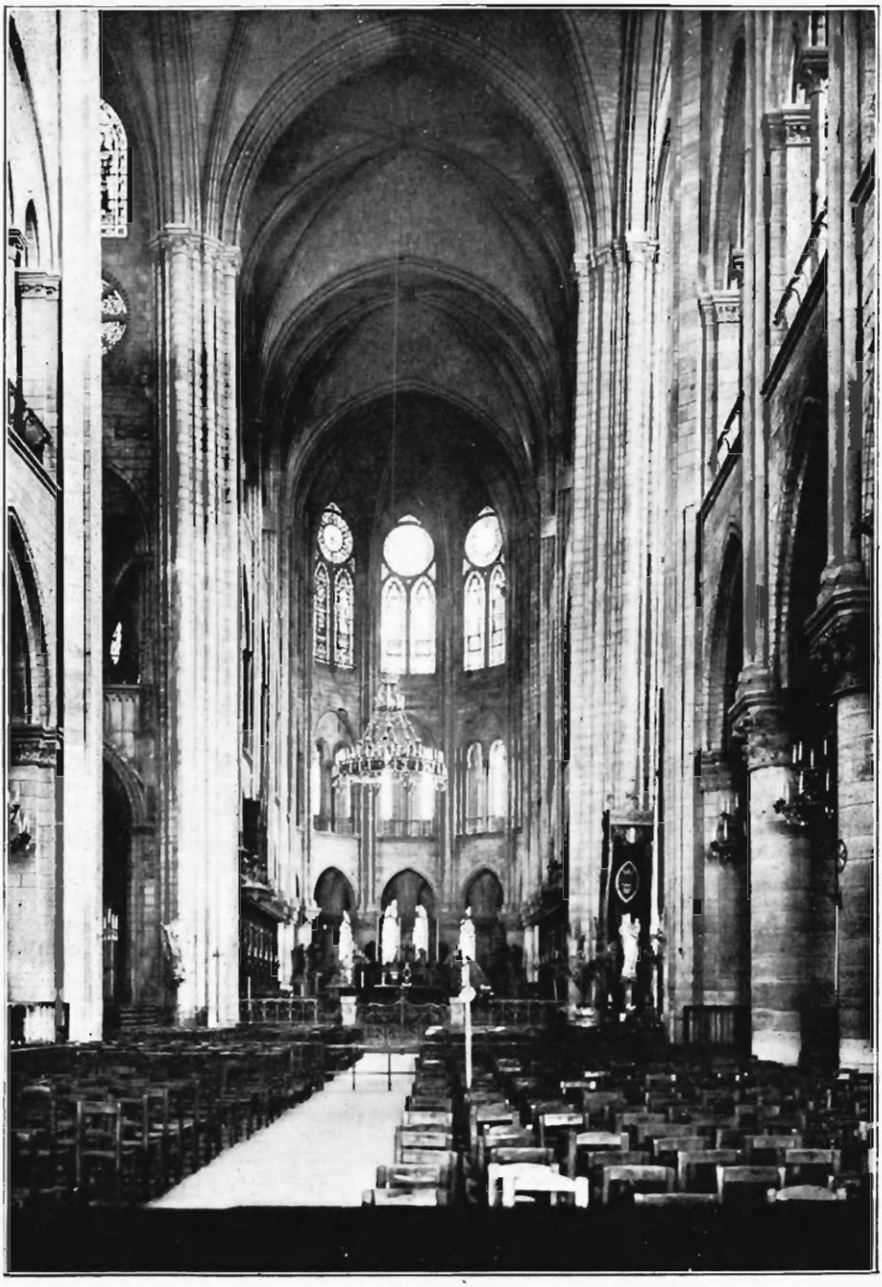


FIG. 1. THE NAVE OF NOTRE-DAME.

Note plumb-line suspended from triforium on the right, beside the pier at the crossing. The chandelier chain does not offer a plumb-line, because it is tied out of perpendicular.

and seventeen photographs which are 18x22 inches. Five photographs of size 25x35 inches and three photographs of size 18x22 inches are devoted to the vertical curves and the widening of the nave in Notre-Dame. For readers in the neighborhood of New York an inspection of these photographs may be recommended. The difference in size between Fig. 1 of this paper and the corresponding large photograph, No. 65, of the Brooklyn exhibit, from the same negative, makes a surprising difference in the appearance of the divergence of the piers at the transept.

In the size of the last-named photograph it even appears more striking than it does in the church itself, where the convergence due to perspective tends to diminish its effect.

In spite of the somewhat inconspicuous character of the divergence, as seen in Fig. 1, it may be asserted with great confidence that no reader of this paper who examines the Brooklyn exhibit (or who examines the building itself) will find it to be inconspicuous or unimportant. Meantime, let a slip of paper be laid across Fig. 1, over the piers at the transept next the choir and marked with a pencil, so that the width of the pavement between these piers may be compared with the width at the capitals.

As a matter of fact, and speaking of observation on the spot, there is no church so far examined in northern France, aside from that of St. Quentin, in which the nave widening is so conspicuous as it is in the farther pair of piers at the crossing in Notre-Dame. As regards the general oversight of this fairly conspicuous fact in Notre-Dame, it may be due to the effect of perspective convergence which tends to make the diverging vertical lines appear parallel. Psychologists have taught us that there is a habit of "expectancy" in the eye which leads us to see what we expect to see, or are in the habit of seeing, under the given circumstances. This is probably another reason why this feature in Notre-Dame is so generally overlooked.*

Aside from the church of St. Quentin and from other churches illustrated in the August Number, and from Notre-Dame, the most conspicuous cases of widening so far observed in France are in St. Pierre at Caen, in the church of the Monastery of Montierneuf at Poitiers, and in the Cathedral of Amiens. Less conspicuous, but well-defined instances are the cathedrals of Rouen, Laon, Rheims, Chalons, Beauvais, Strassburg, and the church of St. Remi at Rheims. In all of these cases the vertical lines also bend or curve. The best French instance of a nave showing uniformly employed and strongly defined vertical curves without widening, is the Cathe-

*This habit of "expectancy" has another result, after one has begun to look for vertical curves and for the widening construction. It then leads one sometimes to see these phenomena where they do not exist. This, at least, is my own experience, so that I have grown to trust nothing but a plumb-line or a carefully made photograph, in the less conspicuous cases.

dral of Noyon, as far as recent observations have gone. The facts are well represented for all these buildings by the Brooklyn exhibit.

For a complete record of all the observations of 1903 in France Museum Memoir No. 4 (Macmillan) may be consulted. This includes mention of the churches and cathedrals which were examined and in which the phenomena described have not been observed. Among these are the cathedrals of Bayeux, Soissons, Poitiers, Chartres, Tours, the churches of St. Ouen and St. Maclou at Rouen, of L'Épine near Chalons, and the Sainte Chapelle at Paris.

Vertical Curves in Notre-Dame.

To return to Notre-Dame at Paris, no time should be lost in mentioning that the marked divergence in the second pair of piers at the crossing (side of the choir) is not to be found to the same extent in the first pair (side of the nave) or in the vaulting-shafts of the nave, in which last, however, the vertical curves are much more prominent than they are in the great leaning piers at the transept.

As for the vaulting-shafts of the choir they have pronounced curves, but they converge instead of diverging vertically. The amount of this narrowing in, for any one pair of vaulting-shafts, has been estimated with approximate accuracy as from 6½ to 7 inches. Thus each vaulting-shaft leans toward the centre of the choir from 3 to 3½ inches, in its upward curve. The vaulting-shafts which bound the walls of the choir before it turns to the curve of the apse neither converge nor diverge. They are perpendicular.

As regards the body of the church we record first the marked difference of inclination as between the two pairs of piers at the crossing. Those next the nave diverge about 12 inches, as contrasted with a divergence of 21 inches for the pair next the choir. The vaulting-shafts of the nave curve much more perceptibly, but have the same amount of divergence, approximately, as the first pair of piers at the crossing, in amounts varying from 7 inches to 12 inches. The amounts of divergence are estimated individually as follows, for the first five pairs of vaulting-shafts, in order from the transepts toward the main entrance—10 inches, 10 inches, 7 inches, 9 inches, 12 inches. The last measurement will hold very closely for the 6th and 7th pairs of vaulting-shafts (in order from the transepts).

The foregoing estimates of measurement are confined to the vaulting-shafts and do not include the round piers which support them, because the alignments do not correspond. The piers lean slightly into the nave, thus increasing the effect of the bend above. For instance, the fourth pier from the entrance on the right was

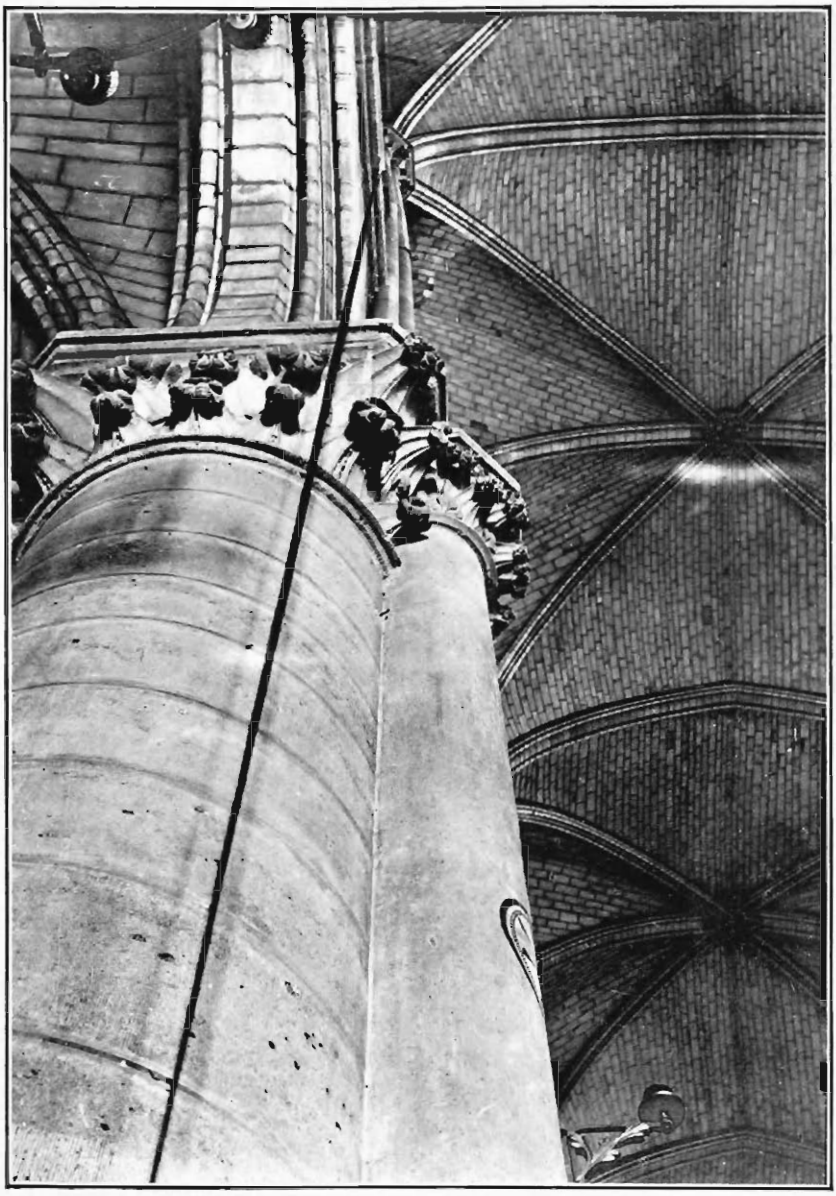


FIG. 2. NOTRE-DAME, PARIS. PIER AND VAULTING-SHAFT LOOKING UP THE PIER.

found, by plumb, to lean into the nave 0.23. (The piers at Amiens also bend into the nave.)

We come next to the great piers of the tower construction, fronting the organ gallery, which are perpendicular as regards the north and south direction, and without curvature.

These piers and all the piers and all the vaulting-shafts of the nave lean laterally west toward the entrance in amounts ranging from six inches upward and increasing in amount toward the entrance, a disposition which contributes to a greater appearance of widening than actually exists, when viewed from the west, but a separate article will be needed to explain these arrangements. They are mentioned now in passing.

As regards variations from the true perpendicular in the north and south direction, they may now be rehearsed, as follows, moving in the direction from entrance to choir.

Piers at the organ gallery—perpendicular. Seven pairs of vaulting-shafts in the nave—strong vertical curves, with divergence ranging from 12 to 7 inches (the individual shafts thus bending outward, and away from the nave, from 6 to 3½ inches each). Piers at the crossing (side of the nave), widening of 12 inches. Piers at the crossing (side of the choir), widening of 21 inches. Vaulting-shafts of the choir—strong vertical curves leaning into the choir, with convergence from 6½ to 7 inches, or individual inward bends of from 3 to 3½ inches. Vaulting-shafts terminating the side walls of the choir—perpendicular.

Fig. 2 shows a vertical curve in the nave of Notre-Dame, as seen when looking up the pier. This photograph shows the second vaulting-shaft on the left of the nave, beyond the great piers next the organ gallery.

As far as my information goes, the widening in Notre-Dame has attracted attention only in consequence of the publications which have been made in the Architectural Record and in the Brooklyn Museum Memoirs, regarding similar phenomena in Italy. Mr. Nelson Goodyear observed it soon after he had assisted in the survey of Sta. Maria della Pieve, in 1895. It was subsequently brought to my notice by the careful observations of Professor John F. Weir and Professor Charles S. Hastings, of Yale University.

Leans of the Transept Vaulting-Shafts.

A most remarkable arrangement in the transepts and transept galleries of Notre-Dame is that the vaulting-shafts of the transepts lean off laterally right and left, so that they continue and repeat the leans of the great piers at the transept. The significance of this observation will appear to every expert who notes that these in-

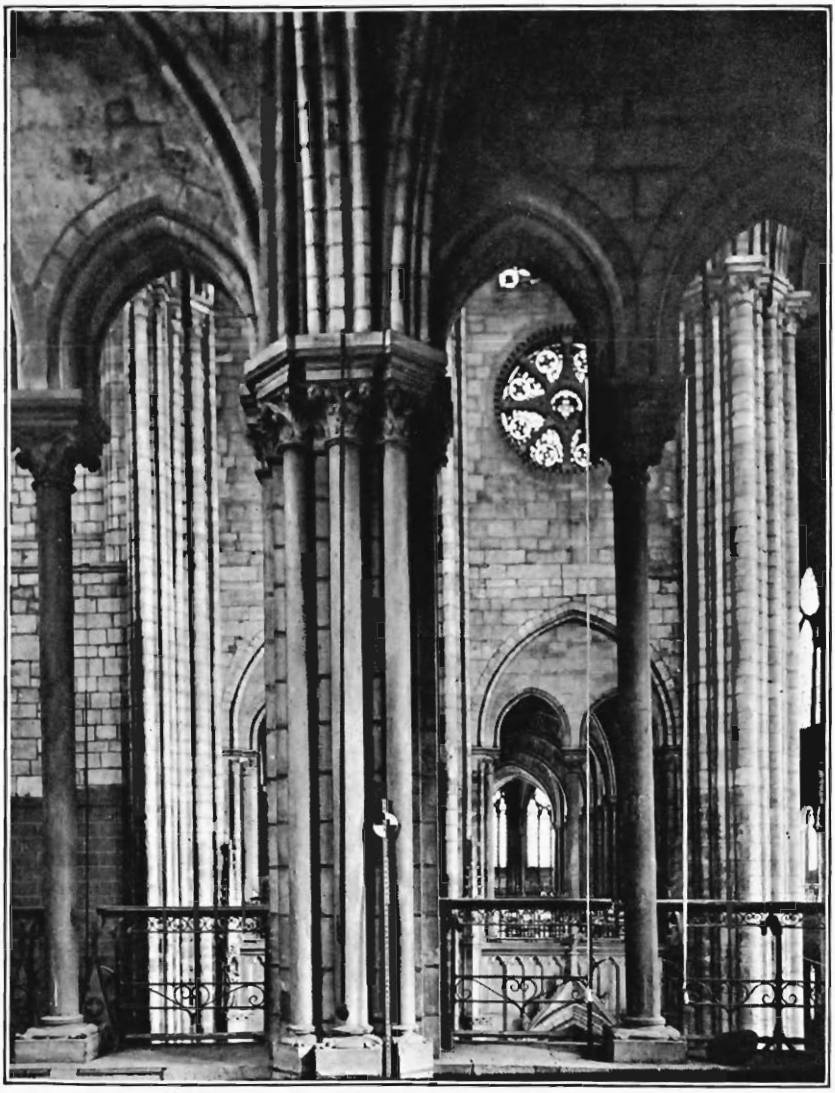


FIG. 3. NOTRE-DAME, PARIS. LEFT TRANSEPT GALLERY, LOOKING TOWARDS THE CHOIR.

clinations are constructed laterally in the solid wall. The columns of the triforium arches are also set parallel with these leans.

If close attention be given to Fig. 3 it will be found to illustrate these arrangements. This cut represents one of seven 5x7 photographs which were devoted to this special class of facts in Notre-Dame, of which four have been enlarged and are now exhibited in Brooklyn.

Fig. 3 is taken from a point of view in the left (north) nave gallery, looking across the left transept to the choir. On the extreme right of the picture is seen the lean of the great pier at the crossing of the left transept and choir. (This is the second of the great piers seen on the left in Fig. 1). In the foreground, on the right, Fig. 3, is a leaning column from which two plumb-lines are suspended. Next to it, in the foreground, is a pier which, on its outer exterior side (fronting on the transept), is a portion of the vaulting-shaft which rises from the pier to the vaulting above. On the side of this pier facing the reader is another plumb-line. On the left, in the foreground, one of the leaning columns of the next adjacent bay is seen and from this another plumb-line is suspended.

These four plumb-lines in the foreground enable the reader to observe the leans of the vaulting-shafts on the farther side of the transept. These vaulting-shafts are imbedded in the wall of the transept and their inclinations are constructed laterally in the wall, so that every suspicion of accidental masonry movement is eliminated. Thus, note first on the left of the picture, the vaulting-shaft on the opposite transept wall, as compared with the perpendicular which is established by the plumb-lines in the foreground.

Note next, the pier in the centre foreground, and then the rib of the vaulting-shaft across the transept, which is visible beyond the right side of this centre foreground pier. The rib leans parallel with the foreground pier. Other photographs show the entire shaft of which this rib is a portion.

Similar facts will appear for the vaulting-shafts of the near side of the left transept, if viewed from the choir. Similar facts appear on both sides of the right transept, as attested by photographs in Brooklyn.

From pavement to vaulting, the leans of these vaulting-shafts, on the choir side of the transepts, amount to about one foot. As measured for the heights directly accessible in the galleries, with a line of 10½ ft., the following results are obtained for the left transept gallery, part of which is seen in Fig. 3:

All leans to the left—pier next the transept end walls 0.15; column 0.12; column* 0.13; pier* (both sides) 0.14, 0.14; column* 0.24; column 0.20; pier next the nave 0.10.

*The stars mark the columns and piers on which the plumb-lines are seen in Fig. 3, in order from left to right.

Plumb-measurements of the same average amount, all uniform in direction, that is, all leaning north in the north transept galleries and all leaning south in the south transept galleries, have been published in Museum Memoir No. 4 for the other transept galleries and are verified by the exhibited photographs.

It is a general rule that the columns lean more than the piers of the same height which belong to the system of the vaulting-shafts. The reason is obvious, that in the case of the latter a small fraction of a uniform lean which runs from pavement to vaulting, is in question, whereas the columns are not portions of this continuous system and could consequently be given a somewhat more defined inclination.

Notre-Dame at Paris does not stand alone in this remarkable feature of the parallel transept leans. Similar arrangements are found in the transepts at Amiens, as subsequently mentioned and illustrated.

Similar facts are found in the transepts of the Church of St. Quentin and four enlargements of them are exhibited in Brooklyn.

Before taking up the Amiens Cathedral a few words may be given to the explanation of these inclinations of the transept triforium columns and transept vaulting-shafts, as described for Notre-Dame. They are probably intended to avoid a contrast between adjacent perpendicular and inclined lines. This amounts to saying that the effort was to evade a conspicuous prominence of the primary leans of the great piers, which would be more easily noted, if perpendiculars were found immediately adjacent to them. It seems unnecessary to dwell on the fact that they emphasize the constructive existence and predetermined artistic purpose of the primary leans of the great piers.

The Cathedral of Notre-Dame has other, and still more remarkable, constructive refinements, to which a following paper will be devoted. For the moment, our attention is now turned to the Cathedral of Amiens.

The Cathedral of Amiens.

It is difficult to realize in looking at a cut of the dimensions of Fig. 4 that the widening of the nave at Amiens is very nearly 3 ft. and that in the building itself the vertical curves are of a clearly visible character.

This instance of the inadequacy of a small cut for illustration of well-defined deflections of considerable amount in cathedrals of lofty dimensions leads me to again emphasize the importance of large photographs for these cases. The Brooklyn Museum exhibit for Amiens includes four large photographs of the nave (all 25x35

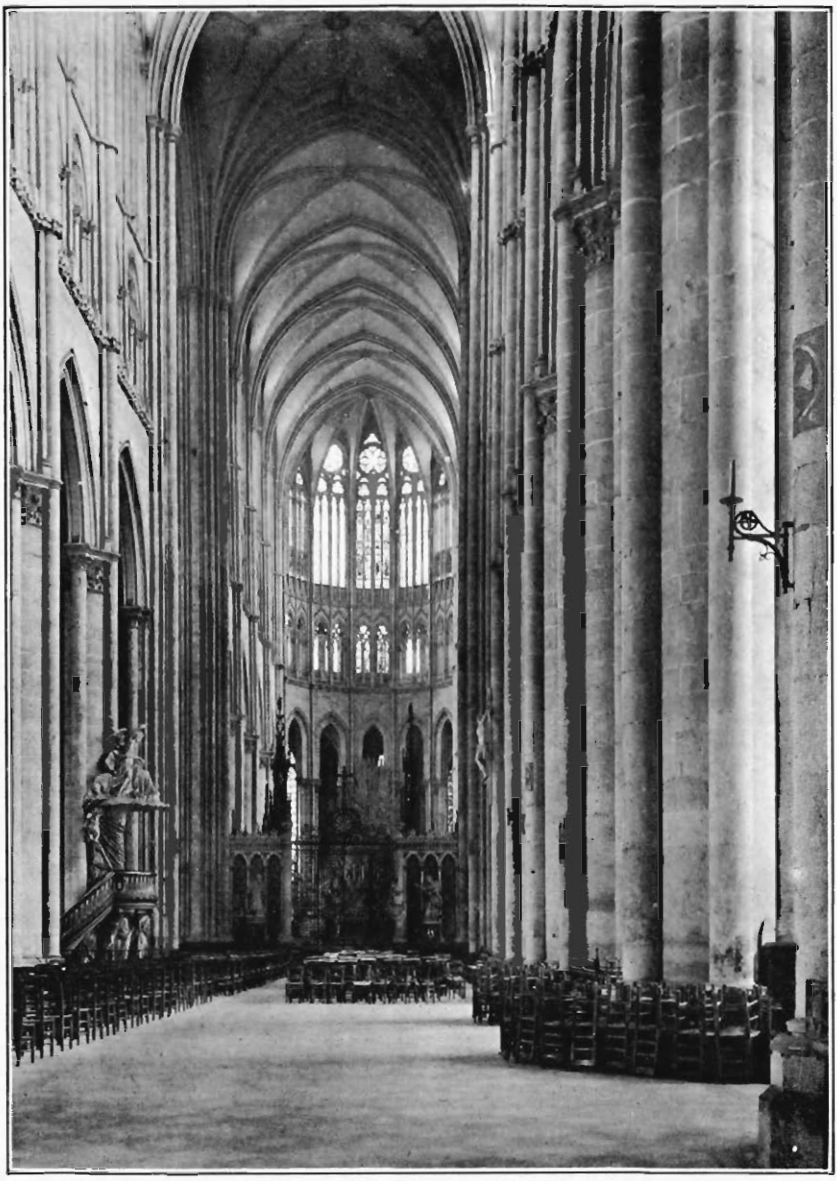


FIG. 4. CATHEDRAL OF AMIENS. RIGHT SIDE OF THE NAVE.

inches), one of which is taken from the pavement, while others are taken from the organ loft and from the choir triforium. In all of these pictures the curves and the widening are shown clearly.

It has been mentioned in the August Number that the widening, as found in St. Loup at Chalons, is known to the architect in charge and that it has been recognized by him as constructive. It was mentioned in the same article that the widening at St. Quentin was known to the recently deceased architect in charge as constructive. The widening at Amiens is also familiar to the cathedral authorities and to other residents of the town, and there is moreover an explanation given regarding it.

The matter came to my knowledge in the following way. Having presented my photographing permit from the Ministry of Cults at Paris to the cathedral authorities on Sept. 14th, 1903, I was accorded all possible facilities for the prosecution of my work. I did not, however, at this time advise them of its nature or purpose. During the inspection of the cathedral I observed, in the setting of the piers of the transepts, a system of inclinations resembling that which has just been described as existing in the transepts of Notre-Dame at Paris.

This involved the photographing of all these leaning piers and the hanging of plumb-lines beside them from the triforium galleries (see Fig. 6). The placing in proper position of these plumb-lines was naturally a matter of some considerable trouble and personal activity, which was calculated to attract attention. Moreover as the lines hung down from the triforium gallery, revealing the marked inclinations of the piers, beside which they were placed (maximum cases about 5 inches for a height of 40 ft.), they were calculated to arouse the curiosity and interest of passing spectators.

It was under these circumstances that I was accosted by the *Bédeau*,* M. Régnaut, whom I found to be a gentleman of great intelligence. He was much interested in the leans of the transept piers, which were previously unknown to him, but when I mentioned the widening of the nave it appeared that he was thoroughly conversant with it. This was my first advice that the nave widening at Amiens was known to the cathedral authorities.

Further conversation with the *Bédeau* and with the *Suisse* developed the fact that the peculiar construction of the nave had been known for over forty years, at least. There is nothing to show at present that the knowledge concerning it has ever been lost in this locality.

The current explanation of the construction is that it is intended to throw the thrust of the vaulting directly against the flying-but-

*The office of *Bedeau* at Amiens is not at all to be confounded with that of the English church Beadle. It appears to combine clerical and lay duties about the cathedral of considerable importance.

tresses; thus avoiding a movement of the masonry by anticipating its natural action, and by making the strain direct instead of indirect. This explanation is insufficient to cover the facts for the transepts and so appeared to M. Régnaut.

I shall presently mention characteristics of the phenomena in other localities which would also make this explanation appear to be an insufficient one. It is, however, an interesting fact that whereas some experts in the United States have been disposed to attribute all instances of the widening to movements of the masonry, the church authorities of Amiens have been persuaded that the widening was intended to prevent such movements.

It may be added here that the divergence of the piers at Amiens is even mentioned in Baedeker's "Northern France," although it is incorrectly described. Baedeker says . . . "The vaulting is borne by 126 remarkably bold columns, tapering toward the top, so that the vaulting seems actually wider than the pavement below." An inspection of the Brooklyn Museum photographs of the Amiens nave, taken from the organ-loft, will show that the columns of the nave do not taper. They curve vertically outward and away from the nave, without diminishing in size. It is also misleading to say that the vaulting seems wider than the pavement. It is actually wider.

The amount of the nave divergence is estimated by the cathedral authorities as being one metre. This estimate tallies very closely with my own observations. By sighting on a plumb-line which was dropped through an opening in the vaulting near the piers at the transept, one of these was found to bend into the nave about 0.20 and then to curve outward about 1.40. The total divergence would thus be about 2.80. As distinct from the varied arrangements in Notre-Dame and at St. Quentin, those at Amiens appear to be uniform and parallel through the choir and nave with the exception that the great piers at the entrance next the organ-gallery do not diverge and that those next them diverge less than the rest.

The Triforium at Amiens.

Fig. 5 represents one of four similar pictures which were taken inside different portions of the triforium at Amiens, all of which are represented by large photographs in the Brooklyn exhibit. This triforium gallery runs entirely around the cathedral, with a uniform width of about 3 ft.

In looking at Fig. 4 of the nave, it will be observed that if the piers diverge outward at the height of the triforium, it ought to be possible to photograph these divergences from the rear, inside the triforium. This is what has been done in Fig. 5. Two plumb-lines

FIG. 5. CATHEDRAL, AMIENS. CHOIR TRIFORIUM, NORTH SIDE.

are seen in the picture, but rather dimly. The reader will obtain the best indication of the purpose of this view by comparing the outer left boundary line of the picture, which furnishes a true perpendicular, with the adjacent pier, which leans to the right, and away from the choir. The facts are uniform in all parts of the triforium, and the amount of inclination is uniform, on both sides of the choir, and on both sides of the nave. Photographs were made on both sides of the choir triforium and on one side of the nave triforium. These photographs would be sufficient to establish the constructive facts at Amiens, even if they were not verified by local observers.

Fig. 6 represents one of a series of ten enlargements in the Brooklyn exhibit which show the Amiens transepts. Eight of these pictures are 25x35 inches.* The description of the arrangements of the transept piers at Amiens will be assisted by reference to a plan of the cathedral. Unless reference is had to such a plan it should be remembered that, beside the continuation of the single aisles of the nave into the choir and ambulatory, the choir has two additional aisles, making three in all, for the choir and for the corresponding divisions of the transepts. (The outer one of these additional choir aisles is so short as to come under the designation of a chapel, if preferred.) Thus each transept has two pairs of piers, beside the piers bordering on the nave.

Of these piers, all four bordering on the nave lean into it to the height of the capitals, each about 0.40 in 40 ft. (The outward bends for the nave widening begin higher up. These bends are clearly shown in the Brooklyn photographs). All four piers next adjacent lean in the opposed outward direction, about 0.30 on their inner sides. This gives a widening at the openings from the transepts into the aisles of the choir and nave of about 0.70 in 40 ft. The outer sides of these same piers, bordering on the second choir aisles, are closely perpendicular. (See the left pier in Fig. 6.) These piers are consequently tapered about 0.30.

The four exterior piers (next the transept walls) all lean outward on the inner side, about 0.40. (See the right pier in Fig. 6.) They appear to be tapered slightly on the outer sides, but the leans continue on this side.

The facts, as above stated, are attested by the Brooklyn photographs, with plumb-lines for each individual pier, as far as the leans are concerned, and the measurements, for the leans as above given, were obtained in each individual case by careful sighting on the plumb-lines. As regards the perpendiculars and the tapering, the facts are believed to be as stated and have been carefully tested

*In the summer of 1903 fifty-five negatives were made in Amiens Cathedral and eighty-four negatives were made in Notre-Dame at Paris. Nearly all of these are available for enlargement and very few of them duplicate the same facts. The Brooklyn exhibit includes twenty enlargements for Amiens and forty-five enlargements for Notre-Dame.

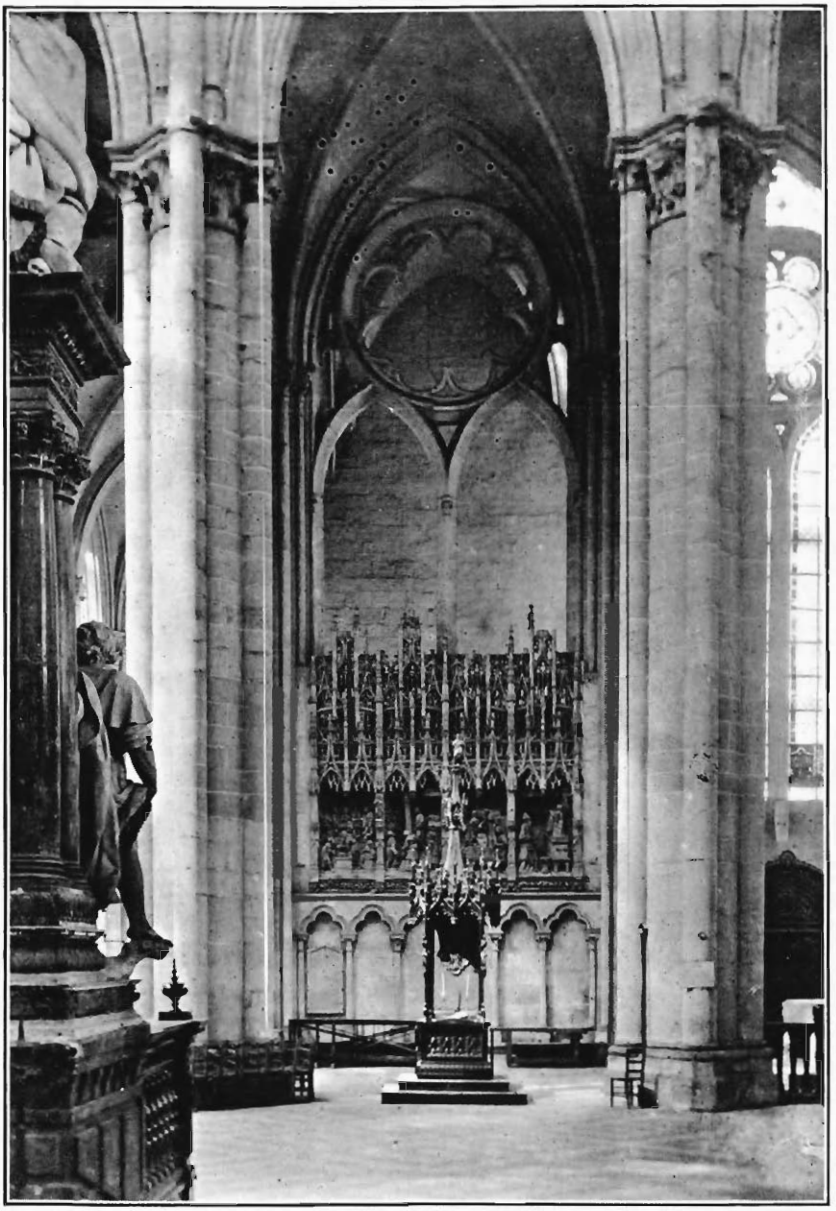


FIG. 6. CATHEDRAL OF AMIENS. FROM THE SECOND LEFT AISLE OF THE CHOIR, LOOKING WEST. VIEW OF THE LEANING MULLION.

in various ways, although there are two instances in which Renaissance monuments placed against the piers, interfered with dropping the plumb-lines for more than half their height.

Aisles or aisle openings widening on both sides of one aisle have been, so far, only observed at Amiens and at St. Quentien. Generally the aisles widen, if at all, only on the exterior sides, as in St. Alpin at Chalons (Fig. 7, August Number). Fig. 12, of the August Number, illustrates the aisle widening at St. Quentin and will show more clearly than verbal description what the arrangement is at Amiens, unless the Brooklyn photographs are consulted. At St. Quentin the vaulting-shaft on the exterior sides of the aisles curve laterally toward the perpendicular in the solid transept walls above the widening, as attested by four photographs, Nos. 37-40 inclusive, in the Brooklyn exhibit, so that there is no doubt about questions of construction.

As regards the outer transept piers at Amiens a conclusive proof of constructive intention is found in the parallel leans of the vaulting-shafts which are connected with the transept walls and partially attached to them. (Note the shaft in Fig. 6, on the right of the sculptured shrine.) These may be observed for both transepts in Nos. 58 and 62 of the Brooklyn exhibit, and are best seen in these large pictures.

The most astonishing feature of these arrangements is the constructive parallel leaning of the window mullion which is shown by Fig. 6 (No. 62 in Brooklyn). There are four churches known at present in which windows are built to make alignments parallel with leaning piers. St. Loup at Chalons is illustrated for this point in the August Number (Fig. 6). A transept window at St. Quentin which has this peculiarity is shown by No. 298 of the 5x7 prints of 1903. For Notre-Dame at Paris the windows will be illustrated in the next article.

The facts regarding these parallel window-leans are fairly incredible from the standpoint of our present stock conceptions of mediaeval architecture as lacking in subtlety of design. Therefore special mention is now made of the large photographs in Brooklyn for the windows of Notre-Dame, to be described in the next paper. In Notre-Dame the facts are uniform on opposite sides of the church. I am unable to speak for Fig. 6 on this important point, because the leaning mullion at Amiens was first noticed in the 5x7 print during the return voyage to the United States.

It should be added that the outward leans of both sets of piers in the transepts are repeated in the piers and vaulting-shafts of the choir aisles (see Brooklyn photographs). Consequently the inclinations of the transept piers may most easily be explained as related to the widening system of these aisles, for they form a portion

of the same vista. This relation is also made probable by a parallelism of tapering (on the outer sides) in the middle series of choir piers, which are perpendicular on their outer sides, like the corresponding transept piers. This tapering adds to the widening effect of the second choir aisle. The original explanation of the whole arrangement may therefore be preferably sought in the vista of the choir aisle of which the transept piers form a portion, and for which the widening effect was considered desirable.

Leaning Triforium Transept Columns at Amiens.

Fig. 3 has illustrated the parallel leans of the triforium transept columns in Notre-Dame at Paris. These are also found at Amiens and at St. Quentin. For Amiens they are shown by Nos. 54 and 60 of the Brooklyn enlargements and by a 5x7 photograph (No. 266) which has not yet been enlarged. In this picture, which is a special detail, taken in the triforium, for the triforium columns, plumb-lines are attached to them. It must, however, be added that these minor parallel leans at Amiens are confined to the triforium bays which are adjacent to the great piers. The leans are moreover carried out in a rather half-hearted manner and the masonry is not in good condition. For a sceptic the parallel leans of triforium columns at Amiens would hardly carry conviction. It is only when they are known in such thoroughly positive and systematic appearance as holds for Paris and St. Quentin that this particular phenomenon at Amiens appears worthy of attention. At St. Quentin the triforium parallel leans are far more definite and important. They are very well shown by Nos. 37, 38, 39, 40, of the Brooklyn exhibit, in all of which plumb-lines appear.

Transept System of Vertical Curves at Amiens.

There is at Amiens a well-defined transept system of vertical curves which intersects the nave system. The widening is less than in the nave, but the curves are stronger. It is a general rule that where transepts exhibit the vertical curves the widening is less conspicuous than in the nave. This is notably to be observed at St. Quentin and in Notre-Dame at Paris. At Beauvais, however, the widening is greater in the transepts than in the choir.

The transept vertical curves at Amiens are well shown by Nos. 44 and 45 of the Brooklyn exhibit. In Notre-Dame the widening of the transepts is not easily perceptible and can hardly be more than a foot.

The Amiens Explanation of the Widening.

The interesting fact has been mentioned that the widening of the nave at Amiens has been long known to the cathedral authorities and to other residents of the town as a constructive fact and that it is believed by them to be a device for the promotion of constructive solidity and in order to throw the thrust of the vaulting directly against the line of resistance which is offered by the flying buttresses. That this theory prevails at Amiens must surely be interesting to those who have doubted the constructive existence of vertically diverging lines in mediaeval churches, on the ground that such a construction would have been detrimental to the safety of the building and, so to speak, contrary to public policy or to common sense.

It appears reasonable to suppose that movements in the masonry, due to vaulting thrust in lofty Gothic churches, would be minimized by leaning the thrust directly against the line of the resisting force. It thus appears more than probable that the Gothic builders knew that they were not risking stability by the outward leans in their lofty interiors.

On the other hand, it must be remembered that we are dealing with a local explanation which could not, and does not, take into account a multitude of facts which have been collected on this topic by the present investigation from other localities. Farther than this the explanation does not account for all the facts which are now made known at Amiens, viz. those relating to the vertical curves of the transepts, to the leaning piers of the transepts and to the widening system of the aisles.

We will first consider the local explanation for Amiens as applied to Amiens alone. It may be noted that this explanation omits consideration of the curves in the nave and does not cover the vertical curves of the transepts. (These curves are well shown by Nos. 44 and 45 of the Brooklyn exhibit.) The widening is so slight in the transepts that the curve is palpably the essential thing in that instance, at least. Moreover the thrust of the vaulting which spans the transepts is taken up laterally, for the most part, by the walls and piers of the nave and choir, and no other counter-resistance is needed.

If constructive solidity, as regards the vaulting thrust, were the main object desired we could not understand the marvellous pains which have been taken with the north and south inclinations of the transept piers. It is also clear that the bending into the nave of the lower part of the great piers at the crossing, which is a means to a widening effect in the openings from the transepts into the aisles, does not add to structural stability.

Leaving now the special problem at Amiens to consider the facts observed elsewhere, it will appear that they are sufficient to set aside the idea that constructive safety was the primary motive of the widening construction. In Notre-Dame at Paris the most pronounced widening, that of 21 inches in the second pair of piers at the crossing, is exactly at the point where no constructive danger exists. For the great piers at the crossing (Fig. 1) lean out against the resistance of the entire transept construction; whereas in the nave, where the clerestory walls are upheld only by the flying buttresses, the widening is much less than 21 inches (from 12 to 7 inches), although the curvature is stronger.

Again, if the nave widening at Paris were explained as at Amiens there would be no explanation for the convergence of vaulting-shafts in the choir. As different phases of curvature the arrangements of the nave and choir at Paris would come under one explanation.

At St. Quentin it also holds that the leans are much stronger at the transepts, where no constructive precautions were necessary, than they are in the nave. (They develop gradually in increasing amount from the entrance and are strongest in the choir.) Again in St. Jean, at Caen,* we find the widening only in the piers which lean against the transept walls, where no precautions were necessary, and in the body and choir of the church the widening does not occur. From the standpoint of optical appearances, as distinct from that of construction, we could understand that the piers at the transepts were leaned more than in the nave, at Paris, at St. Quentin and at Caen, because they were the largest and the most prominent.

Turning to the Italian churches, we find the important churches of Sta Maria della Pieve, at Arezzo, and of Trani, to be timber-roofed and not vaulted. Here, again, the explanation could not apply. Then there are the cases like the apse of the Balaban Aga Mesjid (Fig. 1, August Number), like the apse of the Schottenkirche at Vienna, like the apse of St. Radegonde at Poitiers, the apse of the Capella Palatina at Palermo, and the window of the facade of St. Ambrogio at Milan, all of which are clearly decorative instances, wholly independent of constructive considerations. For the phenomena of the entrance court of St. Ambrogio at Milan† the given explanation would not apply.

Other adverse considerations are connected with the outer leans in side aisles, which are faced by chapels having walls of such depth as to make any expedient against the operation of thrust unneces-

*Fig. 4, August number.

†Museum Memoir No. 2, Plan 1 and Fig. 10. For the window of S. Ambroglo see Fig. 9 of the same Memoir.

sary. Such are St. Loup, Chalons; St. Alpin, Chalons; St. Eutsorgio, Milan; St. Ambrogio, Milan; St. Michele, Pavia.

If the stability of the building were the main purpose of this construction we should find no cause for the elaborate systems of parallel leans at points where constructive stability is not in question. For instance, let the ground-plan of St. Marks, with plumb measurements, as published in Memoir No. 2, be examined for the facts holding of the pilasters in the angles of the transepts.

From the same point of view consider the parallel leans in the vaulting-shafts of the transepts of Notre-Dame at Paris, as described in this article. At St. Quentin it can be shown beyond debate that the widenings of the openings from the transepts into the aisles can have only an aesthetic purpose, because the vaulting-shafts which are imbedded in the transept wall curve back laterally toward the perpendicular above the arches, as already mentioned. (See Nos. 37-40 of the Brooklyn exhibit.) The examination of these photographs is alone sufficient to refute the supposition that constructive stability can be the sole explanation of this device.

The explanation current at Amiens has moreover been devised to meet the peculiar conditions of the flying buttresses of the Gothic, without reference to the Romanesque churches, which show the widening construction and without knowledge of their existence.

It may again be considered a most important suggestion that the given construction would not be detrimental to stability in the naves of such churches as S. Michele at Pavia, St. Mark's at Venice and Sta. Sophia at Constantinople, but it is probable that no engineer would consider the given explanation applicable to these buildings as furnishing a primary motive for its employment.

A conclusive and most important consideration, already referred to briefly, is the one that the Amiens explanation does not consider the element of vertical curvature which appears at Amiens in the widening of the nave, but which appears in other important instances without any widening, as in the choir at Paris. In the Pisa cathedral the piers at the crossing have vertical curves which have been recently certified by the architect in charge to be constructive and which lean into the nave ($3\frac{1}{4}$ inches), without widening. The vertical curves in the Cathedral of Vicenza are found in piers which do not widen perceptibly.

The cathedral at Noyon (Fig. 7) is another instance of this class. The piers at the crossing in this cathedral curve vertically, but they lean into the nave 2 inches, by plumb measurement from the upper gallery. The piers of the nave and choir curve vertically into the nave about $1\frac{3}{4}$ inches, to the height of the first gallery, and then curve away from it about $3\frac{1}{2}$ inches up to the capitals.

FIG. 7. CATHEDRAL, NOYON. FROM THE ORGAN GALLERY.

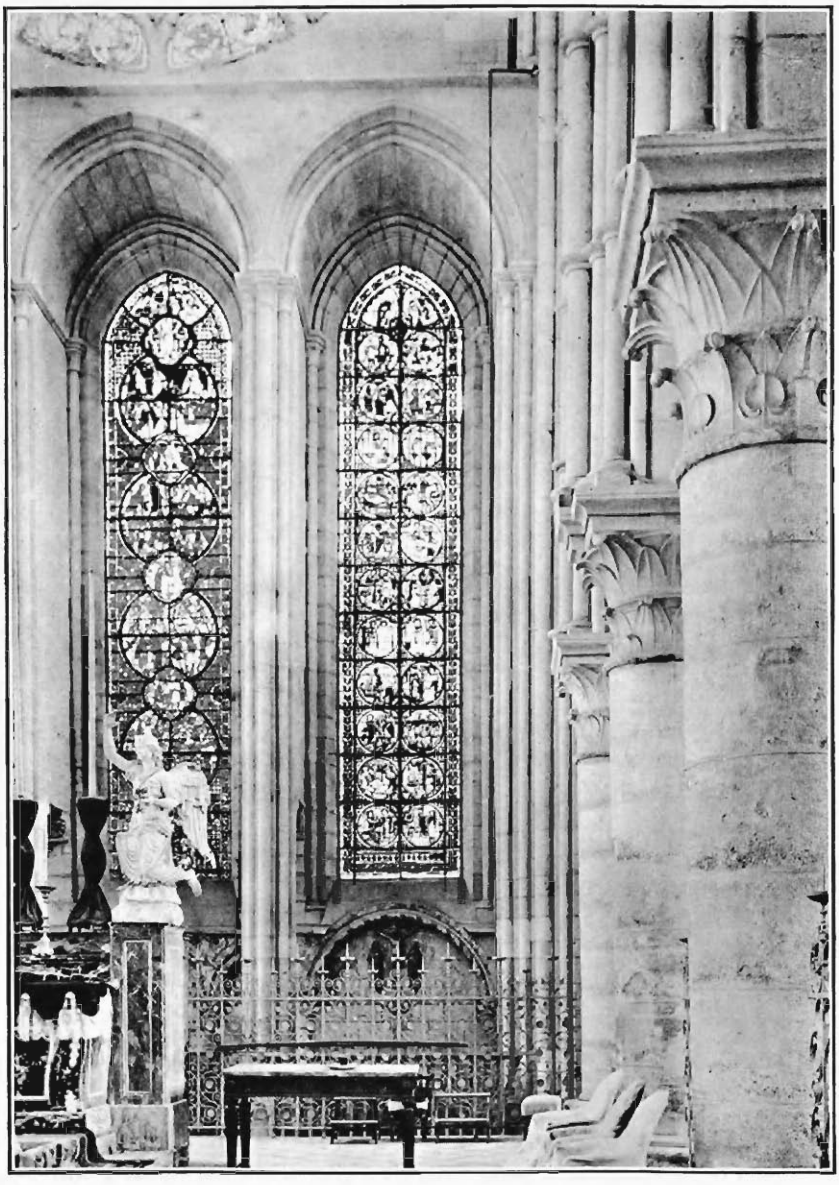


FIG. 8. THE RIGHT SIDE OF THE CHOIR, CATHEDRAL OF LAON.

These curves are uniform in all the piers, but a photograph of smaller size than 25″ x 35″ does not show them to advantage. They are well shown in the Brooklyn exhibit (Nos. 119-122). In Fig. 7, note the plumb-lines, which are offered by the lamp-chains, which much assist in sighting for the curves. A surveyor's plumb-line is also suspended from the second bay of the gallery on the right.

An illustration from the cathedral at Laon will be another instance of the insufficiency of the Amiens explanation to cover the known facts. Vertical curves are found on both sides of the choir in the slender shafts which bound the exterior sides of the triple choir window, two sections of which are shown by Fig. 8. Each of these shafts diverges from the plumb-line about 5 inches in 39 ft. The central arch of the triple window is constructed with a widening of about 4 inches (width of the nave 36 ft.). On either side of the window the wall is solid. Above the window there is no appreciable weight, as its arches support only a light gallery. All these conditions are palpably foreign to the Amiens explanation. They react, however, as a proof of constructive purpose on the arrangements in the body of the church and choir, where delicate bends, with a widening of about 10 inches, are also found to exist (Nos. 22-28, of the Brooklyn exhibit).

Concluding Argument.

The final statement of the concluding argument against the Amiens explanation, as a primary and all-sufficient explanation of the widening construction, would therefore be something as follows: Only in infrequent cases, as hitherto mentioned, does the widening occur without curvature. The phases of the curvature are extremely varied, frequently with only such amount of divergence as is natural to any entasis, and sometimes without any upper divergence whatever. When all the known examples are considered together, including those in which vertical bends take the place of vertical curves (like St. Mark's and Sta Sophia), and including those in which the widening is found without either bend or curvature, the conclusion appears inevitable that two separate devices were easily and naturally united, either one of which might be, and either one of which occasionally was, employed separately. Both of these devices were undoubtedly æsthetic in their purpose, and of great advantage to the beauty of mediæval building. The device which appears most singular to modern taste (although modern taste has long admired the very buildings which possess it, without having noted its importance and its relation to their beauty), was not detrimental to stability in the majority of cases

(in the opinion of the writer, as influenced by the information given at Amiens). In many cases it may have been a constructive, as well as an aesthetic, improvement and may have been employed also for that reason.

Accounts of Durand and Viollet-le-Duc.

The second volume of Viollet-le-Duc's Dictionary contains at p. 333, under the title of "Cathedral," the following passage relating to the Cathedral of Amiens:

"Cependant cette nef, dont la hauteur est de 42^{m}, 50 sous clef, et la largeur d'axe en axe des piles de 14^{m}, 60, ne s'est ni deformée ni déversée. La construction n'a subi aucune altération sensible."

Vol. II. of the Dictionary was published in 1867. Viollet-le-Duc was in charge of the repairs and restorations at Amiens from 1849 to 1874.

This passage would seem sufficient to establish the fact that the spread of 33 inches (2.80) in the nave at Amiens is not accidental. No vaulting could spread to that extent without collapsing, and we have the above assurance of Viollet-le-Duc that no perceptible distortion or warping has occurred in this nave.

Viollet-le-Duc's statement is supported by the recent work of M. Georges Durand,* who furnishes a complete history of the repairs of the Cathedral, based on its archives. As regards the vaulting of the nave, only one repair is quoted. It took place in 1805-6, when the vaulting at the crossing was observed to have settled *three inches* ("trois pouces"). This occasioned great consternation, and the repair of the affected masonry by means of iron cramps, was accomplished by the workman who had discovered the depression (p. 155, Vol. I.).

This record has significance in two directions. It not only indicates the extreme amount of depression which has occurred in the nave vaulting at Amiens, but it also shows what danger of collapse may be connected with a very slight accidental settlement.

It needs no argument to show that there is no relation between a settlement of 3 in. and a spread in the nave piers of 33 in. Three inches of settlement in a vaulting means three inches of spread between piers.

From the accounts of Durand and Viollet-le-Duc, we may argue that no special importance attaches to the alarm which was raised about 1805 by M. Grandclas, engineer of roads and bridges for the Department of the Oise, regarding the Cathedral walls.† Durand intimates that self-interest may have had a share in raising this

*Monographie de l'Église Notre-Dame, Cathedrale d'Amiens, Paris. A. Picard et Fils. 1901.

†Durand, Vol. I., pp. 160-162.

alarm, and records the fact that representations were filed with the Prefect, opposing those of Grandelas.

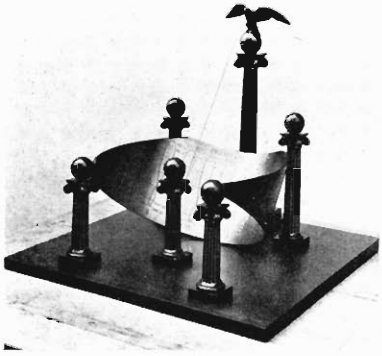
Both Durand and Viollet-le-Duc describe the chain of iron bars which was stretched in 1497 throughout the triforium, in order to stay the great piers at the crossing, which were thought to be bulging inward under the weight of the tower.*

As regards the Cathedral of Amiens, the question of the constructive existence of vertical curves in the nave cannot be separated from the constructive existence of the widening. If the widening be constructive, the curves by which the widening is obtained must also be constructive. The amount of this widening is so great and the records of repairs are so complete that the widening must be accepted as constructive. If the widening has been accented or augmented accidentally at any point, it has not been increased more than three inches.

Wm. H. Goodyear.

(To be continued.)

*Durand, Vol. I., pp. 61, 205. Viollet-le-Duc, Vol. II., p. 404. The latter supposes this tower, which was burned down in 1528, to have been of timber and stone, but Durand shows that it must have been wholly of timber, like the shorter one which replaced it.



THE "CREHORE" SUN-DIAL.

Manufactured by John Williams. Invented by Albert C. Crehore.

FIG. 1. THE NEW YORK STOCK EXCHANGE.

Broad Street, New York City. Geo. B. Post, Architect.