THE MUSEUM
OF THE
BROOKLYN INSTITUTE OF ARTS AND SCIENCES

MEMOIRS OF ART AND ARCHÆOLOGY

Vol. I: No. 2.

THE ARCHITECTURAL REFINEMENTS
OF
ST. MARK'S AT VENICE

With Remarks on other Churches Showing a Similar System of Leaning Verticals; Especially those in Orvieto, Vicenza, Milan, Pavia, Bologna, and Arezzo, and Including the Renaissance Church of S. Giorgio Maggiore at Venice.

BY
WILLIAM HENRY GOODYEAR

WITH FOURTEEN PLANS AND FORTY-FOUR ILLUSTRATIONS

Published by
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THE BROOKLYN INSTITUTE OF ARTS AND SCIENCES
DECEMBER, 1902

PUBLICATIONS OF THE MUSEUM

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These publications will be issued at irregular intervals, and will present the original researches of the Curators and Assistants of the Museum, and work by specialists based upon the Museum Collections. The announcements of the Science Bulletin will be found on the fourth page of the cover.

MEMOIRS OF ART AND ARCHAEOLOGY.

Each Memoir will be a complete publication and is for sale individually. Price of Vol. I., No. 1; "A Renaissance Leaning Façade at Genoa," by Wm. H. Goodyear; 50 cents. Price of Vol. I., No. 2; "The Architectural Refinements of St. Mark's at Venice," by Wm. H. Goodyear; $1.50. In preparation, Vol. I., No. 3.

The Architectural Refinements of the Pisa Cathedral.

This Memoir will contain not less than four double-page and eleven full-page plates of survey and not less than sixty pages of text and illustration.

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Photographic Bromide Enlargements.

Bromide enlargements of the photographs which are reproduced in these Memoirs are for sale by the Museum. The following photographs, which are represented either by half-tones or by pen and ink, or wash, drawings, in Vol. I., No. 2, are obtainable in bromide enlargements, either of 25x35 inches or of 18x22 inches: Figs. 4, 5, 6, 7, 8, 15, 17, 18, 19, 23, 24, 28. 33, 37, 38, 40, 41. The following illustrations are represented by bromide enlargements of 18x22 inches: Figs. 1, 2, 3, 10, 11, 12, 16, 20, 25, 27, 29, 30, 31, 32, 35, 39, 42, 43, 44. Price of the 18x22 enlargements, mounted on white card, $5.00. Price of the 25x35 enlargements, mounted on white card, $10.00. These photographs may also be obtained by exchanges of Museum exhibits, in archæology, anthropology, or Natural History. They will also be exchanged for Library material. Orders or enquiries may be addressed to the Director.

YALE LITERATURE.

Appreciation of Mr. Goodyear's Work.

The Macmillan Company has published Vol. I, No. 2, of the Memoirs of Art and Archaeology of the Brooklyn Institute Museum. This Memoir is by Mr. William H. Goodyear, Yale '67, Curator of Fine Arts, Brooklyn Museum, and relates to those architectural refinements of St. Mark's at Venice of which he has been the discoverer. The entire title of the Memoir is as follows: "The Architectural Refinements of St. Mark's at Venice, with remarks on other Churches showing a similar system of leaning verticles; especially those in Orvieto, Vicenza, Milan, Pavia, Bologna and Arezzo and including the Renaissance Church of S. Giorgio Maggiore at Venice." With fourteen plans and forty-four illustrations.

Mr. Goodyear has sent for publication the following appreciative letters, which have been called forth by the receipt of this publication in Italy. The importance of these letters comes from the high standing of the writers and their close personal relations with the monuments of Venice. Professor Pompeo Molmenti is President of the Venetian Royal Academy of Fine Arts and of its great picture gallery and is also a prominent member of the Italian Chamber of Deputies, in which he recently delivered an address on the fall of the Campanile of St. Mark's. Signor Francesco Saccardo is a Venetian architect who has long been occupied with researches regarding St. Mark's. Two of the chapters of the text of Ongania's magnificent publication on St. Mark's are from his pen. The father of Francesco Saccardo, Commendatore Pietro Saccardo, has been, until quite recently, the architect in charge of St. Mark's and a certificate from him regarding Mr. Goodyear's discoveries in that church, is one of the most important features of the Memoir.

[Translation.]

(Venetian) Royal Academy
of Fine Arts.
The President.
Moniga, Brescia.

Dear Sir and much honored colleague:

Pray accept the expression of my whole profound gratitude for the sending of your publications, which are an important contribution to the history of Italian art in general and of Venetian art in particular. Your observations on the ancient Italian architecture (Venice, Bologna, Verona, etc.) are truly interesting and have all the attraction of originality.

Every Italian must be grateful to you for the profound study which you have devoted to his country's art. But this gratitude must begin with Venice, whose history in the past has so much resemblance with the modern history of your great country.

Accept, dear sir, the expression of my profound respect and of my sincere admiration.

Your very devoted
POMPEO MOLMENTI.

[Translation.]

Venice, Jan. 25th, 1903.

Dear Sir:—I am most grateful for your goodness in sending me your precious "Architectural Refinements of St. Mark's at Venice," which I have gone over with great satisfaction, and in which I have admired your fine talent and your marvellous and patient studies.

I must tell you also that your investigations, which have been crowned with such fine results, give me an especially particular pleasure, because I had myself already made, as an amateur, observations analogous to yours regarding certain monuments of Venice and had acquired the conviction that certain abnormal features of many of our most ancient edifices were not the work of chance or of decay, but were, on the contrary, work of intention by the architects, who secured by these means, that picturesque character which most of the mediaeval monuments possess.

My father, who is somewhat indisposed, has not been able, as yet, to send you his great and hearty thanks for your interesting letters. He will write you directly, as soon as he is able, but he desires that I should express to you, without delay, all his appreciation and all his admiration for your interesting and colossal work, which has no parallel with us. He believes and I also believe, with very firm conviction, that it would be highly useful to make known to the Italians how, and with what enthusiasm and high intelligence, our monuments are being studied in America, and how the philosophy is reaching us from the new world, which had presided over the formation and development of Italian Art.

My father begs me to convey to you his hearty compliments to which I add the expression of my own high consideration.

I am, dear sir,
Your very devoted and
grateful servant,
FRANCESCO SACCARDO.

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Preface.

In the Diary of John Evelyn there is a passage relating to the architectural commission which was appointed, in the reign of Charles the Second, to examine and report upon the old Gothic Cathedral of St. Paul's in London. Evelyn was a member of this commission, which was headed by Sir Christopher Wren. The entry is found under date of July 27th, 1666. The cathedral was destroyed soon after, by the fire of London. Here is the passage:

"I went to see St. Paule's church, where, with Dr. Wren, Mr. Prat, Mr. May, Mr. Thos. Chichley, Mr. Slingsby, the Bishop of London, the Deane of St. Paule's, and several expert workmen, we went about to survey the generall decay of that ancient and venerable church, and to set down in writing the particulars of what was fit to be don, with the charge thereof, giving our opinion from article to article. Finding the maine building to recede outwards, it was the opinion of Mr. Chichley and Mr. Prat that it had been so built ab origine for an effect in perspective, in regard of the height; but I was, with Dr. Wren, quite of another judgment, and so we entered it; we plumbed the uprights in several places."

It was about 1879 that this passage first attracted my attention, as having some possible relation to an observation which had been made in Venice in 1870. In that year it was noticed that the casing of certain piers in St. Mark's had been cut obliquely, so as to fit and correspond with a system of vertical inclinations which also "receded outwards." The leans of the piers could, therefore, not be less ancient than the casing itself.

This casing was undoubtedly ancient. Inasmuch as accidental movements and settlements of the building would probably not all have taken place at once, immediately after the rough construction was finished and before the casing was applied, this again would argue that the leans were constructive.

The note-book of 1870, in which this memorandum was entered, is still extant. So also is a printed syllabus of 1879, in which this observation was recorded. It was not, however, until 1887, that a photograph of the interior of S. Maria della Pieve at Arezzo furnished an additional suggestion that a system of constructive refinements in the matter of leaning verticals which "recede outwards," might be discovered in the architecture of mediæval Europe.

Photographs are notoriously insufficient evidence as to the lean-

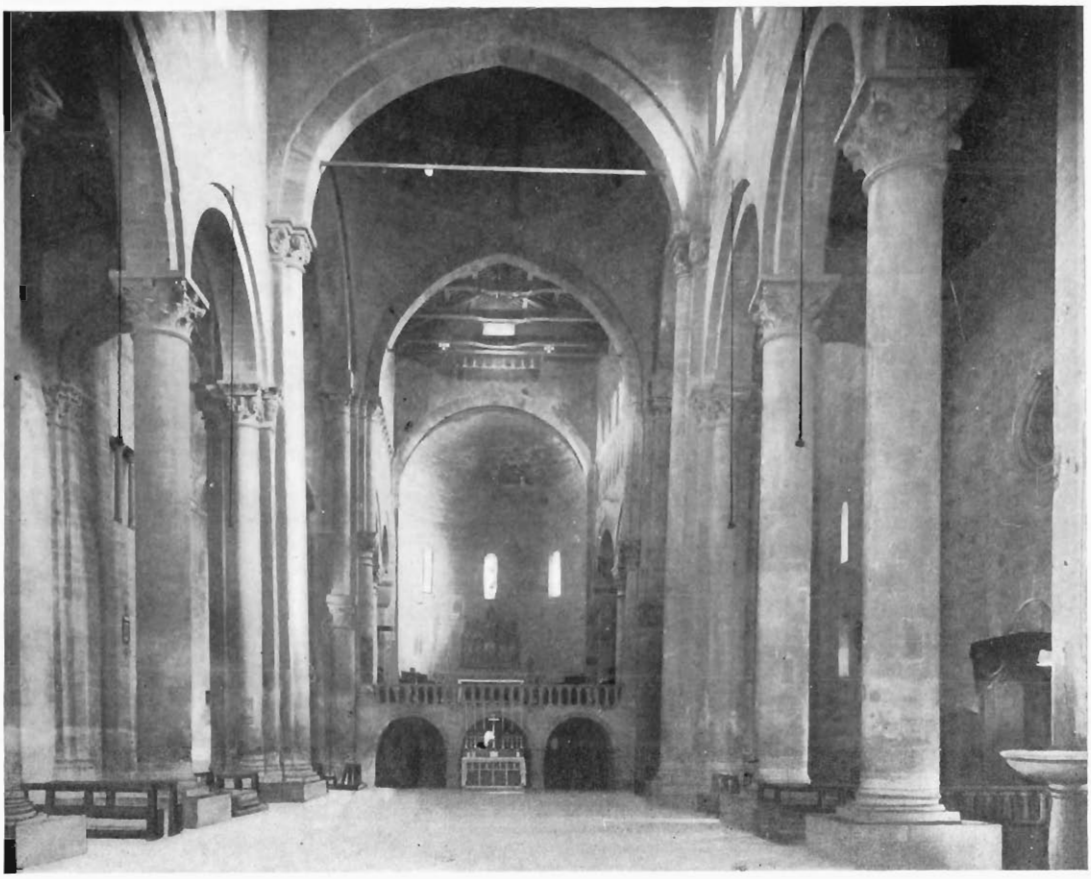


FIG. 1. SANTA MARIA DELLA PIEVE, AREZZO.
From a photograph of the Brooklyn Institute Survey, 1895. The widening in the piers at the transept is about 28 inches.

ing lines of an interior, unless they are made with great care, and a slight tilting of a camera would produce a distortion. The photograph which was examined in 1887 was therefore not regarded as evidence. It was considered purely as a memorandum, making advisable a personal examination of the church itself. This examination was made in 1895.*

A tentative and preliminary examination of the church was made on the dates of July 18th, 19th, and 20th, in company with an architectural assistant. A second visit was made on the dates of August 16th, 17th, 18th, with two assistants, one of whom was an experienced surveyor and engineering architect, and at this time photo-

*During a prolonged surveying trip of six months in which many other phases of asymmetrical mediæval construction were studied. For the general results of this survey see the list of publications on the third page of the cover.

graphs were carefully taken and reliable estimates of the amount of inclination were made (Fig. 1). The ground-plan of the church was also surveyed.*

It was during the later part of the trip of 1895, and subsequent to the Arezzo observations, that the evidence for the constructive existence of this "outward receding" in mediæval architecture was considerably enlarged. In St. Mark's, at Venice, the scanty and hasty observations of 1870 grew into a definite and well-established certainty.

During a six days' stay in Venice (Sept. 6th-11th), many photographs were carefully taken, so as to serve as an exact record concerning the leaning verticals and a few plumb measurements were made. The questions of construction were carefully considered by the engineering expert, Mr. John W. McKecknie, who had been employed by the Survey for such purposes.

Most important observations as to this particular phenomenon were also made during the month of October, 1895, after Mr. McKecknie's departure for the United States, in Pavia, Milan, Borgo San Donnino, and Cremona; but these observations were not corroborated by photographs or by any systematic record of measures, owing to the unusual haste involved in the effort to visit a large number of localities before a fixed sailing date.

After return to the United States it appeared that two of the survey photographs, which had been carefully taken to an exact level and perpendicular, in churches where other refinements had been noticed and surveyed, also supplied the evidence of this refinement. These churches were the Cathedral of Trani and the church of Ss. Giovanni e Paolo at Bologna.

In the Cathedral of Trani the piers of the great arch crossing the nave at the transept recede outwards 12 inches and the very slight thrust of the arch above them is resisted by the entire depth of the transept walls (Fig. 2).

In the church of Ss. Giovanni e Paolo at Bologna (Fig. 3) the clerestory walls recede outwards 10 inches and they are tied in by a transverse wall at the apse, so that accidental outward movement at this point, where the full widening continues, would be impossible.†

Thus, in 1897, it was possible to publish a summary of the evidence which had been secured up to that time on this matter, and inasmuch as the old literary record, which has been quoted, now seemed to have gained considerably in significance, this publication was given the title of "An Echo from Evelyn's Diary."‡

*Architectural Record, Vol. VII., No. 2, 1897: p. 210.

†This church was revisited in 1901, and the facts which were originally discovered in a survey photograph were verified by personal observation.

‡Architectural Record, Vol. VII., No. 2, 1897.

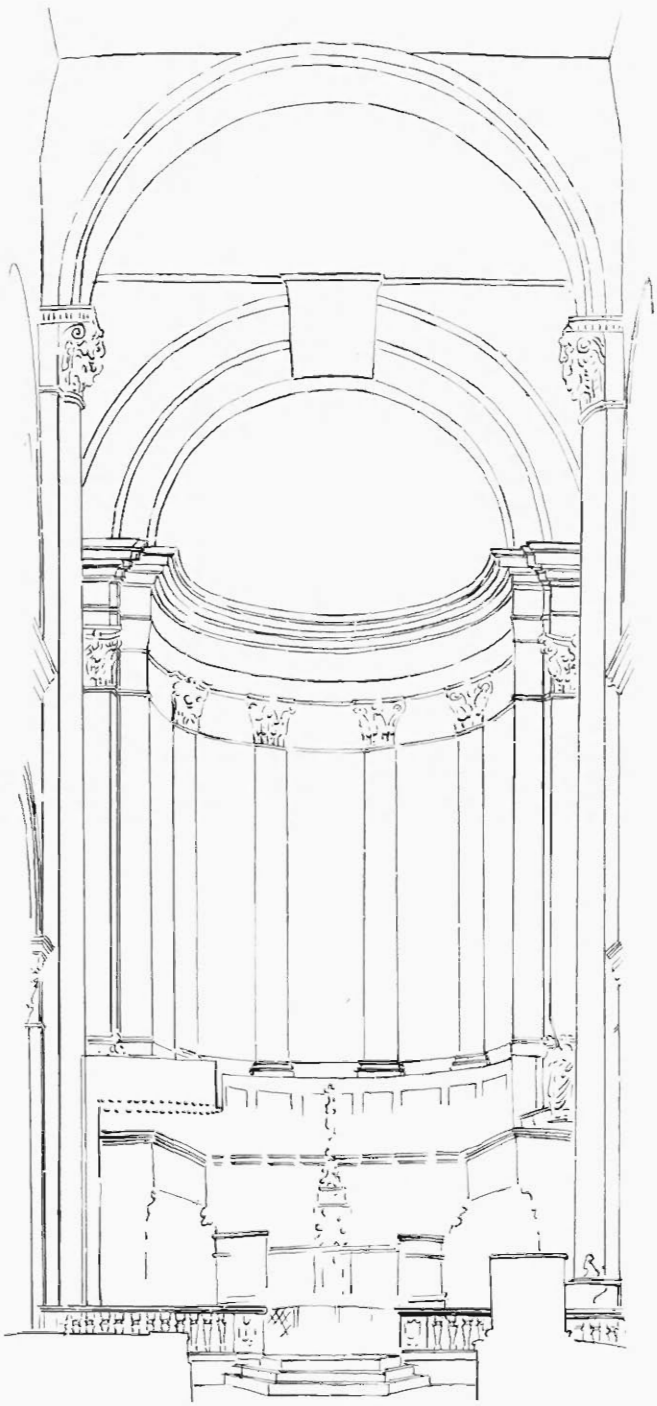


FIG. 2. CATHEDRAL OF TRANI. ARCH SPANNING THE NAVE.

Tracing from a Survey photograph of 1895. The widening in the piers of the arch is about a foot. The walls of the nave curve inward near the ceiling. The original lines of the apse are concealed by Renaissance stucco.

FIG. 3. SS. GIOVANNI E PAOLO, BOLOGNA.

Drawing over a Survey photograph of 1895. The widening in the walls of the nave is 10 inches, and this widening extends to the point where the clerestory walls are tied in by the wall of the apse.

There was still much to be done, even in a preliminary study of this matter. In 1895 our surveying party had employed a well-qualified engineering expert, and his certificate had been published regarding the constructive facts in S. Mark's and at Arezzo, in the paper which has just been cited. Notwithstanding, it appeared that a certificate from the engineering architect in charge of St. Mark's was also to be desired.

It was especially in order to secure this certificate that a trip to Italy was made in 1901. An additional motive for this visit was

the wish to verify and corroborate by photographs and measurements, the hasty and insufficiently substantiated observations of 1895, in Pavia and Milan. The result was, however, not only to make good the deficiencies of record for the evidence already known to exist, but also to secure wholly unexpected additional evidence of a character which will doubtless challenge the attention of every architectural expert.

From this point of our Memoir the evidence will be massed, without regard to the date at which it was obtained. But the reason for this method of approach to the topic lies in the appeal which it suggests for future research; based on the positive certainty, which has now been attained, that the churches which have been found to show this remarkable construction are not the only ones.

Since the survey photographs of S. Maria della Pieve at Arezzo have been the first referred to, it is well to add that this church has been chosen for an important preliminary illustration (Fig. 1), not only because it was the pivot from which our search for the given refinement moved in 1895, with a certainty that somewhere or other, churches with similar phenomena would again be found, but also because it is a peculiarly marked and definite case, and therefore one in which the diverging lines can easily be shown by a photograph.

This again makes it important to say that what is easily seen in a photograph is not always easily seen in a building. The photograph which is accurately made to show an obliquity, or lean, often produces an impression on the observer which is wholly foreign to that actually found in the building. In the buildings themselves these leans are inconspicuous. They are discounted, or translated by the eye, into other effects, whereas the photograph may appear abnormal.

A remarkable indication of the absence of an abnormal appearance in the buildings is the fact that these leans have not been published as constructive. Thus these verticals "receding outward" really do partake of the nature of a refinement; i. e., they are inconspicuous, although they may not so appear to be, in the case of the Arezzo photograph.

On the other hand, certain photographs of St. Mark's approximate to the effect obtained in the building and may assist the student to understand the motive of this construction. On the whole, however, the purpose of this refinement should be studied in the buildings and not in the survey photographs. These are simply illustrations of the existence of such leaning verticals; having been made with all possible precautions to avoid the distortions which are due to the tilting of the photographic plate. Moreover, in the most important cases their evidence is supported by measures with the plumb-line.

As to the purpose of this remarkable constructive system, it may grow to be as much debated, and continue to be as little understood, as the Greek horizontal curves themselves.* It is perhaps not even clear at present, in what sense the suggestion of Chichley and Prat, as quoted by Evelyn, should be taken,—"that it had been so built ab origine, for an effect in perspective, in regard to the height." The main purpose of this publication is to so bring the facts to the knowledge of experts that their views may be obtained. Meantime, it has already been suggested by the writer that one purpose may have been to avoid the contracted and spindling effect which the perspective convergence of vertical lines tends to produce in a lofty nave. There are also several churches, and St. Mark's is one of them, in which the effect may be compared to an emphasized development of that entasis, or vertical curve, which has been proven by the Brooklyn Institute surveys to occur in the piers of some mediæval churches. There is a palpable grace and suavity, a largeness of sweep and an elegance of design about these bending verticals which may be their all-sufficient explanation.†

At present the important point is to collate as many facts as possible and what remains to be said in this paper as to possible motives will be best said after all the known facts have been presented.

No discussion on the point of motive could, however, be satisfactory which does not consider the evidence which has been elsewhere presented for the existence of other phases of architectural refinements in mediæval churches.

The Constructive Evidence at Orvieto and Vicenza.

It is self-evident that outward leaning walls or piers in vaulted churches are presumably to be attributed to accidental causes and that they are to be attributed especially to thrust from the vaulting, unless positive proof to the contrary be furnished. We shall therefore address ourselves to the proofs that the given facts are constructive in certain churches to be named.

For instance, in the Gothic church of S. Agostino at Orvieto the walls lean outward, while buttresses of the same age, and of homogeneous construction with the wall, lean inward. This shows, of course, that the walls do not lean outward accidentally. Several photographs of this church were made on Sept. 17th, 1901, and a drawing from one of them is published in Fig. 4. An enlargement of 25 × 35 inches from this photograph is exhibited in the Museum

*For the various theories which have been advanced as explanations of the Greek horizontal curves, see Journal of the Archæological Institute of America, Vol. VI., No. 2, New Series, 1902: Goodyear; "Architectural Refinements in Italian Churches."

†A very remarkable demonstration for the constructive existence of delicate curves in mediæval piers has been found in the Cathedral of Vicenza. See the Journal of the Archæological Institute of America, Vol. VI., No. 2, New Series, 1902. See also p. 47 of this Memoir.

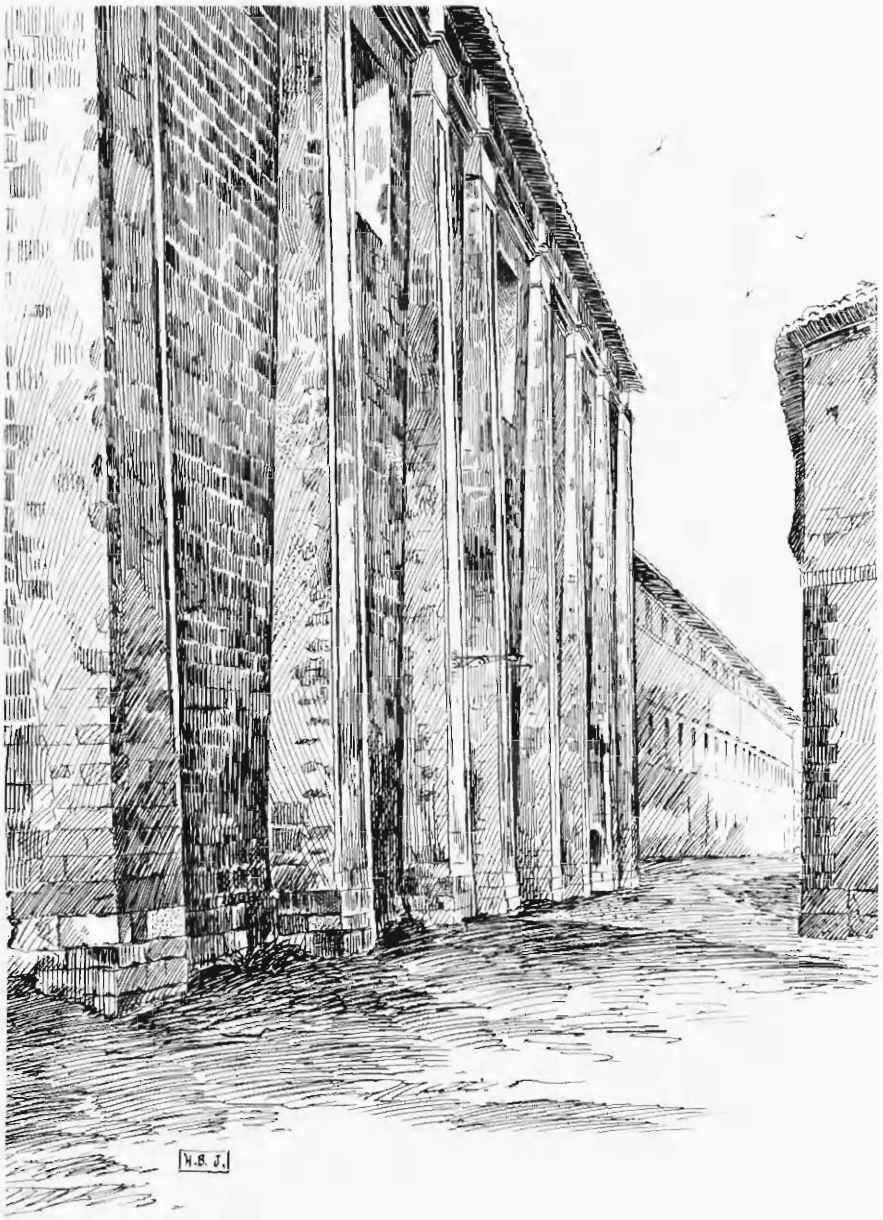


FIG. 4. S. AGOSTINO, ORVIETO.

Drawing from a Survey photograph of 1901. The interior widening is shown in the exterior outward leaning wall. The buttresses lean inward and are a portion of the original construction.

of the Brooklyn Institute. In such enlargements the facts are shown with much greater clearness than in the small dimensions of these pages.

The church is now in possession of the military authorities at Orvieto and the temporary absence of the Commander made it impossible for me to examine the interior, although I had visited Orvieto expressly to make these photographs.

The exterior of this church, then also closed and abandoned as regards the interior, was first examined on July 10th, 1895, but I did not then realize its importance, being absorbed in a survey of the Orvieto Cathedral, and in a study of quite different phenomena.* At that time, my conception of the outward receding verticals was that they would be confined to the clerestory or to the piers of the nave as they have since proven to be at Arezzo, Perugia, Bologna and Cremona. It had never dawned upon me that these leans for interior effect, might be found in the exterior walls of a church. S. Agostino at Orvieto seemed at that date to be a species of freak. It was not till 1901 that the discovery of a similar case in Vicenza led me to revisit Orvieto in order to make these photographs.

On Sept. 2d, 1901, the Gothic church of S. Lorenzo in Vicenza (Fig. 5) was observed to have exterior side walls leaning outward against buttresses of the same age, and of homogeneous construction with the walls, which had outer perpendicular faces. This construction proved to be the exterior phase of an interior outward leaning of the aisle walls.

Several photographs were made in the interior and plumbs were taken at various points. The original of Fig. 6 was taken so as to show the inner side of the wall which appears in the exterior of Fig. 5. The lean continues at the angle of the transept wall, which has a depth of 10 feet.

At this point no movement due to thrust is conceivable, and we have thus an additional corroboration for the constructive facts as shown by the exterior buttresses.

The lean amounts to 6 inches in a height of 32 feet, at the angle, and it amounts to 9 inches at the pilaster which is nearest to the spectator in the photograph.

In the greater height of the exterior wall the lean amounts to about a foot. The thickness of the wall itself is 4 feet and the buttresses project 3 feet from the bottom of the wall. Similar facts are found in the left aisle and a photograph has been taken to represent them.

Fig. 7 shows the nave of the same church, taken from the High Altar, and looking toward the façade. The outward receding, or spreading, in this nave, begins in the clerestory walls. It only

*Architectural Record, Vol. VI., No. 3, p. 389.

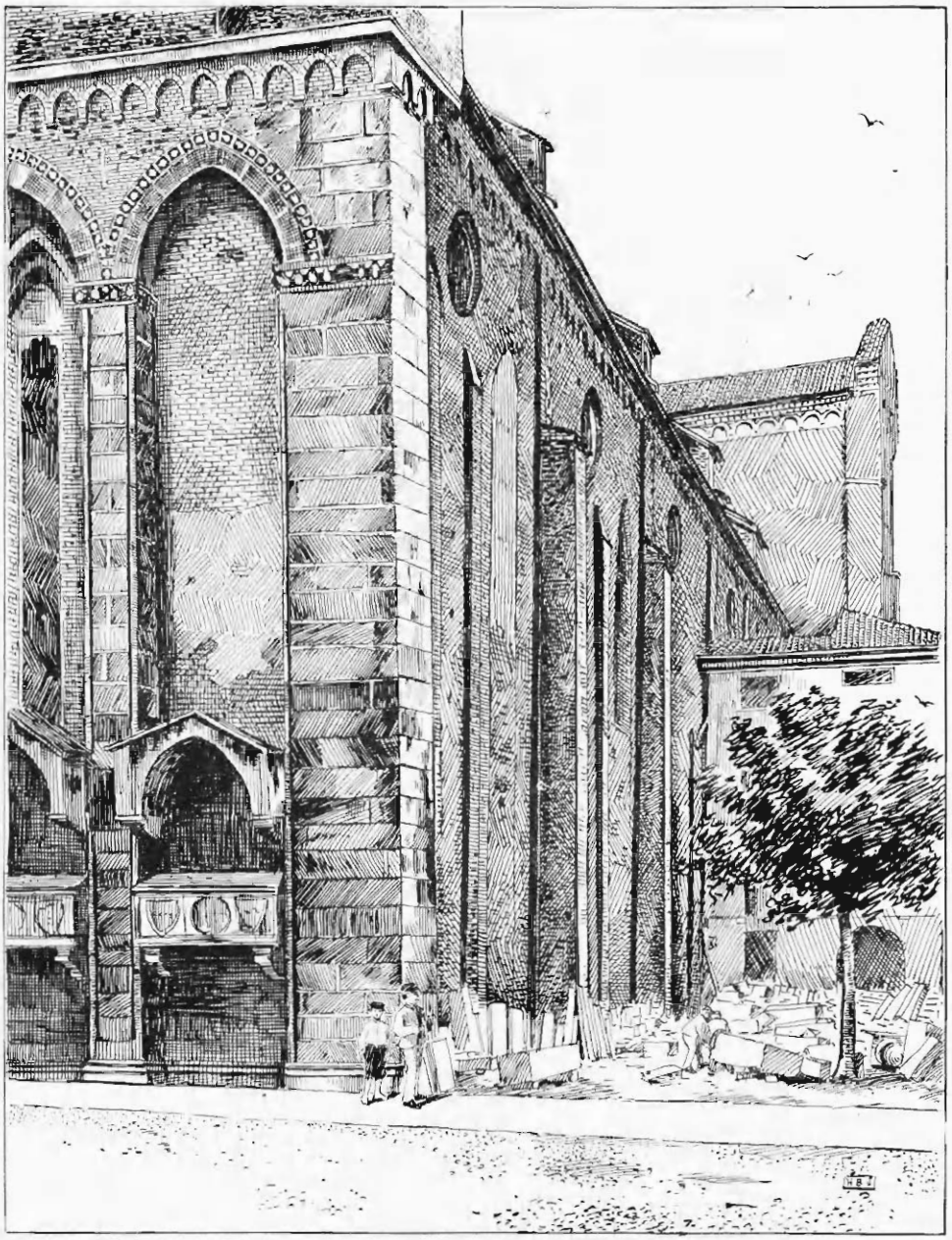


FIG. 5. S. LORENZO, VICENZA.

Drawing from a survey photograph of 1901. The interior widening is shown in the exterior outward leaning wall. The outer faces of the buttresses are perpendicular, and they belong to the original construction.

amounts to about 3 inches on each side in a height of 16 feet; a total divergence of 6 inches. The delicacy of feeling which called for this divergence is certainly remarkable, but we shall find proofs in more than one building that leans of as small an amount as 0.10 were systematically made for heights of 10 or 12 feet.*

FIG. 6. S. LORENZO, VICENZA.

From a Survey photograph of 1901. Wall of the right aisle, looking toward the transept. The outward leaning is partially obscured by Renaissance monuments. It amounts to 9 inches at the first pier on the right, and to 6 inches at the angle of the transept wall, in a height of 32 feet.

S. Agostino at Orvieto and S. Lorenzo at Vicenza are the only buildings, so far observed, in which the outside walls of the building lean out, in connection with a system of interior leaning verticals, but the aisle walls of St. Mark's at Venice also lean outward, as far as the interior surfaces are concerned, as will be shown presently.

There are five other churches, so far found, in which the effect of the outward lean is built into the pilasters of chapel walls which face the side aisles. Thus, eight churches are known at present in which either the fact or the effect of an outward lean is carried into the vertical lines of the side aisles.

The five churches above mentioned are: S. Giorgio Maggiore, at Venice; S. Ambrogio and S. Eustorgio, Milan; S. Michele and S. Francesco, Pavia.

The Constructive Evidence at Milan and Pavia.

The four last mentioned cases were all observed in 1895; but, as already noted, without adequate corroboration or record, on account of hasty observation. All these churches have a system of exterior chapels with walls at right angles to the direction of the aisles and of such depth as to make it positive

*The view of the aisle (Fig. 6) shows a peculiar treatment of the vaulting, which is indicated by the oblique lines of the timber beams, showing that the capitals are lower on the side of the nave. The vaulting is turned with a higher and shorter curve on the side of the wall and with a depressed longer curve on the side of the nave. The purpose seems to have been to throw the thrust of the vaulting towards the nave and away from the outer wall. A similar treatment of the aisle vaultings is found in the Cathedral of Volterra.

FIG. 7. S. LORENZO, VICENZA.

From a Survey photograph of 1901. The widening, which begins above the capitals of the piers, is estimated at 6 inches in 16 feet.

that the sloping pilasters which face the ends of the walls are constructive.

S. Eustorgio at Milan is an ancient Romanesque church. The slopes of the aisle pilasters, as shown by Fig. 8, were noted on Oct. 9th, 1895. Photographs and plumbs were taken on Sept. 11th, 1901. The slope of the pilaster on which the lamp is hanging is 4½

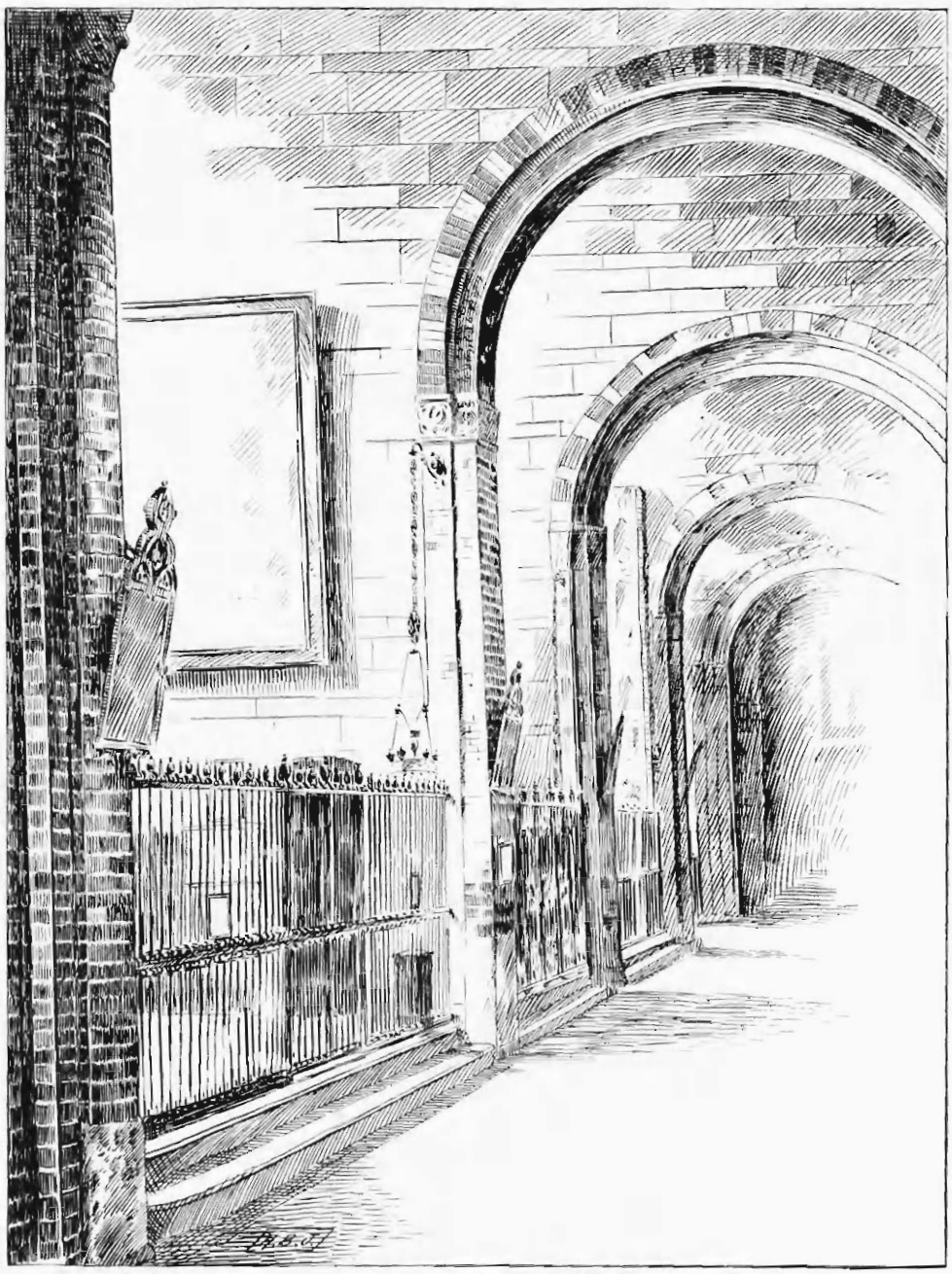


FIG. 8. S. EUSTORGIO, MILAN.

Right aisle, looking toward the façade. Drawing from a Survey photograph of 1901. The average outward lean of the pilasters is 4 inches in 15 feet. All the pilasters of the left aisle have corresponding leans, under similar conditions as regards thrust.

inches in 13 feet. The average slope of six pilasters is 4 inches and the same uniform leans occur in the opposite aisle.

The case of S. Eustorgio is notable because no widening is known to exist in the clerestory of the nave. No sighting was taken from the level of the clerestory, but there is no doubt, at least, that the aisle leans are much the most pronounced in this church. This

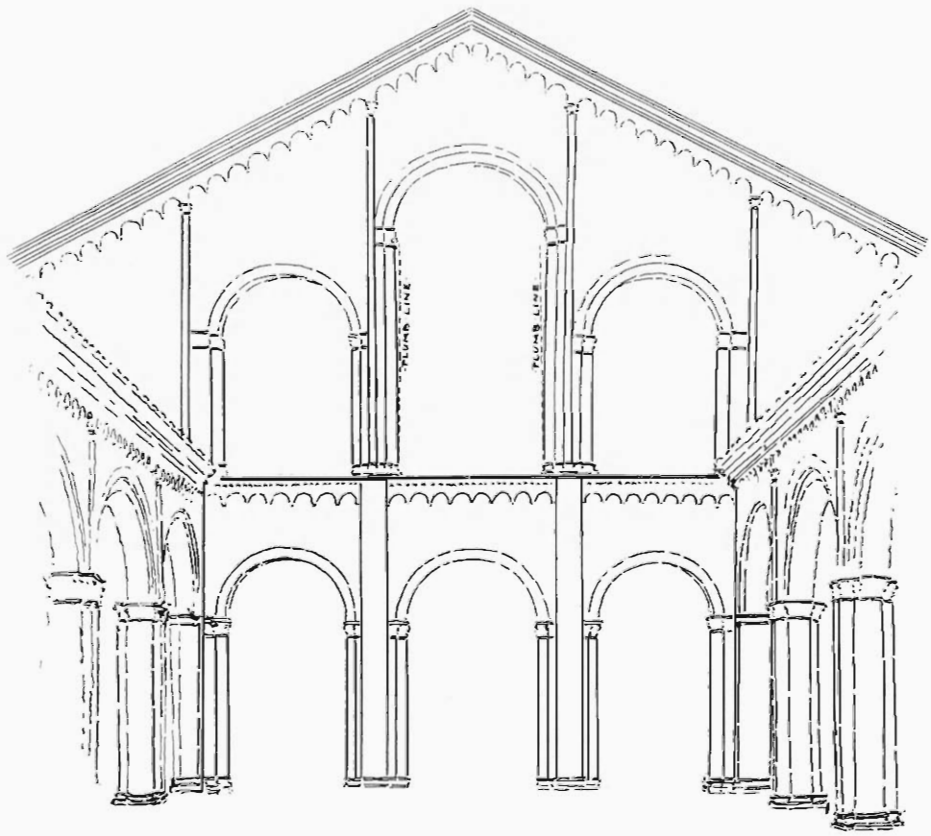
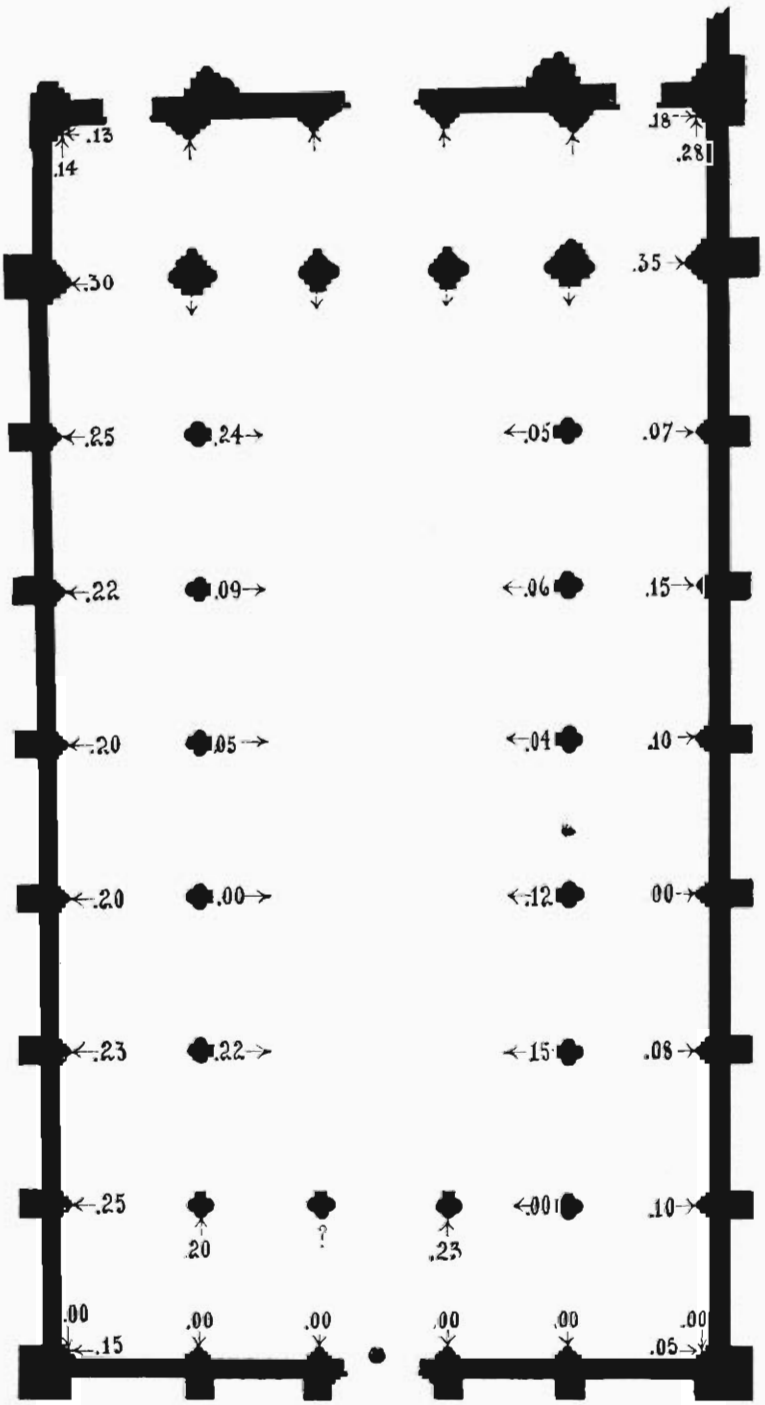


FIG. 9. S. AMBROGIO, MILAN.

The Façade. Tracing from a photograph, to show the widening of the central arch in the upper portico.

would show that the aisle spreads were not merely an afterthought or a parallel treatment derived originally from the naves, but that the aisle leans were considered desirable in themselves, without reference to the nave.

Inasmuch as the aisle walls must have been built before the clerestory, it would be conceivable that the building had meantime fallen into the hands of masons who did not practice the given refinement, but it can be otherwise proven that one motive of the



PLAN 1. THE COURT OF S. AMBROGIO, MILAN.

Showing leans in the pilasters of the angles which are parallel with those of the wall pilasters. At the angles of the west wall of the church these leans are double. (Compare Fig. 10.) The measures (in decimals of a foot) were taken with a plumb-line of 13 feet.

debated construction was based on a feeling which was not limited to the effect of a clerestory or of a church aisle. This is shown by the fact that the arcades of the entrance court of S. Ambrogio exhibit this refinement, and so does the central arch of the upper portico of its façade. (Fig. 9.)

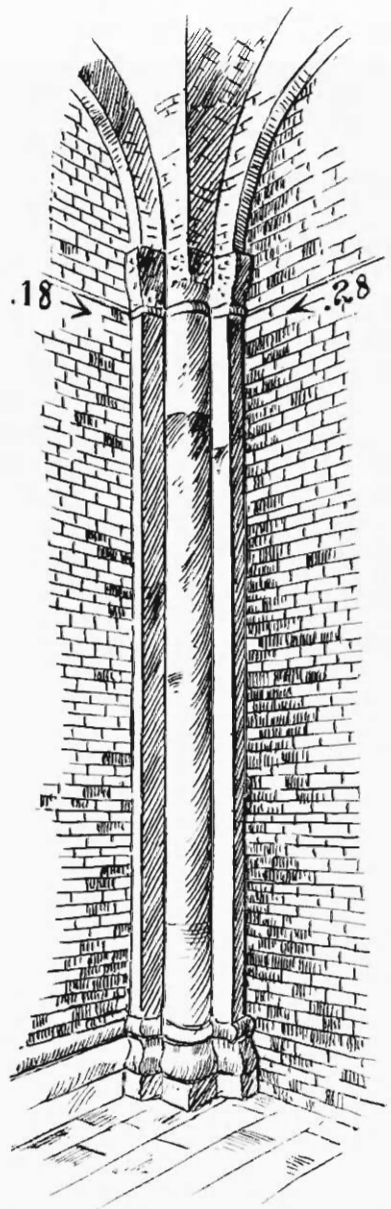


FIG. 10. A PILASTER IN THE COURT OF S. AMBROGIO, MILAN.

Sketch showing the angle of the court near the entrance to the right aisle of the church. The measures representing the lean of the pilaster are to be compared with those of Plan 1, for the other angles of the court. This sketch does not attempt to reproduce the vertical leans. It only represents the conditions under which they occur.

As regards the court of S. Ambrogio; Fig. 10 and Plan 1; we shall confine the proofs for constructive arrangement, as opposed to the natural presumption of thrust, to the observation that the leans are repeated in the pilasters at the four angles of the walls of the court, at points where these pilasters are purely decorative formulas and where no thrust or other accidental movement can be suggested as having affected their vertical directions. The leans in a double direction in the angles of the façade wall of the church, where there is no thrust in either direction, are to be carefully noticed in Plan 1 and Fig. 10. The significance of these leans is, of course, to be related to the fact that they constitute parallels with other leans along the sides of the arcades, which might be open to suspicion as not constructive, if considered without reference to the angles.

In the side aisles of S. Ambrogio (Fig. 11) the evidence for intention is of such a nature that the mere illustration of the facts is sufficient to carry conviction, as it also is in S. Eustorgio. The chapel walls are 21 feet deep (about the same in S. Eustorgio.) Tests with the plumb-line on every pilaster show that the facts are constant and uniform in both aisles. In the illustration of the right aisle the pilaster on which the plumb-line is hanging leans back $2\frac{1}{2}$ inches. The maximum lean in this aisle is $5\frac{1}{4}$ inches. The average lean is 4 inches.

In the nave; Figs. 12, 13; we find the

FIG. 11. S. AMBROGIO, MILAN. RIGHT AISLE.

Drawing from a Survey photograph of 1901, showing the plumb-line. The chapel walls have a depth of 21 feet. With a plumb-line of 13 feet the following plumbs were taken in this aisle (foot-decimals): 1st pilaster (extreme right), .20; 2d pilaster (with plumb-line in the drawing), .20; 3d pilaster, .40; 4th pilaster, .44; 5th pilaster, .42; 6th pilaster, .30. The verticals of the left aisle show corresponding inclinations.

FIG. 12. S. AMBROGIO, MILAN. THE NAVE.

From a Survey photograph of 1901. The piers of the nave vaulting have uniform outward leans, beginning at the pavement, and averaging from 5½ to 6 inches, in a height of 30 feet. Compare Fig. 13.

main piers, which rise to the springing of the vaulting, all constructed with outward receding verticals, and with uniform leans amounting, by plumb measurement from the gallery to the pavement, to $5\frac{1}{2}$ or 6 inches each, in a height of 30 feet. (The alternating piers, which correspond to the smaller bays of the aisles, lean into the nave in some cases. Plumbs from the pavement have still to be taken for several of these alternating piers.)

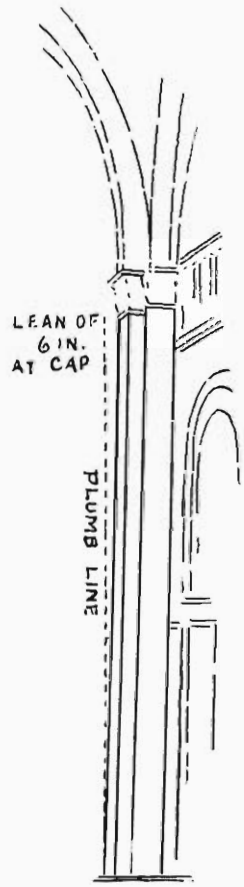


FIG. 13. S. AMBROGIO, MILAN.

Sketch of the pier next the choir, on the right side of the nave.

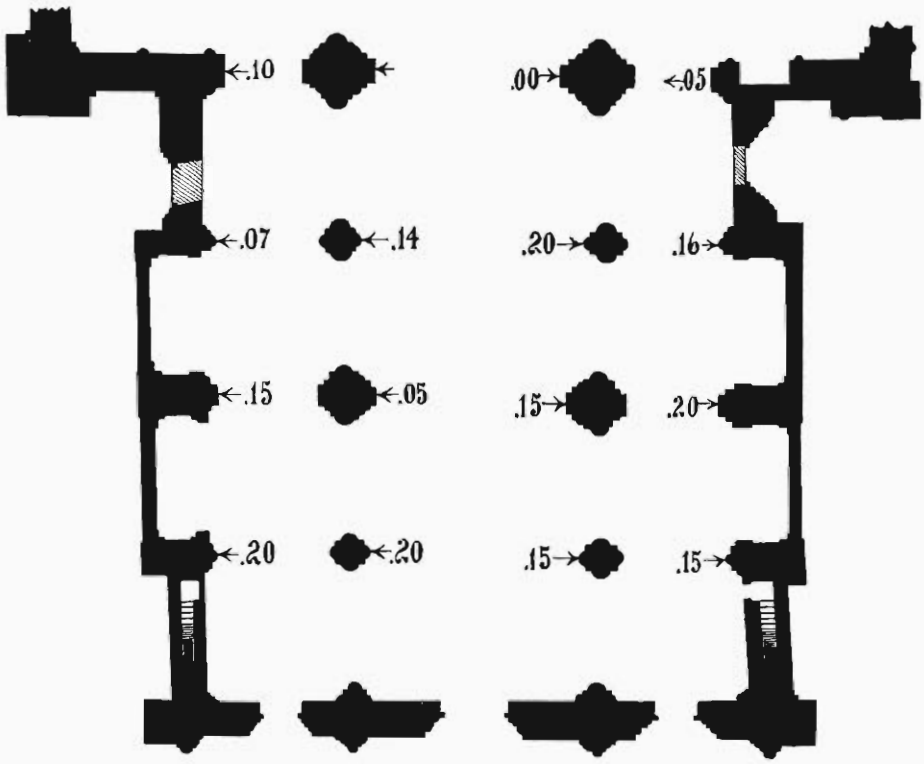
In view of the satisfactory evidence for the side aisles it is hardly necessary to debate the constructive evidence for the nave.

S. Ambrogio, S. Maria della Pieve and the Cathedrals of Perugia and Trani are the only churches observed, in which the leans of the nave piers start from the pavement, with the full amount of the ultimate inclination. Whereas the piers at Arezzo have a delicate but sensible curve, those at Milan have absolutely none. At Prugia the side aisles are nearly as high as the nave and a vaulting thrust has certainly to be considered there as a possibility. On the other hand, when the weight of the galleries, the low side aisles and heavy aisle vaultings of S. Ambrogio are considered, the proposition that the nave vaulting could have pushed over the piers to the amount of 6 inches and in a straight line starting at the pavement, is too absurd even for mention.

In S. Michele at Pavia an aisle photograph was taken with plumb-line in position but was less successful than the pictures in the Milan churches. The facts are of the same nature as regards the aisles and are represented by Plan 2. The small amount of the leans is as notable as their uniformity (one exception.) With a line of 9 feet the minimum is $\frac{3}{4}$ of an inch, the maximum $2\frac{1}{2}$ inches. The only plumbs for the nave are those taken with a short line of 9 feet in length, which was being used in the side aisles. The piers curve back above (as judged by the eye).

As judged by the eye, the first three pairs of piers are marked cases of curving outward, above; but the outer bend of the last pair of nave piers is slight, and no outward receding is perceptible in the arch of the apse. This absence of outward receding in the apse is exceptional, as contrasted with Vicenza, Arezzo, Mi-

lan, Bologna, Borgo San Donnino, St. Mark's and S. Giorgio Maggiore at Venice. In the Capella Palatina of Palermo, it is only in the arch of the apse at the choir that the refinement is found. It may be that repairs have obliterated the lines in S. Michele or that masons were employed, at some date, in the original building who were indifferent to this refinement.



PLAN 2. THE NAVE OF S. MICHELE, PAVIA.

The plumb measurements, in foot-decimals, were taken in the aisles with a line of 9 feet, reaching to the capitals of the pilasters. The same short line was used in the nave. Therefore, the measures for the nave do not represent the amount of widening. They only indicate the vertical direction for the given height.

S. Francesco at Pavia is a Gothic church with chapels opening on the side aisles like the churches just named. The walls of these chapels are 12 feet deep. The pilaster leans are well defined in these aisles and the outward spread appears in the nave. No measures or photographs have been taken here. The observations date from 1895 and the church was not examined in 1901.

Borgo San Donnino and Cremona.

The effort had been made in 1895 to examine all previously unvisited important churches of North Italy, between the dates of Oct. 5th, when survey work was finished at Pisa, and Oct. 17th, when passage had been engaged from Genoa for the United States. After depositing baggage and 550 photographic negatives at Genoa, the following towns were visited, between the 7th and the 17th, in the order named: Pavia, Milan, Piacenza, Cremona, Parma, Borgo San Donnino, Modena, Ravenna, Ancona, Rimini, Padua, Vicenza.

No more attention was paid at this time to the refinement discussed in this Memoir than to many others. The deficiencies of record at Pavia and Milan were made good in 1901, as just described, but Borgo San Donnino was not revisited.

In 1895, the custodian of the Cathedral of Borgo San Donnino allowed a survey of the pier spacings and height of arches to be made on a Sunday morning, during low mass, when the church was crowded with people. The custodian carried the pole with which the heights of the arches were taken and assisted with the tape in taking other measures. It was under such circumstances that a hasty sketch was made of a well-defined outward widening in the pilasters of the arch at the apse, where the absence of strong thrust, on the one hand, and the resistance to thrust, on the other hand, made out a thoroughly impregnable case of construction. An Alinari photograph, which has been recently procured of this church, verifies the sketch made at that time and also indicates that the same spread is found in the clerestory walls. The Alinari photographs of recent date have been found to be very reliable as regards the vertical lines.

During the same trip the Cathedral of Cremona was surveyed for the ground-plan and careful observations were made of a uniform outward receding of the clerestory. The photograph reproduced in Fig. 14 was subsequently made by a Cremona photographer, by direction of the writer, and forwarded to the United States. The photograph is out of perpendicular and the drawing from it (unlike the other drawings of this paper) is rectified. In spite of the unreliability of the photograph as an exact record, the essential facts are shown by the drawing.

Cremona Cathedral offers the only instance which has been noticed, of a defined inward lean below, which reverses to a strong outward bend above. By careful estimate, in sighting by the eye, the piers lean in about 6 inches on each side and the pilasters and clerestory walls lean outward about a foot on each side. The pointed arches of the vaulting are in perfect condition and are ab-

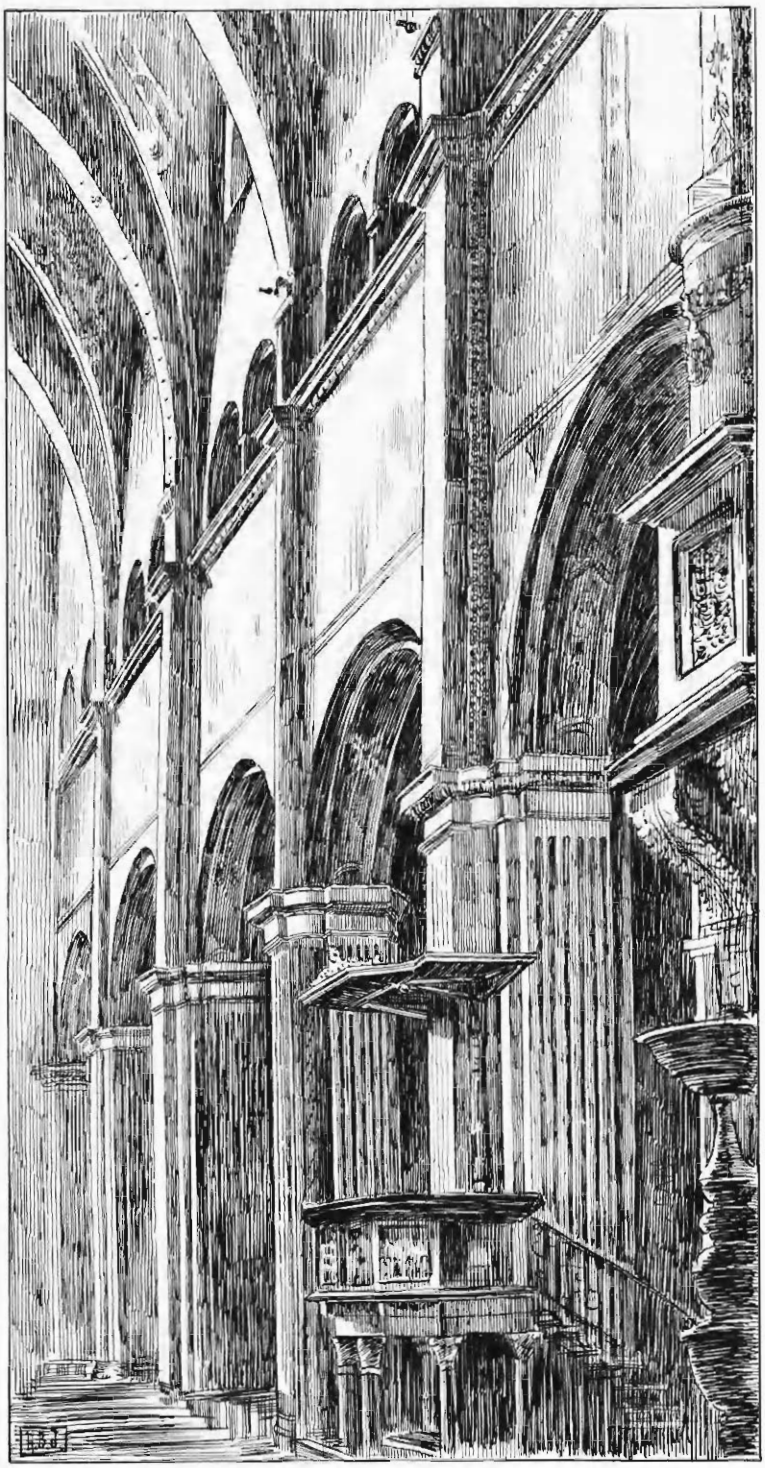


FIG. 14. THE CATHEDRAL, CREMONA.

View looking toward the façade on the left side of the nave. From a local photograph. The drawing is corrected for distortion. The piers lean into the nave, to the height of the capitals, and the pilasters recede outward above the capitals. The widening of the nave is estimated at 24 inches.

solutely without the depression which an accidental widening of two feet in the nave would have carried with it.

Cremona was revisited in 1901, especially in order to take the heights of all the arches, a very difficult task to accomplish with a pole, on account of their great height. The widening was again carefully examined, but a photograph which was made of the nave in parallel perspective proved to be a failure, when it was developed at Pavia. On account of the great size of this church and the difficulty of access to the clerestory openings, which are above the vaulting of the side aisles, it would be very difficult to take plumb measurements in this cathedral for the widening, but a good survey photograph would supply satisfactory means of measuring the exact amount.

The vertical bend at Cremona is not essentially different in principle from that in St. Mark's at Venice, although it is differently planned. This Cremona bend grades towards another type in which there is a curve or entasis in the nave pilasters without any marked recession. In the piers of the great arches which span the nave of the Pisa Cathedral, at the transept crossing, there is a well-defined vertical curve which leans out slightly into the nave and has a delicate return bend at the springing of the arch.* A certificate from the architect in charge of the Cathedral regarding this and other curves was published in No. 1 of these Memoirs.

A fine illustration of this delicate vertical curve is found in the Cathedral of Vicenza (Fig. 15), under circumstances which eliminate all possibility of explanation from accidental causes. As in the quoted churches at Pavia and Milan, the pilasters in the Vicenza Cathedral face chapel walls of great depth (25 feet) with the difference that these chapels open directly on the nave (Fig. 16).

These vertical curves were noticed on October 16th, 1895, the day before sailing from Genoa, and were photographed on Sept. 1st, 1901. Similar vertical curves have been noticed in other churches, but nowhere, outside of S. Paolo Ripa d'Arno at Pisa, where the conditions were so absolutely satisfactory for a demonstration of constructive existence. In S. Paolo Ripa d'Arno the vertical curves are found in flat pilasters which frame the arch of the apse and which are projecting members of a solid wall. These curves were measured and photographed in 1901. Enlargements of these photographs are exhibited in the Brooklyn Museum.

These instances at Vicenza and Pisa will undoubtedly react on the view which will ultimately be taken of similar vertical curves in other churches, but it is not advisable at present to quote doubtful cases. In all vaulted churches with side aisles which are lower than the nave, the aisle vaultings thrust in such

*Architectural Record, Vol. VII., No. 1, p. 77.

FIG. 15. THE CATHEDRAL, VICENZA.

From a Survey photograph of 1901. Showing delicate vertical curves in the piers. The conditions of thrust are shown by Fig. 16.

a way as to tend to produce this kind of a curve accidentally, and this tendency is accented by the upper thrust of the higher nave vaulting in the opposite direction. Under these circumstances two demonstrated cases like those of S. Paola Ripa d'Arno at Pisa and the Cathedral of Vicenza are worth more than hundreds of probabilities. Whatever may be found in the future it is impossible to suppose that these instances could be isolated and they prove the whole point at issue, viz., that mediæval architecture does exhibit very subtle refinements in vertical lines. The absence of aisle thrust at Vicenza is a notable and rare occurrence.

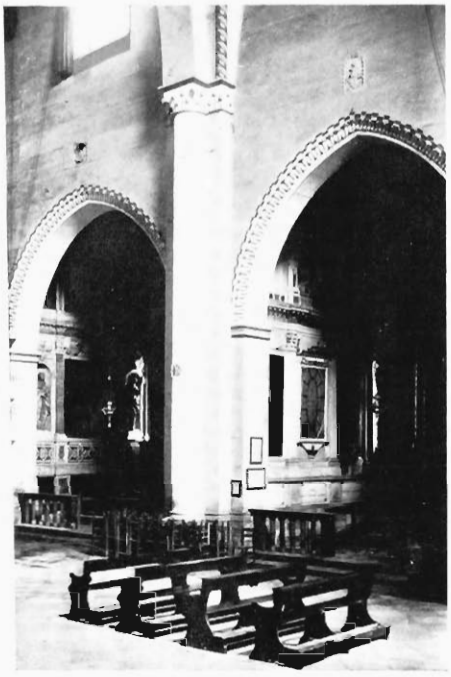


FIG. 16. THE CATHEDRAL, VICENZA.
From a Survey photograph of 1901. Showing the depth of the chapel walls.

Although somewhat aside from the direct problem of this Memoir, all observations which demonstrate the existence of mediæval architectural refinements in the treatment of vertical lines have the greatest possible value for the ultimate comprehension of the system of verticals which diverge outward.

The Cathedral of Siena shows in the ruined and uncompleted part which was to have been the new nave, a very pronounced case of outward curving verticals in the piers. In three separate visits to Siena, twice in 1895 and once in 1901, I have studied these piers without being able to decide whether thrust had only accented, or whether it had wholly caused these bends. Any expert who examines them without knowing of other positively constructive instances will certainly decide that thrust is the only cause. I am not certain that it is, and should not like to affirm that it is not.

In order not to omit any known instance of the spread in Italy, reference is made here to the Cathedral of Aosta as made known to me by my friend, Hugh D. Rooper, Esq., Retired Commander, Royal Navy, of Richmond, Surrey, England. The date of the communication making this announcement is August 12th, 1902.

S. Giorgio Maggiore at Venice.

The evidence supplied by the mentioned churches at Orvieto, Vicenza, Pavia, and Milan, is so firm and definite that it has seemed possible to waive, in this Memoir, those details regarding the church

FIG. 17. S. GIORGIO MAGGIORE, VENICE.

From a Survey photograph of 1901. View looking across the façade wall toward the right aisle. The plumb-line, of broad black tape, is held in position by a pole. The pilaster leans 5½ inches in 20 feet.

of S. Maria della Pieve at Arezzo which have been previously published.* Before taking up the important case of St. Mark's at Venice, we have to record a remarkable survival of "outward receding" in the Renaissance church of S. Giorgio Maggiore at Venice, by Palladio. The facts were overlooked by all the members of our surveying party in 1895. They were noticed and pho-

FIG. 18. S. GIORGIO MAGGIORE, VENICE.
The choir; from a Survey photograph of 1901. The widening is estimated at 10 inches.

tographed in 1901, on various dates between Aug. 16th and Aug. 30th, inclusive.

Fig. 17 shows the first chapel is the right aisle, with a tape and plumb-bob hanging on the pilaster. This pilaster leans back $5\frac{1}{2}$ inches in 20 feet, and the illustration is typical for the entire church.

*Architectural Record, Vol. VII., No. 2, p. 211.

There is absolutely no thrust in question here, because the pilaster plumbed is part of the right side wall of the church. The view is taken looking along the façade wall of the church and the leaning pilaster on the right of the picture is part of this entrance wall. The purpose of the lean in Fig. 17, is obviously to work in a parallel to the outward receding of these great pilasters of the façade wall.

Fig. 19 shows the right aisle with a plumb-line on one of the pilasters. The lean is 5½ inches in 20 feet. The facts as represented in these pictures are uniform throughout the church.

Fig. 18 shows the widening in the choir of S. Giorgio Maggiore, which is also uniform throughout the nave. The outward lean at the choir is not less than 5 inches on each side, between the capitals and the pedestals, a distance of about 30 feet. The plumbs in the nave were taken under great difficulties, on account of the distance from the pavement to the capitals. The widening may be more than the 10 inches, at which the quoted plumbs would place it.

It is, of course, apparent in this church that the strong entasis and the strong related diminution of the classic pilasters, are made the means of obtaining the outward divergence. It is also apparent that the diminution, applied to flat pilasters, as we find it in the choir, or elsewhere, in this church, is wholly unprecedented and wholly inexplicable as a classic treatment. I have already pointed out in the Architectural Record; Vol. VII., No. 1, p. 92; that the entasis in the Teatro Olimpico at Vicenza, by Palladio, is applied to the flat surface of the pilasters in such a way as to produce the same vertical curve which is found in the Gothic Cathedral of Vicenza. This peculiarity is also found in Palladio's church of the Redentore at Venice. The Redentore has, however, no widening or outward receding. The same appearance, as regards use of the entasis (again without widening) is found in S. Stefano at Vicenza, by a pupil of Palladio.

The conceivable suggestion that the widening in S. Giorgio Maggiore is only the result of an exaggerated entasis is furthermore met by the observation that the leans are not found on those sides of the aisles which are adjacent to the nave, although the entasis is equally strong on both sides. This fact has been tested by plumbs in both aisles, and it corresponds to the facts which have been found in the mediæval churches as regards the aisles, viz., that the widening of the aisle is worked in wholly on the outer side. This will also appear in St. Mark's. Thus, in Fig. 19, if measurement be taken from the upper and lower ends of the plumb-line to the edge of the pilaster opposite, the distances will be found equal. The entasis is obviously as strong on one side as on the other; but on the left side of the aisle the pilaster is perpendicular, when its extremities are compared with the plumb-line. The same facts have been found to

FIG. 19 S GIORGIO MAGGIORE, VENICE.

The right aisle; from a Survey photograph of 1901. The black tape plumb-line shows an outward lean of 5½ inches in 20 feet. There is a corresponding entasis on the left side of the aisle, but there is no lean on that side. Compare text.

occur in the other aisle. So in Fig. 17 the right pilaster leans back, but if measurement be made from the plumb-line at top and bottom, to the edge of the pilaster opposite, it will be found to be perpendicular; whereas the entasis is seen to be as strong on the one side as it is on the other.

St. Mark's at Venice.

It has been mentioned that the beginning of this special investigation, as distinct from the examination of other features of mediæval architectural refinements; which were generally first noticed in Pisa in 1870: was an observation in St. Mark's in that same year.

The examination of St. Mark's in 1895 was made as carefully as the six days' stay in Venice would permit. Subsequent study of the church has been much assisted by the survey photographs which were made at that time. These were taken with every precaution which photographic science could suggest, to ensure a record for future use, especially as regards the vertical lines. These records have been abundantly tested and verified by the plumbs taken in 1901.

The main facts for the nave were shown in the publication of 1897, by one of these photographs and were shown still more visibly by a tracing from the same picture; Figs. 20, 21.

For the transepts, only tracings were published, as the original photographs were not suited for half-tone reproduction; Fig. 22.

As regards the main facts for the nave, they are now more adequately illustrated by three photographs (among others) which are reproduced in Figs. 23, 24, 25. These show the changes of direction in the rising line better than Fig. 20, which does not reach far enough down into the nave for that purpose.

In these pictures we are able to distinguish the nearly perpendicular piers, the outward inclination of the walls above the piers to the top of the parapet and the continued lean of less amount, and with a delicate return bend, up to the springing of the arches, The varying measurements for these various divisions of the vertical lines will be mentioned presently.

One main purpose of the Italian trip of 1901 was to bring the publication of 1897 to the attention of Commendatore Pietro Saccardo, the engineering architect in charge of St. Mark's, and to obtain a certificate verifying the facts which were published as being facts of original construction, as far as that church might be concerned. The circumstances under which this certificate was obtained were as follows.

My first call on Commendatore Saccardo was made at his resi-

FIG. 20. ST. MARK'S, VENICE.
The nave, in parallel perspective; from a Survey photograph of 1895. The widening amounts to 2 feet, 10½ inches, at the transepts. Compare Fig. 21.

dence on August 16th. He was politely sceptical as to any constructive widening or spread in St. Mark's, but agreed to meet me at the church on the following day. We then met in the vestibule, where he drew my attention to a parting in the masonry over the main entrance, as indicating an accidental widening of the building. In reply to the question what the amount of the parting might

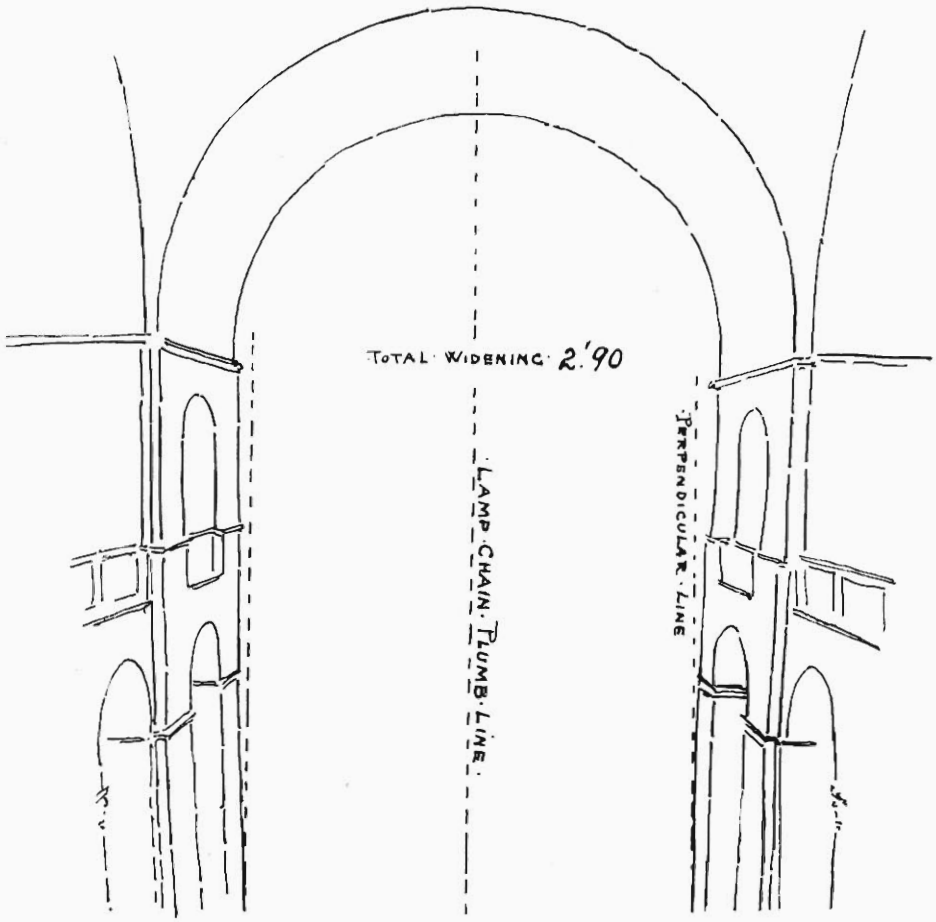


FIG. 21. WIDENING OF THE NAVE IN ST. MARK'S.
Tracing from the photographic original of Fig. 20.

be, he answered that it was about ten centimetres, or four inches. I then entered the church with him and drew his attention to a widening of nearly three feet in the nave (about 2 feet 10½ inches at the transepts) without parting and without flattening of the crown of the arches.

Signor Saccardo thereupon agreed that no yielding of supports would account for such a widening in the upper portion of the

church and that the arches and domes would have fallen, if the supports had gone apart accidentally to such an extent. He frankly admitted that he had not previously realized the full amounts of the outward leans, as these were made known to him through the published measurements of 1897, and by using the illustrations of the Architectural Record in face of the given portions of the church.

That the amount of these spreads has not been realized hitherto by other modern experts, has appeared by personal conversation with many of them. The reason for this oversight, as in the case of several similar oversights on the part of the members of our own survey, is, no doubt, that the leans are about sufficient to correct the perspective convergence in the vertical direction, so that the lines appear perpendicular to casual observation. It may be that this correction was one purpose of the widening. There is also a natural tendency to attribute any individual deviation from the perpendicular, which may be casually noticed, but not fully appreciated, as to amount, to accidental causes.

During the interview with Signor Saccardo, we spent much time in the galleries and among the facts which were pointed out to him were those regarding the terminal north and south walls (and parapets) of the transepts (Figs. 32, 33). These walls lean back about 16 inches (north) and about 15½ inches (south) up to, and including, the parapets, in a height of about 33 feet; while the adjacent arches are perfectly true in both transepts. The arches nearest these walls would have spread, or parted, over a foot, in a width of about eight feet, if yielding foundations had caused a movement of the building. This amounts to saying that the given arches would have collapsed. The leans of these walls were immediately conceded by Signor Saccardo to be constructive.

Signor Saccardo's attention was also drawn, in the galleries of the transepts, to the columns which lean back against the gallery piers, with capitals which are level or tilted downward and not tilted backward like the columns; Figs. 36, 37. He used the words "lavoro immenso," "osservazioni fine," as these facts were pointed out to him. Many remarkable corroborations of the general main facts were only subsequently ascertained and therefore could not be made known to Signor Saccardo at this interview.

Following our tour of the church he kindly undertook to ascertain the amount of the forward constructive lean of the Porta della Carta, which he had been the first to observe and which is mentioned in his letter. We plumbed this together.*

At the close of our interview, which occupied the entire morning, Signor Saccardo deputed Signor Agazzi, who is in charge of the mosaic repairs, to give me access to all parts of the church for

*Memoirs, Vol. I., No. 1, p. 19.

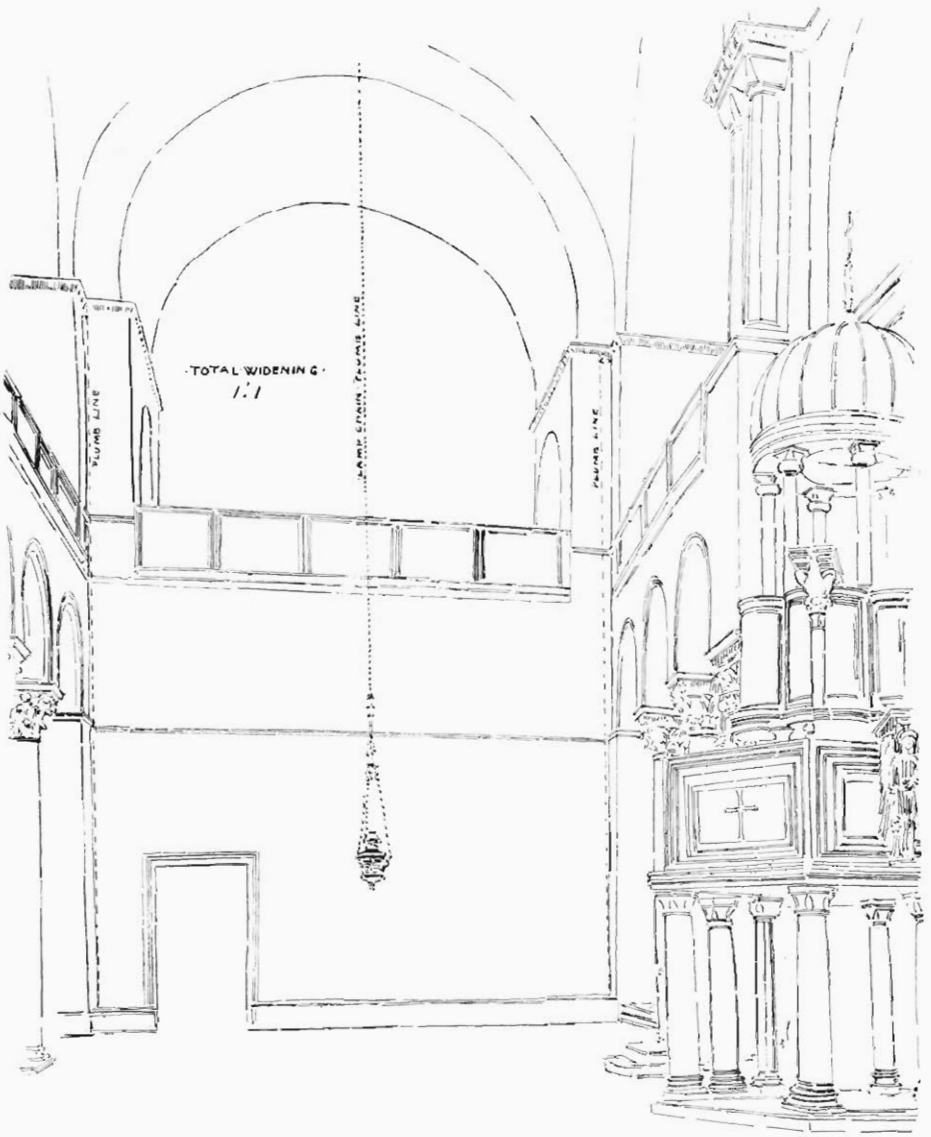


FIG. 22. NORTH TRANSEPT OF ST. MARK'S; FACING NORTH.

Tracing from a Survey photograph of 1895. The wall in face leans north, up to and including the parapet; 16 inches in about 33 feet. The pilasters of this wall face the north and south walls of the Chapel of St. Isidore. Compare Plan 3 and Fig. 31. The tracing shows the east and west leans of the transept, including those of the gallery columns on the east side. The measurement entered on the tracing is an approximate estimate, based on the known width of the transept. The south transept shows the same construction. Compare Figs. 36, 37, 38, for the south transept.

the taking of additional measures and photographs. Assistants were furnished, as needed for this work, from the employees of the Opera. I am also much indebted to Signor Agazzi for many courtesies and for his constant kind attentions, during the remainder of my stay in Venice.

The Certificate.

A few days after this interview the following letter came to hand, in answer to a request for an opinion on the widening of the nave, for an opinion on the outward leaning columns of the façade* and for an opinion on the horizontal curves in elevation of the gallery parapets.†

Signor Saccardo's qualifications as an expert on these points are undoubted. He has been for many years employed on the repairs of St. Mark's and has published a monograph on this subject. He has also been one of the collaborators on the text of the magnificent publication of St. Mark's by Ongania. His researches concerning the piling and foundations of the church have been republished by Boito, and by Mothes, in his history of mediæval architecture in Italy, which is considered the leading German authority on this subject. The diagram of the piling and foundations of St. Mark's which is published by Mothes, is credited to Saccardo.‡

BASILICA DI S. MARCO
IN VENEZIA.
DIREZIONE DEI RESTAURI
E DELLO STUDIO DI MOSAICO.

VENEZIA, 19 Agosto, 1901.

CHIARISSIMO SIGNORE:

Permettemi anzitutto che mi congratuli con Voi degli importanti studi che andate facendo da molti anni sopra i monumenti antichi e in ispecie intorno a certe particolarità di costruzione in gran parte sin qui ignorate e che rivelano sapienti e ingegnosi artifizi usati dagli architetti che li eressero, per ottenere effetti prospettivi singolari. Già si sapeva come, per esempio, ne' monumenti di architettura medioevale si avesse il costume d' inclinare all' infuori i frontoni e le cuspidi con gli ornamenti sovrapposti, come si fa anche in oggi per i quadri e per le statue. In particolare questo artifizio vedesi usato assai marcatamente nelle cuspidi della facciata principale della nostra Basilica di San Marco: non così in quelle delle facciate laterali, perchè l' architetto che le ricostruì, nei restauri di circa trenta anni or sono, non capì il magistero che aveva presieduto al loro collocamento e le mise a piombo. Lo stesso artifizio vedesi usato nella Porta della Carta del Palazzo Ducale e in tanti altri monumenti anche fuori di Venezia, come per esempio nel Sepolcro degli Scaligeri a Verona. Si sa del pari che nella stessa

*Memoirs, Vol. I., No. I, p. 19.
†Architectural Record, Vol. VI., No. 4, p. 503, 1897.
‡Mothes: Die Baukunst des Mittelalters in Italien. Fig. 269, p. 794, Vol. II., showing the foundations of St. Mark's, is borrowed from the work of Boito, and so credited. On p. 798 mention is made of the fact that Boito had republished the investigations and drawing of Saccardo.

nostra Basilica la facciata principale è disposta in curva sensibilmente rientrante.

Così i sei minareti della stessa facciata non sono eguali in altezza, ma vanno salendo da una parte e dall' altra verso la cuspide centrale. Che si fa eccezione quello dell' angolo sud-ovest, egli è perchè fu rifatto in seguito ad un incendio e chi lo rifece non s' accorse dell' artifizio e lo costrusse eguale al penultimo.

Voi poi trovaste nuove particolarità di questo genere che io aveva sempre creduto accidentali, ma che essendo comuni a tanti altri monumenti devono accettarsi quali veri artifizi di costruzione. Tali sono le colonne della facciata della nostra Basilica sensibilmente pendenti all' infuori nell' ordine inferiore e a piombo nel superiore. Tali sono pure i piedritti interni sostinenti le volte maggiori che l' inclinano all' indentro, aumentando così notevolmente la corda dell' arco che si corrisponde, in confronto della base, senza che l' arco presenti qualsiasi abbassamento o deformazione; il che dimostrerebbe che così fossero stati disposti fino dall' origine. Tali sono finalmente i parapetti delle gallerie, composti a plutei, che vanno da un arcata all, altra lungo le braccia della crociera, i quali sono marcatamente curvilinee con la convessità all' insù. Bisogna certo ammettere che specialmente in quest' ultimo esempio qualche deformazione possa essere stata causata, o per lo meno aumentata, dallo squilibrio dei pesi delle masse murali sopra un terreno cedevole come quello di Venezia. Tuttavia il caso è troppo costante perchè si possa ammetterlo siccome puramente accidentale in via assoluta.

Del resto gli studi che voi andate facendo sono molto interessanti e possono condurre anche ad altre scoperte più importanti ancora; per cui sono a congratularmene e in pari tempo vi prego di credermi quale ho l' onore di professarmi.

Vostro dev. servo,

PIETRO SACCARDO.

Sig. Wm. H. Goodyear, Curatore delle Belle Arti
nel Museo di Brooklyn a Nuova York.

TRANSLATION.

Basilica of S. Marco in Venice.
Direction of Repairs and of the Studio of Mosaics.

Venice, August 19th, 1901.

Very Dear Sir:

Allow me first of all to congratulate you on the important studies which you have made for many years of the ancient monuments and especially regarding certain particulars of construction which hitherto have been generally overlooked and which reveal ingenious and scientific artifices, on the part of the architects who built them, for obtaining special optical effects. It has been already known how, for example, it was customary in mediæval architecture to incline forward the gables and pinnacles, as is still done for pictures and statues. This artifice is particularly apparent in the pinnacles of the principal façade of our Basilica of San Marco, but not so in those on the lateral façades, because the architect who restored them some thirty years ago did not comprehend the art

which had directed their original collocation, and therefore he set them upright. The same artifice [of forward leaning] is visible in the Porta della Carta of the Doge's Palace and in many other monuments even outside of Venice; as, for example, in the Tombs of the Scaligers at Verona. It is likewise known that the principal facade of our Basilica is constructed with an inward curve in plan.* The six pinnacles of the same façade are likewise of unequal height and so arranged that they rise toward the centre. If the one at the southwest angle makes an exception, that is because it was restored after a fire by one who did not perceive the artifice and who made it equal to the last but one.

You, however, have found new features of this kind which I had always supposed to be accidental, but which, being common to so many other monuments, must be accepted as true artifices of construction.

Such are the forward leans of the columns of the lower order of our Basilica façade, whereas those over them are perpendicular.†

Such are the interior piers supporting the larger domes, which lean inward,‡ thus considerably increasing the cord of the arch, as compared with the distance between the bases [of the piers] without any settlement or distortion of the arch; which proves that they had been originally built in this manner.

Such are, finally, the parapets of the galleries which connect the arcades of the transepts and which are distinctly curved in elevation and with a rising convexity. It must certainly be admitted in this last instance that some distortion may have been caused, or at least augmented, by the pressure of the masonry masses on the yielding soil of Venice. However, the occurrence is too uniform to be considered as purely accidental.

For the rest, your studies are most interesting and may lead to other discoveries still more important; for which you are to be congratulated, and I beg you to believe me

Your most humble servant,

PIETRO SACCARDO.

[Engineering Architect in charge of St. Mark's at Venice.]

The Plumbing of St. Mark's.

Nothing had been done in 1895 in the way of plumbing the church in detail, on account of the limited stay in Venice. In that year the effort to examine every important mediæval church and cathedral in Italy and the study of many distinct phases of architectural refinements, had involved a close economy of time as regards individual churches.

The work was now undertaken of ascertaining the general direction of the vertical surfaces and supports of the church, as far as this could be done with a pole and plumb-line from the pavement and by taking plumbs from the galleries. For the walls of the

*Architectural Record, Vol. VI., No. 4, 1897, p. 489, and Fig. 44 of this Memoir.
†See Memoirs of Art and Archæology, Vol. I., No. 1, pp. 19-22.
‡*i. e.*, in the downward direction.

side aisles scaffolds or other special arrangements, involving time and expense, would have been necessary, and definite measurements cannot be quoted at present in the aisles, above the height which is accessible from the pavement.

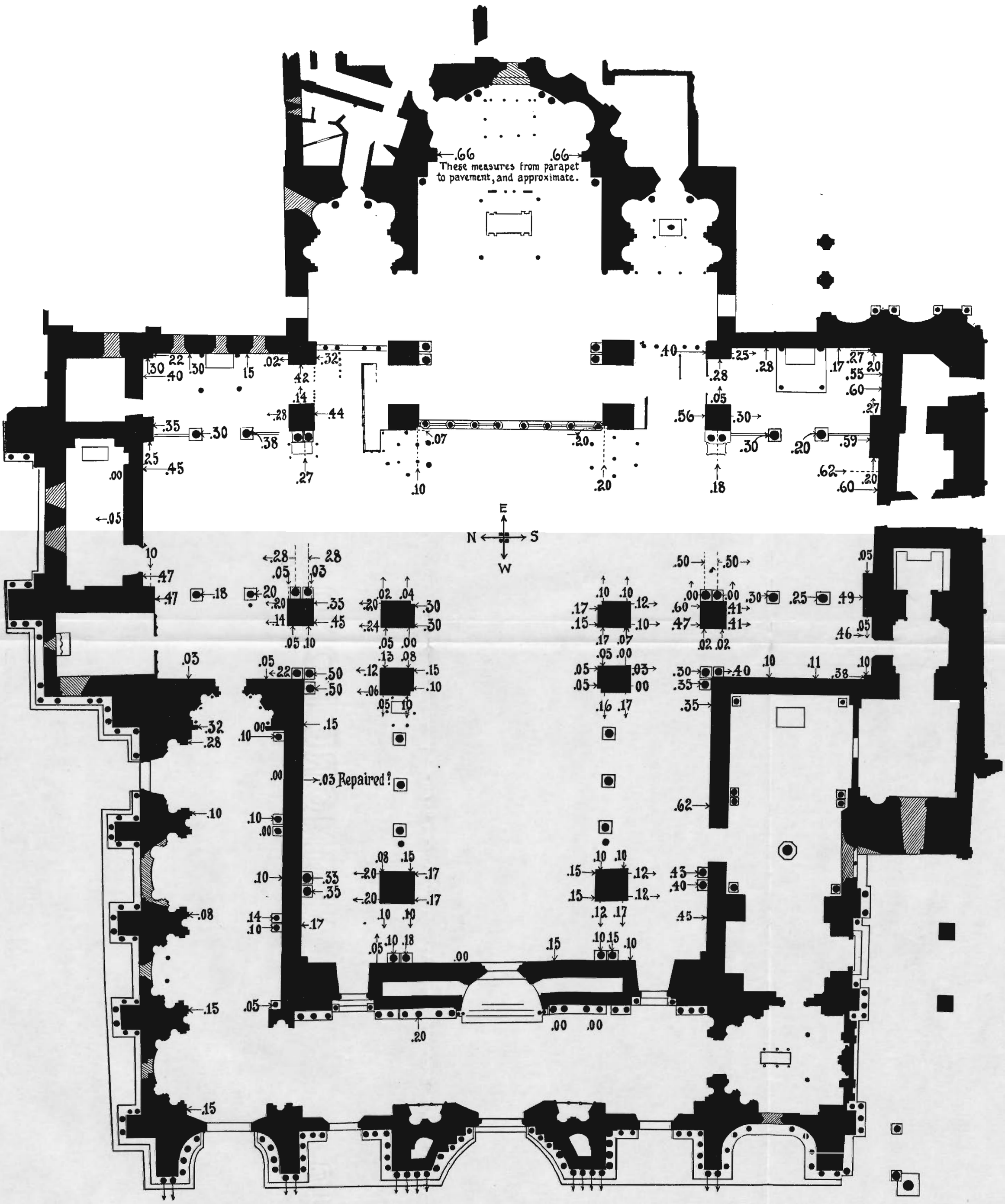
The work was tentative, hastily carried out, and subject to revision, as regards close accuracy; mainly on account of varying lengths of the plumb-line, when obstructions in the way of pulpits, benches, confessional boxes and steps were encountered. Allowances have also to be made for the fact that a plumb-line of $17\frac{1}{2}$ feet was used in the nave, while a line of 15 feet was used in the transepts. Thus the pole measurements in the transepts are slightly under-stated, as compared with those in the nave and in the aisles of the nave. The measurements for the leans of the piers are also slightly under-stated if their whole height be considered, because they are surrounded by settees which prevent dropping a line to the pavement.

The plans which are published for these plumbs are not final, or perfect, as regards details, but they show the necessity for more thorough and more carefully executed surveys. They reveal a very remarkable series of facts as regards the system of vertical widening, in all parts of the building, and as regards the uniformity of direction and relative equality of the vertical leans, at distant but corresponding points. An astonishing series of incidental corroborations has been brought to light for the general main facts, as already published for the nave.

Measurements have been made by the plumb-line at a multitude of points, where even the suggestion of accidental movement is impossible. The correspondences in results at remote, but corresponding, points, render the theory of careless construction in the verticals equally impossible.

In spite of the free-hand irregularities of construction in this church, where errors of several inches and irregularities of marked amount can, in many cases, certainly be nothing more than bold and frank indifference to closely accurate work, it can now be proven that refinements of leaning verticals were planned, in which one-tenth of a foot in twelve feet was the amount of variation deliberately sought in some cases. This appears, for instance, from the measurements for the widening in the north vestibule; Plan 14,p.96.

The quotation of the measures in decimals of hundredths of a foot has, however, no general significance and must not be supposed to argue any effort on the part of the builders at closely accurate results in every given case, or in all corresponding cases. The measures themselves prove the contrary, by their correspondences in direction, on the one hand, as compared with their variations in detail on the other. The measures are quoted in decimals,



GROUND-PLAN OF ST. MARK'S.

Measurements in foot decimals for plumbs from the pavement with a line of length 17.30 ft. in the nave, and 15 ft. in the transepts. The darts show the direction of the leans.

FIG. 23. NORTH SIDE OF THE NAVE OF ST. MARK'S.

From a Survey photograph of 1901. As compared with Fig. 20 (which shows the widening, but does not include the bend), this view shows the outward bend, contrasted with the nearly perpendicular lower piers in the nave. The lamp chain furnishes a plumb-line. For plumb measurements compare p. 65. The curve in elevation of the gallery string-course and parapet is also shown. Compare Fig. 42 for the north gallery curve.

because they are so found in the note-books of record and they are generally mentioned without reduction to the more easily grasped statement in inches, in order that they may appear as taken.

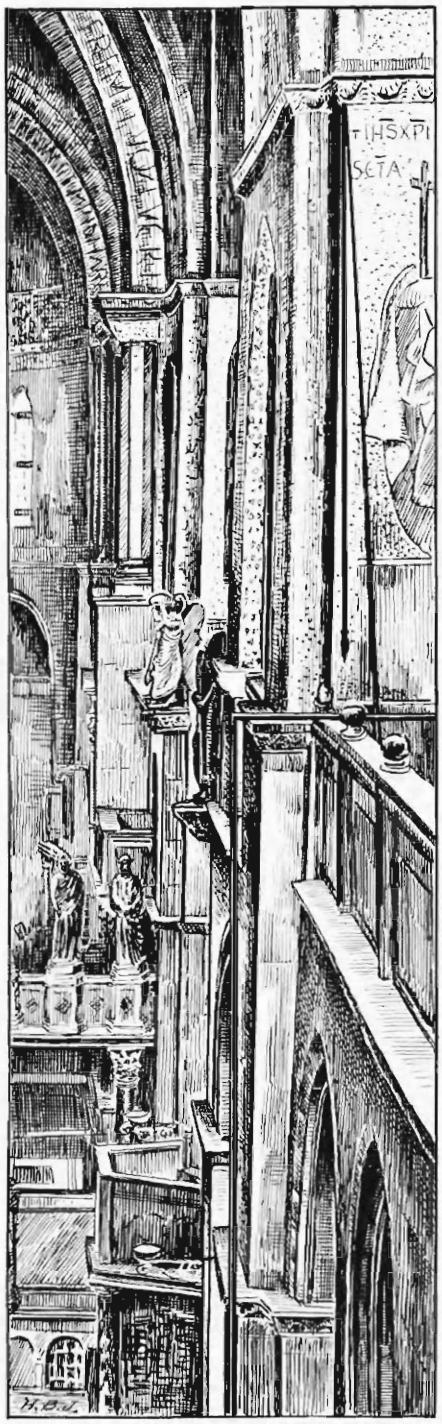


FIG. 24. SOUTH SIDE OF THE NAVE OF ST. MARK'S.
Tracing from a Survey enlargement of 1901.

The general reasons for taking measures in foot hundredths are well known to surveyors. These reasons do not at all imply that the odd hundredths are uniformly important. The reason is simply that measures cannot be quoted, or taken down, in uniform style, when sixteenths, eighths, or quarters of an inch have to be mentioned. For rapid work, and rapid uniform entry, a tape marked off in feet, tenths and hundredths, is much the most convenient. How much importance is to be attached to the odd hundredths in subsequent reading of the measures is quite another matter and a careful examination of this question has also been made (p. 97).

The quotations will begin with the main general facts for the nave.

The Nave of St. Mark's.

The estimate of the survey of 1895 for the widening of the nave at a given point (Fig. 21) was based on a photograph (Fig. 20) so taken in parallel perspective and so carefully levelled for the true perpendicular that the amount of widening might be estimated from the known width of the nave at the pavement.

This estimate is now supplemented and corroborated by plumbs taken in detail on each side of the nave, for the three separate divisions in its height up to the springing of the arches; viz., the piers from the pavement up to the moulding or capital, the pilaster casing or wall from the capitals of the piers to the string-course which corresponds to the top of the parapet, and the mosaic wall, from this string-course up to

the springing of the arch (Figs. 23, 24, 25). Pole measurements cannot be taken in the gallery on this upper face of the wall at the points indicated by the estimate of Fig. 21. All three sections were therefore plumbed on the sides of the piers which are nearest the spectator in Figs. 23, 24, 25.

The measures of the leaning verticals for these various divisions are given below so that they may be read from the pavement up, or from the mosaic wall downward, as follows:

From the top of the parapet to the springing of the arch; about 13 feet.

Left; $3\frac{3}{4}$ inches. Right; 5 inches.

From the capital moulding to the parapet string-course; about 12 feet.

Left; 8 inches. Right; $8\frac{3}{4}$ inches.*

From the settees on the pavement to the capital moulding of the piers; about 18 feet.

Left; $1\frac{1}{2}$ inches. Right; $\frac{1}{2}$ inch.

Total: Left; $13\frac{1}{4}$ inches. Right; $14\frac{1}{4}$ inches.

On the right side of the church, however, the two upper faces step back. At the capital of the pier the right pilaster steps back about 2 inches (Fig. 24). This is included in the plumb from the parapet; but the stepping back of the mosaic wall at the parapet amounts to about $2\frac{1}{2}$ inches. This lies between the plumb taken upward and the plumb taken downward, and must be added to the total widening, which thus amounts to about 30 inches for the given sectional plane.

This result corresponds very closely with the estimate obtained from the survey photograph of 1895; allowing for the fact that the lower piers, at the point there considered, lean off more than those just quoted.

They lean off; right, .17, as against .05 (Plan 4, p. 68).

They lean off; left, .30, as against .15 (Plan 5, p. 76).

This gives an extra widening of .27 or $3\frac{1}{4}$ inches, for the lower piers, which brings the sum total up to about $33\frac{1}{4}$ inches, without knowledge of what the variations may be for the two upper divisions, at the point where the survey photograph of 1895 gives a total of 2.90 or about $34\frac{1}{2}$ inches.

An appearance in the church of having gone over to the right is produced by the leaning verticals of the right pier at the choir (Fig. 39). These are shown by the survey photographs to be more inclined on the right than on the left and they are easily to be noted

*This measurement on the right side of the church includes a stepping back of 2 inches, so that the actual lean is about $6\frac{3}{4}$ inches. The stepping back of faces is mentioned in the text which follows.

FIG. 25. SOUTH SIDE OF THE NAVE OF ST. MARK'S.

View from the pavement; from a Survey photograph of 1895. As compared with Fig. 20, which does not include the vertical bend, this view shows the nearly perpendicular lower piers, as contrasted with the change in vertical direction above their capitals. It also shows the delicate return curve of the mosaic wall, below the arch. The lamp chain furnishes a plumb-line. For plumb measurements compare p. 65.

in Fig. 39, as constructive. Measurements at this point by plumb, are obstructed below by the pulpit and cannot be taken at all from the galleries. The appearance in the church of having gone over to the right is also accented by the stepping back of faces, as already mentioned. Fig. 24, showing plumb-lines in position, is drawn from a tracing over a Museum enlargement, from the photographic series of 1901.

Distribution of Widening in the Nave as Regards the Various Divisions of Its Height.

It has just been observed that there are three separate divisions in the sides of the nave up to the springing of the arches. The amount of inclination in these various divisions appears from the quoted measures (p. 65) to be the greatest in the shortest division of all, i. e., the central division. For instance, on the left side of the nave the central division leans 8 inches in about 12 feet, whereas the pier below leans 1½ inches in about 18 feet, and the wall above leans 3¾ inches in about 13 feet. It may also be observed that the comparisons of amount for each section tally very closely on the two sides of the nave.

The sudden change in the amount of the leans above the capitals of the piers, which is indicated by these measures, is easily perceived in the photographs and in the building. At least, it is easily perceived after it is known to exist. Fig. 25 shows it with special clearness.

This sudden increase of inclination at the given point, which is found to be a uniform and constant fact in all portions of the nave, is a complete and decisive proof that no accidental movement has pushed these verticals out of plumb. No expert, who may have his attention called to this feature of the church in the building itself, will hesitate for an instant as to his verdict regarding construction.

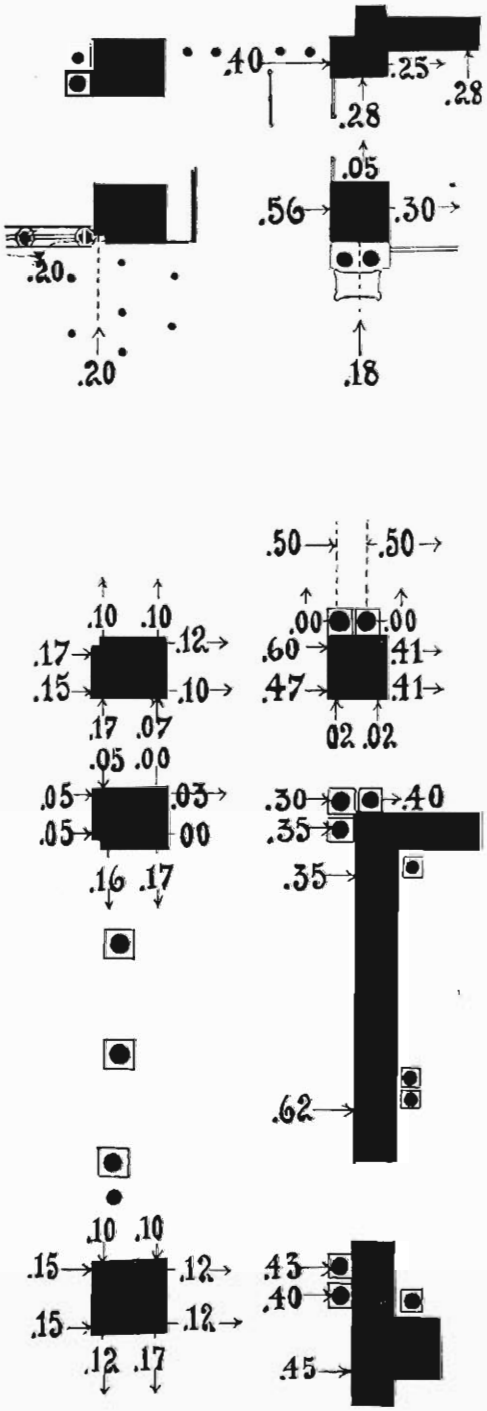
The conditions of resistance and support for this central vertical division of the nave, which is found to have the greatest inclination, are shown by the aisle views (Figs. 26, 30). Plan 3 (p. 62) will show that the detail measures for the nave were taken at a point where the whole length of each solid transept wall has to be reckoned with, in the matter of accidental lateral movement.

The Aisles and Walls of St. Mark's.

So far, the quoted measures have only supplemented in detail an observation for the nave which has already been published, which had already appeared to be of an impregnable character, and which has been verified as constructive by the engineering expert

who was in charge of the church at the time of my most recent visit to Venice.

As regards the matter which follows, for the aisles and walls, the measures were not only taken after the interview with Signor Saccardo, but the results obtained were not anticipated. It seemed advisable, before leaving Venice, to plumb the church in detail, as far as it could be done rapidly and this was undertaken as a matter of record, but as a record which was not expected to supply any especially novel facts. Consequently the measures were not collated at the time when they were taken.



PLAN 4. RIGHT AISLE OF ST. MARK'S.

The mere entry of them on a ground-plan, which is the essential preliminary to any comparison of results, could not be undertaken, owing to the pressure of other occupations, until September, 1902. This will explain some deficiencies of the record. Its value lies in the suggestion that the work of a professional surveyor has been made necessary by its results.

As regards the plumbs for the piers, the capitals could be reached with a pole, by standing on the settees, and no particular apologies are necessary regarding these measures. As regards the walls, the measures have the value of bearing a definite relation to those of the piers, because they were taken with a line of the same length on the walls of the nave (17½ feet). This is really a material point, but the question as to the whole amount of the wall leans has still to be answered.

This uncertainty is connected with the peculiar construction of the galleries of the church, which, aside from the ends of the transepts, are narrow passages standing free from the side walls, which therefore rise to the whole height of the building. There are, how-

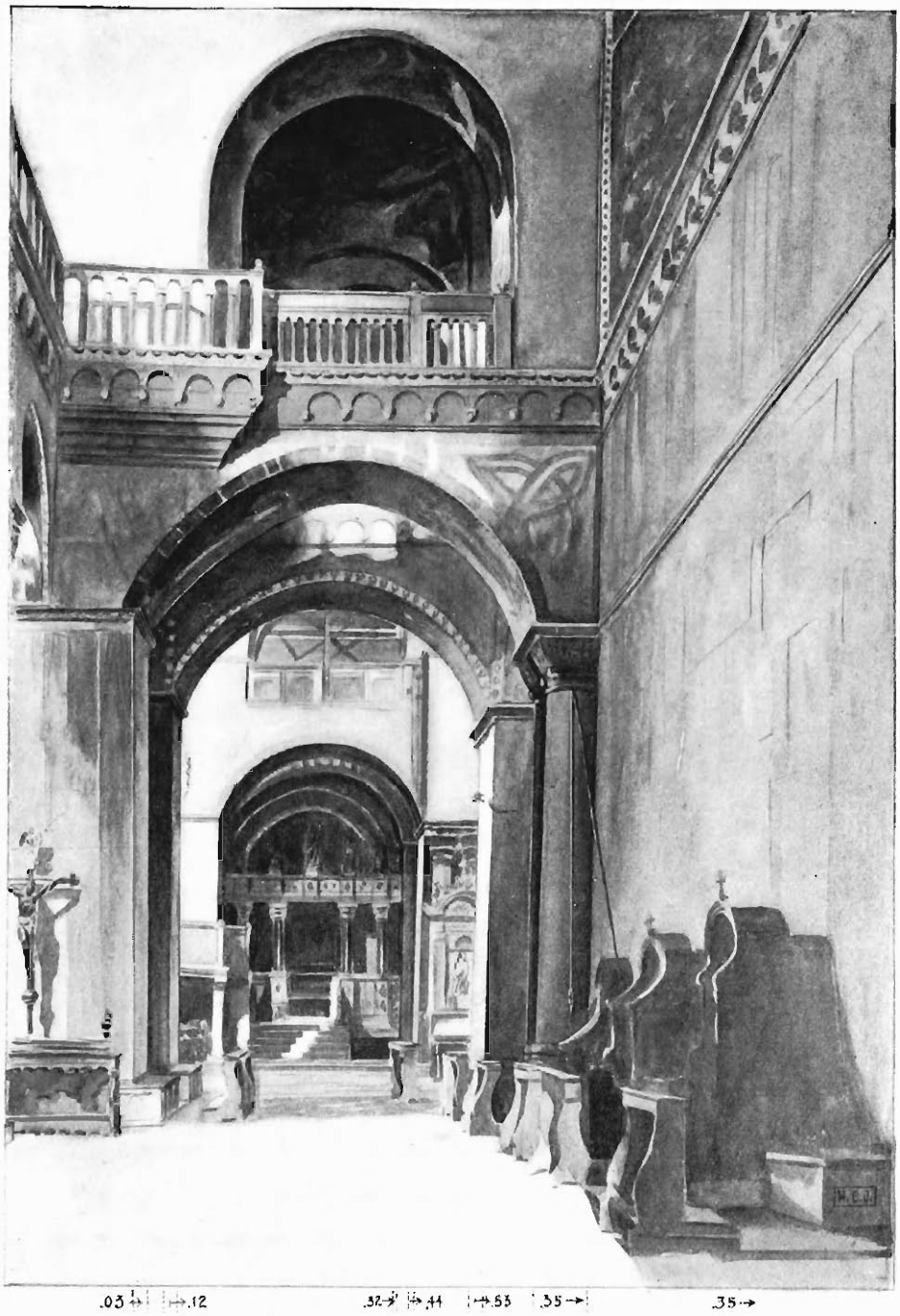


FIG. 26. THE RIGHT AISLE OF ST. MARK'S.

Accurate wash drawing, from a Survey enlargement of 1901. Showing a plumb-line on the engaged column. The plumb measurements entered beneath the drawing are found on Plan 4. As contrasted with the double measurement for each pier in Plan 4, only one plumb is entered for each pier. This view has the importance of showing the upper wall of the aisle. The enlargement indicates no change in the vertical direction of the wall until the mosaic surface is reached.

ever, several survey photographs which indicate continuous leans in these walls, up to the beginning of the mosaic wall (i. e. up to the height of the galleries), and these pictures were very carefully taken for future reference in the matter of the vertical lines. The enlargements which are exhibited in the Brooklyn Institute Museum have great value in this matter and the true perpendiculars are established for two of them with absolute certainty (Figs. 26, 30).

It is with reference to the aisles that we now again draw attention to the fact that a very insignificant amount of the widening in the nave is obtained in the piers, between the pavement and the capital moulding. For the first three piers of the nave, on each side, the amount of leaning on the side of the aisles is as follows, in the direction from façade to transept:

Right: .12, .12; .00, .03; .10, .12 (Plan 4).*
Left: .20, .20; .06, .12; .24, .20 (Plan 5).

Whereas some of these amounts are insignificant, and would hardly be considered, were it not for the proven intention of the widening higher up in the nave, it will appear that the engaged columns of the aisle walls lean outward in much greater degree (Plans 4, 5). These engaged columns of the aisles determine the dominant vertical effect of the walls, on account of their strong projection and massive size (Figs. 26, 30). The piers which continue the lines of the aisles across the transepts are also so placed as to line with these columns, as distinguished from the walls of the nave, and the pilasters of the transept walls at the entrances to the aisles of the choir are again placed in the same line with these engaged columns, as distinguished from the walls of the nave. Thus the vertical effects of the aisles are determined by the columns and by the piers and pilasters which are lined with them.

We will now consider that portion of the entire plan of the plumbs which is limited to the right aisle: Plan 4.

Among the remarkable facts disclosed by this plan, we note the uniformly higher average of the wall and column leans as against those of the piers of the nave. The maximum lean of the nave piers on the right side, is .12, or 1½ inches. The maximum lean of the engaged columns is .43 or 5¼ inches, and the minimum is .35. (Fig. 26.)

We next remark the arrangement by which the piers in the transept are leaned off so as to maintain a parallel direction with the verticals of the engaged columns of the aisle (Figs. 27 and 29).

We next notice the continuation of this parallel outward slope

*As each pier was plumbed twice on each side, at the points marked by darts, the measures are quoted as taken.

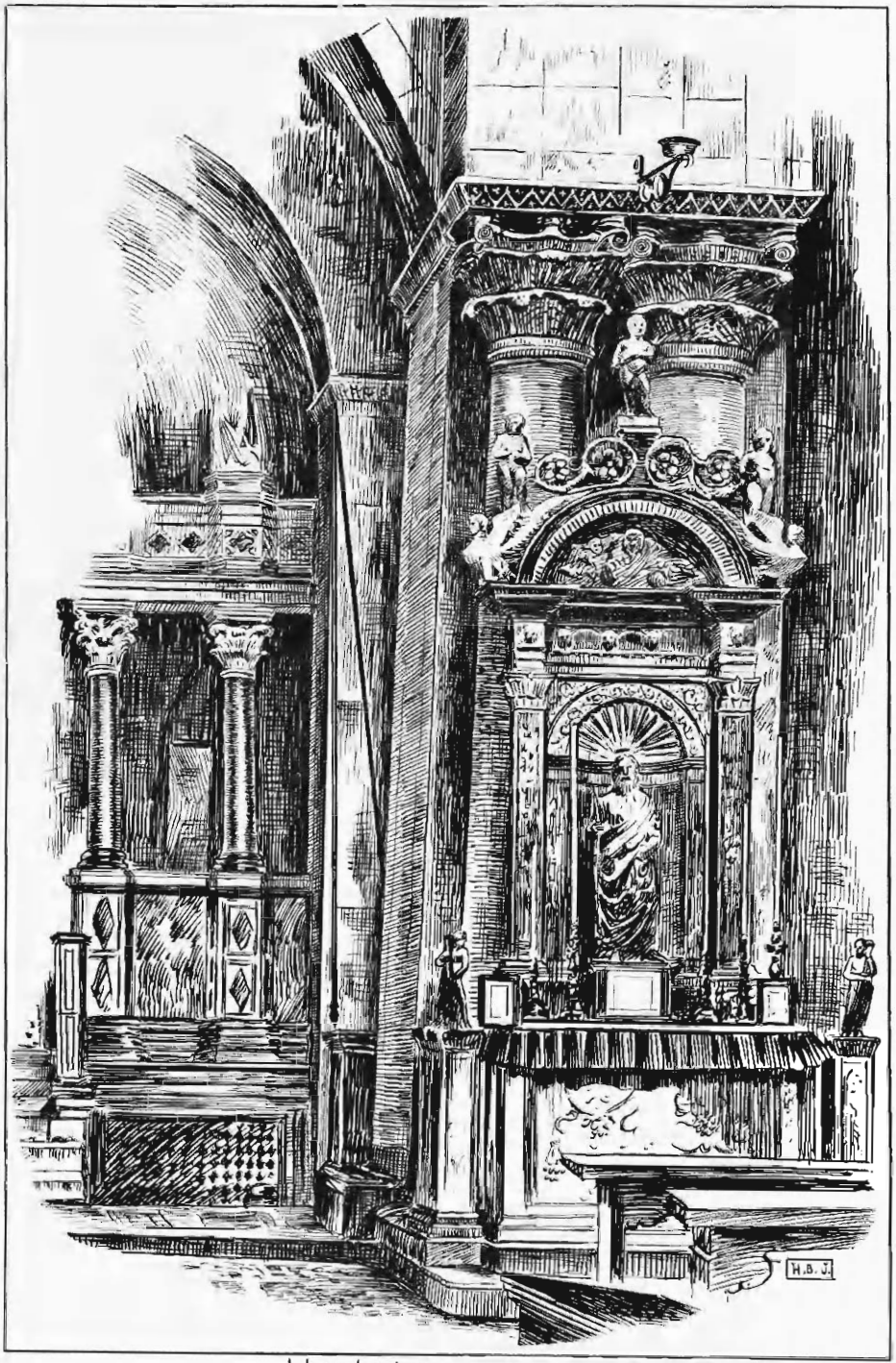


FIG. 27. RIGHT AISLE OF ST. MARK'S, AT THE CHOIR.

Accurate drawing from a Survey enlargement of 1901. The photograph includes a plumb-line. The pier in the foreground is also seen in Fig. 26. The plumb measurements are taken from Plan 4, and allowance has been made in the entry of .40 for the entire height of the pier. The pier in the foreground faces the pier in Fig. 29. For the contrast in measures between the two sides of the pier in the foreground (.56 and .30) compare text, p. 77.

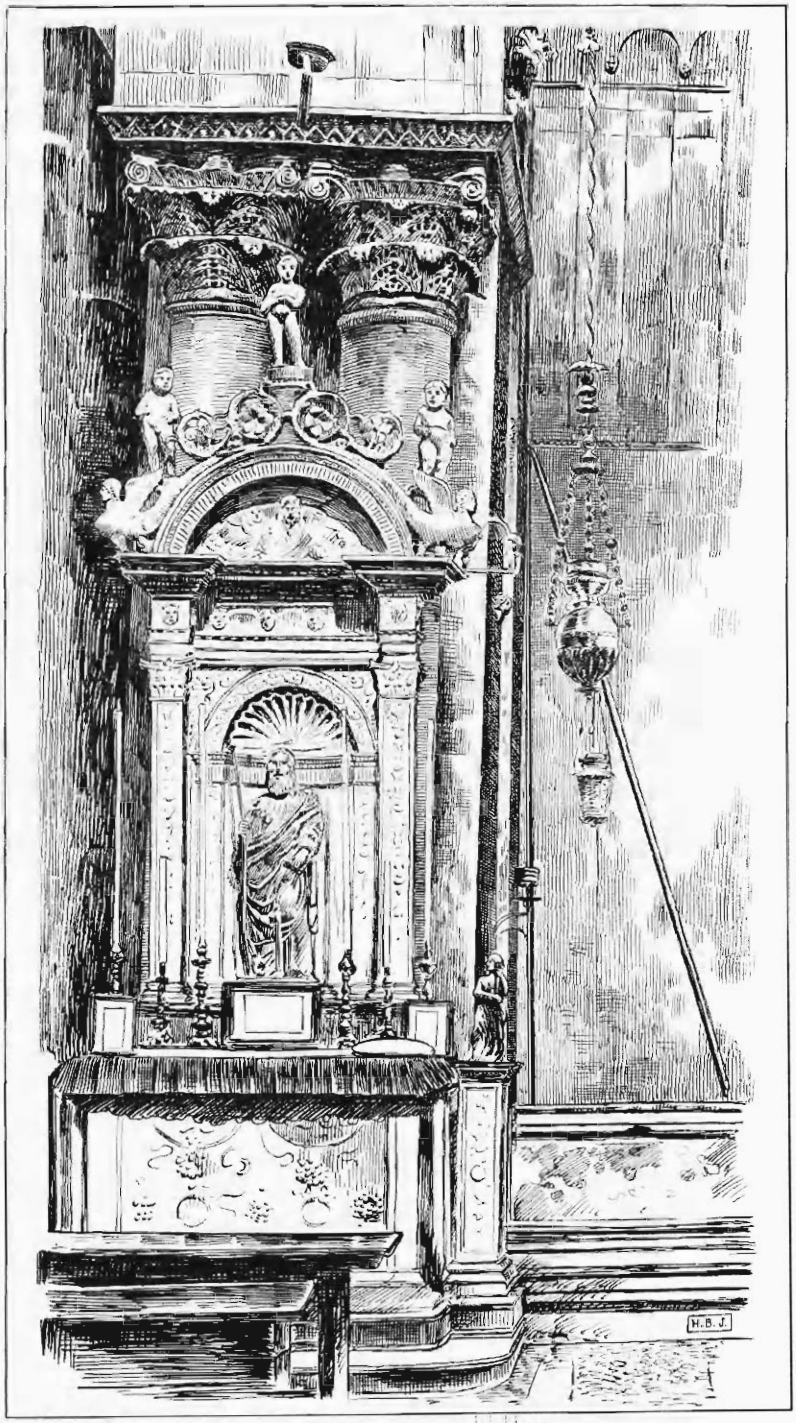


FIG. 28. ST. MARK'S. EAST PIER, SOUTH TRANSEPT, AND PILASTER IN THE REAR.

Accurate drawing from a Survey enlargement of 1901. The photograph was taken to show the plumb-line hanging on the wall pilaster, which leans .25, with line of 16 feet. This wall pilaster is thus constructed in parallel lean with the foreground pier. Compare Plan 4. The foreground pier is the same as shown in Fig. 27. The wall pilaster is shown more clearly, as regards situation and separation from the pier, in Fig. 34.

.30 .41 .50 .50 .60 .43

FIG. 29. ST. MARK'S. WEST PIER, SOUTH TRANSEPT, AND WALL OF THE SOUTH (RIGHT) AISLE, LOOKING WEST.

From a Survey photograph of 1895. Showing the upper wall of the right aisle in the direction opposed to that of Fig. 26. Compare Fig. 4. The view shows the perfect form of the arch in the transept and the diminished lean of the transept column. Compare Fig. 35 for the adjacent arches and columns. For contrast in the plumbs on opposite sides of the pier, compare text, p. 77.

into the aisle of the choir in the pilaster which faces the east wall of the south transept (Fig. 27).

This leads us to consider the points in this series of measures at which even the suggestion of accidental movement by thrust or subsidence is impossible. One of these is the point just indicated where the lean of .40 is entered. This pilaster is a solid portion of the south transept east wall.

On the opposite side of the same pilaster (Plan 4) we read the measure .25 (line of 16 feet). Here the pilaster is purely a decorative formula and yet it continues the lean, parallel with the sides of the piers which are in line with it in the transept.

Fig. 28 shows a plumb-line hanging beside this pilaster.

As regards questions of movement, or thrust, we also notice the engaged column entered in the plan as leaning .35 against the entire length of the west wall, south transept. Fig. 26 shows this column and the plumb-line.

Fig. 29 is a view looking back down this south aisle toward the west entrance. The columns facing the pier have been plumbed and are entered on the plan as leaning off .50 each, or 6 inches each. The pier itself has been plumbed as leaning south .60 at one angle and .47 at the other (on the north side) or an average lean of over 6 inches on the side which lines with the aisle. It was on this pier that the observation of 1870 was first made as regards the oblique cutting of the casing (p. 25).

No attention was paid to the pier casings in 1895 or 1901, as it did not seem necessary to descend to this detail, but the conclusion based upon them in 1870 is now proven to be a valid one.

We have so far confined our attention to the south aisle. Plan 5 will enable us to compare the north aisle with it. The same general facts are found here, with the qualification that the wall measures are not quite uniform. There are indications of a repair at the point where the entry of .03 toward the south is found on the plan, and more exact information is needed here as to repairs which may have obliterated the old construction. On the other hand, the facts are uniform for all the engaged columns and these determine the vertical effect by their heavy projection.

Fig. 30 shows one of these columns with a plumb-line. The inclination is 6 inches. This column leans against the entire length of the north transept west wall. Here again the theory of thrust or accidental movement must be abandoned. Moreover, on the opposite side of the north aisle wall the engaged columns lean in the direction opposed to those inside the same wall (Plan 5). This arrangement is connected with the construction of a spread, or widening, in the verticals of the north vestibule (Plan 14 or Plan 3).

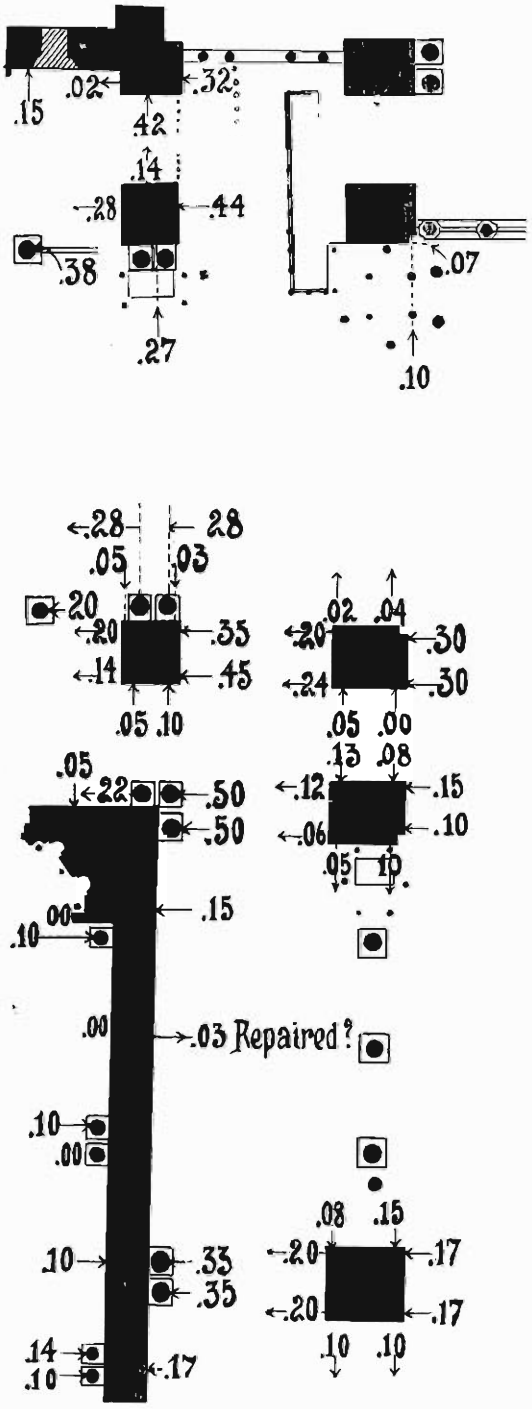
We now return to Plan 5, in order to notice the correspondences

FIG. 30. LEFT (NORTH) AISLE OF ST. MARK'S.

Accurate drawing from a Survey enlargement of 1907. Showing a plumb-line on the engaged column and continuation of parallel leans in the transept piers and in the aisle of the choir. Compare Plan 5, from which the plumb measurements under the drawing are taken. The entry of .40 is an average for the double measures on the plan (.35 and .45).

with the south aisle as regards the continuation of the leaning verticals through the transept and into the aisle of the choir.

At the beginning of the choir aisle we find the entry .32 for the pilaster terminating the north transept east wall. Here again is a point where accidental movement is out of the question. The entry of .02 north, on the opposite side of this pilaster practically represents a perpendicular and does not repeat the interesting continuity of parallels observed at the corresponding point in the south transept, as shown by Fig. 28.



PLAN 5. LEFT AISLE OF ST. MARK'S.

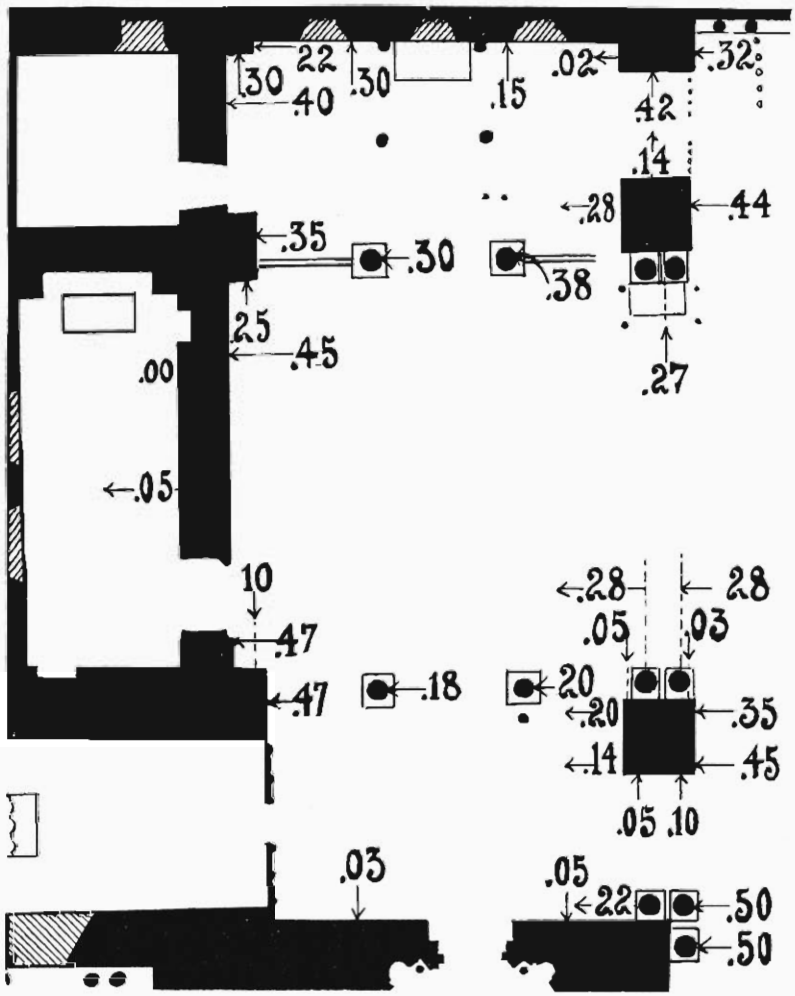
The Transepts.

We now turn into the transepts (Plans 6, 7) and notice; first, that all four columns, in each transept (columns as distinct from piers), continue, with closely corresponding measurements, as regards their own verticals, but in much less amount than the aisle sides of the adjacent piers, the north and south leans of the aisles and nave.

There is one columnar lean of .38; north transept, east side; but the average for eight columns is only .26. There is no exception to the rule that the column next the pier leans more than the one next the wall. Most remarkable is the fact, to which there is no exception, that every one of the four piers adjacent to the transept columns leans heavily on the side which lines with the aisle, but leans considerably less on the side adjacent to the column. Thus in the north transept (Plan 6) the average lean of the west pier is .40 on the aisle side and .17 on the column side. (These averages are obtained by adding together the two measures on one face of the pier and dividing by two.)

The east pier in the same transept leans average .44 on the aisle side

and average .28 on the column side. In the south transept (Plan 7) the west pier leans average .53 on the aisle side and average .41 on the column side (compare Fig. 29). The east pier in



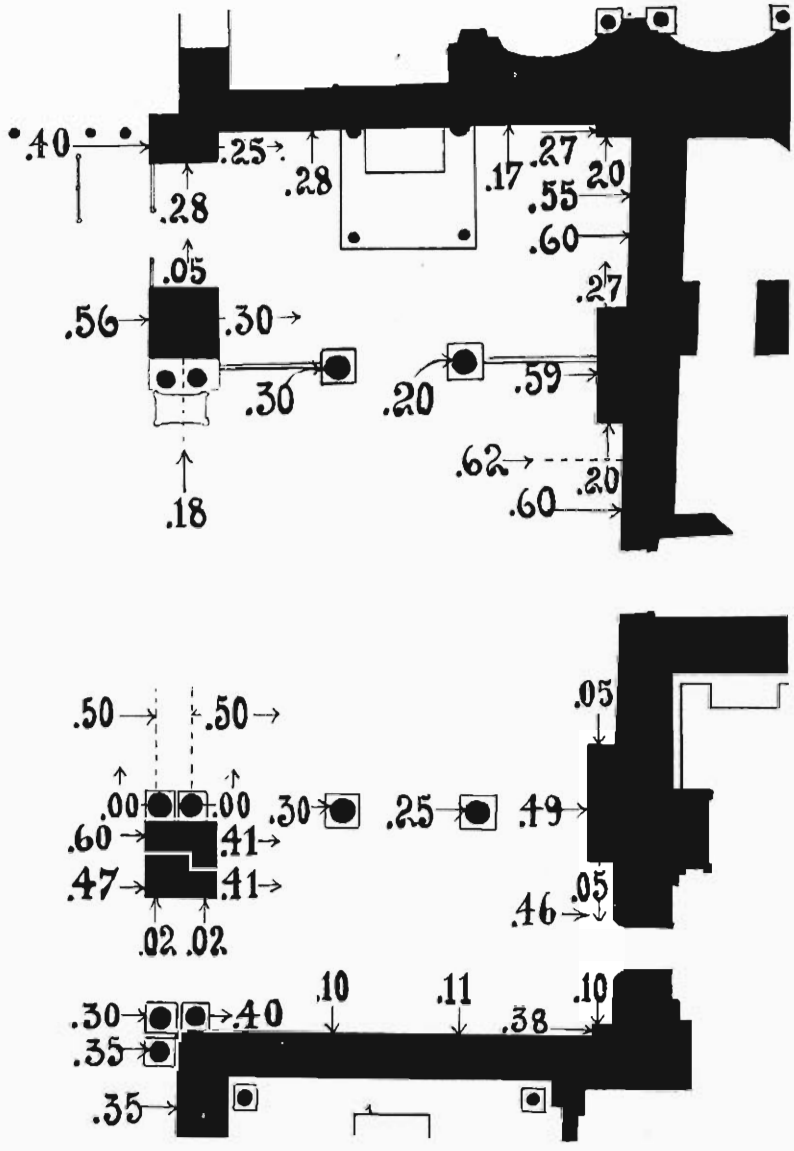
PLAN 6. NORTH TRANSEPT OF ST. MARK'S.

Sectional portion of Plan 3. Plumbs for a line of 15 feet on all transept walls and columns. Figs. 22, 31, 32, relate to this plan.

the same transept leans .56 on the aisle side and .30 on the column side (compare Figs. 27, 28).

The uniformity of these variations could not well be accidental and movement due to thrust or subsidence would have been the same on two opposite sides of one pier. An obvious explanation

would be that the columns of the transept are placed in line with the engaged columns which face the piers and are not in line with the piers themselves. These piers have therefore no counter thrust from the transept arches to assist in preserving their equili-



PLAN 7. SOUTH TRANSEPT OF ST. MARK'S.

Sectional portion of Plan 3. Plumbs for a line of 15 feet on transept walls and columns. Figs. 33, 34, 35, 36 relate to this plan. Figs. 37, 38, are gallery views in this transept.

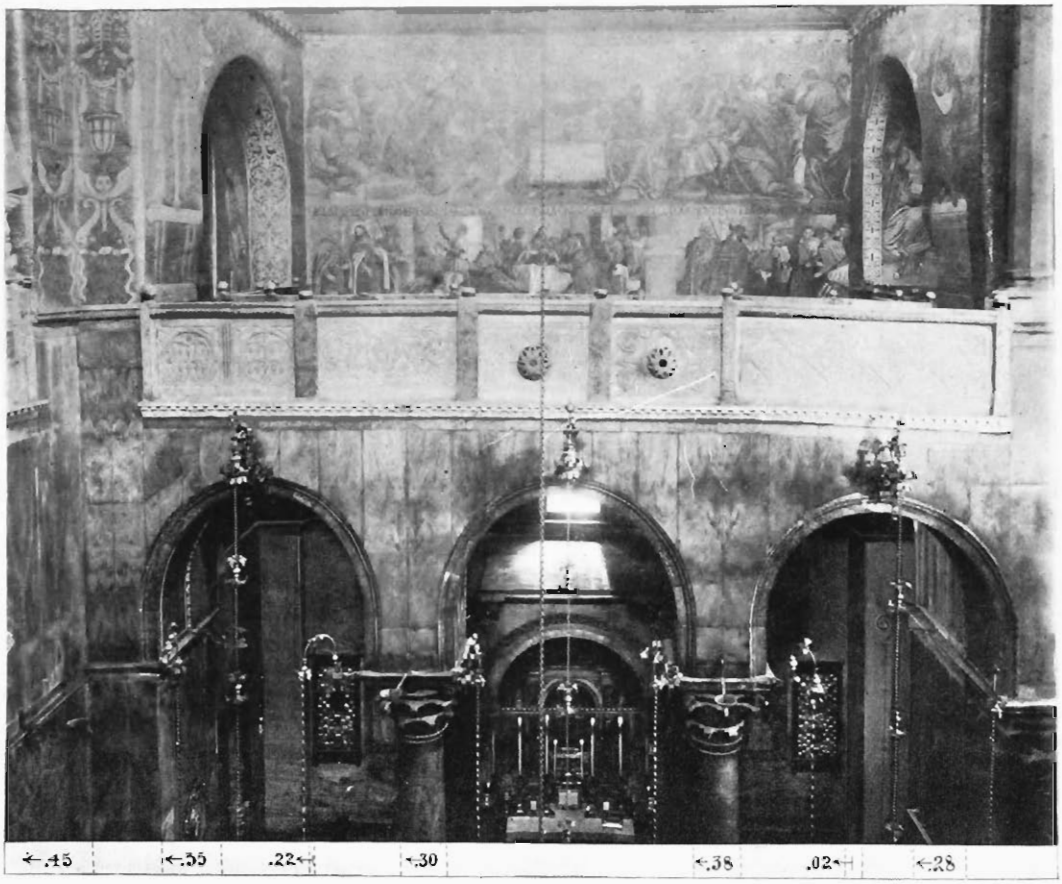


FIG. 31. ST. MARK'S. NORTH TRANSEPT, EAST GALLERY.

From a Survey photograph of 1895. Showing the northward lean of the north wall. For plumb from the parapet, compare Fig. 32. The measures below the picture are pavement plumbs, line of 15 feet. Note the pilaster in northeast angle of the transept aisle, with lean .22. Compare Plan 6. The arches are true. The view also shows a horizontal curve in elevation of the gallery parapet. Compare Figs. 33, 34, 35 for the south transept.

brium. Therefore the leans were diminished on the outside of each pier as a means to stability. This, at least, is a plausible explanation of a curious fact.

It is also to be remarked that, in spite of the leans of these piers and of their engaged columns, the arches of the transepts are perfectly true (Figs. 29, 31, 34, 35).

The Transept End Walls.

From the columns of the transepts we pass to the north and south walls of the transepts (Plans 6, 7). Here the leans increase to a phenomenal extent. In three instances the pilasters of the

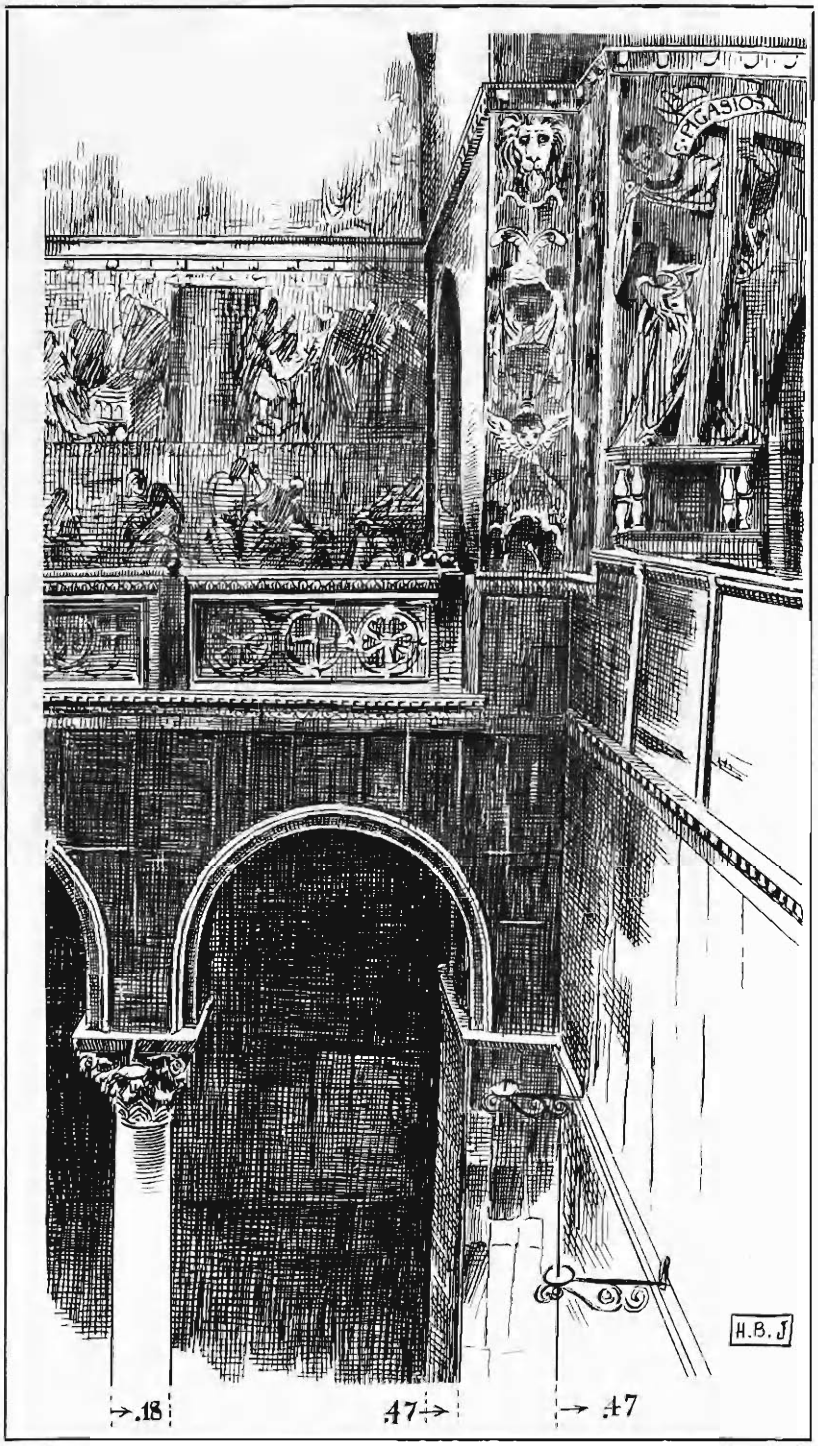


FIG. 32. ST. MARK'S. NORTH TRANSEPT, WEST ANGLE.

Accurate drawing from a Survey photograph of 1895. Under the drawing are plumbs from the pavement, with line of 15 feet (Plan G). By plumb from the parapet (about 33 feet) the pilaster leans north 16 inches (the same average amount for the entire north wall). Plan G shows approximate perpendiculars on the opposite side of the same wall. The arch adjacent to the pilaster is true. The adjacent column leans .18, or about 2 inches. Compare Fig. 31 for the opposite angle of the wall. Compare Fig. 33 for the south transept.

end walls lean twice as much or over twice as much, in the same height, as the columns do. In the north transept the fourth instance shows no great change (east side). The adjacent arches are true in all cases; Figs. 31, 32, north transept; Figs. 34, 35, south transept.

At this point, we are able to supplement the plumbs from the pavement by the plumbs which have been taken from the galleries. Before quoting these we shall, however, stop to notice that these north and south leans are not only found in the pilasters which are in line with the columns, but that they also appear in the wall surfaces, throughout their entire extent, including the pilasters in the transept aisle angles (Plans 6, 7).

The outward leans of these terminal transept walls are most remarkable. They are not appreciated by the eye as to their full amount, except by sighting, even when the observer has full knowledge of the measurements. These end walls rise only to the height of the galleries (Fig. 22). They terminate in parapets which also lean outward (Fig. 32).* Behind these are deep galleries reaching back to the exterior walls; whereas elsewhere the galleries are narrow passages standing free from the walls.

The broad pilasters which face these walls in line with the columns of the transept aisles, correspond to wall faces above, which rise to the springing of the arches (Fig. 32).

The plumbs of the ground-plan for these walls, represent less than half the height to the top of the parapets and the plumbs from the galleries must now be quoted.

By plumb from the top of the parapet in the west angle of the north transept (Fig. 32) the lean of the pilaster is 16 inches in 33 feet (approximate height).

By plumb from the top of the parapet in the east angle of the south transept the lean of the pilaster is 15½ inches in the same height. Fig. 33 shows the plumb-line which records this result and is the most remarkable picture of the entire series. This measure is an understatement, having been taken from a plumb-bob hanging level with the top of a confessional box.

By plumb of the face of the same wall near the center and to right of the door leading to the Doge's Palace the wall leans 13½ inches in 30 feet. (Fig. 35.) In this south transept gallery the central part of the parapet consists of an open railing which allows of dropping a plumb-line from the level of the gallery floor. The height is therefore less, than in plumbing from the parapet, as shown in Fig. 33. (In the north transept gallery the parapet is a solid wall, so that the line cannot be dropped from the floor level.)

*This is a positive and remarkable fact for the solid parapet of the north transept and was one of the points which especially interested Signor Saccardo. I have no record for the open railing of the south transept gallery.

FIG. 33. ST. MARK'S. SOUTH TRANSEPT, LOOKING EAST.

Wash drawing from a Survey photograph of 1901. The plumb-line hanging on the pilaster records a lean of 1⅝ inches. The adjacent column leans .20, or under 2½ inches. The arches are true; compare Fig. 34. The wall as plumbed near the centre leans 13 inches, not including the parapet; line of 30 feet. Compare Plan 7 for pavement plumbs. The opposite side of the south wall (in the magazine) is not perpendicular, as in the north transept. The lean has the same amount on both sides (no entry in plan).

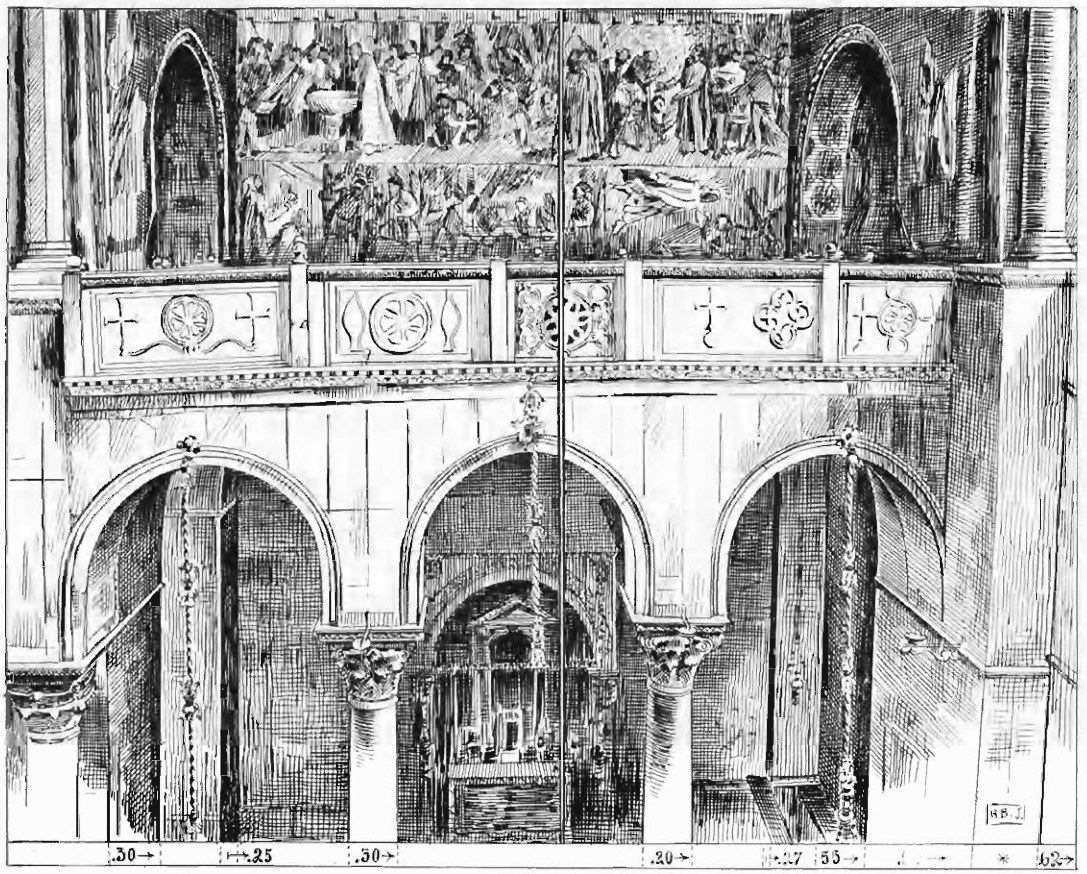


FIG. 34. ST. MARK'S. SOUTH TRANSEPT, EAST GALLERY.

Accurate drawing from a Survey photograph of 1895. See p. 101 for the apparent obliquity in elevation, of the parapet, as an illusion. Below the drawing are entries of pavement plumbs, from Plan 7. The star shows the locality of the parapet plumb as represented in Fig. 33. This view (Fig. 34) shows more clearly than Fig. 28 the situation of the wall pilaster with lean .25. It also shows the pilaster in the south-east angle of the transept aisle, with lean .27. The double leans of these pilasters, east as well as south, are entered on Plan 7. The curve in elevation of the gallery parapet is to be noted.

Let us now examine Fig. 33 with reference to the possible suggestion of accidental movement. In that case the wall would have moved away from the adjacent arch about 14 inches at the level of the top of the arch (the whole lean being more than 15½ inches to the top of the parapet). This arch itself is only 8 feet wide. It is perfectly true and the column which supports it only leans .20 or 2½ inches. This arch would have collapsed if the wall had gone over to the extent of 15½ inches.

Fig. 34 gives a better view of these arches and includes a series of natural plumb-lines which are furnished by the lamp chains. At

FIG. 35. ST. MARK'S. SOUTH TRANSEPT. WEST GALLERY.

Accurate wash drawing, from a Survey photograph of 1895. The star below the drawing is near the location of the gallery plumb of 13 inches lean for the wall (line of 30 feet). The pavement plumb .38 marks the pilaster in the aisle angle. Compare Plan 7 for the double leans. The column leans of .25 and .30 are to be compared with the pilaster (.49). The column and wall above this pilaster are perpendicular. The arches are true. The gallery parapet has a curve in elevation.

three other corresponding points the conditions are the same, as regards the ruin which would have befallen the arches if the walls had moved outward accidentally. These points are shown by Figs. 35, 31, 32.

It is hardly necessary to draw attention to the fact that in no instance does the column next to the wall pilaster show the same lean. In the pavement measures for the north transept (Plan 6), the west pilaster leans .47 and the adjacent column leans .18. The east pilaster leans .35 and the column leans .30 (the only close approximation). In the south transept (Plan 7) the west pilaster

leans .49 and the column leans .25. The east pilaster leans .59 and the column leans .20.

It has already been stated that the leans of these end walls were first observed in 1895,* that they were examined by Signor Saccardo in my company, and that they were included in his verdict as to construction, although not specifically mentioned in his certificate.

In view of this verdict, it is really superfluous to point to the lines of resistance in the side walls of the chapel of St. Isidore (Plan 6) and in the walls of the exit passage to the Doge's Palace (Plan 7), or to point to the east and west walls of the transepts, up to which these slopes are carried even in the pilasters at the angles of the transept aisles.

It may, perhaps, be worth mentioning that both of these transept end walls lean against thrust. The north wall leans against the vaulting of the chapel of St. Isidore and is perpendicular inside that chapel. The south wall leans against the thrust of the vaulting of the magazine and of the chapel of the treasury. Inside the magazine the inclination continues; the chapel wall was inaccessible.

Before leaving Venice I took the levels in both galleries of the south transept. I found the east gallery of the south transept (Fig. 34) to be level within .07, and the west gallery to be level within .10 (Fig. 35). This proves that the depressions of the pavement, however caused, have not affected the galleries or the end walls. An apparent obliquity in Fig. 34 is an optical illusion, as explained at p. 101. The irregularities of the pavement are considered at p. 104.

As regards the piers and walls of the transept galleries above the line of the parapet, they return very nearly, if not quite, to the true perpendicular in the south transept, Figs. 34, 35. At one angle of the north transept (east side) the upper wall is nearly perpendicular (Fig. 31). The upper wall of the west angle shows a continuation of the inclination which is found in the pilaster below but in less amount (Fig. 32). The facts regarding the perpendiculars above the leaning walls are of the highest importance. They are especially well shown in Fig. 35, but also in Fig. 34; if it be noted that the wall face is more closely perpendicular than the engaged column. The drawings for these illustrations give strictly accurate reproductions of the verticals of the survey photographs. In both photographs and drawings the facts may be tested by the natural plumb-lines which are offered by the lamp chains in the centres of the pictures.

*Architectural Record, Vol. VII., No. 2, 1897: Fig. 6.

East and West Widening of the Transepts.

The transepts have another system of leaning verticals, which is at right angles to the one so far described; that is to say, a system of widening from east to west (Fig. 22). This system crosses the system of the nave and relates to the transverse direction of the transepts. But whereas in the transept system so far described, the verticals are nearly, or quite, perpendicular above the parapets, with marked leans below; this second system shows a contrary arrangement, at least on the west side of both transepts. On the west side of both transepts the westward leans are accentuated above as they are in the nave, but they are not found as regards the piers. Plan 3 gives a connected view of both transepts.

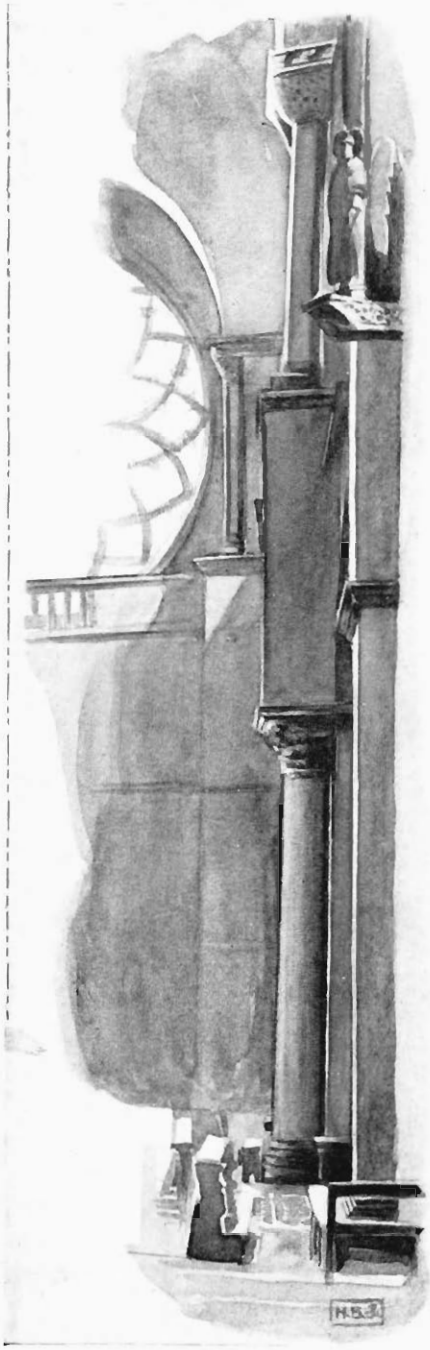


FIG. 36. ST. MARK'S. SOUTH TRANSEPT, WEST SIDE, LOOKING SOUTH.

The same piers which lean south .60, .47 (Plan 7) and north .45, .35 (Plan 6) and with engaged columns also leaning south .50, .50, and north, .28, .28; are practically perpendicular, as regards the east and west direction. In the adjacent piers similar facts are observed.

On the other hand, Fig. 36 shows the westward lean of the engaged column in the west gallery of the south transept. The capital is set, however, so as to tip forward; undoubtedly so as to avoid the foreshortening of its carved decoration. Fig. 36 is an accurate wash drawing from a Naya photograph.

Fig. 37 shows the corresponding westward lean of the companion column, as photographed in the west gallery of the south transept from the opposite direction, and again with a capital which does not lean westward, but which is set to a level. The plumbing of this column gives a lean of .24, or about 3 inches, with a line of length 9.64.

Fig. 38 shows the leaning column, corresponding to the last, in the op-

FIG. 37. ST. MARK'S. SOUTH TRANSEPT, WEST GALLERY, LOOKING NORTH.

From a Survey photograph of 1901. Showing column which is the mate of the gallery column shown by Fig. 36. By plumb measurement this column leans west .24 or 3 inches (line of 9.64). The capital is set to dip downward and does not lean back with the column. Typical for the westward widening on the west side of both transepts. Compare Fig. 38 for a column of the east gallery.

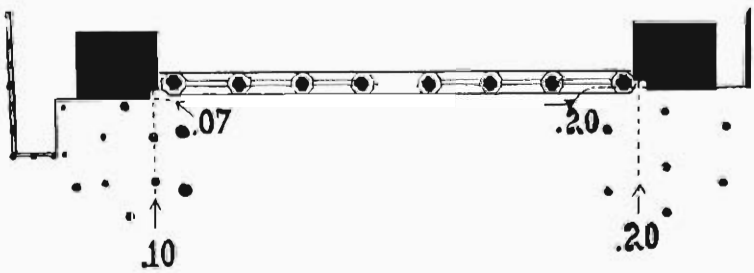
FIG. 38. ST. MARK'S. SOUTH TRANSEPT, EAST GALLERY, LOOKING NORTH.

From a Survey photograph of 1901. Showing a leaning column, to be compared with the plumb-line of the lamp chain. The column is opposite to the one shown by Fig. 37. For the north transept compare Fig. 22 for the leaning columns of the east gallery.

posite transept gallery. The enlargements of these photographs up to 25X35 inches, in the Brooklyn Institute Museum, are very valuable for illustration of the more remote columnar leans on the gallery walls of the north transept.

As regards the piers on the east side of the transepts, all four of them lean east, from the pavement up, in amounts which are shown by Plans 6, 7, 8, and by Plan 3, which has the advantage of showing these piers in one connected line. The plumbs of the piers which are faced by the pulpits are especially interesting (Plan 8, Fig. 39).

We next observe the remarkable fact that these east and west leans are repeated in the same pilasters of the north and south



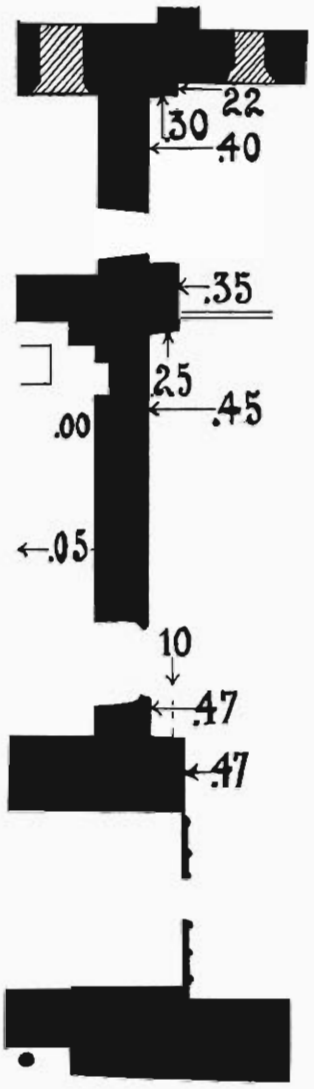
PLAN 8. ST. MARK'S. THE ENTRANCE TO THE CHOIR.

Sectional portion of Plan 3. Compare Fig. 39. Pavement plumb with a line of 15 feet. Showing the double leans of the piers, as called for by the intersection of the north and south widening of the nave and transepts with the east and west widening of the transepts. Compare Plans 6, 7, or Plan 3, for the entire line of eastward leans, which extends to the pilasters of the north and south transept walls.

transept end walls, which have been already described as having the phenomenal outward (north and south) leans. We now find the same pilasters showing also east and west leans (Plans 9, 10), obviously under conditions eliminating any possible suggestion of accident.

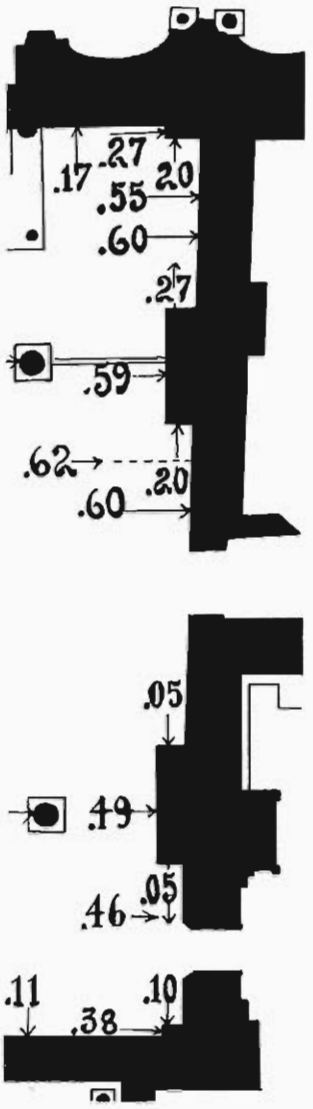
Plans 9, 10, also show that the same east and west leans are repeated in the pilasters of the transept aisle angles which have already been specified for north and south leans. Thus each one has a double lean, like the pilasters just mentioned. (No measures were taken in the northwest angle of the north transept on account of the modifications in plan which are connected with the exit.)

We next notice the east transept walls (Plans 11, 12); with leans uniformly east; and with pilasters, at the turn into the choir, also showing double leans. The north and south leans at these points



PLAN 9. ST. MARK'S. NORTH TRANSEPT, NORTH WALL.

To illustrate the east and west widening system of the three pilasters. The northeast angle pilaster, leaning .30 east and .22 north, is shown by Fig. 31, on which the eastward plumbs are omitted.



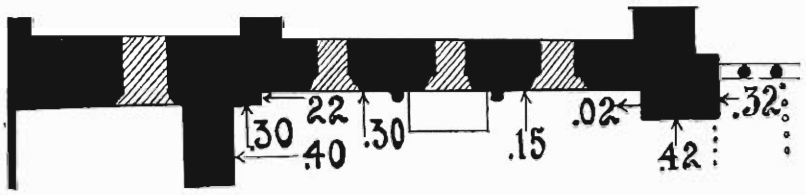
PLAN 10. ST. MARK'S. SOUTH TRANSEPT, SOUTH WALL.

To illustrate the east and west widening system of the four pilasters. The southeast angle pilaster, leaning .20 east and .27 south, is shown by Fig. 34, on which the eastward leans are omitted. The southwest angle pilaster, leaning .10 west and .38 south, is shown by Fig. 35, on which the westward plumbs are omitted.

have already been described in connection with the aisles of the nave (pp. 74, 76, Fig. 27).

Here again are points where the constructive facts are beyond cavil of any sort.

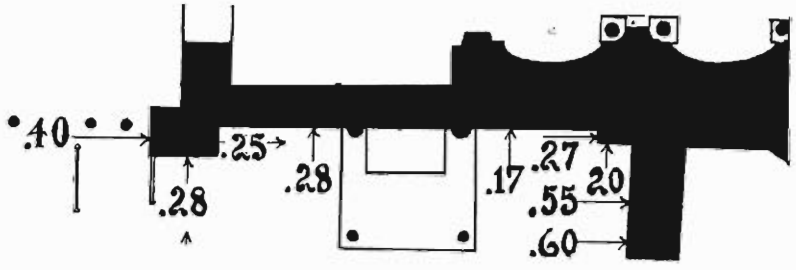
The west walls of both transepts show uniform outward leans,



PLAN 11. ST. MARK'S. NORTH TRANSEPT. EAST WALL.

To illustrate the eastward widening system and the double lean at the choir angle, as called for by its intersection with the north and south system. This pilaster, leaning .42 east and .32 north, is shown by Fig. 30, on which the entry of .32 north denotes it.

but of insignificant amount (Plan 3). It has still to be ascertained what the facts may be above the height of 15 feet. The repetition of the same slope in the pilaster of the southwest aisle angle of the south transept is significant and leads us to pay more attention, than we otherwise might do, to the small amounts of leaning in



PLAN 12. ST. MARK'S. SOUTH TRANSEPT. EAST WALL.

To illustrate the eastward widening system and the double lean at the choir angle, as called for by its intersection with the north and south system. This pilaster, leaning .28 east and .40 south, is shown by Fig. 27, on which the entry of .40 south and the plumb-line denote it. The opposite side of the same pilaster is shown by Fig. 28.

these walls. The slight amount of these measures for the height recorded, repeats a peculiarity already described in the west line of transept piers which corresponds to them (p. 86). These have been already noted as practically perpendicular as regards east and west direction (Plan 3.)

Widening of the Choir.

As regards the casing wall of the choir, plumbs were taken on both sides. The plumb-line measurement on the south side of the choir is shown by Figs. 40, 41; Plan 13. For the length of line used (obstruction farther down) the same amount of inclination was found on both sides, viz., 4 inches. The entire slope from pavement to parapet is probably about 8 inches. No plumbs were

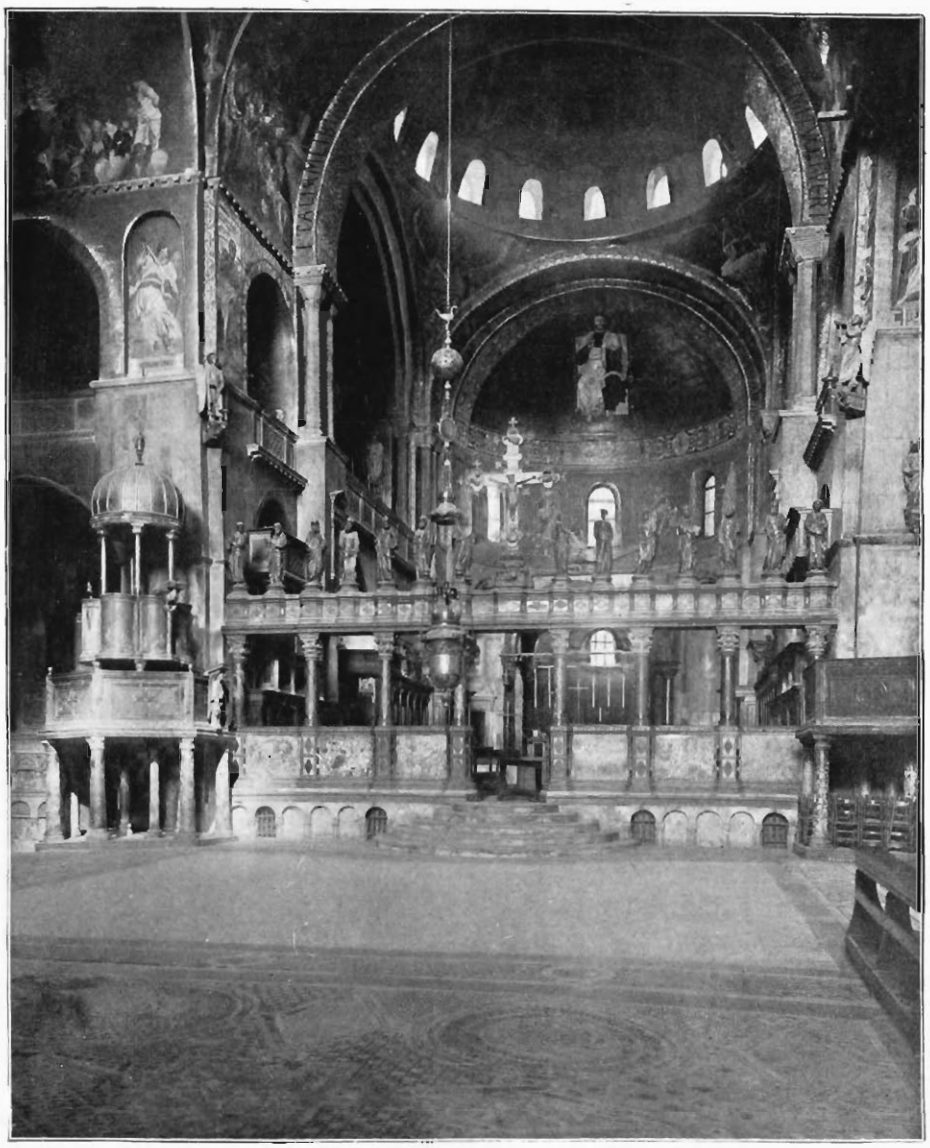


FIG. 39. THE CHOIR OF ST. MARK'S.

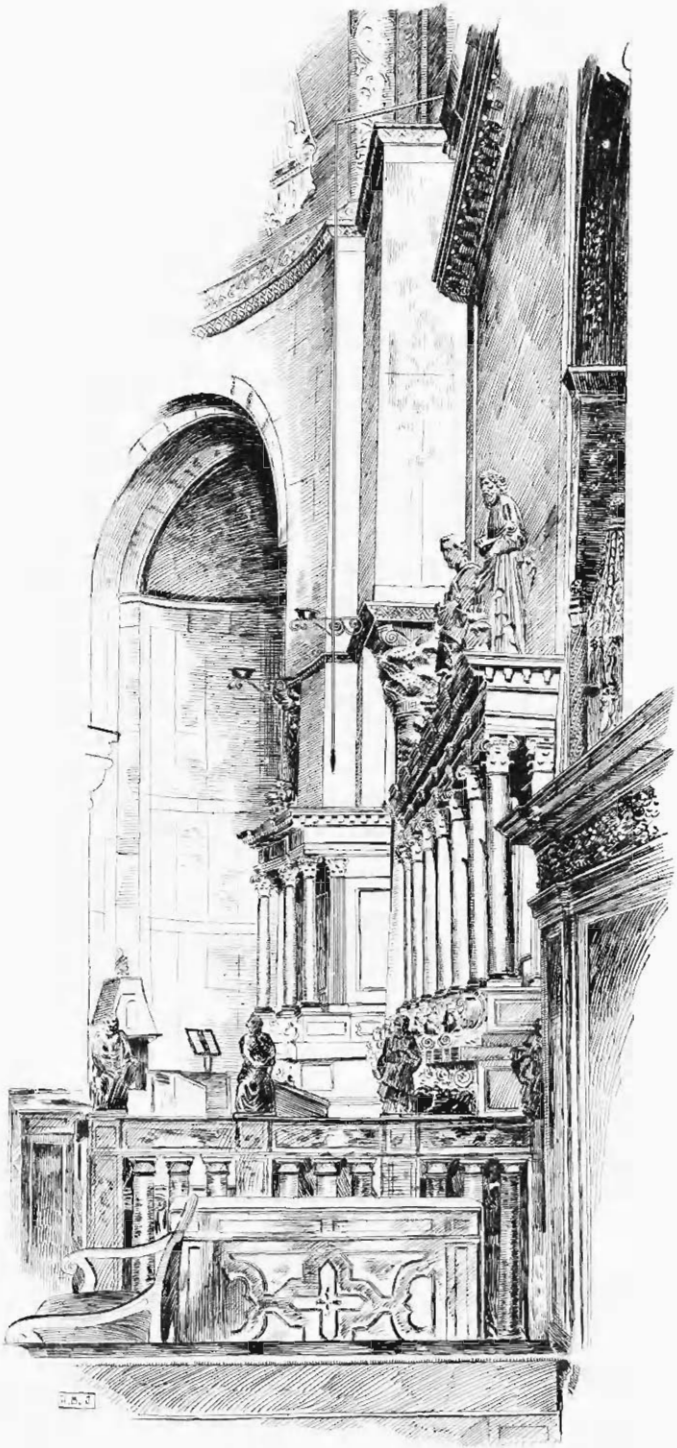


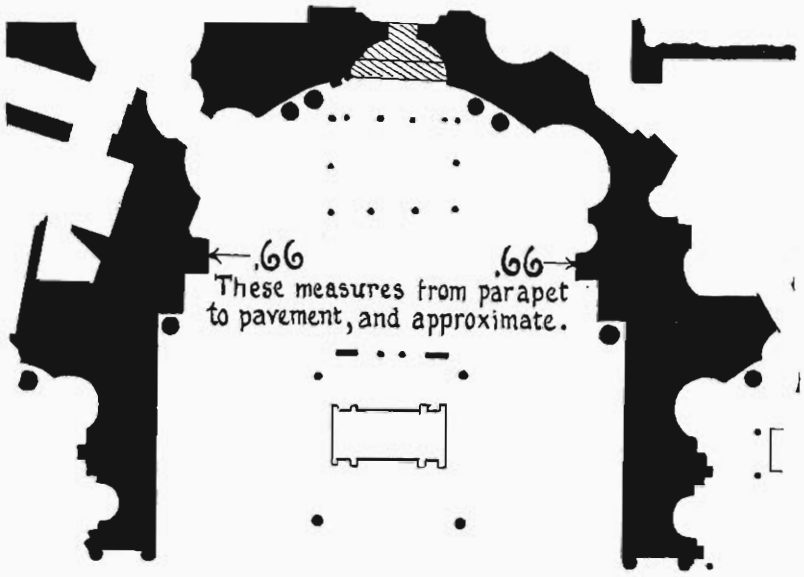
FIG. 40. ST. MARK'S. VIEW OF THE APSE.

Accurate drawing from a Survey enlargement of 1901. The plumb-line appears in the original photograph. The lean is 4 inches at the plumb-bob. Compare Fig. 41 and Plan 13.

FIG. 41. ST. MARK'S. PLUMBING THE APSE.

Detail of Fig. 40. Accurately drawn to scale, from an enlargement of the original photograph. The same amount of widening was plumbed at the corresponding point on the opposite side of the choir. Compare Plan 13.

taken for the upward direction in the galleries of the choir. The downward tilt of the capital of the engaged column in the right choir gallery is very notable (Fig. 39). This appears to be another



PLAN 13. ST. MARK'S. THE APSE.

To illustrate the location of the plumb-line in Figs. 40 and 41. These measures are the only ones entered on any of the ground-plans for plumbs from the gallery, and are approximations. The obstructions to accurate plumbing are shown by Fig. 40.

case of an arrangement intended to evade foreshortening of the decoration of the capital.

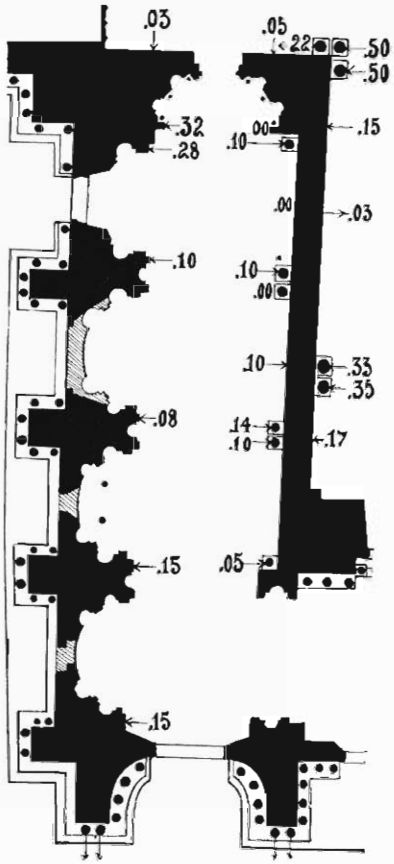
Westward Leans in the Nave.

We now return to the nave, in order to notice the westward leans of the piers (Plan 3). These are repeated in the engaged columns of the west (entrance) wall, which is perpendicular in the vestibule, on the other side of the gallery stairs. What the facts may be for the upper west wall has still to be ascertained. The measures for the limited height are not uniform in results on the northern half of this wall, but they are uniform as regards the engaged columns. The changes of direction in the wall may be due to repairs. It would have been easy to take plumbs from the gallery parapet, but I omitted to do this; not having realized until my return to the United States, that as far as piers and engaged columns are concerned, the facts are uniform with those in the transepts. This is an omission which results from lack of time to study carefully the results of the measures taken, while still in Venice. The omission of

plumbs for the columns of the nave has the same explanation (Plan 3).

The Vestibules.

The vestibule measures have next to be considered. Plan 14 shows the north vestibule which also has a constructive widening.



PLAN 14. ST. MARK'S, NORTH VESTIBULE.

To illustrate the system of widening. The columns lean in opposite directions on opposite sides of the church wall. The length of plumb-line was 11.70, and the vestibule columns have about that height, exclusive of capitals.

The verticals of the west vestibule were not systematically plumbed, as there were indications that the columns on the right of the main central entrance had been reset during modern repairs.

Summary for St. Mark's.

We are now in a position to summarize the results of all these plumbs, as regards the correspondences of vertical direction.

There are eleven wall surfaces of the church, not including the vestibule walls, in which the system of an outward widening has been found. These walls are: the north wall of the nave; east, north, and west walls of the north transept; north and south inner walls of the choir (outer walls not plumbed); east, south, and west walls of the south transept; south wall and west wall of the nave.

In two of these walls the system is discovered in all of the engaged columns which give the dominant vertical effect to the aisles, although the measures, as found in the note-book record, are not uniform as regards direction for the walls themselves, up to the height attainable. On one of these walls (north wall of the nave) a survey photograph shows the lean in the wall itself at a higher altitude and at the same point where a perpendicular was found by the line. For both of these walls the question whether repairs may have vitiated some of the measures has still to be examined and plumbs from above have still to be taken.

The whole number of plumbs taken from the pavement inside the church and in the north vestibule was 169.

All of these plumbs show uniform and corresponding results, as regards direction of the verticals, in the dominant direction for the given member or surface, with the exception above mentioned and an insignificant exception in the north vestibule. One column is perpendicular in the north vestibule and has probably been reset. (Plan 14). The perpendiculars on the south wall of the north vestibule can hardly be regarded as exceptions. The wall is very low and the columns project from it at such short intervals as to control the vertical effect.

In all of those architectural members of the transepts, both pilasters and piers, where a double lean is called for, by the meeting or intersection of the two systems of dominant leans, the double lean is found.

Accuracy of Masonry Construction in St. Mark's.

Certain results as to the margin or limit of error in the mechanical accuracy of the masonry of St. Mark's may be gathered from a comparison of some of the measurements. Before these comparisons are made, it may be recalled that the appearances of rough construction are generally found in the galleries and in the surfaces which are covered by mosaics. In the marble casing of the church the close fitting of the slabs speaks for itself, and this presupposes careful cutting and accurate cutting, at least after the curves of the galleries have been recognized as constructive, together with certain other obliquities of the galleries which have been proven to be constructive at Pisa, and which probably are constructive here.

To take up the tests for accuracy we will begin with the south transept end wall (Plan 10). The plumbs run as follows (outside of the pilasters in the aisle angles):

.55, .60, .59, .62, .60, .49, .46.

The limit of error is therefore .16, or $1\frac{3}{4}$ inches in 15 feet.

The series of plumbs from the pavement for the north transept end wall (Plan 9) is as follows (omitting the aisle angle):

.47, .47, .45, .35, .40.

The limit of error is .12 or $1\frac{1}{2}$ inches in 15 feet.

These discrepancies may, of course, be due to accidental movement, as well as to inaccurate building. We have already seen that the plumbs for the entire amount of widening in the nave tally within one inch, on the two sides, as regards the sum total, and that they also tally quite closely as compared for the three separate vertical divisions.

If we examine the entire series of plumbs for the east side of

both transepts, including the aisle angles (Plans 11, 12) they are found to run as follows (the pilaster plumbs are entered in parenthesis):

.30, .30, .15, (.42); (.28), .28, .17, .20.

The slopes of the walls, as distinct from the pilasters, show an extreme variation, or error, of .15 or 1¾ inches. This corresponds to the limit of error in the end walls. The pilasters (measures in parenthesis), at the angles of the choir walls, vary .14, or about 1¾ inches.

Another test as to accuracy is obtained by comparing the measures for the vertical deviations in piers which were certainly meant to be perpendicular on two opposite sides.

For instance, the west transept pier in line with the south wall of the nave (Plan 4) has the following east and west measures: west side: .02, .02, lean east; east side: .00, .00. The limit of error here is .02 in 17 feet. The corresponding pier (Plan 5) in line with the north nave wall, shows inclinations on the west side of .05 and .10, leaning east; and inclinations on the east side of .03 and .05, leaning west. This pier must have been intended to be perpendicular as regards the east and west verticals. The limit of error is .10 in 17 feet.

It appears also that the accuracy of the masonry varies with the amount of widening which was desired. Thus it is clear that the columns in the north vestibule were set to a maximum lean of .10 in 11 feet, with one error of .05 and one column perpendicular, which we must consider an error of .10, unless it has been reset by a modern repair.

Some interesting conclusions are reached by comparing the piers of the nave. The leans on the nave side of the piers are given below:

South Side (Plan 4): .15, .15; .05, .05; .15, .17.
North Side (Plan 5): .17, .17; .10, .15; .30, 30.

Here the limit of error, as regards the two angles on the same side of any one pier, is .05. As regards the contrast of corresponding measures on opposite sides of the nave the limit of error is .15. As regards variation between the piers of one line, the limit is close to .15.

Let us next consider the opposite sides of each separate pier. We begin at the left nave pier next the entrance (Plan 5), adding together the measures of each side, dividing by two, and contrasting the results.

First pier: The limit of error in contrasting the north and south sides is .03.

Second pier: Error about .04, in contrasting the north and south sides.

Third pier: Error about .08, in contrasting the north and south sides.

Similar comparisons for the right nave line of piers have the following results: Limit of error; for the first pier .03; for the second pier .04; for the third pier .05.

These figures show, as regards single piers in the nave, that the variations from exact correspondence of two opposite sides may run up to .08 (line of about 17 feet). The figures also show that piers were intentionally leaned which do not lean over .10, because the uniform correspondence, as regards direction of the two sides, of piers which lean about .10 would be otherwise inexplicable. In other words it must not be concluded that a pier was meant to be perpendicular simply because it only leans .10. This would also appear from the north vestibule plumbs (Plan 14).

These figures would also show that the much larger variations between the two sides of the four particular piers which have been described at pp. 76, 77 must be intentional. It would be incredible that such correspondences of variation as are there described could be accidental inaccuracies and impossible that two sides of one pier should vary from accidental movement.

It is extremely important to observe that there are only two piers in the church having opposite sides which do not lean in the same direction. These are the two west piers of the transepts which line with the walls of the nave. The west pier in the north transept (Plan 5) has the following measures for east and west direction. The opposite sides lean together, but very slightly; .05, .10, lean east; .05, .03, lean west.

The west pier of the south transept (Plan 4) has the measures: .02, .02, lean east on the west side; .00, .00 (or perpendicular) on the east side.

Strictly speaking, only one of these piers has sides which lean together, and there are only two piers in the church whose opposite sides do not lean in one direction. The small amount of variation in the two instances is notable. For if variations of .20 or .30 were due to inaccurate construction, we should find piers in which the opposite sides would diverge, or converge, to the amount of .40 or .60. If variations of .10 were generally due to careless construction, we should find piers in which the sides would diverge, or converge, .20.

These comparisons lead to the result that practically none of the leans of St. Mark's are due to careless construction, although the variations of amount in different cases, as regards a given direction, sometimes represent variations of accuracy in the masonry. We are thus obliged to eliminate inaccurate construction as a cause of the phenomena, by a process of reasoning wholly different

FIG. 42. ST. MARK'S. NORTH GALLERY OF THE NAVE.
From a Survey photograph of 1895. Showing the curve in elevation of the parapet. Compare Fig. 23, which also shows this curve. Similar curves are shown by Figs. 31, 34, 35.

from that which was based on the series of correspondences at remote but corresponding points. We are therefore reduced to three alternatives: systematic purpose, subsidence, or thrust, as being the cause of any particular lean.

It would be unreasonable to conceive that no accidental movements have taken place in a building as old as St. Mark's and one such movement has been mentioned in this paper (p. 56). It may be considered as proven, however, that no accidental movement has taken place, in the particular verticals which have been plumbed by this survey, of a greater amount than .15 in 15 feet, or in that ratio for greater heights. This limit of error, already established by our comparisons, may represent accidental movement, as well as the limitations of accuracy in the masonry.

Gallery Levels and Gallery Curves.

There are some apparent obliquities in elevation in the galleries, suggesting settlement, which are simply optical illusions, produced by obliquities in plan. These are translated by the eye into obliquities in elevation, which might then be naturally presumed to be owing to settlement of the piers and generally are so interpreted. For instance, in the accurate drawing from a survey photograph (Fig. 34) it is impossible for the eye not to assume a downward direction of the south gallery parapet from south to north. However, if subsidence of foundations had taken place in connection with the quoted 15½ inches lean of the end wall to the south, of course, the parapet would be oblique in the contrary direction.

As already mentioned, I have taken the levels in this gallery and found the two ends of the curving parapet to be level within .07. The appearance of obliquity in elevation is due to an obliquity in plan which is shown by the ground-plan, No. 3.

When the photograph original of Fig. 34 was made in 1895, the line of the transept wall was assumed to be the normal east and west line and the apparent obliquity of the gallery parapet is due to this error. After the obliquity in plan has been observed, it still appears to the eye to be in the east gallery rather than in the south gallery and is translated by the eye into a northward dip of the east gallery in the church itself, just as it appears in the photograph. The divergence of the east gallery from a true rectangle, as regards the south gallery, amounts to over 18 inches in 30 feet.

When the given obliquity in plan is seen above the level of the eye it produces an effect contrary to that of Fig. 34. Thus in Fig. 33 the gallery appears to go down to the right. Here again the south transept south wall was assumed as the normal line.

The parapet of the north gallery of the nave (Fig. 42) appears, to an observer in the south gallery, to dip downward in the direction of the choir. I have taken the levels between the two ends of this parapet and found it to be level within .10. Here again an obliquity of plan (see ground-plan No. 3) is partly responsible for this appearance, but, aside from the effect of obliquity in plan, all the gallery curves in St. Mark's are built with a gradual rise and a rather abrupt dip at the end of the curve.

This dip is well shown in the gallery and parapet curves which are illustrated by Figs. 31 and 34. There is a consequent appearance in the curves of being out of level and consequently an inference that they are due to settlement. It was to ascertain what might be the facts in this regard that I took the levels in the central north and south galleries of the nave and in the east and west galleries of the

south transept. No obliquities in elevation were found. The limit of variation from a true level was nowhere over .10.

The two short galleries next the gallery over the west vestibule have marked obliquities in elevation (Fig. 43), but as soon as we notice that one side of the arch is longer than the other, it is evident that they are not due to settlement. The drop of the short south gallery was found by level to be about .40.

These notes bear in two directions. They draw attention to the construction of the horizontal curves in elevation, which are mentioned in Commendatore Saccardo's certificate and they tend

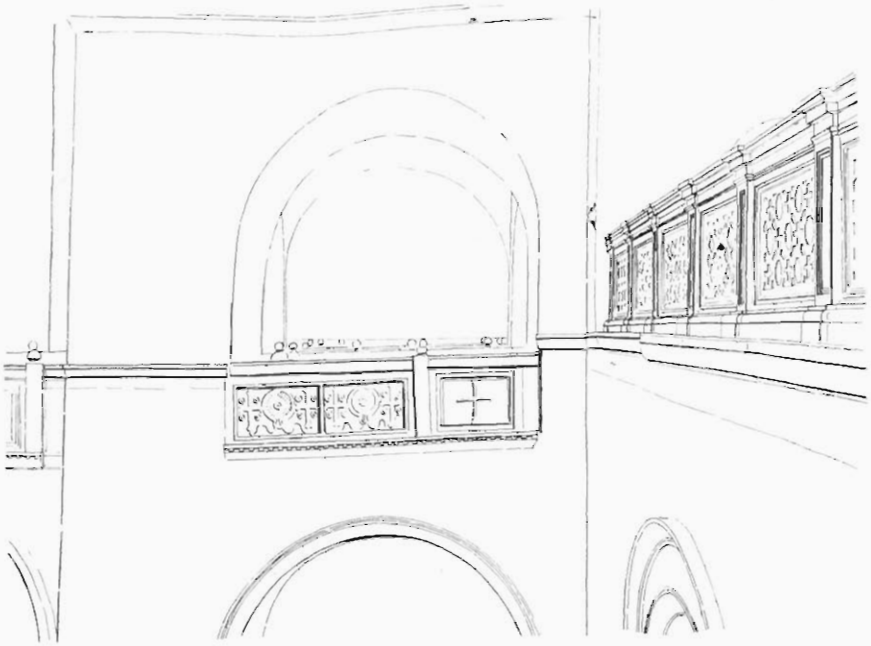


FIG. 43. ST. MARK'S SOUTH SHORT GALLERY OF THE NAVE.

Tracing from a Survey enlargement of 1901. The gallery is oblique .40, by construction. The north short gallery of the nave has the same obliquity.

to show that the accidental movements in St. Mark's have not been of an important character.

The general problem of the horizontal curves in St. Mark's is so bound up with the problem in other Italian churches and cloisters that we must dismiss the subject here, as far as the question of intention is concerned, with a reference to the verdict of Saccardo and with the remark that the existence of constructive curves in mediæval Italian architecture has been decisively proven for other buildings.*

*Architectural Record, Vol. VI., No. 4, 1897; Journal of the Archæological Institute of America, Vol. VI., No 2 (New Series), 1902. The latter publication contains a certificate from the engineering architect in charge of the Pisa Cathedral for the curves in that building, which is also published in Vol. I., No. 1, of these Memoirs

Horizontal curves in elevation are found in the main north and south galleries of the nave (Fig. 42); in the east and west galleries of the south transept (Figs. 34, 35); and in the east gallery of the

FIG. 44. ST. MARK'S FAÇADE.

From a Survey photograph of 1901. Showing the bend or curve in plan, concave to the Piazza. The amount of curve is 10 inches.

north transept (Fig. 31). The west gallery of the north transept has no curve. There are also curves in plan in the transept end galleries. The careful cutting and fitting of the casing which is connected with the curves in elevation is shown by the half-tones.

Figs. 31 and 42, and has been accurately reproduced in the drawings which were made for Figs. 34, 35. It is clear, if these curves had been due to settlement, that the casing must have been laid on after the settlement had ended. It would be absurd to suppose that any such series of uniform movements in all parts of the church had uniformly antedated the period of the casing.

Fig. 44 shows the curve in plan of St. Mark's façade which is mentioned as an æsthetic device in Signor Saccardo's letter. This curve was measured in 1895 as having ten inches deflection. An illustration was published in the Architectural Record, Vol. VI., No. 4, 1897; p. 489.

As regards the obliquities in the short galleries of the nave which have been mentioned (Fig. 43) they may be, and probably are, related in purpose, to obliquities in the Pisa Cathedral which have been published and which have been verified as constructive by the architect in charge of the Cathedral.*

The Pavement of St. Mark's.

Many depressions in the pavement of St. Mark's are obviously due to accidental causes. One change of level in the pavement of the church is certainly constructive. This is a gradual upward slope from entrance to choir, amounting to 7½ inches (survey of 1895). Inasmuch as eighty-five churches in Italy have been observed to have a constructive slope in the rising direction, from entrance to choir, there is no doubt that this instance is constructive.†

There is no reason why the rises in the transept pavement toward the choir should not be of the same class. The fact that the transept galleries are found to be level as far as tested (no levels were taken in the north transept) indicates that these pavement slopes are also constructive. If change of level in the transept pavement were due to subsidence the galleries would be out of level.

As regards the great rising curve of the pavement across the nave, which is especially strong near the choir, no expert should venture an opinion before examining the pavement of S. Donato at Murano. The ancient pavement, in opus Alexandrinum, of this church, has a rising curve across the nave of a very marked amount which is certainly constructive. This may be the first published mention regarding this curving pavement, although it has been noticed by more than one observer. The English architect Street was the first to announce that certain main undulations in the pavement of St. Mark's are constructive.‡ These undulations have undoubt-

*Memoirs of the Museum, Vol. I., No. 1, and Journal of the Archæological Institute of America, Vol. VI., No. 2, New Series.
†Architectural Record, Vol. VI., No. 2; 1896
‡Brick and Marble in the Middle Ages, p. 159.

edly contributed to the general oversight of the fact that the leaning verticals of St. Mark's are intentional.

As regards the questions which are raised by the pavement of St. Mark's it may be added that most instructive remarks on the science of piling as practiced in Venice, have been published by Mr. C. H. Blackall, an architect of Boston.* In 1885, when Signor Boni was in charge of St. Mark's, Mr. Blackall was able, with his co-operation, to undertake the necessary excavations and to make an exhaustive examination of the piling of the Campanile. It was proven by this examination that "the foundations have stood the test for centuries without moving an inch."

In the 16th century Vasari mentioned in his Life of Arnolfo di Cambio, that the Campanile of St. Mark's "has never sunk, even by a hair's breadth."

The weight of the Campanile is estimated by Mr. Blackall at about 13,000 tons. The piers of St. Mark's have individually only a fraction of such a weight to support and there is no cause to suppose that they were less carefully founded. The special causes which led to the downfall of the Campanile have been mentioned by Signor Saccardo, in the Architectural Record, Vol. XII., No. 7, 1902.

From these various considerations we should again conclude that the accidental movements in St. Mark's have not been very important. These considerations were all mentioned in the "Echo from Evelyn's Diary," but for casual or inattentive observers the phenomena which have been described tend to suggest accidental movement by thrust and subsidence. It was on this account that the opinion of Signor Saccardo, who is so thoroughly familiar with the piling and foundations of the church, was so especially desired, and it is on this account that the corroborations of this opinion, which were subsequently obtained, have been carefully narrated.

The Question of Repairs.

One main purpose of this publication is to forestall the farther obliteration of the architectural refinements of St. Mark's, which had assumed alarming proportions under the predecessors of Signor Boni and Signor Saccardo.

The fall of the Campanile (which itself had a northward lean, not due to settlement†) is destined to awaken doubts as to the stability of other ancient buildings and it is destined to draw attention to all leaning verticals in the ancient monuments and to awaken consequent suspicion as to their stability.

*"American Architect" for August 29th, 1885.
†See the quoted article by Mr. Blackall.

The importance of calling the attention of the Italian authorities, of all European governments, and of all experts in charge of ancient buildings, to the facts which are herewith published is sufficiently obvious. The phenomena of the spread or widening are certainly not confined to Italy and they are certainly to be found there in many churches, aside from those described in this Memoir.

The danger that authorities in charge of repairs may innocently destroy important features of architectural refinement is sufficiently apparent. St. Mark's, especially, should be handled as carefully as a canvas of Titian or a statue by Praxiteles. It may be not less aptly compared to a piece of old lace as regards the care which should be given it.

That the danger is not imaginary is shown by the announcement in these Memoirs, Vol. I., No. 1, that the lower line of columns on St. Mark's façade has a constructive forward lean (as mentioned in Saccardo's certificate) and by the fact that the columns at the southwest angle of the facade have been reset in a perpendicular position by the modern repairs of that angle. The incorrect resetting of the pinnacles and statues of the north and south facades has been mentioned in Saccardo's letter. It also appears probable that the evidence for a widening in the west vestibule has been destroyed by a resetting of the columns.

Although most of the churches in Northern Europe, and a certain number in Italy, have still to be examined as regards the existence of this remarkable refinement of widening the vertical lines in the rising direction, it is safe to predict that no other church will be found to show so consistent and far-reaching an application of it as St. Mark's. It is also true that this church is peculiarly exposed to the obliteration of the evidence, through repairs of the casing and the resetting of columns and through the natural presumption that accidental movements are responsible for the deflected verticals.

Purpose of the Widening.

The discussion of the purposes of this refinement has been avoided in this paper, as involving a possible element of debate, of uncertainty, or of difference of opinion; and because, the important thing at present is to establish the facts and to induce experts to consider the resulting effects in the given churches, and especially in St. Mark's.

The ultimate explanation of any such refinement must be that it appeared to the builders an improvement, as against other churches which did not possess it. The ultimate essence of this improvement may probably lie in the feeling which leads us to prefer a free-hand drawing to a mechanically executed architectural elevation or archi-

tectural section. That the widening effect is an improvement in St. Mark's, as against churches which do not possess it, is indubitable in the opinion of the writer.

To an age which has been thoroughly satisfied, for three or four centuries, with absolutely rectilinear buildings, with mathematically accurate measurements of construction, and with absolutely symmetrical correspondences in all architectural members and features; which has even exalted these things as an ideal of perfection in building; the whole subject of architectural refinements is a matter of difficult apprehension. It is probable, however, that no artist who compares a rectified and schematic drawing of any portion of St. Mark's with a survey drawing or photograph for the corresponding view, will hesitate to prefer the latter. For example, let Fig. 20 be conceived as rectified and corrected into a drawing with straight and rigid upright lines and it will obviously lose charm and beauty. No other explanation seems really necessary.

Nothing has been said, so far, of the fact that the great side arches of the nave also recede outward, in continuation of the vertical inclination of the walls below (Fig. 20). This is a very essential feature, and probably the most important element, in the general effect of this device. If some attention be given to this detail it will probably be of material assistance to an appreciation of this refinement.

In the case of St. Mark's there is no doubt that the effect of spaciousness in the upper portion of the church is much enhanced by the given device. It is also clear that the graceful bend of the verticals (for instance, in Fig. 25) is preferable to the rigidity of the straight line. The real question at stake is whether we have not a demonstration in such devices of the formalism and decadence of modern architectural taste. The most significant fact is probably the one that we have to labor for an explanation. It is quite certain that those who are best aware of the admitted deficiencies of modern architecture will be most sensitive to the beauties which are undoubtedly inherent in this refinement.

The fact that vertical curves of a very delicate character have been discovered by the writer in other churches is undoubtedly in point. The fact that vertical bends have been found at Cremona and Pisa, of a somewhat different character, should not be overlooked.

It is also probable that a careful discussion of the vertical bends of St. Mark's would involve giving a less summary consideration to the horizontal curves of this church than they have received in this paper.

The refinement of forward leaning and bending verticals on the facade of this church has been discussed in the preceding Memoir

and has also its bearing here on the general question. So have those refinements in the setting of the pinnacles and statues of the facade which were discovered by Signor Saccardo.

Various other architectural refinements of mediæval Italian architecture which have been elsewhere published by the writer, have a bearing on the general question. So also have those preliminary observations of Mr. Ruskin which preceded all others in this direction, as far as mediæval building is concerned.*

If all these various devices be interpreted to demonstrate a profound distaste for formal and rigid architecture, it becomes easier to comprehend the widening of the verticals. Contrariwise it will be difficult to conceive that the widening and bending of the verticals was intentional without giving serious thought to the significance of the horizontal curves.†

A peculiarly interesting problem is offered by the leaning walls at the north and south extremities of the transepts. In this instance a widening effect pure and simple can hardly be in question. The north and south widening does not continue above the parapets to any marked degree and the faces of the walls which continue the vertical lines of the pilasters of these walls are either perpendicular, or bend toward the perpendicular, above the level of the parapets. It is difficult to suppose that a widening effect could be attempted by a device which does not widen above. In the second place these walls are, for the most part, seen in face. It would be impossible, moreover, in view of the distance between the transept walls, for the eye to include them in one view. It may be conceived that the widening in the nave would logically carry with it a parallel treatment in the supports and surfaces of the transepts, but it is questionable whether this motive would suffice to explain the additional amount of inclination. On the other hand, if the bend of the entire line, rather than the lean of a part of it, be considered, we find a motive which unites with that which must probably be ascribed to the horizontal curves and to the obliquities in elevation.

The refinements of St. Mark's have peculiar significance, on account of the rough, and to modern ways of thinking, frequently careless, workmanship in this church. No other important church in Italy is so roughly built in certain particulars. It is such workmanship, especially as shown in the use of heterogenous materials, which has given our modern critics the impression that mediæval builders were incapable of subtleties. It is, no doubt, difficult for modern taste to understand the co-existence of offhand indiffer-

*Seven Lamps of Architecture: "The Lamp of Life." A list of publications by the writer, on architectural refinements, is given on the third page of the cover.

†The excellent article on "Refinements," by Mr. G. L. Heins, in the Dictionary of Architecture, which has been edited by Mr. Russell Sturgis (Macmillan) offers a solid basis for future discussion.

ence to formal regularity with the carefully planned construction of intentional subtleties. But it must now be admitted that these things did co-exist.

Outside of the buildings themselves, any satisfactory study of the phenomena, and of their purpose, must be made with the assistance of enlarged photographs. Illustrations of the size employed in this paper can hardly be considered as satisfactory, on account of the reduction of dimensions. The Brooklyn Institute Museum is, at present, the only centre in which such enlarged photographs are exhibited. It is believed that the importance of the facts which are illustrated by them is such as to make similar enlargements of value also to other institutions of learning. All of the drawings and half-tones which are mentioned in the titles of the illustrations as reproducing survey photographs, represent negatives which have furnished very satisfactory enlargements, with two exceptions. Many have the unusual dimensions of 25 × 35 inches.* It is hardly necessary to say that the drawings which are published, have been made with scrupulous fidelity, over tracings from the photographs. All of these drawings have been made by Mr. Herbert B. Judy of the Museum staff, with a few exceptions which were drawn or traced by Mr. McKeeknie for the earlier Architectural Record publication.† The survey photographs, which are dated by the captions of 1895, were all made by Mr. McKeeknie under direction of the writer. All photographs which are dated to 1901 were made by the writer.

Disappearance of the Tradition.

The problem offered by the disappearance of mediæval architectural refinements, without a survival of record or tradition regarding them has been elsewhere considered by the writer.‡ It has been elsewhere shown that the number of Italian churches which exhibit architectural refinements is much smaller in the late Italian Gothic than in earlier periods and that these refinements dwindle very decidedly in amount and in variety, as the Renaissance period approaches. On the other hand, although it was undoubtedly the Renaissance which led to the abandonment of these refinements, the surveys of the Brooklyn Institute Museum have recently discovered very interesting instances of isolated Renaissance survivals of them. One of great importance has still to be published. Another

*The exceptions are Figs. 26 and 34, but the right aisle is also represented by an excellent unpublished enlargement, taken without the plumb-line. The illustrations which represent enlargements of size 25 × 35 inches are named on the second page of the cover. The Museum exhibit includes many unpublished enlargements of great importance.

†The following drawings and tracings were made by Mr. McKeeknie: Figs. 3, 9, 21, 22.

‡Especially in the Architectural Record, Vol. VII., No. 1, "A Discovery of the Entasis in Mediæval Italian Architecture," 1897, and in these Memoirs, Vol. I., No. 1, "A Renaissance Leaning Façade at Genoa."

was published in the last Memoir, and in the present paper we have the instance of S. Giorgio Maggiore at Venice.

It is hardly necessary to re-emphasize the significant fact that a refinement was practiced as recently as the time of Palladio, of which only one literary record has survived, and that record made by a man who did not himself agree with the two architects who believed that the main building of the old St. Paul's "receded outwards" for an optical reason. The disappearance of tradition, regarding the mediæval refinements shows that we have much to learn as historians. We are more than familiar with the overthrow and disappearance of classic ancient culture in early mediæval Europe, but we are less disposed to realize the overthrow and disappearance of the mediæval culture which was effected by the Renaissance.

The isolated case of Renaissance survival which was shown for mediæval leaning façades in the preceding Memoir, is here paralleled by an isolated case of Renaissance survival for the widening or spread. It may possibly be found in other Renaissance churches, but it is quite certain that it will not be found in many.

It is probable, on the other hand, that a very considerable number of mediæval instances remain to be noticed in Italy alone. It is also certain that a very large number of Italian Mediæval churches and cathedrals, and many which show other refinements, do not show this one.

No solid foundation for the study of mediæval architectural refinements can be laid without systematic publication of the cathedrals and churches which are destitute of refinements. Generally speaking, matters are in shape for such a publication, on the part of the Brooklyn Institute Survey, in the case of the Italian peninsula, as far as all the well known and generally quoted monuments are concerned. My experience has, however, led me to the conclusion that no refinement so easily escapes notice as the widening refinement, and I am inclined to believe that it may have been overlooked by our examination in some instances. It may simply be said that all the well known churches of Italy, and many which are not well known, have been examined and that all known cases in Italy have been mentioned. Some known instances in northern Europe are reserved.

Since there is no church in Italy in which this refinement is so widely and carefully applied as St. Mark's at Venice, the probabilities are at present that a Byzantine subtlety is originally in question, but farther researches in the original centres of Byzantine building must be made, before this can be considered as more than a probability. Nothing of the kind has been noticed in S. Vitale at Ravenna or in S. Ciriaco at Ancona.

The presence of this particular refinement in some churches, when considered in connection with its absence in others, shows either that the tradition was limited to certain masonic guilds or that it was limited to an esoteric knowledge, possessed and handed down by individual architects or master masons. Motives of economy may explain the omission in some cases.

The given refinement has not been found in the large class of Italian timber-roofed columnar basilicas, of which the Pisa Cathedral is the most famous example, although it is found, as mentioned (p. 27), in the nave arch of the timber-roofed Cathedral of Trani and in the apse arch of the timber-roofed Capella Palatina at Palermo. Santa Maria della Pieve at Arezzo was also originally a timber-roofed building and, although it was vaulted by Vasari, it has been restored to its original form. It has, however, pier supports and has other relations to Lombard and northern architecture.

In conclusion it should not be overlooked that the world of archæology is much indebted to Mr. and Mrs. August Lewis, of New York, and to the Trustees of the Brooklyn Institute Museum, for their encouragement and support of these surveys.

Museum of the Brooklyn Institute of Arts and Sciences,
Dec., 1902.