TRANSACTIONS.

I.—*Account of the Bridge over the Severn, near the Town of Tewkesbury, in the County of Gloucester, designed by* THOMAS TELFORD, *and erected under his superintendence. By* W. MACKENZIE, *M.Inst.C.E.*

THE Tewkesbury Severn bridge was one of the works of Telford which that distinguished man thought deserving of especial notice, from its being a work of considerable magnitude, and attended with no small degree of difficulty in the execution, and having, after several years experience, been found to answer its intended purpose *.

The rendering more perfect the interior communication of the country, having of late years engaged much of the public attention, it became obvious that there was wanted a more direct line of intercourse between the rich districts which occupy the vale of the Severn, adjacent to the town of Tewkesbury; and that the construction of a bridge over the river at this place, and of a commodious road in the direction of Ledbury, would open an important communication into South Wales.

Act of Parliament.

These considerations led to obtaining an act of parliament to construct a bridge and also roads of approach to it, and to levy tolls, upon the credit of which, money might be borrowed.

Telford consulted, Oct. 1823.

The trustees appointed by the act having procured a plan consisting of three cast iron arches, proceeded to carry the same into effect; but misunderstandings having taken place between the trustees and the

* See account of Tewkesbury Bridge, communicated Aug. 11, 1828, by Thomas Telford. Original Communications, Vol. I., No. 46.

architect, all the parties interested solicited Telford to examine into and report upon the case. This after much hesitation he agreed to do.

Report, Dec. 12, 1823.

Having conferred with the trustees, their solicitor, and the contractor, Mr. M'Intosh—and having along with them examined the operations of the bridge, the draft of the contract, and the working drawings, Telford made the following report.

"1st. With regard to the works now in progress—the masonry of the abutment on the Tewkesbury side as far as performed, seems executed in a very proper manner; and the Shropshire stone which has been provided, appears in general to be of sufficiently good quality; some few are objectionable, as being subject to decomposition, and as it requires unremitting attention to discover those which are defective, as well as to watch over the quality of the mortar, and the manner in which the masonry is constructed, and the construction of the pilings and platforms, which have been unavoidable, and in general to attend on the part of the trustees, to see that the materials and workmanship are in every respect perfect in their several sorts, and agreeable to the plans and specifications, I consider it my duty to recommend that an experienced and otherwise properly qualified person be employed to attend the bridge operations.

"2d. As upon excavating the foundations it has been discovered that instead of rock or firm ground, as was expected and provided for in the specification and plans, there has on the eastern or Tewkesbury side been found only sand and gravel, so little united as to require a substantial platform laid at two feet greater depth than shewn in the drawings or described in the specification; and that in order to render the work sufficiently secure, a row of sheet piling must still be driven along the front and returns of this abutment; and further, that on the western side the foundation at the level of the river bed, and for ten feet under that level, consists of a clean fine sand, requiring to be either wholly excavated to get at firm ground, or the whole space for the abutment to be secured by long piles with a substantial platform formed by good sheet piling, all constructed in the most perfect manner. And this being the case with the two abutments, there is every reason to expect that the two piers in the river will require similar precautions.

"Now as all these operations are unprovided for in the specification and plans, and will unavoidably amount to a very serious expense, it is of the utmost importance that the trustees should be made acquainted with the amount

as nearly as can be ascertained. I have therefore required of the contractor to state the amount of what has been already incurred, and also to furnish an estimate of what those foundations, which are beyond what is comprehended by his proposal, will probably cost.

"The following is his statement:

	£	s.	d.
Platform and sheet piling to foundation of eastern abutment, including 2 feet of extra depth of masonry, and using Shropshire stone facing	352	2	6½
Foundation of western abutment, including long piling, sheet piling, platform complete, including pumping, &c. .	805	13	5
Two river pier foundations, supposed to cost . . .	1800	0	0
	£2957	15	11½

"3d. Upon comparing the specification and figured drawings with the draft of the contract, and these with what is required by some of the clauses in the act of parliament, it appears that sundry small differences exist which the trustees are bound to guard against; for instance, the act provides that the two river piers taken together shall not in any place above the line of low water be more than eighteen feet, whereas upon the working drawing at that level twenty feet are marked. I must therefore recommend that the plans and specifications be revised, and made to accord with the clauses of the act.

"4th. As Aberthaw lime has, from long experience, been proved by much the fittest for all masonry exposed to water, I recommend that the contractor be restricted to the use of it fresh from the kiln, mixed hot, and particularly well mixed and beat.

"Any small saving which would be made by using any other sort is ill acquired at the expense of certain excellence.

"5th. When once the plans, specifications, and contracts have been carefully revised and finally settled, no deviation therefrom of any consequence should be admissible, unless authorized in writing under the hand of the principal engineer or architect employed by the trustees and sanctioned by them; and where practicable the amount of the expense should be previously ascertained, and agreed to in writing by the contractor.

"6th. Some further explanation appears necessary with regard to the fencing of the roads and embankments, also with regard to the field-gates, with the roads into the fields, and culverts under them.

"7th. Some provision should be made for sinking pannels and grooves in the masonry, to receive the iron work perhaps under the direction and at the expense of the iron contractor.

"8th. There should be a very distinct understanding as to where the earth for embankments, &c., is to be procured, how the ground is to be left, and who is to pay for land and damages. It should, if possible, be left in a state to be drained: the embankments should be protected both along the tops and bottoms."

Telford appointed engineer.

This report having been made, and fresh difficulties having arisen in the progress of the work, Telford was, early in February, 1824, requested to revise all the contracts, and to recommend what plan should be adopted; and on the 3d of March he made the following report.

Telford's Report, March 3d, 1824.

"Having taken a section of the river Severn at the intended site of the bridge, when the water had risen to about 2 feet 8 inches of the top of the bank on the western side of the river, and having also proved the nature of the river bed by boring, and measured and compared the relative breadths of different parts of the channel; and having duly considered the nature of the navigation which is carried on, and the great and frequent floods to which the said river is subject, I am of opinion, under all the circumstances of the case, that it is most advisable to have one arch of cast iron, which shall span across the whole breadth of the channel, and of course leave the whole of the water (while the river is within its banks) quite unobstructed. I consider that an arch of 170 feet span is sufficient for this purpose, and that it may be constructed of proper stability without raising the roadway higher than has already been proposed. For the flood water when risen above the surface of the meadows, I propose providing, as always intended, 160 feet of opening, measured on the horizontal line, besides two culverts of 3 feet diameter each, and this I consider a sufficient water-way for the purposes of the country, as required by act of parliament.

"The distribution of this flood water-way I propose to be by having six small openings upon each abutment, and nine arches, of 12 feet span each, placed at three different places on the western side of the river, where a discharge of water is most required.

"I am of opinion, that with a view to economy, without entrenching upon the proper and necessary accommodation of the intercourse, the bridge may be made 24 feet in width between the side railings, this being 4 feet more than an

iron bridge I have constructed upon the great Holyhead Road, which being found quite sufficient, the only reason I have not recommended this of the same width is, that being near a town, and subject to a toll upon foot passengers, it seems advisable to have a footpath on each side; these I propose to be 3½ feet each, which will leave a clear carriage way of 17 feet.

"In the several public roads lately made under my directions, none of the embankments have been more than 30 feet at the top, the protecting rails being set along the extreme edge, and the thorn quicksets planted at three feet without them. This width being found by experience to be as much as necessary, I recommend that those which will form the approaches to the bridge shall be made 30 feet instead of 45; this being still further necessary in order to keep the skirts of the slopes within the limit of 60 feet, as assigned by the act.

"I have made the outlines of a design which corresponds with what I have here recommended for the bridge and its abutments, the detailed dimensions and particulars of construction remain to be described by working drawings and a written specification, but they will be regulated by what I have found by experience to answer in four several instances, three of them upon navigable rivers and tideways.

"Upon this newly arranged plan and the before mentioned conditions, I have, along with the contractors, carefully gone through the calculations and comparisons with the former plans upon which their proposals were founded, and the result is—that although the quantity of iron required by the present plan is greater than by the former, yet, as Mr. Hazeldine has at his works some of the apparatus used in the three similar bridges he has constructed for me, and his works being adapted and his workmen accustomed to the management of all the parts, he will execute this proposed plan of one arch of 170 feet span for the same sum as his former proposal contained, that is to say £4500.

"On the works comprehended in Mr. M'Intosh's contract for the former plan a small saving will be effected, thus—

Amount of proposal for former plan	£11400
Ditto of extra works in foundation, as per my Report, Dec. 12. .	2957
	14357
Estimated expense by the present plan	14052
Saving	£305

"Considering the present situation of the works, it will be necessary to extend the time for completion from May until the last day of July, 1825; but that all the masonry of the bridge necessary to receive the iron work shall be completed by the last day of October next.

"In the above mentioned estimates it is understood that the contractors are to give security for the due completion of the works, and maintaining them in a perfect state for the term of three years afterwards.

"Mr. M'Intosh is to pay damage for the land necessary for procuring earth for the embankments, but not for that upon which the embankments stand, or for any expense attending making gates or roads of accommodation to the adjacent fields.

"The modes of payment to be distinctly arranged, so as to be made at stated times upon the certificate of the resident engineer, countersigned by the principal engineer in the usual way.

"The trustees having now before them a full statement of my ideas as regards the nature of the plan best adapted to the situation, the mode of conducting the work, and the expense to be incurred, it remains with them to determine whether they will approve of the same; and if so to give me directions to prepare a perfect copy of the plan now signed by the parties, also proper working drawings and specifications, and an outline for contracts upon the same; and also to authorize me to give directions to the contractors to take the necessary measures to proceed with the works agreeably to this newly arranged plan for an arch of 170 feet span, with its approaches and embankments."

Plan accepted.

The trustees approved of the design of one arch, and the contractors agreed to the above statement, and to execute proper contracts for the performance of the work as soon as the plans and specifications should be prepared and adopted; the work was proceeded in without further delay. With the preceding report Telford presented a sketch of the proposed bridge, and so great was the confidence entertained by all parties of his talents and integrity, that they were willing to proceed with the work, without any other agreement than the following, which is written on the drawing.

"This is the outline of a design intended to be completed, with proper dissected drawings and specifications, and which design is referred to in the report of the undersigned Thomas Telford, dated this 3d day of March 1824, and

which we have all subscribed our names to. Dated this 3d day of March 1824.

THOS. TELFORD, Engineer.
W. HAZELDINE, Contractor for Iron Work.
HUGH M'INTOSH, Contractor.
J. PROSSER, Chairman, } Committee appointed by the Trustees.
WM. PHELPS, }
JOSEPH LONGMORE, }
JAS. SUTTON OLIVE, Clerk to the Trustees.

SPECIFICATIONS.

Masonry and approaches.

"The bridge to be constructed near the Mythe Hill, at the place now marked out, and some part of the work begun. It is to consist of one opening for the river channel, where the faces of the abutments at the springing of the arch are to be 170 feet apart. This springing is to be at the level of 1 foot 6 inches below the Grindstone level, or 5 feet 6 inches below the former flood line. The foundations of the masonry of the main abutments are to be sunk to and laid at 21 feet below the said Grindstone level, or 19 feet 6 inches below the aforesaid springing. These abutments are to be 20 feet in thickness and 31 feet 6 inches in length, and these dimensions are to be carried up to the springing, with the addition of the projecting string course.

"The land pier on the Tewkesbury side to be taken down to receive the springing of the underground arch and the aforesaid string course. The land pier on the Bushley side to have its foundations sunk to and the masonry laid at the depth of 13 feet under the aforesaid Grindstone, or 11 feet 6 inches below the springing of the main arch; it is to be 10 feet in thickness, and both the land piers are to be 31 feet 6 inches in length, and carried of these dimensions up to the springing of the main arch, with the addition of the projecting string course. Between the main abutments and land piers arches are to be made, that on the Tewkesbury side to be 20, and that on the Bushley side 24 feet span, the arch stones two feet in depth, with proper spandril walls. From the level of the springing of the main arch the masonry is to be carried up 3 feet to the bottom of the open land arches;—this portion of the work will be 30 feet 6 inches in width across upon an average.

"In the main abutments the outside work of their faces and sides is to consist of ashlar work of Shropshire stone, not less than 2 feet 6 inches in

breadth on the bed, on an average, including headers. The arch stones of the underground arches to be of square masonry, the springing stones of the large arch are to be 6 feet in breadth from the front edge, along the sides and back to be 3 feet in breadth. All the rest of the masonry is to be built with the flat bedded lias lime-stone from Brockeridge Common, or from Breedon Hill, or other stone of equally good shape and quality. The whole of the masonry under the level of flood line to be laid in mortar of Aberthaw pebbles; above the flood line the mortar may be made from the Brockeridge lias lime-stone, the mortar for all work 2 feet 6 inches inwards from the outside to be two parts of unslaked lime to three of clean sharp sand; the backing or inside mortar to be composed of two parts of unslaked lime to four of clean sharp sand; the whole to be made with fresh burnt lime carefully slaked with as little water as possible, and well beat.

"From the top of the aforesaid springing course up to the level of the roadway, the structure is to consist of arches, piers, and pilasters, also the pedestals above the roadway to be all agreeable to the annexed drawing, (Plate II. Fig. 2,) the outside facings of which are to be made with the best Breedon Hill stone neatly dressed and squared. The ashlars of the before mentioned outside work to be 18 inches broad on the bed, on an average, excepting the plinth course for the railing, which is to be 15 inches only.

"The walls of the aforesaid land arches, and the arches themselves, and their spandrils, are to be of good sound hard burnt brick, laid in lime mortar and from the lias lime-stone of the country.

Platforms, Plate II. Fig. 6.

"Under the main abutment on the Tewkesbury side there is to be a platform consisting of two thicknesses of half baulk laid across, and pinned together with oak pins, to be 33 feet 6 inches in length and 22 feet in breadth, with a row of pile planking of elm or beech timber shod with iron, 10 feet long and 5 or 6 inches in thickness, secured to sills by $\frac{3}{4}$inch screw bolts; the sills to be fir or elm, 10 inches by 8, secured by strong iron rag bolts. The pile planking to be placed along the whole of the front, and for 8 feet returned along on each side.

Plate II. Figs. 1, 5.

"Under the whole space of foundation of the abutment, on the Bushley side, there are to be driven bearing piles 21 feet long and 12 or 13 inches square, placed at the distance of 3 feet from centre to centre, upon these transverse sills 12 inches by 6 inches are to be placed and spiked to the heads of the piles by rag bolts, and crossed by other

sills of similar dimensions spiked to the before mentioned, the spaces between the sills and pile heads to be filled with rubble stone rammed in and grouted with Aberthaw lime mortar; the whole of this grating to be covered with 6-inch planking pinned down with oaken pins, the whole of the piles, grating, and planking to be of good Baltic timber, the piles to be shod with iron. Sheeting piles of elm or beech 12 feet long and 6 inches thick to be driven along the whole of the front, and for 10 feet along each side. Under the foundation of the land abutment on the Bushley side, there is to be a grated platform consisting of two rows of sills and planking with round piles under them, as per annexed plan.

"The spandrils of the land arches are to be filled up either with brick work or flat bedded lias limestone to the level of the lower side of the roadway, but along the face of the abutments next the iron arch the whole outside stones are to be squared ashlars, not less than 2 feet broad on the bed on an average; the two top courses to be not less than 3 feet in breadth, and in both those facings grooves are to be cut to receive the springing plates and the plates for the lozenge standards and bearing bars.

"From the extremity of the wing walls of the bridge, rubble walls with a proper coping to be built with lime to prevent the embankment slopes from encroaching on the aforesaid wing walls of the bridge, in the manner and to the extent of the general plan and elevation signed by Thomas Telford, and to his satisfaction.

Roadway over the bridge and land arches.

"The whole of the iron plates over the main arch and the whole space over the land arches and piers to be covered with a coat of good clay properly punned so as to render it water tight; upon this, along each side of the bridge, a footpath, 3 feet 6 inches in breadth, is to be formed in the following manner; that is to say, to have a curb stone of squared granite 1 foot 6 inches in depth, and 9 inches in thickness, the space between the curbing and the iron work to be composed of suitable gravel.

"The carriage way between the curbings to be 17 feet in width, to be covered with stone for the whole width, the foundation or first course to consist of such hard materials as may be procured from the fields or limestone quarries in the neighbourhood, and to be 7 inches thick on the middle and 3 inches at the sides, and the upper coat of best Bristol limestone of an average thickness of 5 inches; the whole to be broken into pieces, none exceeding 6 ounces.

Flood Arches.

"There are to be nine flood arches, that is three sets of

three arches each, and each arch to be 12 feet span, they are to be placed where the discharge of water in the low ground on the western side is most required, the foundations to be sunk to such a depth that the inverts may suit the natural watercourses and the surface of the adjacent ground; the abutments are each to be 3 feet in thickness, with two counterforts behind each, each 4 feet by 3; the piers are each to be 1 foot 6 inches in thickness, and both abutments and piers to be 36 feet in length, the arches are to be 14 inches in thickness and 36 feet in length across the road. The inverted arches are each to be 9 inches in thickness with a curve of 12 inches. The spandril walls are to be 1 foot 10 inches in thickness, the wing walls are to be from 3 feet in thickness to 14 inches, and to have a coping of 4½ inches. At the springing of the arches there are to be courses of stone 18 inches broad by 12 inches thick. All the rest of the work is to consist of good, sound, hard burnt bricks laid in proper lime mortar. The sprandrils of the arches are to be made up with either brickwork or flat bedded lias limestone laid in lime mortar. Over the top of all the arches and spandrils there is to be laid six inches of clay well punned. Besides the aforesaid arches there are to be two culverts, 3 feet diameter, of a proper length to extend to the skirts of the embankment where they are placed.

Embanked Approaches.

"The approaches to each end of the bridge to be agreeable to the annexed plan and section signed by the said Thomas Telford. The longitudinal line of roadway in no case to rise more than 1 in 35. The width of the finished top to be 30 feet, and the side slopes to be 1½ horizontal to 1 perpendicular. The roadway to be made with stone 27 feet in width, constructed of the same thickness and manner as described for the carriage way over the main bridge.

"Each side of the road to be formed with sawed oak posts, and Baltic fir rail fences, three rails in height according to the drawing, the posts to be fixed 8 feet asunder, to be 8 feet 6 inches long, and 4 feet 6 inches above the ground, with proper spurs at the butt-end, equal to 1 foot diameter and 4 feet in the ground at least.

"The rails to be morticed and tennoned into the posts, to be rounded on the upper surface and secured by oak pins, the top rail to be 6 inches by 4 inches, the middle 5 inches by 4 inches, and the bottom 5 inches by 3½ inches; the posts and rails to be free from sap, and to be covered with paint, of three coats, of a light stone colour, of a quality prepared and generally used for that purpose.

"The road from the termination of the embankment to the intersection of the old Ledbury road, to be fenced on each side with cleft oak post and rail fencing, three rails between the posts, the posts to be fixed upon the quickset banks, which are to be raised of a sufficient height and breadth as may be necessary for the lands adjoining.

River Banks. "The river banks on each side of the eastern abutment to be embanked with earth so as to range with the front of the abutment, its face to have a slope of 2 horizontals to 1 perpendicular above low water mark, and all below low water mark to be secured with stakes and faggots. The face of the embankment to be covered with good turf fixed down with wooden pins. On the western side, above and below the abutments, the river bank to be dressed to range with the front of the abutment, the slope to be the same as described for the eastern side, and to be covered and secured in a similar manner.

Iron Work, Plate III. "The bridge is to be constructed over the river Severn, near the Mythe Hill, where the site is marked out and the work begun. The main opening for which this arch is to be adapted is to be one hundred and seventy feet between the abutments' springing plates, the springing is to be 1 foot 6 inches below the grindstone level, or 5 feet 6 inches below the former flood line, the rise or versed sine is to be 17 feet, and the width to be such as to leave 24 feet clear between the skirting of the roadway railing; there are to be six ribs placed at equal distances from each other, they are to be placed upon strong abutment-plates, firmly bedded in the masonry; they are to be secured in their places by gauge pipes and connecting wrought iron bolts, covered with grated plates fixed by mortices fitted to joggles in the main ribs, and screwed flanches; upon these the lozenge spandril standards are placed, which are also secured by gauge pipes and cross ties in the middle, and by mortices and tenons at top and bottom, besides diagonal braces in the spandrils. Upon the top of these the road bearers are to be fixed one over each rib, upon these bearers the road plates are to be laid joggled upon the bearers and screwed together by their own flanches and pins; upon these road plates the iron skirting is to be placed, to protect the road and receive the common railing; the main rails are to be placed and screwed upon the road plates, the railing is to be capped with a hand rail. The whole of the cast iron work to be of the best Shropshire iron, No. 2, cast, fitted, and put up complete, in the most perfect manner.

"The contractor is to provide all materials, tools, utensils, machinery, scaffolding,

and labour of all sorts which may be required for making, carrying, fitting up, and completing the said arch, spandrils, roadway, and railing agreeably to the before mentioned drawings, and the general plan and elevation of the bridge made out and signed by Thomas Telford, where it will be observed the cast iron railing is carried not only along the great iron arch, but also over the six land arches on each side, and that the columns between the small arches in the bridge wings are to be made of cast iron."

REFERENCES TO PLATES.

PLATE I.

General plan and elevation of the bridge.

PLATE II.

Fig. 1. Elevation of abutment, with the piles on the Bushley side.

Fig. 2. Elevation of abutment on the Tewkesbury side, with the open land arches.

Fig. 3. Plan of ditto.

Fig. 4. Cross section through the Bushley side abutment, and first land arch.

Fig. 5. Plan of platform for the main abutment on the Bushley side.

Fig. 6. Plan of platform for the main abutment on the Tewkesbury side.

PLATE III.

Fig. 1. Elevation of a main rib, lozenges, skirting and railing.

Fig. 2. Plate for connecting main ribs.

Fig. 3. Shews the manner in which the several pieces of the main ribs are connected together. The flanges of the ribs are 4 inches deep. In the four middle ribs, where there are double flanges, there are three $1\frac{1}{2}$ inch bolts in each flange; but in the two outside ribs, where there is only a single flange, it has four of these bolts.

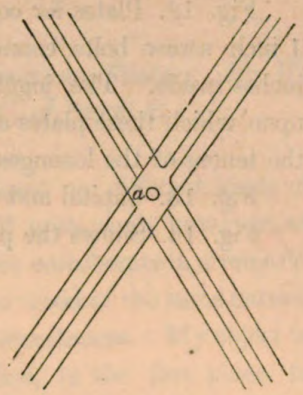

Fig. 4. Section of one of the lozenges of the spandrils taken at the middle of the length. They diminish to $3\frac{1}{2}$ inches square at the ends; they are joined at the middle by a mortice and tenon (as in accompanying sketch); they are connected breadthways of the bridge by wrought iron bolts, $1\frac{1}{2}$ inch diameter, passed quite across through holes in the middle of the crosses, (as at *a*, in the figure,) and also through cast iron tubes, placed between each row of lozenges, to prevent their being drawn out of their places when the bolts are screwed up. These tubes are represented in the following figure. External diameter $2\frac{1}{2}$ inches. Internal diameter $1\frac{1}{2}$ inch.

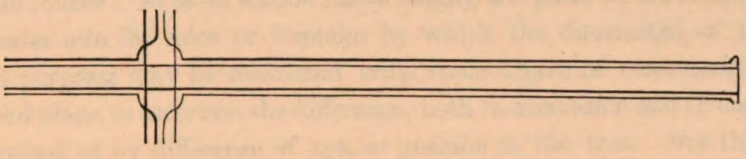

Fig. 5. Main ballusters.

Fig. 6. Section of handrail.

Fig. 7. Skirting.

Fig. 8. Road plates $\frac{7}{8}$ inch thick; flanges 3 inches high inside; dovetailed joggles to fasten the plates to the road-bearers, 6 inches long, $1\frac{1}{4}$ thick, and $1\frac{1}{2}$ high; $\frac{7}{8}$ screw-pins.

Fig. 9. Section of diagonal braces; in the middle they are $5\frac{1}{2}$ inches square, at the ends only 4 inches. Instead of being joined together where the two parts of the cross meet by a mortice and tenon, they are simply halved into each other, and a bolt holds the two together. There are two pair of these braces on each side of the crown of the arch; they meet at the joining of the second and third rib plates, from the crown of the arch on each side.

Fig. 10. Shews the manner in which the road-bearers are connected with the abutments; the road-bearers are cast in four lengths on each side of the crown of the arch, and are joined to each other with two $1\frac{1}{8}$ inch bolts, as in annexed figure.

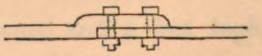

Fig. 11. Springing plate.

Fig. 12. Plates for connecting and covering the top of the main ribs; nine 1 inch screw bolts connect every two of these plates. Flanges stand up 3 inches inside. The joggles, which are cast upon the top of the main ribs, and upon which these plates are let down, have each a mortice in the top to receive the tenons of the lozenges or crosses of the spandrils.

Fig. 13. Capital and base of the cast iron columns.

Fig. 14. Shews the proportional lengths of the cast iron columns.

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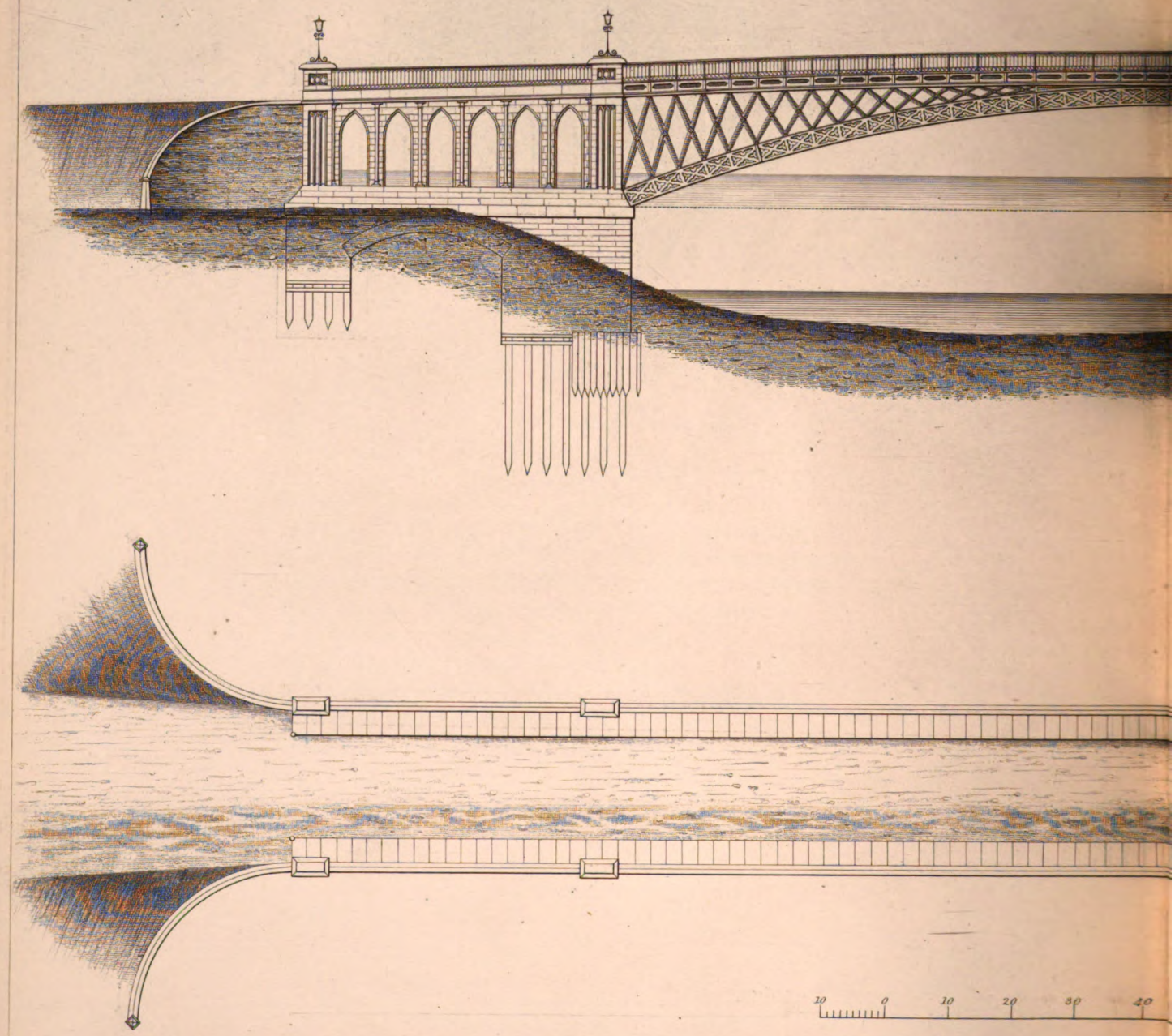

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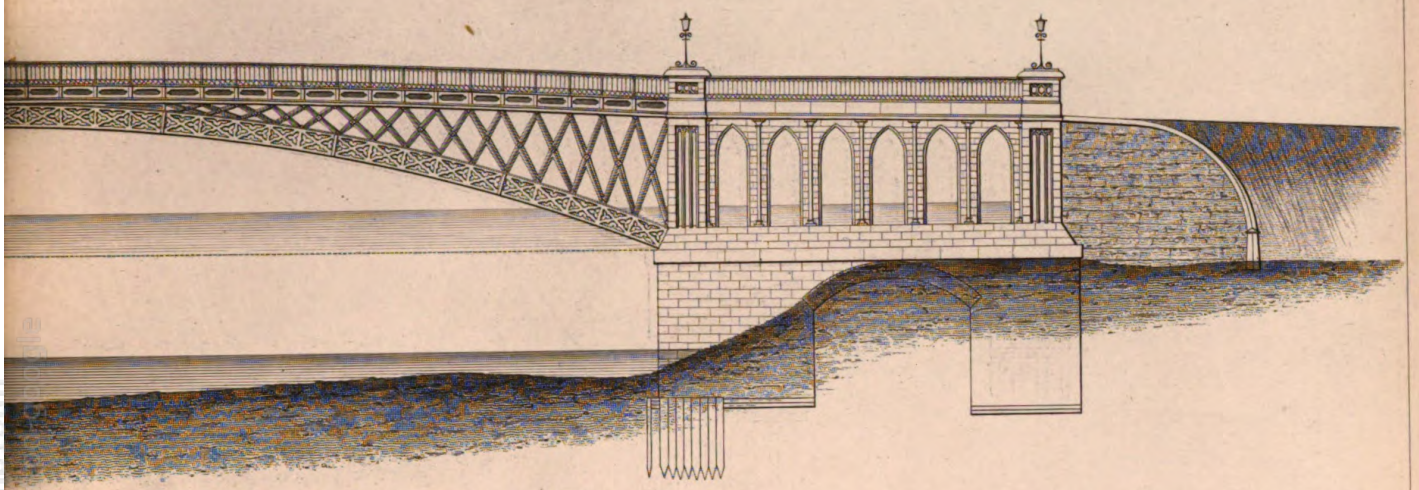

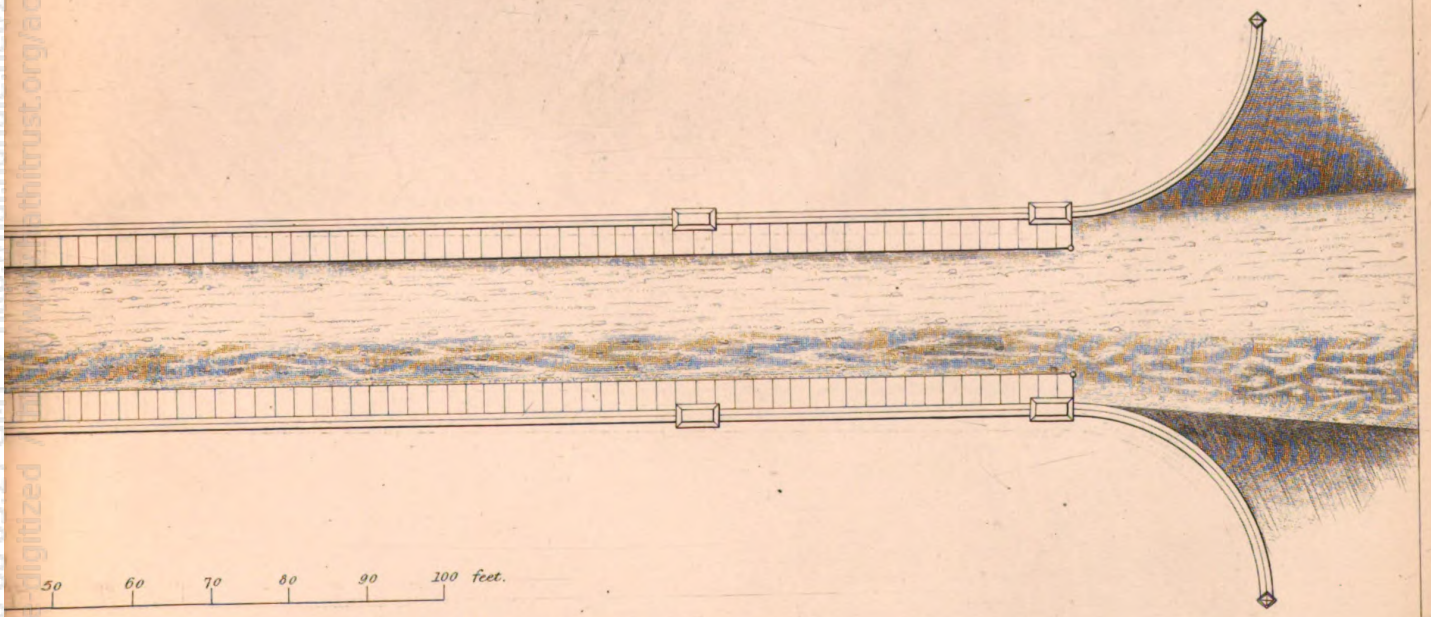

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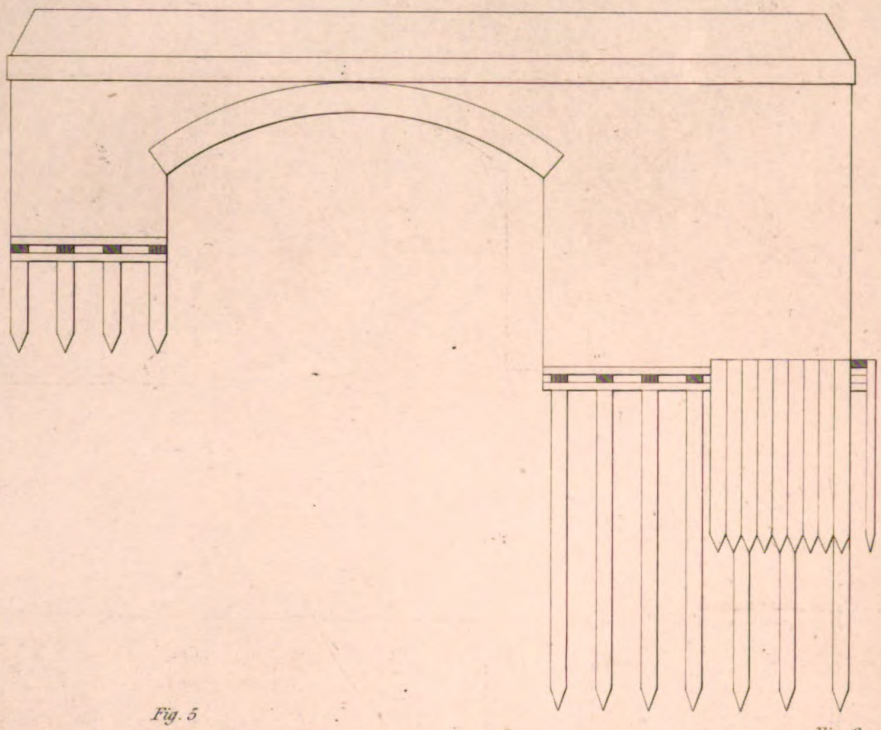
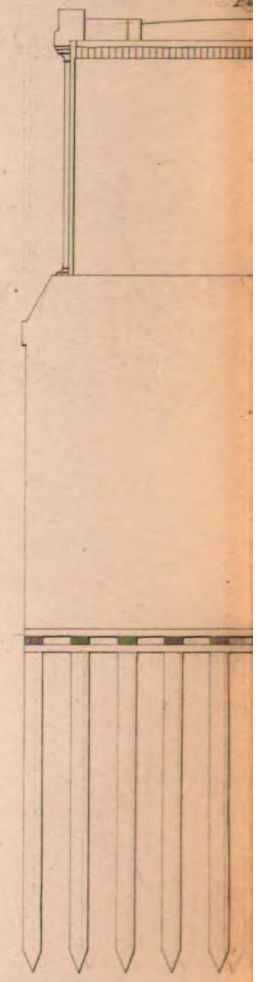
Fig. 1





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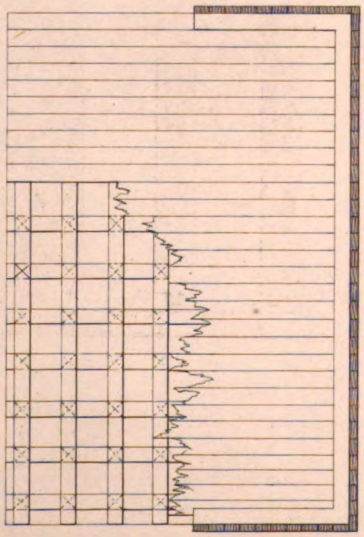

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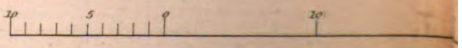

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Fig. 4.

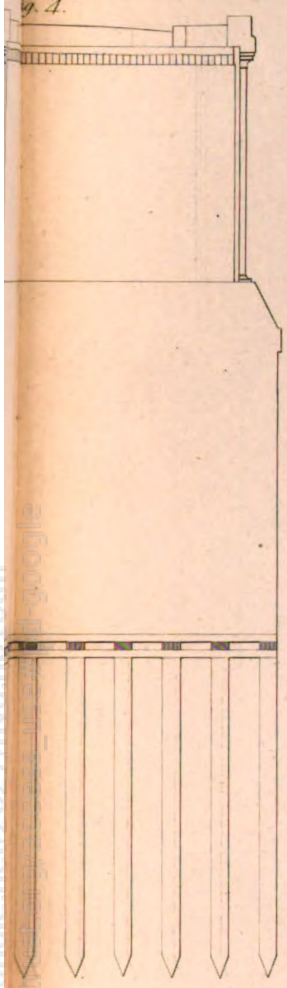
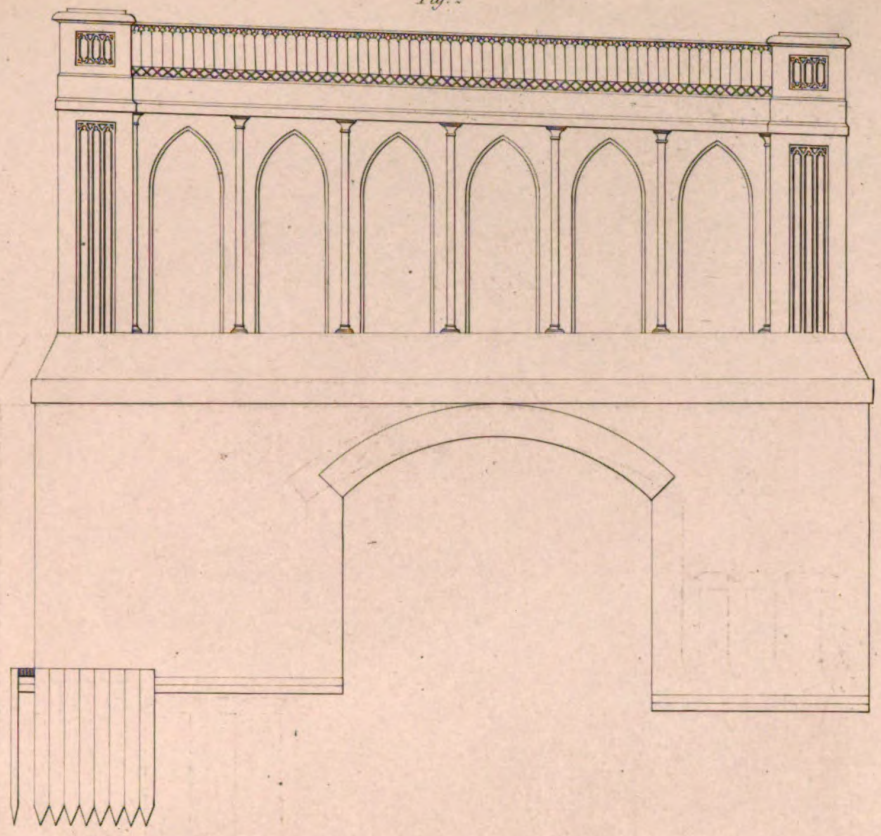


Fig. 2



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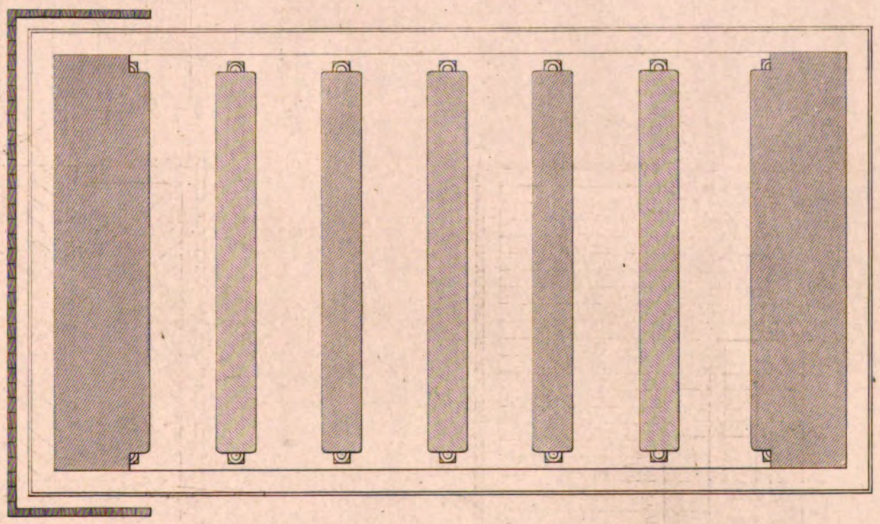

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Fig. 1

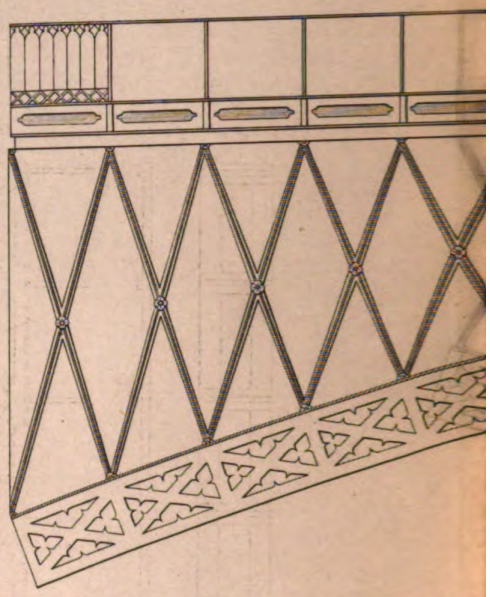
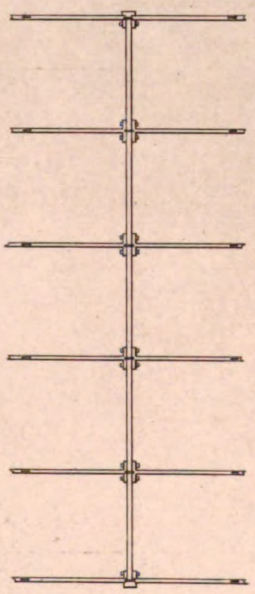


Fig. 4

Fig. 3



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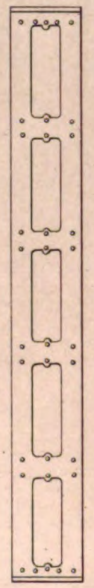
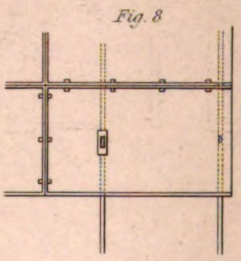


Fig. 5

Fig. 6

Fig. 8



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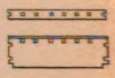

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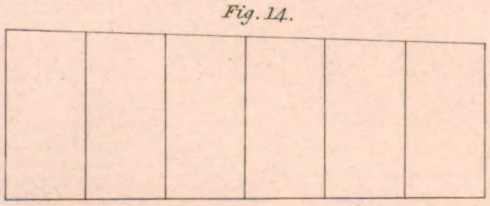

Scale

10 9 8 7 6 5 4 3 2 1 0

Scale to 6 9 & 14.

12 11 10 9 8 7 6 5 4 3 2 1 0 1 Foot.

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Fig. 9

Fig. 11

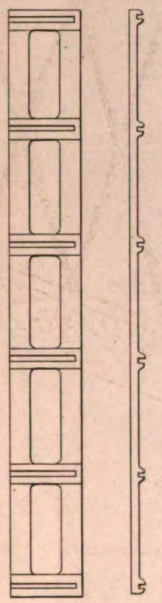


Fig. 12

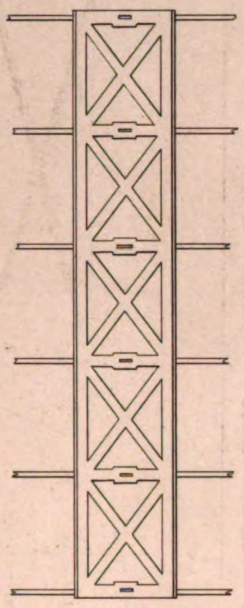


Fig. 10

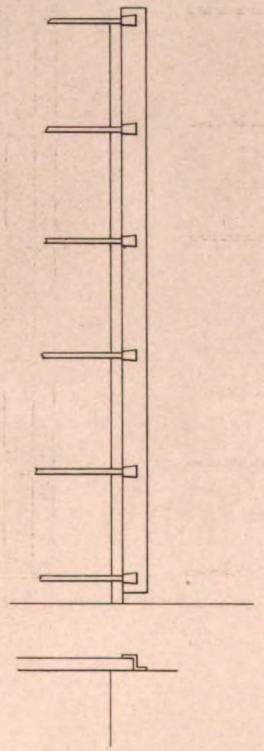
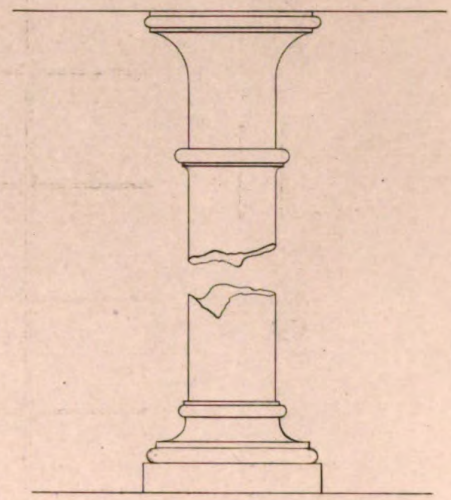


Fig. 13



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