



Royal Terrace Pier and Gardens, 1830.

April 8, 1845.

SIR JOHN RENNIE, President, in the Chair.

No. 706. "Account of the new Cast Iron Pier, at Milton-on-Thames, next Gravesend, in the county of Kent; with details of the mode of Construction adopted in its erection." By John Baldry Redman, Grad. Inst. C. E.

Gravesend, comprising the adjoining parish to the eastward, called Milton, has at all times been much frequented, and has been indebted, to a great extent, for its rapid growth, to the resort of

shipping of all nations, whether arriving in, or departing from, the Thames.

A hythe, or causeway, at this town, is described in Domesday-Book, as a place of embarkation and disembarkation both for the ferry across to Essex, and for what was formerly termed the Long Ferry, namely, the passage between Gravesend and London. The ancient causeway, which was situate within the parish of Milton, was merely a wooden stage, subject to constant repairs from injuries received in stormy weather, and from the decay incident to the ravages of the worm, "*Teredo navalis*," which is so destructive in this locality. In 1765 the corporation resolved to build a new bridge (as it was called) of stone, but the work appears to have progressed tardily, as it was not until the expiration of several years, that it was completed: an approach was afterwards formed of Moor-stone steps, connecting this bridge with the top of the wharf.

The first steamer on the Gravesend station commenced running in January, 1815; the communication in early times had been by barges; these were followed by tilt-boats, which were open boats shaded aft by an awning stretched upon hoops called tilts: these were succeeded in 1737 by decked sailing boats, which gradually improved in size, accommodation, and number, for in 1826 there were twenty-six of them, varying in size from 22 tons to 45 tons each, plying between Gravesend and the various stations in London.

The first steamer continued on the station a few months; she was of 70 tons burthen, with engines of 14 H.P., and it was frequently necessary to lay her up for several days to repair the machinery. About the year 1817 there appears to have been two steamers on the station, one of which was of 80 tons burthen, with an engine of 20 H.P.

The benefits accruing to the town by the introduction of steam navigation quickly developed themselves, and to it may be attributed the rapid growth of the town during the last quarter of a century.*

In 1827, from the large increase of visitors to the town, and the inadequate accommodation afforded by the town quay, the want of increased facilities for landing and embarking passengers was manifest, and in August of that year, at a meeting of persons connected with the Corporation and the local commissions, a resolution was passed to the effect, "That it was proper and expedient, that exertions should be made in order to provide accommodation corresponding to the public patronage bestowed upon the town. That improved accommodation should be provided at the water side; and that the

* See Appendices (A) and (B).

removal of the house (the property of the Corporation) standing across the bottom of the High-street, and the erection of a roof over an enclosed space for the accommodation of visitors attending their friends to or from the landing-place,—would be important and valuable improvements." The result was, the obtaining an Act of Parliament in 1828, for improving and maintaining the town quay and the landing-place.

The improvements effected under this Act were, the removal of several buildings, enlarging the space for wharfage, improving the wharf line, and the erection of a new flight of steps. The landing-place thus improved was re-opened in June, 1829. This, at the time, was considered a great local improvement; but circumstances soon arose which imperatively called for more extensive accommodation. The steam traffic had increased steadily, and in the spring of 1830, a steam-packet wharf was opened at the St. Catherine's Docks, in London, when the great advantages of embarking and disembarking, without the intervention of wherries, was immediately appreciated by the public, and the managers of packets found themselves obliged to afford equal accommodation at their own stations. The old Gravesend Company resorted immediately to this wharf, and the Margate and other Gravesend packets eventually had access to Fresh Wharf, near London Bridge. The necessity for similar accommodation at Gravesend was obvious, and in September, 1830, a public meeting of the inhabitants was held, to consider the expediency of erecting a pier; it was, however, believed generally, at that time, that its effect would be prejudicial, by depriving a large body of industrious watermen of employment. In the following year, Mr. Pitcher, of Northfleet, erected a landing jetty, which was much frequented, and it was soon evident, that if exertions were not made, a large portion of the traffic would be diverted from the town of Gravesend.

In 1831 several meetings were held at Gravesend on the subject of erecting a pier, in front of the town quay, and in the month of November of that year, a meeting of the watermen was convened at the Town Hall, when the proceedings of the previous meetings were laid before them, with the intimation that the corporation had not decided on more than this, namely, that they would not consent to the erection of a pier on their estate, unless provision was made for the watermen. Notwithstanding this, the watermen organized themselves and offered so vigorous an opposition to the measure, that in the session of 1832 the Bill was lost, after a long and expensive struggle. An Act was, however, obtained in the next session, the royal assent being given on the 28th June, 1833; not, however, until

after a most violent and protracted contest. A clause in this Act gives the Corporation power to compensate the watermen, by allowing them wages for work and labour on the pier.

The town pier was completed and opened on the 29th July, 1834.* During the proceedings in Parliament a temporary jetty had been erected in front of the town quay, under the Act 9 Geo. IV. c. 56, and when it was necessary to remove this for the erection of the pier, another was constructed to the westward, and used until its completion.

In 1833 the number of steam-boat passengers had increased to 290,000 per annum, and with the prospect of a progressive increase; a new company was formed, called the Star Steam Packet Company, which, in April and May, 1834, launched four new and powerful boats.

In March, 1835, the Block-house Fort in the parish of Milton, after having been in the possession of the Crown for nearly three centuries, was sold, the purchase being effected by a committee of the inhabitants of Gravesend, to prevent its application to purposes injurious to the community. The advantages of this site for a pier were apparent, and the purchasers of the Block-house Fort estate actively availed themselves of it; a temporary wooden pier, 10 feet in width, roofed in, and terminated by a T head, and a double flight of steps, was finished on the 7th June following, and was immediately resorted to by the Star steamers: a proposition previously made to the Corporation to take the pier, having been rejected. The vast increase of passengers to, with the consequent enlargement of the town,† was sufficient to warrant this step, and the necessity of increasing the accommodation at Gravesend was apparent, when the establishment of a pier near Northfleet was talked of.

An amount of £10,000 to cover the purchase, the expense of erecting the pier, &c., was shortly raised; at the end of the season of resort of 1835, the Terrace Gardens were laid out on the ground of the block-house fort, from the designs of the late Mr. Loudon, and the grounds have deservedly received universal commendation.

In the same year, the capital of the shareholders of the Terrace Gardens was extended, to provide approaches to the pier, three houses purchased in the terrace, and land was taken at the back of it, on which Harmer-street has since been erected.

* In Part 3, vol. iii. of the Trans. Inst. C. E., is a Memoir and drawings, by W. Tierney Clark, Esq., M. Inst. C. E., engineer of the work, descriptive of this structure, with a memoir of the struggles that occurred to obtain powers for its erection, and of the destruction of the temporary pier by the watermen.

† See Appendix (B).

In 1836 a capital of £60,000, in 2,400 shares of £25 each, was raised, and the Gravesend Freehold Investment Company was formed; 24 acres of ground, now called the Milton Park Estate, were purchased on the south side of the Dover road, and a new eastern town was shortly called into existence.

The increased facilities of access afforded at the termini, by the formation of these piers, and the general use of the Brunswick Wharf, in connexion with the Blackwall Railway, as a steam-boat station, since July, 1840, when it was thrown open by the Railway Company, under a contract with the East and West India Dock Company, have called into existence low-water jetties, or piers, at the intermediate stations of Erith, Greenhithe, Grays, and Rosherville near Northfleet.

The Directors of the Terrace Gardens and Pier had been in communication with the Corporation for the transfer of their property to them, but no arrangement could be arrived at; and several law suits ensued respecting the tolls, but at length in June, 1842, an arrangement was effected, by which it was agreed that the temporary wooden pier should be removed, and one of larger dimensions and more permanent materials should be erected in front of the centre of the gardens (the wooden pier being on the west side, and out of the line of the road of approach); and then, that the whole establishment, with the block-house, or bulwark, adjoining, and its appurtenances, should be transferred to the Corporation for the sum of £40,500.*

A Bill was prepared in the early part of the session of 1842, and plans were deposited for the erection of a new and permanent pier in front of the Terrace Gardens; the approach to which was to be in a line with Harmer-street, which was already partly formed.

The author was appointed the engineer, by the Directors of the Terrace property, and designs of the proposed work were prepared by him and submitted to and approved by the Admiralty and the Thames Navigation Committee, as conservators of the river. An Act was shortly after obtained, without any opposition having been raised; the rights of the various bodies likely to be affected having been duly regarded, and the designs of the work prepared, so as to

* Nearly the whole of the information contained in the above introductory remarks has been compiled from Mr. Cruden's carefully written History, which contains a large amount of information, in an historical, antiquarian, and commercial point of view. The histories of the Port of London and of the embankments of the river Thames are alike interesting to the professional man. "The History of the Town of Gravesend, in the County of Kent, and of the Port of London; by Robert Peirce Cruden" (8vo.; London and Gravesend, 1843).

meet, as nearly as possible, the views of the conservators of the river. The Royal assent was given to the Bill on the 18th June, 1842.

By this Act Commissioners were appointed for carrying out the work: this Commission included the Terrace Directors and other gentlemen, who were empowered to borrow money on mortgage of the several rates, or tolls, granted by the Act, and other property vested in the Commissioners; such sums being limited to £50,000. The Parliamentary estimate being £44,000, namely, £30,500 for the estate, and £13,500 for the pier and approaches. The rates to be applied in paying the interest of monies borrowed, the salaries of officers, in maintaining the pier and approaches, in repayment of the principal monies borrowed, and in forming an accumulating fund to the amount of £25,000, when the rates are to cease, and the interest of such fund to be applied to the support of the pier.

Detailed designs for the work were submitted to meetings of Directors, to a general meeting of Commissioners held in accordance with the Act, and to the Town Council, and being approved, in the month of July the author received instructions to prepare working-drawings. In the month of November the tender of Messrs. Fox, Henderson, and Co., of the London Works, Birmingham, was accepted, and a contract was entered into between the Commissioners and those gentlemen, in January, 1843, for the execution of the works; but preliminary operations were not commenced until the month of April following.

It may be well in the first place to observe, that from its particular locality, and on account of the desire expressed by the Admiralty and City authorities, to have a structure as little as possible detrimental to the navigation, both as regarded obstruction to the tideway and to the passage of boats between the pier-head and the shore, some peculiarity of construction was necessary; with this view a perfectly horizontal design was adopted,—keeping the soffit of the pier as lofty as circumstances would admit, which afforded the same headway underneath, for its total extent, and an uninterrupted in-shore navigation; two additional objects were thus gained, namely, headway for the promenade next the river, underneath the pier, and a lofty horizontal road of approach, meeting the sloping road from the end of Harmer-street, which is considerably above the level of the platform of the pier, thus checking the descent of carriages, and affording a commodious approach to the entrance.

The new pier is constructed principally of cast iron, and projects 200 feet into the river from high water; or from the line of the proposed Thames embankment, laid down in the late reports on that subject by Mr. James Walker, M. Inst. C. E., Capt. Bullock, R.N.,

and the City Officers, and which line is very nearly coincident with the present dwarf piling in front of the esplanade, up to which the water flows. The total length of the work, including the abutment and lodges, is 250 feet; it is terminated next the river by a T head, 90 feet long by 30 feet wide, which is the width of the pier throughout. The platform is supported upon twenty-two Doric columns, of cast iron, and is formed by horizontal girders of the same material, supporting transverse timber-joints, and a planked floor. The external girders are enclosed by an iron Doric entablature, which also forms the parapet. The whole is surmounted by a wrought iron roof, with planking and slates, supported upon iron pilasters, and the sides are enclosed by panels and traversing shutters of corrugated iron. The ascent from the river is by a double flight of oak steps, supported upon iron bearers. The land approach, which is formed by the materials from the excavations for the foundations of the pier, and from the site of new houses in the town, is level with the platform of the pier; the entrance is flanked east and west by stone lodges, and the promenade in front of the gardens and underneath the pier is approached on each side by granite steps leading from the platform. The lodges are surmounted by cast iron turrets, supporting respectively, a clock and a belfry, and the junction of the T head with the longitudinal portion of the pier is surmounted by a cast iron lighthouse, from which is exhibited a powerful light to mark the extent of the pier. The plans for this lighthouse were submitted to, and approved of, by the Elder Brethren of the Trinity House.

The first tier of columns (each tier being formed of three columns in the width of the pier) is in the proposed line of the embankment; girders of 22 feet span, support the platform over the esplanade, from the abutment. The three main spans from thence to the T head, are, between the caps of the columns, two of 50 feet; and one (next the T head) of 51 feet. The columns are (except the first tier) 28 feet long, their bases being level with low water of spring tides, and their caps 8 feet above the level of high water spring tides, which rise 20 feet; there is thus 8 feet headway throughout at that time of tide.

It has been shown, that the inhabitants were aware of the importance of affording shelter from the weather to passengers, and more particularly to their friends awaiting their arrival, or viewing their departure. In the wording of the resolution for the improvement of the town quay, a "shed" was mentioned; this proposition, however, does not appear to have been adopted in any shape, until the erection of the town pier, and even then only two small pavilions, supported by iron columns, and covering each wing of the T head,

were provided, and these, from the fact of their sides being open, and the platform of the pier being enclosed by an open railing, afford only a partial shelter, and this otherwise handsome structure is disfigured by poles and an awning, together with tarpaulin hangings, when the weather requires them. The Commissioners for the erection of the new pier, seeing how desirable it was to afford protection from the weather, both for passengers and for the persons frequenting it as a promenade, by their experience of the temporary pier, which, although only covered by a low planked roof, and the windward side enclosed in bad weather by canvas hangings, proved a great resort in bad or cold weather, where the benefits of fresh air, without the concomitant disagreeables, could be enjoyed.

Lightness of effect has been, to a certain extent, sacrificed to utility in this structure; first, by adopting horizontal, and necessarily, heavier girders for the platform; secondly, by the adoption of a close parapet; and, thirdly, by roofing it in for its whole area, and by enclosing the sides by wide pilastres, panels, and traversing-shutters. The great convenience thus afforded will, however, no doubt, amply compensate for this, and the various parts have been designed so as to meet the circumstances of the case, and to render the horizontal enclosed structure as little objectionable in appearance as possible.

The site occupied by the new pier is very advantageous. The sloping road of approach commences at the Terrace, at its junction with the end of Harmer-street, which is 30 feet above the level of high water of spring tides; from thence to high water mark are situate the gardens and the slopes of the road of approach. The entrances to the pier are well planted. From high water mark the shore rapidly descends to low water mark, a distance of nearly 200 feet. At low water is situate what is termed the Kant Edge, being the edge of a precipitous bank formed by the rapid deepening of the bed of the river beyond low water mark. The foreshore of the river is composed of mud, which varies in depth according to the slope of the shore; it also varies in consistency, increasing in tenacity according to its depth, until where it overlies the silt and sand, it acquires the nature of clay; the flint and gravel bed, overlying the chalk, varies in depth from 9 feet to 14 feet below the level of low water of spring tides, and above the flints is a stratum of yellow loamy sand from 2 feet to 4 feet in thickness, over which there has generally been found about 2 feet of silt and brown sand, upon which lies the alluvial clay deposit.

From May, 1842, up to the present time a register of the tides has been kept at Gravesend, by means of a gauge affixed to the head of the temporary pier. One foot on this gauge was assumed as the

level of a good spring ebb, and zero an extreme ebb; 21 feet on the index marking the rise of a good spring tide, was taken as the datum line for setting out the work by, in the first instance, and the experience of twelve months, before the work was commenced, confirmed this approximation. The greatest rise of tide, during the time over which these observations extended, was 22 feet 9 inches, and the lowest ebb was 1 foot 9 inches below the zero, giving a total lift of tide of 24 feet 6 inches, and the very high tide of October 18, 1841, rose one foot higher, equal in all to a lift of 25 feet 6 inches; this is an extreme case, but it shows there is a greater lift of tide in the river Thames than is sometimes accounted for.

The wind has generally blown from W.N.W. to N.W. at the highest tides, and if it happened to come from a different quarter, it was usually after a prevalence of winds from the N.W., which acting upon the large area of the North Sea, caused a great accumulation of water towards the mouth of the Thames, and a consequent increased lift of tide. The standard usually referred to in the Port of London, called Trinity Standard, is level with 20 feet 6 inches on the index at Gravesend, or 6 inches below the datum level; this is an approximation, by comparing the levels of the same tides at Gravesend and Blackwall.

The first operation in commencing the works, was to enclose the whole area of the site for the pier, with timber fender piles, placed at regular distances apart, to protect the works from injury by passing craft; the intervening spaces being sufficient for the passage of boats. A double purpose was served by these piles, as they were braced together longitudinally and transversely and supported longitudinal timbers, upon which were placed iron rails, the whole forming a railway five feet above the datum level, 40 feet in width, upon which a large timber traveller was worked, supporting a powerful transverse traversing crab, which was altogether 40 feet in height above datum or 60 feet above low water mark; the object of this altitude was to raise the columns vertically over the tops of the cylinders used for the foundations.

While these temporary works were in hand, the foundations of the abutment, wing walls, lodges, and the first tier of columns, were proceeded with; the excavations for them were got out perpendicularly, the sides being supported by planks. These excavations averaged a depth of 25 feet below the surface of the ground, and the foundations were all 21 feet below datum level, or 1 foot below low-water of spring tides. The columns in the first tier are only 15 feet long, on account of their position; they are bedded and secured upon stone bases, and the foundation piers of brick 7 feet 6 inches



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square, are carried down to the chalk; the spaces between and around them, being filled up with closely punned chalk backing. The foundations of the abutment, &c., are supported upon a body of concrete 15 feet in height, brought up from the chalk; great care was taken when drawing the planks from the foundations, to fill up the cavities left by them, with thin concrete, an iron rod the depth of the foundation, being used to assist in forcing it down; this precaution was taken, to make all solid and to prevent the face of the green concrete from falling.

The foundations of the rest of the columns were got in by a somewhat novel process, the means applied having been but seldom used for foundations in this country and then not until very recently, and never before, it is believed, on so large a scale (Plate 13).

Cast-iron cylinders 6 feet in diameter, formed of four segmental plates bolted together, the plates of each ring, or height, breaking joint over those immediately below, were sunk down through the bed of the river, by excavating the ground from within them and weighting them to force them down; fresh lengths were bolted on as they sunk, and they were always kept above the flow of the tide, thus forming caissons or rather miniature coffer-dams. Great care was necessary in pitching them correctly, and in keeping them in position as they were sunk, by counteracting their tendency to diverge from the vertical line. In the case of the second tier of columns, or first tier of cylinders, on account of the great inequality in the pressure around, involved by the sloping foreshore of the river, the two outer cylinders got out of perpendicular, and great trouble was entailed in re-sinking them; in the case of this and the next tier, which form the piers of support between the embankment and the T head, as the shore was so much higher and a larger amount of excavation was involved, than with the rest, external cylinders 7 feet in diameter, were used, which were sunk about half the required depth from the surface of the ground and were supported in that position by clamps and baulks of timber, laid on the shore and bolted to the frame-work enclosing the foundations; these cylinders were carried up above high-water mark and the permanent cylinders, 6 feet in diameter, were pitched within them; by this means they were relieved of a large amount of pressure and were guided more easily, by inserting planks between the concentric cylinders. Before these outer cylinders were adopted, a wooden curb 9 feet deep and 7 feet in diameter, was used for the centre foundation of the tier next the T head, to effect the same object, which it did most completely; but an evil was involved, viz., that at high-water the tide penetrated, between it and the cylinders, into the more porous stratum below, frequently causing

a "blow" or rush of water, bringing with it sand and mud, underneath the cylinders and rising within very suddenly, and it was eventually necessary to drill holes in the cylinder, to allow the water to attain the same height within as without, and to sink the cylinder until near the bottom, by means of a large "miserling" tool, as is done in sinking wells; this process was found very tedious. In consequence of this, the outer cylinders carried above high-water, were adopted. For the foundations of the T head, these outer cylinders were dispensed with; guides were formed, by placing whole timbers upon the shore, which were bolted to the fender piles and so placed as to enclose a tier of three cylinders, across these timbers planks were nailed, so that there was a square space, through which the cylinders could sink freely; they were guided above, at the level of high-water, by a wrought iron ring, held in position by four chain guys, attached to the fender piles: these chains could be tightened or slackened, as circumstances required, by means of screws and sockets; four iron rollers were attached to this metal ring, so that the cylinder slid easily through it, and sufficient play was also allowed at the bottom, between the timbers, to effect the same object. By adopting this plan, the cylinders were sunk very correctly, and from the fact that the ground was but little disturbed, they were got down very quickly, some of them reaching their depth in three or four tides, and from the ground being so little disturbed, the sand stratum was got out quite dry.

The cylinder plates are $\frac{1}{4}$ inch in thickness; a proportion of them were cast 3 feet and 4 feet in depth, to vary the dimensions and thus to suit the irregularity of the substratum, the general depth of the plates, however, was 5 feet. The bottom rings are terminated by sharp edges; at first they were all cast alike, but the return flanch at the bottom was found to offer too much resistance, and facilitated the admission of water down the sides of the cylinders. The joints of the rings which were left in, were made with iron cement, as were also the vertical ones of the temporary lengths; but the horizontal joints were formed with felt and white lead, for the convenience of taking them easily to pieces.

When the cylinders were placed in their positions, they were weighted with from 5 tons to 10 tons, by placing base stones and castings upon them and in some cases, where much resistance was met with, one of the columns was laid horizontally upon the top of the other weights, and thus more than 20 tons was placed on the cylinders to force them down; they were thus sunk to various depths according to circumstances, from 1 foot to 6 feet at a time and this was generally found to take place immediately after the cylinders

were in motion; for when they had once obtained a state of rest, or a "set," no weight that could be placed upon them would affect them. When they were thus sunk an additional depth, the ground from within them was excavated, to 12 inches below the bottom edge, when the weights were again applied, and so on seriatim until they reached the requisite depth; pumps were fixed in them near the circumference and the suction pipe was lowered with the cylinders.

When the cylinders were sunk to the required depth, upon the solid substratum, and the bottom was levelled, a floor was formed, of two courses of dry bricks, and a thickness of 18 inches or 2 feet of brickwork was brought up in Roman cement, with two courses of plain tiles also in cement, the more effectually to break the joints and to keep out the spring water, which in some of the foundations came up in considerable volume. The water was led up, through the work, by an iron pipe 6 inches in diameter, bedded upon the dry courses below, drains being led to the mouth of it from where the water was most abundant. These pipes were connected at the top with the suction of the pump; by this means the water was led away from and kept below the level of the work while it was being got in; when this thickness of cement work was finished, it was generally left several hours, the spring water from the pipe freely flowing over it; when the water was pumped out, if the bottom was found sound, the pipe was filled up with concrete, formed of fine Thames ballast and Roman cement, and a blank flanch was screwed on the top: the floors thus formed were, with the first six cylinders, usually left several hours, in order to ascertain that they were water-tight at high water. This fact was rather curiously proved with the east cylinder of the tier next the T head. The cement floor having been got in and the pipe closed up, it was left during a night, and a very considerable weight, viz., the outer cylinders, was disengaged from the inner cylinders, for fear of its breaking the joint between the brickwork and the iron plates; when the men returned to work in the morning, the cylinder was found to have risen bodily 3 feet, during the night, when a high spring tide occurred and filled the cylinders. When the water was pumped out, the bottom was found perfectly sound and undisturbed, though slightly convex on the surface, from the great pressure to which it had been exposed; the bottom was broken up, the cylinder was resunk and weighted, and the bottom was again got in, and when the cylinder was levelled, there was no perceptible difference from the former level: there would appear to be some difficulty in accounting for the rising of the cylinder, as it was found full of water, but there is no doubt, that the concentric space between the cylinders was first filled, either by the water gently flow-

ing over the outer cylinders, or, as is most probable, by forcing its way down between them and the mud and establishing a communication with the spring water below, which rises up very powerfully at high water; the inner cylinders and the bottom, forming a water-tight vessel, were thus floated up, before sufficient time had elapsed, for the tidal water overflowing it to equalize the pressure.

After this occurrence it was considered prudent, particularly at the T head, where the ground was of less depth and where the cylinders would consequently have a greater tendency to rise, or float up, to dispense with the trial of the bottoms, by so great an hydrostatic pressure, and allow the tidal water to flow over them by means of plug-holes in the cylinders, thus equalising the pressure and allowing the work to set under water, a tide generally occurring after finishing the bottom, before proceeding with the rest of the work. In most cases, after the experience of a "blow" at high water in the first tier of cylinders, no digging was done when near the bottom, nor yet cement brickwork, except for an hour or two before and the same time after low water, to avoid the possibility of a "blow" occurring with a great pressure of water, and also on account of the springs being much weaker at that time of tide; the rest of the work was uninfluenced by the tide.

When the cement bottom of a foundation was finished, a cast-iron cross with a wrought-iron holding-down bolt through it, was bedded in the work, the bolt being carefully adjusted and set to the centre for the column, without reference to the cylinders, (which in some cases diverged a little). The rest of the brickwork was set in mortar, composed of blue lias lime and pozzolana in equal proportions, with $2\frac{1}{2}$ measures of river sand; every fifth course was laid diagonally and iron hooping was also introduced; a space $4\frac{1}{2}$ inches square was left around the through-bolt, to prevent its becoming fixed in the event of its not retaining its perpendicularity; when the brickwork was finished, the bolt was again plumbed and fixed correctly, by driving wedges between it and the brickwork, and the space around it was filled up solidly with thin concrete.

Upon the brickwork was set a circular base of Bramley Fall stone, fairly bedded on its under side and bored to receive the bolt; these stones were attached to the chain of the travelling machinery by slings fastened around the rough sides; the mortar having been laid upon the brickwork, and the stone well wetted underneath, and the workmen having left the cylinder, it was lowered down into its place and then well beetled, if any irregularity was discovered, the stone was raised and reset; the top bed was left rough and was kept about 2 inches above the level of low water of spring tides.

The column was then lowered down and blocked up upon the stone, truly as regarded position and perpendicularity, and was then correctly levelled, and a small piece of deal cut out, of the length the column had to be lowered, as a gauge for the masons, which was applied in numerous points of the circle (the stone being prepared to receive it) between the bed flanch of the column and the stone; a marginal concentric band was thus cut out by connecting these points, varying from $1\frac{1}{2}$ inches to 2 inches in depth, parallel to the seat of the column, which was thus bedded fairly upon the stone, and was let into it for the thickness of its bed flanch. A cast iron cross, sufficiently cambered to clear the rough stone in the middle, was bedded upon the inner flanch of the column, and the nut of the through-bolt was tightly screwed down upon the boss of the cross.

When the brickwork of the foundations was built up to the horizontal joint, where the temporary lengths of cylinders had to be raised from those left in, the bolts were taken out; at first, a proportion of them were left in to prevent the joint being broken, but from the difficulty experienced in getting them out after the stone was set, the whole were afterwards taken out together, and although the joint was in consequence at times leaky, it did not form any serious inconvenience.

The foundations of the two first tiers and of the south row of columns of the T head were thus formed, but with the centre and the outer row of the T head (eight foundations in all) a modification of the plan was adopted, on account of the much larger supply and greater power of the springs; for a more powerful pump was used for these foundations, throwing about 80 gallons per minute, but even then, the water could only be kept down to within 9 inches of the bottom of the cylinders, and that only for a short time, immediately before and after low water. Several trials were made, of placing concentric rings of clamped bricks on edge in cement, but this proved abortive, as the force of the water disarranged them soon after they were placed, and it was evident, that unless pumps of a much greater power, moved by machinery, were used, brick bottoms could not be got in; in this emergency, the following plan was adopted.

Concrete was formed of five parts of rough screened Thames ballast, and one part of Roman cement, which was lowered in buckets and upset below by a man standing to receive it, and who trod it down at the same time. About two feet in thickness of this concrete was got in between each tide, and when sufficiently high, the iron cross was bedded in it. The concrete, although it set very hard and solid, did not form a perfectly water-tight body, for the springs which penetrated it while soft, created small veins which were pervious to

the water, after the concrete had set; a bottom of brick and cement was put in, after a sufficient body of concrete had been got in, to keep down the main pressure of the springs and raise the work above their influence: a pipe was in each case led up through the concrete as described for the other foundations, and was stopped up at the surface of the brick bottom; it was set at bottom in a wooden box prepared for the purpose, to prevent the suction of the pump drawing up the finer particles of the concrete, and the water was led to it by a circular brick drain next the cylinder.

It may be observed, in conclusion, with reference to these foundations, that it is the first instance of cylinders being used for such a purpose on so large a scale, and that the chief novelty consists in applying them so as to exclude the tidal flow of a rapid river, and thus effecting the same object as a coffer-dam; as the few instances of cylinders used in this country for foundations of hydraulic works have been in such a locality as not to be influenced by the tide, or else have been sunk with the water within them by misering tools, which is a tedious process. The cylinders or wells of brickwork, used for foundations in India, are also sunk with the water standing in them, by means of divers, as described by Captain Goodwyn, Session 1842.*

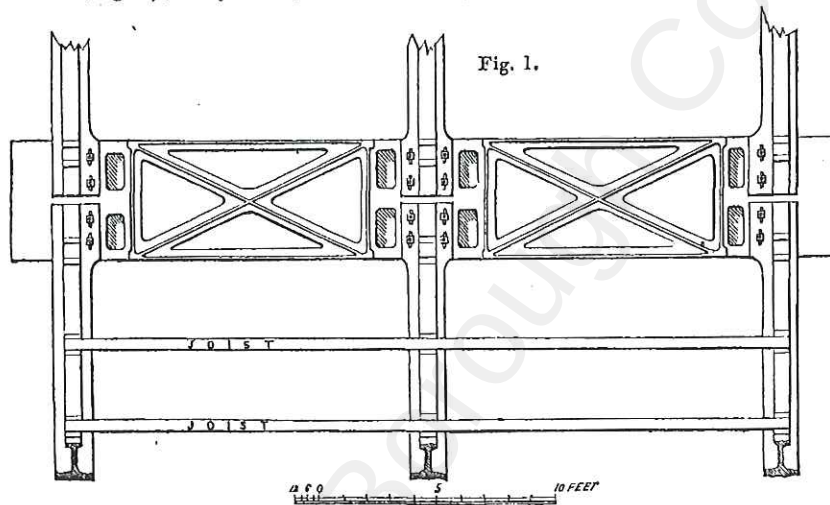
The principal difficulty that occurs in using cylinders, is the tendency they have to diverge from a vertical position when meeting any obstruction; but this may be completely obviated by the fixed lower framing and the upper chain guys. Great care must, however, be taken that the guides do not bind at any point, so that the cylinders may sink freely. Another point to be attended to is, keeping the bottom of the cylinders well down, before digging, to prevent the sand or loose strata from blowing in underneath, when mixed with water. This may be prevented, if the position will admit of it, first, by digging at such a period of tide, that the bottom edge of the cylinder is reached and exposed at low water, when there is the least amount of pressure; and, secondly, by judiciously weighting the cylinders, so as to drive them well in, and to make a water-tight joint before the digging is recommenced.

The shaft of each of the columns is in one casting, 26 feet long and 4 feet in diameter at the base, diminishing to 3 feet at the top, where it is terminated by an internal bracketed flanch, to which the cap is bolted; the base flanch only projects $1\frac{1}{2}$ inch on the inside, being made proportionally thicker so as not to interfere with the drawing of the core-bar in casting. The first large column weighed,

* *Vide* 'Minutes of Proceedings,' 1842, vol. ii, p. 63.

with its cap, fully 10 tons, but it rather exceeded $1\frac{1}{2}$ inch in thickness; the rest averaged $9\frac{1}{2}$ tons in weight.

The columns are held together at their tops by means of cast-iron cross-bracing frames, fitted between the caps and bolted to them (Fig. 1); they were provided with a projecting clip at each angle,



to support them while fitting, before the bolts were placed in. The seven columns forming the junction at the T head and the tier next to it, are stiffened by means of diagonal tie rods, 2 inches diameter; these ties are secured to the outer columns by projecting brackets, and at their junction with the centre column, they are bolted to a flat wrought-iron tie, which passes through the column, the round ends corresponding in appearance with the cast-iron brackets of the other columns; the rods are tightened at this coupling by gibs and keys.

The three girders which support the platform over the esplanade, from the abutments to the first tier of columns, and those of the T head, are cast to one section (Fig. 2); the nine girders forming the three main openings are also of one section (Fig. 3); six of them are 54 feet 9 inches long, and the three next the T head are 55 feet 9 inches long; they are all of a parallel depth and breadth top and bottom, and the long girders are cambered $1\frac{1}{4}$ inch in their length; they are all provided with projections on the top flanch to receive the joists. The weight of these girders is very materially reduced, by making the sectional area of the ends about one-half of that at the centre (Figs. 2 and 3). The smaller girders were proved to

20 tons on the centre, with which they deflected, on an average, $\frac{7}{8}$ inch, and the large girders were proved to 45 tons on the middle. Their deflection averaged $1\frac{1}{2}$ inch, and the results, as shown by the table of experiments (Appendix C), were very regular.

Fig. 2.

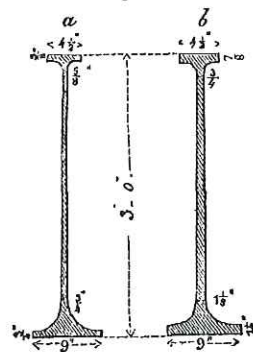
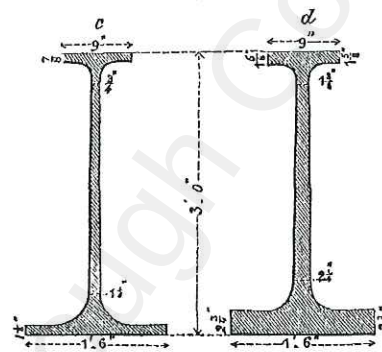


Fig. 3.



End and centre Sections.

The girders are secured from lateral twist and vibration by wrought-iron ties, 2 inches diameter, with clip ends, embracing the top flanges of the outer girders, and keyed to them; they are screwed up to a casting fitted and keyed upon the centre girder. These ties are fixed over the centres of the main spans; the abutment girders and those of the T head on the N.E., S.E., N.W., and S.W. sides (which are most exposed) are secured in a similar manner, the ties being, however, shorter, and secured to the joists which form the tie.

To test the quality of the iron, bars 1 inch square and 3 feet 3 inches long, were cast horizontally from the ladles from which the castings were run, and were broken across with a bearing of 3 feet. The average breaking weight, of sixteen experiments, was 782 lbs.; the highest result was 896 lbs., and the lowest 672 lbs.; in this latter case the bar was barely of the prescribed size, and two small air-holes appeared in the fracture. The other cases that yielded the least amount of resistance were also, generally, barely of the proper dimensions, or there were air vacuities. In most cases, where air-bubbles occurred, the bars did not break at the centre, but they discovered the faulty place nearest to the centre, in some cases as much as 2 inches from it.

The importance of the facility and completeness of the means of landing on, and embarking from, a structure of this kind must be obvious, and with a variable and ever-changing level of water, and

a constant traffic, the floating platform, or dumb barge, is certainly the most advantageous manner of obtaining the first landing from a vessel, in such a situation ; as it would be quite out of the question for vessels to come close alongside an open structure of this kind without some such intervention. Three dolphins are accordingly placed in front of the pier, one at the centre, and one outside each wing ; the piles are protected for 4 feet above, and the same distance below low-water mark, by copper sheathing, which penetrates the mud to preserve them from the ravages of the worm, which in fourteen months committed great depredations upon the temporary piles enclosing the T head, a specimen of which, with a description, has lately been before the Institution.* These dolphins keep the barge at a parallel distance from the T head, where the platform is approached by two flights of stairs, with landings at convenient levels between the outer rows of columns, and a transverse flight from the upper landing, in the same direction as the main body of the pier. The cast-iron strings are supported upon brackets cast on the columns, and they support oak steps and landings, the latter of which project so as to be lineable with the outside of the columns. The steps are protected on either side by cast-iron railings, with open spaces at the landings next the river, where the hand-rails can be lifted up.

The platform is formed of Memel timber ; the joists are caulked down upon the girders, between the shoulders prepared to receive them, and are secured to the top flanches of the girders by clip bolts, to avoid wounding the girders by bolt holes ; the deck planks are 3 inches thick, the edges shot, and planed on the top surface, each board being doubly nailed upon every joist.

The standards supporting the roof are firmly secured to the girders ; projecting shoulders from the back of the standard, with a clip, embrace the top flanch of the girder, and similar projections abut against the face of the girder, at the bottom of the standard, which is secured by a bolt 1 inch in diameter, passing through the centre of the girder.

The Doric entablature enclosing the external girders and forming the parapet is 7 feet in height, rising 2 feet 9 inches above the platform ; it is formed of four tiers of castings ; the architrave, frieze, and cornice, form three distinct heights of castings, and the string, or band, separating the architrave and frieze, and connecting the lower parts of the triglyphs is also cast separately. The entablature is secured laterally, by being bolted to projecting lugs on the faces of the standards, and is kept in position, by cast-iron distance pipes, through

* *Vide ante*, page 77.

which the bolts are passed; the cornice abuts against the standards, and the intervening space between and the projection behind them, is made up by cast-iron cill-pieces, supported upon corresponding brackets on the standards; these cill-pieces are provided, on the surface, with two parallel lines of rails, to carry the traversing shutters, and underneath, with similar projections to receive the corrugated iron lining, forming the inside of the parapet. The architrave of the entablature abuts against the lower flanch of the girders, and where the joints occur, it rests upon it; but the connexions are so arranged, as to leave the entablature uninfluenced by any deflection that may take place in the girders; allowance has been made in every part of the work for expansion and contraction, by slotting all the bolt holes, and by introducing expansion joints, where the castings are confined. For the entablature, a provision is made by grooves cut into the stone-work of the abutment. The extent to which many bridges, with iron parapets and railings confined between stone piers, have suffered, from the expansion of the metal, by large pieces being broken off the stone-work, shows the great necessity for this precaution.

The standards support a cast-iron cornice, which forms the gutter to the roof, it is cast in lengths of 13 feet 9 inches each, the joints being situated over each pair of standards.

The roof is on nearly the same construction as those at the Croydon Railway at New Cross, and other stations, that have been covered by Messrs. Fox, Henderson, and Co., the contractors for this work, with some modifications added to their methods of supporting, and was substituted for a corrugated iron roof trussed with wrought iron, with which it was originally intended to cover the pier.

The principals are formed of two pieces of wrought angle iron with a wood flitch between them, to which the slate boards are nailed; they are trussed with wrought-iron, with a cast-iron strut on either side. The supporting brackets are secured to the gutters by two wrought-iron bolts, which are carried through the gutter at the same inclination as the principals, terminated by an elbow, which is secured to the front of the gutter by a counter-sunk bolt. By this arrangement, the thrust of the roof is carried down to the bottom of the gutter, and is more immediately connected with the standard, and the upright side of the gutter is relieved from cross strain; the principals are connected together by wrought-iron diagonal wind-ties and three ties longitudinally.

Six small skylights are introduced between the T head and the entrance, to light the platform when one side is closed by the shutters, which are provided for each side, so as to close the windward side in bad weather; they, and the panels between the standards, are formed

of corrugated iron, and the spaces are so arranged, that when open, the shutters are stowed away in pairs behind the panels.

The lighthouse, which surmounts the junction of the roofs, over the centre of the T head, is supported upon four inclined trussed bearers, ranging with the roof, springing from the four corresponding standards, and the thrust is taken off by wrought-iron tie rods; these diagonal trusses are 43 feet in span. The octagonal base, formed of cast-iron frames, with corrugated iron panels, is open below for access to the light, and supports an octagonal cornice and lantern, surmounted by a copper ball and vane.

The centre of the lantern is 40 feet above the datum level of high water, and 60 feet above low-water, and the total height, from the base of the outer foundations to the summit of the vane is 82 feet.

The walls of the lodges are formed of Kentish Wragg ashlar, the beds and joints are worked fair, and the faces are left quite rough. The plinths, quoins, cornices, and dressings, to the doors and windows, are of Derbyshire stone, as also the abutment cap stones, quoins, &c.; the copings of the wing walls and a proportion of the column bases are of the same material; the rest of the bases and the abutment pilasters, are of Yorkshire Bramley Fall.

All the foundation walls, as also the abutment and wing walls, were carefully backed with chalk, and a large proportion of the embankment forming the approach was formed of chalk, together with the materials from the excavations. The approaches, around the offices, are covered with concrete 9 inches in thickness, to receive the asphalt pavement. The coping which terminates the platform is of Aberdeen granite, as also the curbs and garden steps.

The lodge roofs are covered with lead, and are surmounted by cast-iron turrets, with corrugated iron panels; each is terminated by a cupola covered with lead and surmounted by a copper ball, vane, and spire.

The pier is lighted by gas from twelve pendant octagonal copper lamps from the centre of the roof, the main running along the west gutter; the lodges and the lighthouse are lighted in the same manner.

In conclusion, the author refers to the Appendices A and B, as arguments for the necessity of this structure, and when reference is made to the table in Appendix A, and the progressive and regular increase of passengers in the last fourteen years is seen, during which a majority has gradually been attained by the Terrace pier, and when it is considered, that of the number of persons landed at the town last summer, a large majority made use of the temporary erection, only 10 feet wide, and which from wear and tear was rather disabled, the necessity for such a work will be obvious.

[1845.]

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The table in Appendix B, showing the population returns from the Parliamentary Census, and also the increase of houses, in both which respects there is a majority in favour of the eastern or Milton portion of the town, of very nearly fifty per cent., is an additional argument in favour of the establishment of this pier.

Appendix D contains a tabular abstract of dimensions and weights, of which details, the foregoing account has been kept as free as possible.

The pier was opened to the public on Easter Monday, after occupying a period of two years in its erection.

The communication is illustrated by three drawings, Nos. 3707 to 3709, showing the details of construction of the several parts of the structure, and an engraved view of the pier is presented by the Author, for the Minutes of Proceedings.

APPENDIX (A).

Statistics of Steam Traffic.

Years.	Number of Passengers landing and embarking.
1821	27,291
1822	44,778
1823	55,101
1824	57,248
1825	71,469

During the early years of steam navigation to Gravesend, the traffic was monopolized by the London and Margate Company. Between the years 1825 and 1829 other boats were employed upon the station, and the numbers probably increased in proportion; but no account could then be kept, until the imposition of a toll in 1829; since which, an account of the number of passengers has been regularly kept, as follows :—

Years.	Town Pier.	Terrace Pier.	TOTAL.
1830-31	291,681	. .	291,681
1831-32	187,687	. .	187,687
1832-33	290,420	. .	290,420
1833-34	292,169	. .	292,169
1834-35	570,452	68,882	639,334
1835-36	550,267	153,192	703,459
1836-37	362,285	262,768	625,053
1837-38	342,622	291,120	633,742
1838-39	359,008	328,928	687,936
1839-40	468,186	344,668	812,854
1840-41	589,194	454,505	1,043,699
1841-42	570,059	571,226	1,141,285
1842-43	. .	. .	1,153,579
1843-44	. .	. .	1,017,102
1844-45	. .	. .	1,750,571

THE TERRACE PIER, GRAVESEND.

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RETURN of PASSENGERS LANDED and EMBARKED at the TERRACE and TOWN PIERS, GRAVESEND, from the 1st of June to the 30th of September, 1844.

	No. of Boats.	June.	July.	August.	September.	TOTAL.
*Star Company . . .	5	100,916	118,334	95,764	81,970	396,984
Diamond Company . .	7	95,444	114,352	78,737	61,429	349,962
*Blackwall Company .	3	77,299	98,169	86,645	70,603	332,716
Sons of Thames Comp.	2	31,356	37,126	31,399	17,535	117,416
Eagle Company . . .	2	11,647	15,278	12,024	7,812	46,761
*Commercial Company.	1	8,374	8,132	6,273	2,236	25,015
Ditto	1	6,608	316	..	..	6,924
Corporation Tugs . .	2	95	..	..	50	145
Total	..	331,739	391,707	310,842	341,635	1,275,923

The packets of the Companies marked * resort to the Terrace Pier.

Terrace Pier, with 9 boats	754,715
Town Pier, with 12 boats and two Corporation tugs	521,208
Balance in favour of the Terrace Pier during the four months	233,507
Gross number	1,275,923
Of which,—	
To and from Blackwall	848,914
To and from Hungerford Market, Waterloo Bridge, Old Swan, } London Bridge, and other places through the Pool . . . }	427,009

APPENDIX (B.)

Population Returns.

(From the Parliamentary Census taken every tenth year.)

Parish of GRAVESEND.				
Years.	Houses.	PERSONS.		TOTAL.
		Males.	Females.	
1801	401	1205	1278	2483
1811	525	1505	1614	3119
1821	646	1796	2018	3814
1831	756	2555	2542	5097
1841	939	3058	3356	6414
Parish of MILTON.				
1801	316	953	1103	2056
1811	398	1159	1311	2470
1821	462	1310	1459	2769
1831	685	1939	2409	4348
1841	1354	4028	5228	9256

Total Population of the Town, comprising both Parishes.

1801	.	.	.	4,539
1811	.	.	.	5,589
1821	.	.	.	6,583
1831	.	.	.	9,445
1841	.	.	.	15,670

APPENDIX (C).

Tables of Experimental Tests of the Strength of the Cast Iron Girders.

TABLE NO. 1.—ABUTMENT AND T-HEAD GIRDERS.

Weight in Tons.	DEFLECTIONS AT CENTRES OF GIRDERS, IN INCHES.						Average of all.
	No. 2 Abutment Girders.	No. 1 Abutment and No. 1 T-head Cantilever.	T-head E. and W. Girders.	T-head S.E. & S.W. Girders.	No. 2 T-head Cantilever.	No. 2 T-head Cantilever.	
5	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{1}{8}$
10	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{8}$ $\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$ $\frac{1}{8}$	$\frac{1}{8}$
15	$\frac{1}{8}$ $\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$ $\frac{1}{8}$	$\frac{1}{8}$ $\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$ $\frac{1}{8}$	$\frac{1}{8}$
20	$\frac{1}{8}$ $\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{8}$ $\frac{1}{8}$
Bearing	22 feet	22 feet	25 feet	21 feet	21 feet	21 feet	22 feet

TABLE NO. 2.—LONG GIRDERS.

Weight in Tons.	DEFLECTIONS AT CENTRES OF GIRDERS, IN INCHES.					Average of all.
	No. 2 Girders 54' 9" long.	No. 2. 54' 9".	No. 2. 55' 9".	No. 2. 54' 9".	No. 2. 54' 9" and 55' 9".	
5	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{8}$
10	$\frac{1}{8}$	$\frac{3}{8}$ $\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$ $\frac{1}{8}$	$\frac{1}{4}$ $\frac{1}{8}$	$\frac{1}{8}$ $\frac{1}{8}$
15	$\frac{1}{8}$	$\frac{1}{8}$ $\frac{1}{8}$	$\frac{3}{8}$ $\frac{1}{8}$	$\frac{3}{8}$ $\frac{1}{8}$	$\frac{3}{8}$ $\frac{1}{8}$	$\frac{3}{8}$
20	$\frac{7}{8}$ $\frac{1}{8}$	$\frac{1}{2}$ $\frac{1}{8}$	$\frac{1}{2}$ $\frac{1}{8}$	$\frac{1}{2}$ $\frac{1}{8}$	$\frac{5}{8}$	$\frac{1}{2}$ $\frac{1}{8}$
25	$\frac{5}{8}$ $\frac{1}{8}$	$\frac{5}{8}$ $\frac{1}{8}$	$\frac{5}{8}$ $\frac{3}{8}$	$\frac{3}{4}$	$\frac{3}{4}$ $\frac{1}{8}$	$\frac{5}{8}$ $\frac{1}{8}$
30	$\frac{3}{4}$ $\frac{1}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$ $\frac{3}{8}$	$\frac{7}{8}$
35	$1\frac{1}{8}$	$1\frac{3}{8}$	$1\frac{3}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$
40	$1\frac{1}{4}$	$1\frac{1}{4}$ $\frac{1}{8}$	$1\frac{1}{4}$ $\frac{3}{8}$	$1\frac{1}{4}$ $\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{4}$ $\frac{1}{8}$
45	$1\frac{3}{8}$	$1\frac{3}{8}$ $\frac{1}{8}$	$1\frac{3}{8}$ $\frac{1}{8}$	$1\frac{3}{8}$	$1\frac{1}{8}$	$1\frac{3}{8}$ $\frac{1}{8}$
50	..	$1\frac{3}{8}$ $\frac{1}{8}$	..	..	..	..
Bearing	50 feet.	46 feet	50 feet	50 feet	50 feet	49.2 ft.

APPENDIX (D).

Tabular Abstract of Dimensions and Weights.

	Ft.	In.
Length of pier	250	0
Breadth between parapets and standards	30	0
T head 90 feet ×	30	0
Brick foundation piers, including cylinders . . . diameter	6	0
Base stones, 2 feet 3 inches to 2 feet 6 inches thick . . do.	5	0
No. 3 columns, 1st tier { 4 feet diameter at base, 3 feet } length	15	0
No. 19 do. at top. } do.	28	0
Capitals of do., 5 feet square at abacus depth	2	0
Cross bracing frames between capitals, 10 feet long × 5 feet wide.		
No. 6 girders, 54 feet 9 inches long span	50	0
No. 3 do., 55 feet 9 inches long do.	51	0
No. 3 do., at abutment, 28 feet long do.	22	0
No. 2 do., E. and W. of T head, 29 feet 9 inches long, } two spans, each	10	0
No. 2 do., S.E. and S.W. of do., 25 feet 9 inches long, span	21	0
No. 4 do., N. side of do., and along centre of same, longi- } tudinally, with projecting cantilever ends, 35 feet long, span	21	0
Standards supporting roof length	13	6
Height of entablature	7	0
Height from do. to roof cornice	6	10
From under side of cornice to apex of roof	6	8
Inclination of rafters of roof, $2\frac{1}{2}$ to 1, or $21^{\circ} 40'$.		
Average depth of foundations of columns below low-water springs	12	0
From low-water springs and bases of columns to datum level of } high water	20	0
From datum level to soffit of pier, waterway throughout . . .	8	0
Soffit of pier to surface of platform	4	3
Height of parapets above platform	2	9
From platform to horizontal tie of roof (headway)	11	7
From do. to ridge of roof	15	7
From datum level, high water, to centre of lantern	40	0
From do., low water, to do.	60	0
From base of foundations of outer columns to lantern vane . . .	82	0
Span of diagonal trussing to support lighthouse	43	0
No. 4 girders to do. length of each	20	2
No. 4 inclined cranked girders to lower landing steps, &c., } 30 feet long horizontal span	25	0
No. 2 curved and cranked girders, joined at the centre to upper } flights of steps, &c., 36 feet long horizontal span	29	0
One horizontal girder supporting transverse flight span	26	0
Three inclined girders to transverse flight, 19 feet long, } horizontal span	15	0
From platform to summit of lodge vanes	30	0
From bottom of foundations to vanes of lodges	63	0

Thickness of Castings.

	Inches.		Inches.
Cylinders	$\frac{3}{8}$	Entablature plates	$\frac{3}{8}$
Columns	$1\frac{1}{2}$	Roof cornice (gutters)	$\frac{1}{4}$ to $\frac{3}{8}$
Girders	varying from $\frac{5}{8}$ to $2\frac{3}{4}$	Lighthouse bearers	1
(see sections).		Lighthouse plates	$\frac{1}{2}$ to 1
Cross braces to columns	1	Lodge Turrets	$\frac{1}{2}$
Standards	from $\frac{1}{2}$ to $\frac{3}{4}$		

Wrought-Iron Work, &c.

	Inches in Diameter.		Inches in Diameter.
Foundation Bolts	2	Joist clip bolts	$\frac{1}{2}$
Diagonal ties to columns	$2\frac{1}{8}$	Standard connecting bolts	1
Girder ties	2	Bolts connecting standards and entablature	1 and $\frac{3}{4}$
Lighthouse truss rods	$1\frac{1}{4}$	Entablature bolts	$\frac{1}{2}$
Tie rods to roof:—		Stair girders, connecting bolts	1
Lower raking ties	$\frac{3}{4}$	Ditto to steps and railings	$\frac{3}{4}$
Upper do.	$\frac{5}{8}$	Ditto to gutter castings	$\frac{1}{2}$
Horizontal do.	$\frac{5}{8}$ $\frac{1}{16}$	Ditto gutters and standards	$\frac{5}{8}$
Cylinder bolts	$\frac{5}{8}$	Ditto roof and gutters	$\frac{5}{8}$
Bolts to diagonal ties to columns	$1\frac{1}{2}$	Ditto to roof trusses	$\frac{1}{2}$ and $\frac{5}{8}$
Ditto to column caps	$1\frac{3}{8}$	Ditto to lighthouse and turrets, and to panels	$\frac{1}{2}$
Ditto to cross braces	$\frac{3}{4}$		
Ditto to seats of girders	1		

Weights of principal Castings.

	Tons	cwt.	qrs.	lbs.
Each ring of cylinders, 6 feet diameter and 5 feet high	1	0	6	0
Per 1 foot in height	0	4	0	0
No. 19 large columns each	9	11	0	0
No. 3 short do., same section, &c. do.	6	0	0	0
Cross braces to columns do.	0	17	2	0
Large girders do.	8	1	0	0
Abutment girders do.	2	0	0	0
T-head girders average weight of each	2	10	0	0
Total weight of stair-strings and girders	7	5	0	0
Small standards supporting roof each	0	7	2	21
Large do. do. do.	0	18	2	0
Large do., at angles do.	1	5	0	0
Weight of entablature, at per foot run	0	1	3	0
Weight of gutter cornice, at do.	0	0	2	5

Mr. REDMAN expressed his obligation to Mr. Fox, and also to Mr. Clarke, for the suggestions offered by them, in the course of the construction of the foundations, particularly with reference to the mode of applying the cylinders and of sinking them.