# TRAFFIC BRIDGE ERECTION.

NOTES on setting out Traffic Bridges, with special references to the observations necessary for the proper location and alignment of Caissons and Cylinders during sinking by the pneumatic or other process.

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The triangulation for long span steel bridges calls for extreme accuracy, and there is no excuse whatsoever for any serious error in the location of the piers. Unfortunately there are cases on record where the superstructure has had to be lengthened or shortened owing to location errors, which could never have crept in had a proper system of cross-checking been adopted.

The Jefferson City Bridge, U.S.A., with a distance between the base lines on the bridge tangent of fifteen hundred feet, was carried out by J. A. L. Waddell, C.E., with errors not exceeding 3-16 of an inch in any part of the work. The triangulation for the Sioux City bridge, made by L. Treadwell, M.Am. Soc., C.E., having a bridge tangent about two thousand two hundred feet long between base-lines, was practically perfect, for, when the falsework was erected, and direct measurements made on top, no appreciable error could be detected.

A very interesting account of the base-line measurements and triangulations for the famous Forth Bridge, was written by R. E. Middleton, M. Inst., C.E., and published by F. N. Spon, London. A copy of this little book is probably to be found in the University Library. It gives very complete details of the special means taken to secure accuracy in the location of the enormous piers, where the main central spans were 1710 feet from centre to centre of vertical columns, and the waterway 5700 feet. Observatories with concrete piers, carrying specially constructed theodolites, were erected at triangulation points, and numerous other costly works carried out in connection with the triangulation surveys to secure the maximum accuracy in the setting out of this important structure.

It is not however, the province of this paper to deal with the surveys for such huge structures as have been mentioned, where each bridge is treated differently, with special reference to local conditions, and where the absence of temporary staging around the piers requires that all locations must be made, and any rotation of the piers during sinking watched, entirely by direct triangulation.

The following notes are gathered from actual experience in the construction of many traffic bridges for the Public Works Department of New South Wales, and give what may perhaps be called a few "wrinkles" which the author has found useful in locating bridge piers, and keeping a constant watch on all movements during sinking.

Three bridges have been selected, which have been erected under his supervision, and which, of their kind, are the largest traffic bridges yet constructed in the State. Helios of the general elevations of these bridges have been kindly lent by Mr. W. J. Hanna, the Commissioner and Principal Engineer for Roads and Bridges, for the purpose of illustrating this paper.

In each case, temporary staging was used for guiding the caissons or cylinders during descent.

KEMPSEY BRIDGE.—The main, or waterway structure of this bridge consists of four truss spans of 154 feet centre to centre, supported on five iron cylinder piers of the usual pattern adopted by the Works Department in rivers liable to heavy floods. The piers are iron cylinders 6 feet diameter; cast-iron, in sections 6 feet long below H.W.M., and wrought-iron above; spaced 27 feet apart, and braced above water level with elliptical sheet and angle-iron bracing.

As this bridge gives a typical example of cylinder sinking and the foundations were carried to the great depth of 84 feet below L.W.M., ranking among the deepest in the world sunk by the pneumatic process, it will, as far as possible, be used as an illustration for setting-out work.

As is usual with this type of bridge construction, a start was made with the cylinder sinking as soon as the preliminary work of plant erection was finished, so as to have the piers completed ready to receive the superstructure, which is, of course, put in hand immediately the contract is let.

Eight heavy guide piles were first driven at the site of the first river pier as shown on sketch. These piles were placed in such positions as to give ample room for the cross-bracings and guide timbers for the cylinders.

A slight error in the positions of these temporary piles is of no consequence, as the vertical guide timbers, which direct the exact location of the cylinders, are placed at a later stage, when the piles have been well tied together with top and bottom walings, cross braces and struts. Direct measurements, with a long steel wire riband, if carefully done, will be found sufficiently exact for the work, the lines being given with the theodolite. It is a very different matter, however, when it comes to placing the cylinders in their correct position in the guides—and keeping them there. There is no more difficult measurement to make correctly than one with a long steel wire between the piers, without intermediate supports, and as there is always danger from floods, the falsework to carry the trusses is not erected until actually wanted, and direct measurements having real values cannot well be obtained.

The trusses of this bridge were of Ironbark timber, built at the site, with timber chords having iron cover-plates over joints. It may, perhaps, be thought that a small error between the piers would be of little consequence with a superstructure of this class. The timber chords could have been lengthened or shortened without serious cost in this case, no doubt, but, still, there cannot be one error alone. If the first pier was too close inshore, the following span would be too long, unless the same error was repeated, when the accumulated shortness would give endless trouble in the event of the chords being completed before the piers.

It is just as easy, and much more workmanlike, to consider the superstructure to be a steel truss, built elsewhere, exactly to a drawing with given dimensions between end pins, and to permit no error in the location of the piers beyond what could be rectified by a slight adjustment of the bed-plates, centred on the concrete pier by the holding-down bolts.

The Macleay, over which this bridge was erected at Kempsey is a navigable tidal river, with deep water channel. The contour of the banks gave opportunities for what may be called an ideal system of setting out; that is base-lines could be run at exactly right angles to the longitudinal axis of the bridge, two on each side of the river, and station points located thereon having centres corresponding to the distances from the base-line to the piers, so that all sighting lines would intersect the centre line at angles of 45 degrees. This, of course, cannot always be done, but a similar system, with small modifications will readily suggest itself.

Commencing the setting-out work, the permanent centre-line has first to be established on both sides of the river, and should be staked out with solid 4-inch spare pegs, driven to within half-an-inch of the ground, and furnished with tacks on which the centre line is cut with a file edge.

To young engineers it may not be amiss to suggest here, that if the centre line has to be continued across a river by reversing the telescope from a back sight on a spike-head, the collimation of the instrument should be carefully attended to. In any case, to avoid any chance of error, it is advisable to take double reverse readings on the top of a clean peg across the river, and take the mean for the tack point. To facilitate this work, the author has devised a special target, here exhibited, which gives a clear sight at a long distance, and is provided with an arrow point for describing the exact position on the peg. It is, perhaps, unnecessary to add that the chainman must be carefully instructed as to what he has to do, before crossing the river, and a proper system of signals arranged.

At this stage, much attention need not be paid to the distanees between pegs. Spots can be chosen, and pegs put in at suitable positions, merely to locate the centre line.

Omitting the locating of the timber piers for the approach spans, which involves simple chaining, and cross-section or square lines only, the exact position of the first iron pier on the river bank has now to be determined.

If the pegs from the original survey remain standing, they can be accepted temporarily as correct. If knocked out, one must be put in by careful chaining from a marked spike, or station point already located. Taking this pier as a starting point for setting out the river piers, it was found that by going back a certain distance—say 30 feet on the centre-line, base-lines could be run on the high banks at exactly right-angles to the longitudinal axis of the bridge, as shown on sketch. One line on the up-stream side of the bridge was first staked out for a distance somewhat exceeding that of the total length of the river spans, as shown on plans, from bank to bank.

Waddell's system of measuring a base-line is generally used by the author; it is simple and practical, the steel tape measurements being adopted in preference to rods, as being more accurate. The objection to using rods is that it is almost impossible to run a line a thousand feet long with three rods that must always be made to actually touch each other without some times disturbing slightly the position of two of the rods when either lifting or putting down the third rod.

A line of pegs, say 3 x 2 inches, and about 18 inches long are spaced at intervals of say 10 feet, and put in to exact line and level, with a large flat-headed tack driven to line on each stake, and the true base-line scratched with a knife or file edge along the top of each tack. The line is measured by stretching the tape with a uniform pull or six pounds over the line of stakes, keeping the zero mark over the centre that is cut on the peg at the start of the base-line on the bridge centre, and scratching with a knife on the tack where the fifty-foot mark on the tape comes; then, starting from this point to measure another fifty feet, and so on, until the centre of the peg at the far end of the base-line is reached.

The next time that the line is measured, starting from the same place, the first length should be forty feet, so as to avoid using the same tacks, succeeding first length should be ten feet shorter. This not only involves the use of fresh tacks for each measurement, but also prevents any manipulation of the tape so as to make the partial measurements agree with those made previously.

In case that a perfectly level line cannot be obtained, the line should be divided into level stretches, and where each break occurs the length should be measured on the incline, and corrected afterwards for the effect of rise and fall, so as to obtain the true horizontal distance. All these measurements should be made in cloudy weather, just after sunset, or even at night; and the temperature should be noted for each fifty feet measured, as all LENGTHS MUST BE REDUCED TO THOSE FOR AN ASSUMED STANDARD SHOP TEMPERATURE of 70 degress Fahrenheit. Even slight variations of temperature will cause errors of importance in the length of an ordinary base-line, the change in length per degree of temperature and per unit of length being about 0·0000066. For a base line of one thousand feet and a variation of one degree, the change in the length would be eight one-hundredths of one inch. Thus is not much, but there is always a liability of there being a difference of as much as ten degrees between the average temperatures for measurements made on two different days, and as much as two or three degrees in a single measurement of a base-line.

Assuming that the base-line has been right-angled at a point 30 feet back from the first cylinder pier inshore, and that the distance from centre to centre of piers is to be 154 feet, it is clear that to make the sighting line at an angle of 45 degrees, the first distance to be established must be 154 x 30 - 184 feet, measured from the bridge longitudinal axis. There will, of course, be a tacked peg already established at 180 feet, so that it will now be necessary to put in a permanent and heavy peg, four feet ahead. This peg should be at least 6 x 6 inches, driven well down, arrises taken off, painted white, and clearly branded with the number of pier to which it belongs. The centre line is scratched in, right across the peg, and, at the exact 184 feet, a small hole is drilled with a No. 5 Boker bit. All permanent pegs are thus marked, to enable them to be easily recognised; the drilled hole being used to hold the arrowpoint of the special targets, as illustrated. These targets are very useful at different points in the work, as will be explained later. Protecting tripods of heavy stakes should be driven over these main pegs in such a manner as to permit a view of the target through the legs, and the dropping of a plumb-bob over the centre hole when the theodolite is set up over them, without having to disturb the protecting stakes.

Permanent pegs are now continued, spaced 154 feet apart. The peg from which a sighting line at 45 degrees will run to locate the No. 5 Pier on the opposite bank will be at chainage 30 x (154 x 4) - 646 feet. The line may be continued to, say 700 feet to allow of the opposite base-line being located within about 50 feet back from the pier, on solid ground. These, and similar points can be settled by a previous rough inspection of the country, with a compass and metallic tape.

Setting up now over the peg marked No. 5 at chainage 646 feet, and turning an angle of 45 degrees, will give the first trial location for its position on the opposite bank. It oftentimes happens that by digging a little below the surface where the target-rod is held up by the chainman, on the bridge centre line, that the original survey peg will be discovered. This, if found is, of course, a very useful independent check on the work so far. The author has, on occasions, unearthed a peg, and closed exactly on a small tack put in years before by another surveyor, using an entirely different system of base-line triangulation.

A check on the first trial location for this pier, and which is also used for the other river piers, is obtained by running another and exactly similar base-line, below, or on the downstream side of the bridge centre, as shown on sketch.

A final check of the triangulation, and a permanent record of the locations, can be obtained in this case by running two exactly similar base-lines on the opposite side of the river, with station pegs established, bored with a centre hole as already described, which can be used for holding targets, or setting up over, as occasion demands.

Removing the instrument from the up-stream base-line, and setting up over No. 5 peg on the down-stream line, a 45 degree angle is again turned, which may, or may not intersect the first target put in to locate the pier. It is well to turn the angles, and measure all lines, many times, until the intersection of the three lines on the one peg comes within a tack head. This should not be difficult on moderate lines.

The inshore piers on both banks having been permanently located, cross-section pegs at right-angles can be put in, with pegs giving the centre of each cylinder. It is desirable to run a line or two, parallel with these piers, well clear of all crib-work or staging, pegged with bridge and cylinder centres. All distances and references should be carefully booked, as when sinking starts, all the pegs put in at the site of the pier will be removed by the excavators. "Wing-pegs," at carefully chained distances, well clear of all operations, should also be put in and well protected.

When sinking operations are ready to start for the river piers in deep water channel, all locations can now be promptly given from the base-lines permanently established.

Starting, say at pier No.2. The staging piles, located and driven, have been fitted with walings; one set near water level and another set, say ten or twelve feet up near the pile heads, all securely bolted and braced. Heavy timbers, say 12 x 6 can now be bolted across the walings at top and bottom, and a true centre line given by the theodolite, and cut in by a deep saw-cut right across the upper faces. Setting up now on the pegs marked No. 2 on the up and down-stream base-lines, and sighting to the targets fixed in the pegs on the opposite lines, two points are given which should intersect on these timbers, on the saw-cut bridge centre.

It will, of course, be noticed that when this system is adopted, with proper targets permanently located on the base-lines, it is not necessary to turn the angle when giving a location. The instrument is set up over the required peg, levelled, and sighted direct to the target, which bears in distinct figures the number of the pier to which it belongs.

To enable the guides, for directing the descent of the cylinders, to be set in their proper position, it is sometimes convenient, after the pier centre has been located as described, to take the theodolite, mounted on a wall tripod, on to the pier staging, and setting up over the 12 x 6 timbers on the centre, turn a right angle in each direction, driving nails in the staging to mark the exact square line of pier.

Now, it oftentimes happens, especially when the overhead system of wire tramways is used for erecting purposes, that a view of the targets on the bridge centre line is very soon obstructed by derricks and piles, and unless some other additional means have been arranged beforehand to locate and watch the cylinders, considerable trouble and delay may arise. The author's practice has been to run two additional lines, parallel with the longitudinal axis of the bridge, starting from the base, or sighting lines, at such a distance up and down-stream, as will clear the outside edges of the cylinders by about one foot; this gives about six inches clearance beyond the vertical guides. The outside staging piles are usually kept far enough apart to allow of a clear sight between them and the guides, and a sight always obtained, right down to the water's edge. These lines are shown on sketch.

The cylinders being 6 feet diameter, and spaced, say 27 feet apart, the distance from the bridge centre to the outside edge of cylinders will be 13' - 6" + 3' - 0" = 16' - 6". By making the lines 17' - 6" from the centre, permanently pegged on the base-lines on each side of the river, a sight can ben given for each cylinder—one foot clear of the edge.

The author has devised a hand level, here shown, conspicuously painted, and graduated to hundredths of a foot, in a manner similar to an engineer's levelling staff. By setting up on he base-line pegs, and sighting to the opposite targets, lines are given exactly one foot from the cylinder edges. Now, if this hand-level is held by a workman, first at top, and then at the bottom on the outside alignment edges of the cylinders, the reading should be, of course, exactly one foot. Any error in plumb is, therefore, read off simultaneously with any error in alignment.

Watching the longitudinal alignment of the cylinders is thus a simple matter, and if the theodolite is kept in perfect adjustment in altitude, the column out of water, which is often of considerable height, can be set, and kept plumb, without frequent plumb-bob checks inside.

For the convenience of the ganger, or cylinder foreman, the author has devised a small telescope with cross hairs and eye-piece, mounted in a flanged boss which is secured to a pine batten as shown. This can be fixed on a post, so as to allow the centre of cross-hairs to come over the peg on the base-line, and sighted to the cross river target. This device is not intended to supersede the proper instrumental check, but is useful as a guide to the foreman, who can himself, at any time, have a look at his alignment. This device also makes a very different long-distance boning-rod for camber, etc.

After the cylinders have been placed in position with the air-lock and other plant in place on top, all further sights on the cross section of the pier will be obstructed. To watch any rotation of the pier, or any deflection from the square line, the author's practice has been to establish two points on the walings of the pier staging, put in by sighting from the base lines, as shown on sketch, the angles being as before, all 45 degrees. It will be noticed that one line can be sighted from the base-line to a target fixed on the opposite bank base-line. The view of the check line from the adjoining base-line is obstructed by the cylinder, so that the angle must be turned when making an observation after the cylinders are in position. Staging of the class usually adopted for this work, especially when the piles are in deep water, and only braced above the water line, is very liable to movement, and these points, established by nails driven into the walings, should be constantly checked. If found correct, by running, say a chalk line between these nails on the staging, and measuring the distance from the line to the edge of the cylinder, any error in position, as regards the cross section line can at once be detected.

Plumb-bobs are usually kept hanging on two sides of a cylinder column during sinking, but occasionally it is advisable to check the plumb of the column from the inside. To do this, a batten is placed across the air-lock floor, over the open man-hole, and a heavy plumb-bob suspended, with its point nearly down to the cutting edge. By using a small pine straight-edge about 4 feet long, the plumb-bob string can be accurately centred at top of the column. It is well to have the bucket drawn up out of the way, and to run a "tom" from flange to flange of a cylinder to stand upon, under the air-lock floor, clear of the string. When centred, an assistant can read off down below at the same time, taking care, of course, to have the up and down-stream marks noted on the inside walls of the cylinders. The column will at times slowly revolve during sinking, and a marked flange will deviate considerably from its original position.

Daily notes should be kept as to the exact horizontal position of the cutting edges of the cylinders, the position of the top of the pier—the elevation of the cutting edges—the errors of plumb, and any deviation of the pier from the true square line. The contractor, or his foreman, should be given, at least once daily the relative position of the pier, and the engineer must satisfy himself that the necessary action is taken to remedy any errors promptly.

Extra precautions are necessary during the first few feet of sinking. If a cylinder column is located, and landed correctly and started evenly, and well watched during the early part of its descent, half the battle has been won. Once a pier gets out of plumb or position, it is generally very troublesome to get it back again, and the difficulty increases with the depth sunk in the gravel. This is specially true with piers sunk by open diving.

At the bridge under notice, owing to the great depth of the foundations, the business of sinking by the pneumatic process was a very hazardous one, many of the workmen being temporarily incapacitated by the pressure. Fortunately, no loss of life resulted, but it was considered advisable, after some experience, to try divers for some of the channel piers—the river formation being of such a nature as to be easily removed by this means.

The iron cutting-edge is first placed on the staging, and correctly located by the methods already described, and a sufficient number of 6 feet cylinder lengths bolted together by internal flanges, as to permit of the top lengths showing out of water after the column is lowered to the river bed. The weight of the column will, when lowered, bury the cutting edge some distance in the sand. Levels taken around the upper flange will be of some assistance in ascertaining if the column has descended truly plumb, and the position of the top should be carefully checked before any more cylinders are added. When an air-lock is used, it is the practice to bolt on if possible, a sufficient number of cylinders to reach rock without shifting the air-lock and connections. Owing to the great depth here, this was not possible, but a long column was generally showing above water on which to make observations, which, of course, could be supplemented by internal checks for plumb as already explained. When diving was resorted to, however, the cylinders were never much higher than the staging, and obviously a plumb-bob could not be used inside. As sinking proceeded, additional cylinders could be added with little trouble, the only plant to be removed being the small hand windlass on the usual diver's outfit. By constantly levelling with a good hand-level and straightedge on the top flanges, and serious departure from plumb could be detected, and the diver instructed accordingly. By digging away the gravel more on one side than the other, it is possible to give a cylinder column a considerable lateral movement.

When completed, the alignment and position of the five piers of this bridge was practically perfect, the errors of location being within the limits mentioned in the first part of this paper.

LUSKINTYRE BRIDGE.—The main or waterway structure of this bridge consists of two steel trusses of 198 feet centres of bearings. These main spans, which are the longest truss road bridge spans yet erected in the State, consist of each of a pair of steel trusses 25 feet deep between centres of chords, in 11 bays of 18 feet each.

Owing to the great height of the river pier, the wrought iron cylinders were placed at a batter of 1 in 12 in order to obtain a wide base. These cylinders are secured together by lattice bracing, and connected to cast-iron cylinders 6 feet diameter, sunk to rock rock at a depth of 38 feet below the river bed—all the cylinders being filled with concrete. The two main land piers are each formed of a pair of cylinders 4' 6" inches diameter sunk to rock, which, in the deeper pier was met at 64 feet below the river bed.

Here, owing to the contour of the country, it was only possible to run one base line. The independent triangulation made by the author, closed exactly with carefully marked pegs put in by Mr. Robert FitzGerald in his original survey.

The central pier was located by observations from the baseline stations, and checked by direct measurements. There was an old low-level bridge, close to, and nearly parallel with the new work, and this was used for direct chaining. Setting up over the pegs locating the main land piers on the high banks, right angle lines were run out crossing the main road leading to the old bridge. Putting in pegs at equal distances from these piers, a line was staked out on the longitudinal axis of the old bridge, exactly parallel with the new bridge line. The line was carefully chained in sections, all heavy slopes down the precipitous banks being measured on the incline, and corrected for rise and fall.

The position of the central pier was located on this line, and spiked on the old bridge floor. Another spike was also driven four feet from the actual centre, and was used to keep to the pier perfectly square on the cross-section line, the sighting level previously described, being used for the purpose.

This pier being very lofty, and constructed on a batter, precluded the use of a plumb-bob inside, when erecting the wrought-iron cylinders. For the same reasons, a plumb-bob was of little value outside the pier, as the bracing only could be checked by this method. In addition it may be mentioned that heavy winds prevailed during nearly the entire term of construction, and a plumb-line could seldom or never be used with advantage. The theodolite was kept in perfect adjustment in altitude, and all plumb readings taken from a marked peg near the base of the pier, to the sighting level held against various points of the cylinders as required.

The steel trusses were manufactured in Sydney. Direct measurements were taken over the bottom chords when completed, by a steel riband having a stated pull and recorded temperature. The same wires, spring balance, and thermometer used in these measurements, were sent to the author at Luskintyre, the actual distance between centres of bearings being marked on the wires. Following as nearly as possible the same conditions, this wire was stretched over the false-work, and the centre of bearings marked on the granite blocks forming the tops of the piers. Beyond a slight adjustment of the bed-plates carrying the expansion rollers, there was no error whatsoever in the work. The bed-plates were bolted down, the rollers placed, and when the girders were run out into position and connected to the rocking plates, the work was found to be perfect in every particular, requiring no further adjustments of any kind.

RICHMOND BRIDGE.—This bridge consists of 13 re-inforced concrete arch spans, each 50 feet in the clear, with an overall length of 722 feet and a roadway width of 21½ feet. The arches were constructed on the Monier principle, with round steel bars forming a three inch mesh, imbedded in the concrete. The caissons were all sunk under air-pressure to rock, into which they were carried about two feet.

This is the first application of this class of foundation in the State, and as far as there is any record, only the second bridge constructed of this character—a low—level structure of re-inforced concrete in a river subject to high floods.

The piers consist of two elliptical caissons, each 10 feet by 5 feet 6 inches, built entirely of concrete. These caissons were sunk to about 30 feet below the river bed, and finished with their tops about summer level. An arch was then sprung, joining the two caissons, and the pier carried up in solid concrete to the required height.

It will noticed on reference to the general elevation of this bridge, that the designers have given absolutely no latitude to the constructing engineers as regards the position and alignment of the caissons. There is no convenient offset at the junction of the caissons with the batter pier, to cover up any signs of location. It is a curious thing, but these long caissons have a tendency to rotate on their vertical axis during descent, even when well wedged between six sets of guide timbers. A pair of caissons will also unfortunately, rotate at times in opposite directions, and if allowed to continue, would make a very ugly break at the junction with the pier proper. Unremitting attention was needed to keep a pair of these caissons exactly on the square line.

Altogether there were 24 caissons to sink, and the location in each case had to be practically perfect—there was no help for it. This is probably the largest amount of caisson sinking ever done in one bridge in Australia.

Fortunately, again there was an old bridge running nearly parallel with the new structure, and it was decided to use this for setting out purposes. No base-line or triangulation was adopted in this case, all measurements being made by direct chaining.

After locating the centre line in the usual manner, two short lines were run on the high banks on each side of the river, at right angles to the longitudinal axis. These lines were kept well back from the abutments, and as far as possible, out of the way. Two pegs were put in on each line, at such a distance from the centre as to give one foot clear of the outside edges of the caisson, up and down-stream as before described.

On a concrete job of this class, with constant carting, etc., it is practically impossible to keep ordinary pegs safely guarded. To preserve the alignment points on the banks from all damage, the author had short lengths of pile heads, about 20 inches in diameter and four feet long, sunk into the ground and well rammed, the heads being square cut, the tops slightly below ground level. Waggons have at times passed over these pegs without disturbing the marks, which consisted of drilled holes as before described. Constant friction often takes places on works of this description, between the engineer and contractor, owing to disturbed pegs. The fault can rarely be located, and a careless workman fined or otherwise punished; and the author has found it the better policy, to either put the pegs out of the way, or to so adjust matters that a collision between a man and a peg would be much in favour of the latter. These sunken ironbark piles meet the case admirably.

Staging, exactly similar to that already described, was used on this bridge.

The alignment only was given from the shore pegs. Permanent targets, protected by tripods, were stationed out of the way on the opposite banks, and by direct sight, nails were driven in each waling of the staging. When setting the cutting edge, it was only necessary to keep the face one foot inside of a straight-edge laid across the nails.

The location of the pier centres was done entirely from the old bridge. Off-setting from the face lines of the abutments a line was carefully chained, and station points for each pier put in. The deck of the old bridge consisted of tarred metal. Where a peg was required, a small hole was cut, and a pan-headed rivet run in with lead. After lining up and re-chaining, a permanent pop-mark was punched in the rivet head. Constant and heavy traffic did not disturb one of these rivet marks during the erection period of more than eighteen months. These station points were not put in for the exact centre of the pier, but were kept, in each case, one foot clear of what was to be the finished side of the caisson, that was, 3' 9" past the centre. Permanent targets were located at each end of the line, and to give a cross section line, for setting the caissons, the instrument would be set up over the station point, sighted to the farthest target, a right angle turned, and nails put in on the staging—again one foot away from the true face. Fore-sights could not be permanently located here, owing to the river contour, but as the line to the caissons, forming one leg of the right angle, was very short compared with the other line to the target, a little care enabled the same nail to be picked up every time an angle was turned.

The caissons could be watched by means of the graduated level before described, and any wrong movement at once detected.

With the modern air-lock in use on this work, the sinking of these caissons was very rapid, and it was necessary to have the instruments in constant use daily. Considerable quantities of timber were met with during sinking, and the most vigilant observations were necessary to keep to caissons in proper line.

The short lines on the high banks, carrying the caisson alignment pegs, were later on supplemented with other pegs (or piles) to line up the arches, spandril and coping walls. The overhead system of wire-rope tramway being in use, it was never possible to get a sight through on the centre. Pegs on each side of the centre were used at convenient distances, for lining up the trusses and lagging for supporting the arches during erection. When the concrete coping walls were started, pegs were put in on the high bank line spaced one foot less than the over-all width of the bridge; setting up on these pegs, and sighting to corresponding targets on the opposite side, gave, of course, a line six inches inside of the finished coping walls. As the walls were erected, and before cement rendering, numbers of cement pats, were set 10 feet apart on the rough concrete. These pats were smoothed off to the exact finished height of the wall, and, when partially set, the line was given on them, and cut in with a knife.

A 6 inch by 3 inch groove ran from end to end of these walls, carrying a collapsible handrail. This cut-in line was found to be very convenient for setting this work.

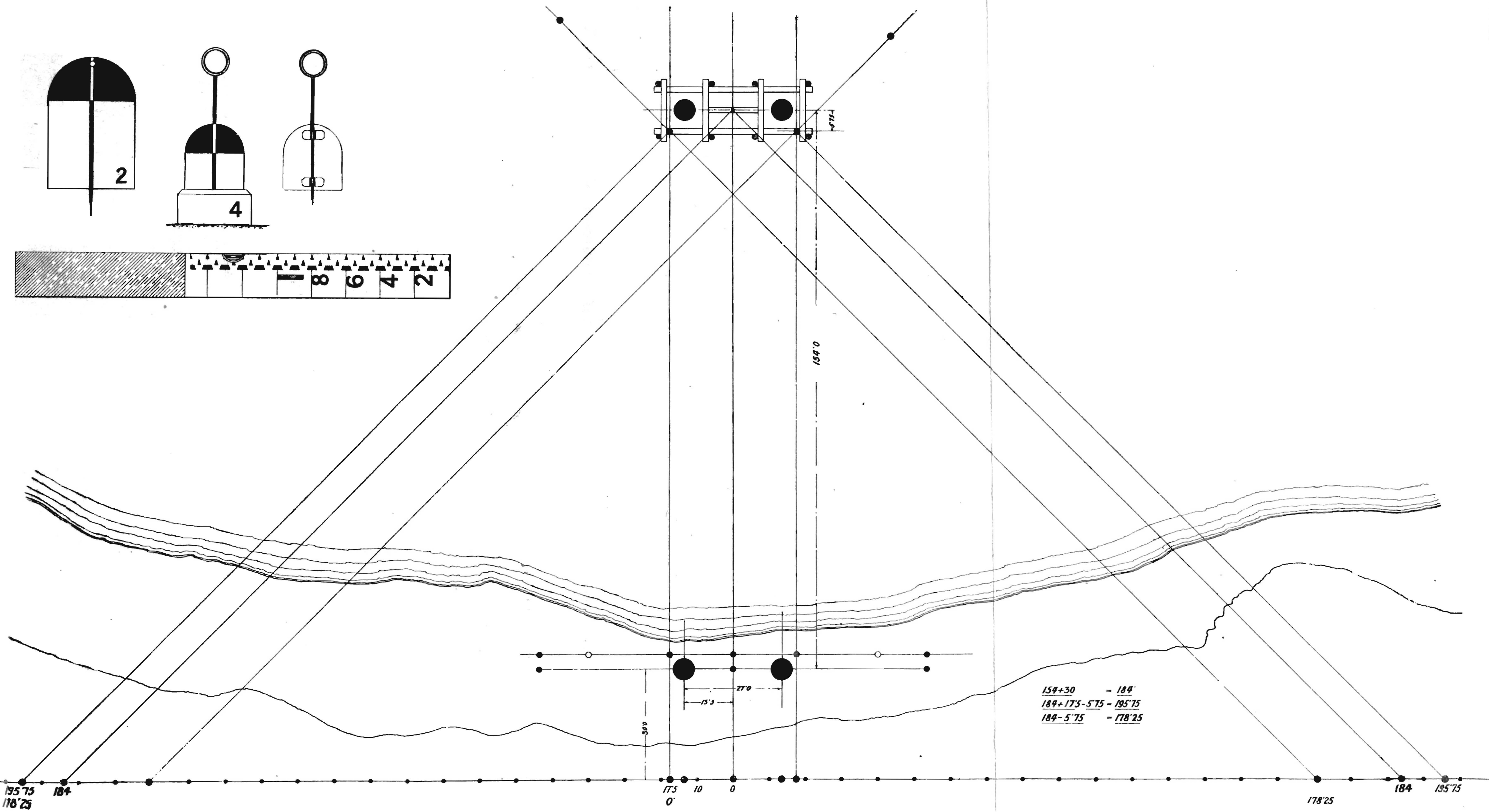
The plasterers were provided with templates, made exactly to the form of the outside rounded coping, and inside gutters. These templates were made in angle form, the top leg being designed to rest on the concrete pats, with their ends coincident with the cut in line on the cement. By this method, the finished cement work was brought to perfect line and level. It was also a simple matter to check the plasterers' work, and keep them up to a proper standard—to take these templates, and try them on the work in progress.

In respect to the levels for these bridges: bench marks are cut and recorded on the original survey, usually one at each end of the bridge, at specified heights above the bridge datum. Before starting work, these bench marks should be checked, to ascertain if their relative values are correct, and agree with the plans. The author has met with a case where levels, taken from bench marks on opposite sides of a river, to give the cut-off for abutment piles were found, by direct sighting with boning rods, to be about two feet out of truth. Investigation by the foreman in charge of the work discovered the fact that one bench mark had been cut on an old tree stump, situated near the river bank. Floods had occurred during the interval between the original survey, and erection, causing a scour in the banks, and the partial dislodgment of the tree stump.

In giving levels for river piers, it will often be found necessary to have long fore-sights, owing to the impracticability of setting up the level near the piers. In such cases a back-sight should be taken to a bench-mark about the same distance from the instrument as the piers, and in the opposite direction, so as to offset a possible slight lack of adjustment in the level, and to compensate for curvature.

It is advisable to establish several bench-marks in handy places throughout the work, on thoroughly stable posts, or masonry, and to book their descriptions and values. These marks should be checked, until their absolute reliability is assured. Levels are constantly asked for on an important job, and very often in a hurry. It is bad policy at such times to have to run a line of levels from a distant bench-mark, occupying a lot of time, when a little forethought would have provided a mark near at hand.

In concluding these notes, which may be said to have touched only the fringe of the subject, the author does not wish to take credit for anything particularly new. It is understood that he has written especially for the benefit of young engineers, who may not have had much practical field experience, and he trusts sincerely that the matter may prove of some slight service to them when engaged in similar work. He would plead for accuracy in small matters as well as in great, in all engineerinng works. It is astonishing from what a small blunder, mountans of trouble, expense, and often costly litigation may arise.



2
4
8
6
4
2
154'0
27'0
13'5
30'0
154+30 = 184
184+17'5-5'75 = 195'75
184-5'75 = 178'25
195'75
178'25
184
17'5
0'
10
0
178'25
184
195'75