THE HUELVA PIER OF THE RIO TINTO RAILWAY

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WILLIAM HENRY BARLOW, F.R.S., Vice-President, in the Chair.

The following Candidates were balloted for and duly elected:— Robert Rowan Greene, Thomas Hack, Arthur Willoughby Hemans, Charles Minns, Patrick O'Meara, and Charles John Wood, as Members; Thomas Armstrong, James MacLellan Blair, John James Bodmer, Charles Archibald Grieve, William Hayward, Maurice Kingsley, Samuel Robert Lansing, Edwin Melville Richards, John Salter, Charles Walter Scriven, Stud. Inst. C.E., George Henry Stayton, Matthew William Thompson, and Arthur Ventris, Stud. Inst. C.E., as Associates.

It was announced that the following Candidates, having been duly recommended, had been admitted by the Council, under the provisions of Sect. IV. of the Bye-Laws, as Students of the Institution:—Sydney Walker Barnaby, John Edward Compton, Henry Croft, John Douglas, Eduardo de Moraes Gomes Ferreira, Hugh Nettlefold, Camilo Guillermo Pardo, and Leonard Taylor Simpson.

No. 1,550.—"The Huelva Pier of the Rio Tinto Railway." By Thomas Gibson, Assoc. Inst. C.E.

The cupriferous iron pyrites mining property of Rio Tinto, containing nearly 5,000 English acres in one connected tract, was purchased from the Spanish Government by a combination of capitalists, and was transferred by them to a company now designated the Rio Tinto Company (Limited), in 1873. It is situated about 50 miles from the seaport of Huelva, which is about 12 miles from the bar of the River Odiel in Andalusia. To provide a sufficient and economical means of transport, a single line of railway was constructed of the gauge of 3 feet 6 inches, having uniformly favourable gradients to the port. The mines were worked by the Romans, and subsequently by the Spanish Government; and during 1877 the output of ore was 750,000 tons.

There being no dock or wharfage accommodation for the shipping, the traffic was formerly conveyed between the vessels and the beach by barges and other small craft—a mode of shipment only suited for a small export of ore. The banks of the river are scarcely 2 feet above high-water. The sub-stratum consists of soft blue clay more than 80 feet in depth, which extends also into the bed of the river. After careful consideration of the natural formation of the harbour, the depth of water, the rise and fall of the tide, and the nature of the sub-stratum, it was resolved that the most effectual means of providing a cheaper and more expeditious mode of shipping the minerals would be to construct a pier upon screw piles. In order to obtain a sufficient depth of water at low tide, the pier was extended a considerable distance into the river, but even now the pier-head scarcely enters the fairway.

In preparing the design, advantage was taken of the methods in use for the shipment of minerals at most of the large shipping ports in England, especially those adopted by Mr. Harrison, Past President, Inst. C.E., at the Tyne docks.[1]

The question to be considered was, whether to carry the level of the roadway of the pier at a comparatively small height above the high-water line, and to take the wagons to the ships at that level, and then use hydraulic or some other power to lift each wagon and tip its contents into the hold of the vessel; or to construct the pier upon a rising gradient, so that trains of wagons could be pushed up by a locomotive, and the shipment of the ore be effected by gravitation. It was decided to adopt the latter plan, though the pier so constructed necessarily cost more money. An advantage gained by this course was that a lower deck was provided for the ordinary traffic of the port.

The pier might have had a T head, and the wagons been turned upon tables when they were passed on to the ships; but this would have involved more labour in the handling of the wagons, and would have been a slower process. The pier, therefore, has been so constructed that the wagons are run direct to the spouts, and require no handling after leaving the engine. To enable the ore to be shipped readily, the highest point was fixed at 32 feet 6 inches above ordinary spring tides, and the pier was carried into such a depth of water that vessels can be loaded at all times. A light vessel can be begun at the top of the tide, and the loading can be continued when the tide is at its lowest.

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxiii., p. 490.

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The principal engineering difficulty was the extreme badness of the foundation, which proved worse than was at first anticipated. Having virtually to carry two lines of railway, one above the other, a greater load had to be borne than if the pier had simply to do the work of the mines. It was found that a sufficient area of base could not be got by screw piles alone, without going to a great expense. It was therefore decided to provide additional bearing surface by the introduction of timber platforms resting on the bed of the river and fastened to the piles.

The approach from the station-yard to the pier is on an embankment 750 feet in length (Plate 8); for the remaining distance of 744 feet, the ground being incapable of supporting an embankment, it is constructed upon timber trestle frames, arranged in pairs, on which are laid longitudinal bearers covered with cross planking; these carry the rails, the whole being supported by platforms composed of railway sleepers.

For a length of 600 feet the pier stands out into the river in a westerly direction; thence a length of 775 feet is curved round to the south to a radius of 600 feet, to bring the pier head and shipping deck wharf parallel with the set of the tide, and the remaining length of 525 feet is straight. The radial lines connecting the curved portion with the two straight portions subtend an angle of 70°. The total length of the pier between the centres of the first and last screw pile is 1,900 feet. This distance is made up of twenty-nine spans of 50 feet each, and thirty groups of cast-iron screw piles and columns, these being 15 feet from centre to centre of the columns. One advantage in a screw-pile structure is the small surface presented to the ebb and flow of the reflujo tide, or to the stroke of a wave, whilst there are great facilities for making a rigid structure. By the system of bracing and ties introduced, there is scarcely any vibration. The little obstruction offered by the piles to the tide produces no change in the bed of the river, and there is no possibility of the accumulation of sand in the various channels. The velocity of the tidal current varies from 1 knot to 3½ knots an hour in the vicinity of the pier.

The pier head, alongside which the ships are moored, is protected by the shipping deck wharf, which is quite independent of the cast-iron piling, and is composed of creosoted red wood Memel timber fenders, supported by timber creosoted Memel piles, cross bearers, transomes, and longitudinal walings. The face of the shipping deck wharf opposite to each spout is close sheeted with 12-inch by 6-inch timber for a distance of 50 feet, the remaining portion being protected by vertical fenders at intervals of 3 feet from centre to centre. The shipping deck wharf is in a depth of water of 15 feet at low spring tides. The difference between high and low water spring tides is about 12 feet 6 inches.

The pier consists of three different levels or floors, upon which are laid seven lines of rails. On the first or lowest floor, for a distance of 925 feet from the shore end, a single line of rails is laid; then it branches out into three lines which continue to the pier head. This is used entirely for ordinary traffic other than ore.

On the second floor, the two lines of rails have a continuous falling gradient from the pier head to the standage point at the shore end, at which point they are curved round and form a junction with the centre line leading to the station yard.

On the third floor, from the pier head for a distance of 1,120 feet, two lines of rails are laid on reverse gradients. The remaining distance is laid with a single line on a falling gradient towards the station yard.

The pier is constructed upon cast-iron screw piles and columns, braced together with wrought-iron struts, stays, and tie rods. The piles are arranged in groups of eight, viz., two rows of four in each row. At the shore end their distances apart transversely are 7 feet 6 inches, 12 feet, and 7 feet 6 inches respectively (Plate 1, fig. 4), and longitudinally they are 15 feet apart from centre to centre. In the deep-water portion (Fig. 3), the piles are all 12 feet apart transversely, and longitudinally 15 feet from centre to centre.

The cast-iron screw piles forming the base of the pier are 16 inches in diameter, and 1¼ inch thick. These are in lengths arranged to suit the respective depths to which they are inserted in the ground. On the lower length of the pile shaft a screw blade 5 feet in diameter, with a 6-inch pitch, is held in place by two bolts. A collar fits into the boss of the screw blades (Plate 9, Figs. 5 and 6), so that all pressures are transmitted through the pile-shaft collar to the screw blades. The screws were cast separately from the piles for convenience of transit from England to Spain. In case any of the piles should work out of position during the operation of fixing them, a radial joint of 4-feet radius was arranged at the surface of the ground at the shore end, and in the deep-water portion at low-water level for adjusting the upper lengths of the piles. After they were adjusted the joint was well stemmed with iron cement.

The piles were screwed to the following depths below the surface of the ground;—from the 3rd to the 18th row inclusive, 15 feet; 19th to 26th row, 28 feet 9 inches; 27th to 32nd row, 32 feet;

33rd to 50th row, 31 feet 6 inches; and from the 51st to the 62nd row inclusive, 32 feet. To get them down, a shaft key was bolted to the pile head, upon which a capstan head was fixed and furnished with eight arms varying in length from 8 to 15 feet, and worked on the shore end by sixteen men, though in the deep-water section from forty-five to one hundred and ten men have been employed. The piles at the shore end were fixed from two travelling gantries, one in advance of the other. The gantries were roughly constructed of timber, and set upon wheels in the usual manner. The timber floor, on which the men worked, was suspended at the four corners by chains working in differential pulley-blocks, to adjust it to the height required for screwing the piles; guide booms were fixed to the side sills of each gantry near the ground for the purpose of holding the piles in place. Two cross-joist bearers in the gantry-frame floor were arranged so that by placing two planks across them, they answered the purpose of an upper guide boom.

The piles in the deep-water section of the pier were fixed from a timber staging, consisting of six timber piles driven into the ground, and standing 2 feet above high-water level. The piles were placed three in a row with a capsill across them, upon which ten longitudinal bearers were laid to carry the floor. The staging was further stiffened by cross-transomes and side diagonals. In some instances it was necessary to construct these stages with two floors, the top floor being about 3 feet above high-water level, and the second floor at about half-tide level, or about 8 feet below the top floor. The object of this arrangement was to bring two capstan heads, and two sets of men to work simultaneously on one shaft. The guide booms in which the piles were adjusted were fixed near low-water level and also in the top floor of the staging. The screw piles were lifted from barges by a derrick floated upon a raft of timber. Having been jointed and bolted together to the requisite length, they were lifted by a sling chain attached to the top flange by eye-bolts and suspended to the tackle from the derrick raft, so that the piles hung vertically before being placed in the situation it was intended to occupy in the guide booms. At the shore end the piles were pitched by a winch set upon a traverser on the top of the gantry framing, directly above the position in which they had to be placed.

From the 3rd to the 32nd row the material forming the bed of the river opposed little resistance to the piles. The screw-blades, except in a few instances, carried the pile down in each revolution the full pitch of 6 inches. While passing through a layer of cockle-shells the pile did not advance more than from 4½ to 5 inches in a revolution, but in some instances near the shore the pile went as much as from 8 to 9 inches in a revolution, and continued to do so for a distance of from 5 to 6 feet below the surface, after which the strata became more consolidated. Sixty-two piles were fixed at the shore end between the 31st of July and the 28th of September, 1874, when the operation was stopped for three and a half months, during which time experiments were made to ascertain the weight that could be sustained by the screw piles and the platforms singly and combined. The results of these experiments are given in the Appendix. Work was resumed in January 1875, and the remaining fifty-eight piles to the thirty-second row were in place by the 16th of April, 1875. From this date to the 7th of December, 1875, the piles from the 33rd to the 62nd row, one hundred and twenty in all, were fixed. Thus the time occupied in fixing the two hundred and forty screw piles, representing 6,452 lineal feet of work, was only thirteen months, the proportion being as follows:—

	Lineal feet.
Shore end, from the 3rd to the 32nd row.	2,648
Deep-water section, from the 33rd to the 62nd row . .	3,804
Total amount of screwing	6,452

The ground in the deep-water section gradually changed from soft blue mud to a mixture of sand and clay, varying in thickness from 18 inches to 20 feet, below which soft blue clay again occurred. Hence the reason why an increased number of men were required in this part of the work. It was necessary to clear each pile of its core between the 41st and the 62nd row, and to loosen the sand into which it was being screwed. This was mostly done by forcing water down through the inside of the piles; but many other devices were tried. The Author is of opinion that the most effectual machine for this purpose is the sand shell pump, worked by a single rope over a whip-gin block, during the time the pile is being turned round. By this mode the whole of the core is removed from the pile, causing the ground at the point and at the cutting edge of the screw to "boil" from the action of the shell. The head of water on the outside of the pile relieves the shaft and screw blades from the friction arising from the ground becoming compressed during the operation of screwing.

At the shore end of the pier the ground was proved by repeated experiments to be incapable of supporting more than about 700 lbs.

per square foot; therefore, as sufficient bearing surface could not be obtained in the area of a screw, the following mode was adopted as the most expeditious and effectual for obtaining the necessary power to support the load.

Timber platforms composed of whole balks of timber 12 inches square, were placed round each group of piles transversely to the centre line of the pier, and arranged so as to break joint under the main bearing sills, or at the centre between two of them. The main sills rested upon the platform floor, consisting of eight balks laid longitudinally one on each side of the screw piles. The platform floors were made on the beach in three separate pieces, then floated off at high water, and adjusted round the piles; after which the bearing sills were placed upon them and bolted to the floor. The platforms were weighted with a load greater than would have to be supported by the piles when the pier was completed. On their coming to rest with the load upon them, a connection was made between them and the piles, by cast-iron discs, arranged to clamp the respective piles below a collar cast specially on the pile shaft so as to rest upon the disc. In this way the load on the pier is transmitted through the columns, piles, and discs, to the bearing area of the platform, thereby giving the necessary resistance to support the load. At the shore end they were weighted by stacking railway and pig-iron on a cradle formed by putting eight timber bearers across the main bearing sills, until the required load of 500 tons per platform was completed.

Before sinking the platforms in the deep-water section, eight timber sills were laid across the main bearing sills, until the height of the cradle was from 2 to 3 feet above low water level. The platforms were sunk by rubble-stone and shingle, at low water neap tides, care being taken to keep them in a horizontal position. The load of 500 tons, consisting of railway and pig-iron, was placed upon the cradles. In testing them, two platforms were always under operation at the same time, six timber cradles, four sets of rails, and two lots of pig-iron, being employed for the purpose. To keep the respective loads moving forward systematically the following plan was adopted. Assuming the whole load to be upon the cradle at platform A, the second cradle with the second set of rails, equal to one-third of the load, would be on platform B; and on platform A ceasing to sink, the pig-iron was removed from A to B, thus completing the load on B. The third cradle was then set upon platform C, and the rails transferred from A to C.

Details of the depth to which each platform sank are given in the Appendix. Generally each platform subsided about 1 foot under the applied load, although at low water mark, or from about the 21st to the 26th rows, the registered amount increased to 1·11 foot; at the 21st and the 22nd rows to 3·89 feet; and at the 23rd to the 26th rows to as much as 5·40 feet. These, however, were exceptional cases. At the shore end, before the platforms were placed in position, the surface mud was removed to a depth of about 3 feet, and the space filled with rubble-stone and gravel, but in the deep-water section this was not necessary.

When the loaded platforms had ceased sinking, and before any portion of the load was removed, a diver was sent down to insert chocks between the pile collars, and the main bearing sills on the platforms, to prevent their rising (Fig. 8). The pig-iron portion of the load was then removed, and the diver sent back to fix the discs. When the space between the main bearing sills and the collar on the pile was greater than the depth of the disc, the diver wedged the disc up to the collar, after which the exact space between the underside of the disc and the bearing sill was measured, and fitted with timber dressed specially in two pieces. Where the space was less than 16 inches, discs had to be cast with a bearing collar shown in Figs. 7 and 8.

Plate 9, Fig. 4, shows the maximum height of the structure at the shore end of the pier. Fig. 3 represents the maximum height of the structure in the deep-water section.

The weight in one bay of the structure, and the load to be supported by each pile, are as follows:—

SHORE END.

	Cwt.
Total weight of the structure in a bay	2,400
Total weight of movable load on all four lines at 15 cwt. per lineal foot (bay 65 lineal feet) . . .	3,900
Total weight in one bay	6,300

Distributing this weight between the eight piles, it will be found that the maximum weight on each pile is 787½ cwt.

In the deep-water section the following are the results:—

	Cwt.
Total weight of the structure in a bay	3,800
Total weight of movable load on all seven lines at 15 cwt. per lineal foot (bay 65 lineal feet) . . .	6,825
Total weight in one bay	10,625

This weight divided between the eight piles gives 1328½ cwt. as the maximum load on each pile.

The platforms at the shore end are arranged with a bearing area of 864 square feet; adding 157 square feet for the screw blades, a total of 1,021 square feet is obtained. In the deep-water section the area of the platforms is 1,500 square feet, which, with that of the screw blades, gives a bearing area equal to 1,657 square feet. The combined areas of the platforms and screw blades, with the loads they are required to support, are respectively 691 lbs. per square foot on the shore-end platforms, and 718 lbs. per square foot in the deep-water platforms. The load applied in testing the platforms was equal to 778 lbs. per square foot in the shore-end platforms, and 747 lbs. in the deep-water platforms. Taking into consideration that previous to fixing the platforms the piles supported the superstructure, the platforms were weighted to about one-third more than the load required to be supported by them. The calculated load per square foot is slightly exaggerated, when the actual weight of the rolling stock and the mode in which the traffic is worked, are taken into consideration. Engines weighing about 17 tons are provided to work the pier traffic exclusively; loaded trains pass along the centre lines, and the empty wagons return by gravitation on the two outside lines of the second floor to the shore, where they are made up into trains. At the pier head, five out of the seven lines might on exceptional occasions be covered with loaded trains; but even then the maximum rolling-load, taken as the basis of the foregoing calculation, will never be reached.

The columns which rest on the screw piles are 15 inches in diameter, and of metal 1 inch thick, upon which caps and girder beds are cast at levels to suit the varying gradients. These piles and columns are 15 feet apart from centre to centre, and are made up in lengths with external flanges. The flanges are faced, jointed, and bolted together, making one continuous length of shaft from the screw blades to the cap on the column. By this arrangement great facility is gained in erecting the superstructure, as the work can be executed independently of the respective floors.

The piles and columns constituting a bay are strutted and braced together by longitudinal and cross girders. They are also strutted and stayed horizontally and transversely by rolled H and channel irons. The diagonal bracing is effected by tie rods 1¼ to 1¾-inch in diameter. Angle-iron diagonal stays are also used. Groups of piles, 50 feet apart, form a series of piers, or pile buttresses, upon which the wrought-iron lattice girders supporting the respective floors are erected, and bolted to the metal caps.

The main lattice girders over the 15-feet and the 50-feet openings are 4 feet deep. On the lowest floor they are fixed to the caps between the end plates of the cross-stay girders. These end plates form a fish plate, the full depth of the longitudinal girders on each side of the columns, thus joining the girders together longitudinally. The holes in the side plates are made oval, to allow for expansion and contraction. At the centre of the 50-feet spans, a cross stay-plate girder with ⊤-iron knees is riveted to the top booms of the main girders, thereby binding them together transversely at their centres. (Figs. 10 and 11.)

The second-floor main girders are also 4 feet deep. They are bolted to the caps by 1¼-inch bolts, and joined together longitudinally by 1-inch bolts; they are also braced and stayed over the caps, from the centre columns, by angle-iron frames. At the centres of the 50-feet girders on this floor, there is a double bracing, consisting of a rectangular lattice box frame composed of angle irons and flat bars, with vertical and horizontal angle irons at intervals of 12 feet. Where the second and third floors run near the same level, the main girders are bound together by single iron frames, stays, and knees, made of angle and ⊤-irons.

The third floor main girders are uniformly 4 feet deep, and are braced together with single angle-iron frames. They are riveted to the top and bottom booms of the main girders at intervals of 10 feet and 15 feet; that is, at the column caps, and at the three intermediates. Horizontal bracings, or wind-ties, are riveted to the under side of the bottom booms of the first and third floor main girders throughout the entire length of the pier. The first and third floor girders on the centre columns, were put in place first; then the two outside girders of the first floor, after which the second floor girders were erected. The plates, angles and vertical ⊤-irons, and diagonal bars of which the main girders are made, were drilled and punched to template in England, and sent to Huelva, where they were put together on the beach. When the girders were required for erection, they were floated from the beach by a raft arranged with skids for the girders to lie upon, and moored alongside the derrick raft. The girders were then slung by the centre, and lifted into place by the derrick. The erection of the girders was commenced in January 1875, and completed in January 1876.

The roadway of the first floor is supported by cross bearers of pitch pine 11 inches square, riveted to two vertical angle-irons forming a pocket 18 inches above the bottom boom of the main girder; on the cross bearers, which are 5 feet from centre to centre, are laid the longitudinal rail bearers 12 inches wide by 9 inches deep. The planking forming the flooring is also laid longitudinally on each side of the rail bearers, and is spiked to the cross bearers. The floor between the rail bearers is covered with ballast about 3 inches thick. The second floor is arranged upon corbels 5 feet long by 12 inches square, which rest on and are bolted to the single main girder, upon which are fastened the cross bearers, the longitudinal rail bearers, and barge combing bolted to the cross bearers. The intermediate spaces are filled in with 3-inch planking laid longitudinally to form the floor. The third floor is composed of corbels 12 inches square, resting on and bolted to the girders. On these corbels the cross transomes support the longitudinal rail bearers, barge combing, and the planking. The space between the rail bearers on this floor is also covered with ballast. The main bearers, transomes, &c., in the respective floors consist of pitch pine timber, the planking being creosoted red wood. The second and third floors are appointed for working the mineral trains, and for the shipment of ore from the pier.

In working the traffic the wagons are pushed by an engine up a gradient of 1 in 75 from the station yard to the summit of the pier (Plate 8). From thence they descend by gravitation along a gradient of 1 in 200 to the respective positions fixed for standing. Here the trains are divided into sets of three wagons, and are then passed over falling gradients of 1 in 100 and 1 in 132, where they acquire sufficient impetus to take the reverse rising gradient of 1 in 30 at the pier end. Having crossed over the switches between the falling and the rising gradients, the switches are reversed, and the wagons return into the outside road of the second floor level, along which they descend on a gradient of 1 in 100 to the requisite position over the spout. After the wagons have discharged their loads into the spout the hand brakes are taken off, and they descend on a gradient of 1 in 100 to one of 1 in 200, until they reach the level forming the standing ground at the shore. They are then dragged to the station yard by the engine on her return from pushing the loaded wagons up to the summit.

The average time occupied in discharging a wagon containing about 7 tons of minerals into the spout is from forty-five to sixty seconds, the time being calculated from the wagon leaving the standing-ground on the third floor until it leaves the spout. In other words, about 7 tons of ore per minute could be passed through one spout. The wagons are of the hopper type, with a door in the bottom, and are worked by a side lever brake fitted with self-acting buffers.

There are four sets of shipping spouts, two on each side of the pier-head. They are constructed to meet the varying levels in the rise and fall of the tide, and the different heights in vessels. Each set of spouts has four fixed divisions. The shoot is raised or lowered by side chains working in sheaves on a cross bar spindle under the inner end, and is adjusted to an angle of about $1\frac{3}{4}$ to 1. A steeper angle than this allows a too rapid descent of the ore. At a less inclination than $1\frac{3}{4}$ to 1 the ore does not readily clear itself from the spout.

The quadrant and pinion with hand gear, fitted to the derrick frame for moving the spout horizontally over the ship's hold, are most useful in trimming the ship during the operation of loading. The flow of the mineral from the shoot is regulated by a door at its lower end, as is usually done in the shipment of coal. The door is actuated by two side chains, one on each side of the shoot. The chains are worked from two oak drums fixed on one spindle working in two carriages on the derrick frame.

The pier-head is surrounded by a timber wharf, constructed independently of the iron screw pile structure with the object of preventing shocks, or blows from vessels striking the wharf being communicated to the pier. The piles composing the wharf are arranged in two rows on each side of the iron structure, with a row of piles along the centre forming, as it were, five rows of piles longitudinally. Through cross transomes are fastened to the piles at low water level, and at 8 inches below the under side of the main girders in the iron structure.

Between the top and bottom transomes, and cross-sill bearers, diagonal struts and stays are fixed to the timber piles, these being also bound together transversely and longitudinally by walings arranged in pairs; they are also strutted and braced horizontally and diagonally. The floor of the wharf consists of 3-inch planking laid across longitudinal bearers and joists. Upon the floor are lines of rails for travelling cranes, and for wagons discharging or loading close to the side of the vessels. The wagons are placed upon the wharf by a traverser shifting them from one line of way to another. At the pier end a connection is formed by turn-out roads from the iron structure on to the wharf. The shipping deck wharf is 65½ feet across, with a frontage of 1,350 feet. It is furnished with one fixed 15-ton hand power crane, and one 3-ton travelling steam crane, which latter is elevated upon a timber gantry for discharging coals or ballast. This crane being in an elevated position space is economised, permitting two lines of rails to be brought within the sweep of the crane.

Mooring buoys are arranged round the pier-head, and are placed in the fair way of the river, so that vessels lie fore and aft in line with the set of the tide, at a distance of 300 feet from the side of the shipping deck wharf.

Special provision has been made in case of fire breaking out. A 3-inch water main has been laid along the entire length of the pier or pier approach, to which hydrants and stand-pipes, with stop cocks, leather hose, &c., &c., are fixed. Six buckets, with ropes attached to them for drawing water from the river, are placed at each hydrant. Barrels and buckets are also arranged along the third floor, and are filled with water from the stand-pipes. The water supply is obtained from a 10,000 gallon tank erected at the shore end of the pier.

The works were constructed in accordance with the designs of Mr. G. B. Bruce, M. Inst. C.E., and were carried out under his directions, the Author being the resident engineer, and Mr. John Dixon, Assoc. Inst. C.E., the contractor.

The total cost of the pier and timber viaduct approach, including spouts, cranes, permanent way, &c., was £145,166. The cost of the pier per lineal foot, including shipping deck wharf, cranes, spouts, screw moorings, and buoys, was £74. The cost of the timber viaduct approach per lineal foot was £6 2s. 9d.

The disposition of materials in the pier is as follows:—

	Tons.	cwt.	Tons.	cwt.
Cast-iron work, viz.:—				
Screw-blades, screw-pile shafts, columns, discs, bollards, &c.			1,834	6
Wrought-iron work, viz.:—				
Girders, and wrought-iron frames, over-crossing	1,162	18		
Struts, stays, clasps, tie-rods, wind-ties, &c.	319	16		
Fastenings	100	0		
			1,582	14
Total			3,417	0

		Cubic feet.
Timber-work, viz.:—	Cubic feet.	
Platforms in foundations	45,941	
Superstructure, transomes, rail-bearers, spout-framing, &c.	88,442	
Shipping deck-wharf, dolphin, &c.	63,319	
		197,702
	Lineal feet.	
Pier approach:	744	
Timber viaduct		17,663
Total		215,365
		Lineal yards.
Permanent way laid		4,230

The Paper is illustrated by a series of drawings from which Plates 8 and 9, and two woodcuts have been compiled.

[APPENDIX.

APPENDIX.

SINKAGE of the TIMBER PLATFORMS UNDER TEST WEIGHTS.

Groups of Piles.				Average Sinkage.	Load.
Row Number.	Sinkage.	Row Number.	Sinkage.		
	Feet.		Feet.	Feet.	Tons.
No. 3	0·43	No. 4	0·66	0·54	400
" 5	0·98	" 6	1·51	1·24	402
" 7	0·58	" 8	0·51	0·54	400
" 9	0·18	" 10	0·22	0·20	300
" 11	0·27	" 12	0·27	0·27	300
" 13	0·17	" 14	0·20	0·18	300
" 15	0·24	" 16	0·25	0·25	300
" 17	0·42	" 18	0·49	0·45	412
" 19	0·77	" 20	0·78	0·77	410
" 21	1·05	" 22	1·18	1·11	485
" 23	3·93	" 24	3·86	3·89	485
" 25	5·60	" 26	5·20	5·40	425
" 27	1·90	" 28	1·30	1·60	500
" 29	1·24	" 30	1·27	1·25	500
" 31	0·52	" 32	0·55	0·53	500
" 33	2·33	" 34	1·87	2·10	500
" 35	1·62	" 36	1·12	1·37	500
" 37	1·20	" 38	1·27	1·23	500
" 39	1·06	" 40	1·07	1·06	500
" 41	0·44	" 42	0·34	0·39	470
" 43	0·88	" 44	0·85	0·86	500
" 45	0·46	" 46	0·46	0·46	500
" 47	0·08	" 48	0·07	0·07	500
" 49	0·63	" 50	0·57	0·60	500
" 51	0·26	" 52	0·17	0·21	500
" 53	0·18	" 54	0·19	0·18	500
" 55	0·14	" 56	0·18	0·16	500
" 57	0·92	" 58	0·79	0·85	500
" 59	0·33	" 60	0·35	0·34	500
" 61	4·70	" 62	0·70	0·70	500

PLATFORM TESTING RESULTS. SINKAGE UNDER the RESPECTIVE LOADS APPLIED.

Date.	Time.	Weight Applied.	Sinkage. A.	Sinkage. B.	Sinkage. C.	Sinkage. D.	Sinkage. A.	Sinkage. B.	Sinkage. C.	Sinkage. D.
		Tons. cwt.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1874 Dec. 10	Cradle fixed.			Row 3.				Row 4.		
" 11	10 A.M.	140 0	·04	·06	·07	·06	·05	·03	·07	·08
" 11	5 P.M.	200 0*	·13	·09	·14	·29	·16	·05	·10	·27
" 12	..	305 12	·15	·14	·19	·35	·21	·14	·30	·28
" 14	..	325 0†	·21	·19	·27	·42	·28	·21	·30	·46
" 15	..	375 0	·19	·17	·25	·42	·27	·20	·30	·47
Sinkage after twenty-four hours' standing.										
" 21	12.30 P.M.	400 0	·23	·23	·32	·50	·38	·33	·53	·62
" 22	"	"	·27	·27	·36	·53	·44	·40	·61	·69
" 23	"	" †	·20	·20	·39	·55	·48	·43	·64	·74
" 24	"	"	·28	·28	·39	·54	·49	·44	·65	·75
" 26	"	"	·31	·31	·41	·57	·52	·47	·69	·79
" 28	"	"	·34	·35	·44	·59	·56	·51	·78	·82
" 30	"	"	·33	·34	·44	·60	·56	·52	·74	·84

NOTES.—The load was placed direct upon the piles.

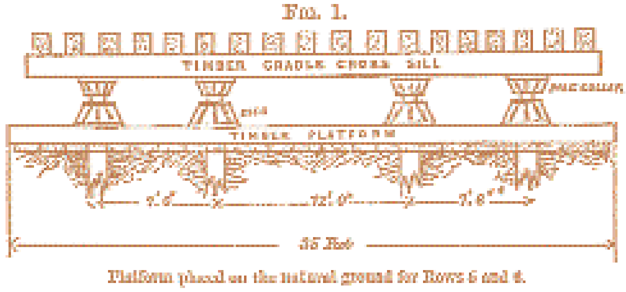
* The piles were left standing with their collars $1\frac{1}{2}$-inch above the disc, when the load on them was increased to 200 tons, they subsided as given above, and took their bearing on the discs, thereby transmitting their load through the discs to the platform.

The platform has a layer of stone 2 feet 6 inches in thickness under it, and is 24 feet in length, and 35 feet in breadth.

† Strong wind blowing at the time the levels were taken.

Date.	Time.	Weight Applied.	Sinkage. Row 5. A.	B.	C.	D.	Sinkage. Row 6. A.	B.	C.	D.
1874		Tons. cwt.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Sept. 30	Cradle fixed.		Row 5.				Row 6.			
Oct. 1	..	90 0	Nil.				Nil.			
,, 2			Sinkage after twenty-four hours' standing.							
,, 2	..	200 0	·08	·05	0·04	0·04	0·09	0·06	0·04	0·06
,, 3			Sinkage after forty-eight hours' standing.							
,, 3	..	200 0	·10	·08	0·04	0·04	0·11	0·05	0·04	0·06
,, 5			Sinkage after forty-six hours' standing.							
,, 6	..	240 0	·16	·13	0·10	0·09	0·19	0·12	0·08	0·10
,, 8	10 A.M.	392 0	·37	·30	0·32	0·40	0·55	0·57	0·57	0·56
,, 9			Sinkage after twenty-four hours' standing.							
,, 9	..	402 0	·59	·70	0·79	0·81	1·04	1·17	1·31	1·36
,, 10			Sinkage after forty-eight hours' standing.							
,, 10	..	402 0	·65	·76	0·87	0·90	1·18	1·27	1·42	1·47
,, 12			Sinkage after ninety-six hours' standing.							
,, 12	..	402 0	·74	·86	0·98	0·99	1·28	1·38	1·52	1·58
,, 13	10.30 A.M.	402 0	·74	·87	0·99	1·01	1·23	1·38	1·53	1·60
,, 14	,,	,,	·76	·88	1·00	1·02	1·24	1·39	1·56	1·61
,, 15	,,	,,	·78	·90	1·01	1·03	1·25	1·40	1·57	1·62
,, 16	,,	,,	·79	·91	1·02	1·04	1·25	1·42	1·57	1·64
,, 17	,,	,,	·83	·92	1·04	1·05	1·26	1·42	1·58	1·64
,, 19	8 P.M.	,,	·81	·94	1·06	1·07	1·29	1·45	1·60	1·66
,, 20	11 A.M.	,,	·81	·94	1·07	1·09	1·29	1·45	1·60	1·66
,, 21	,,	,, *	·85	·98	1·07	1·10	1·30	1·46	1·62	1·68
,, 22	,,	,, *	·85	·96	1·08	1·09	1·30	1·46	1·63	1·70
,, 23	10.30 A.M.	,, *	·83	·96	1·09	1·10	1·31	1·46	1·63	1·70
,, 24	,,	,, *	·85	·98	1·08	1·12	1·30	1·46	1·68	1·68
,, 26	,,	,, *	·85	·97	1·08	1·09	1·30	1·46	1·68	1·69
,, 29	,,	,, *	·86	·98	1·07	1·12	1·30	1·46	1·68	1·69
Nov. 5	11 P.M.	,, *	·85	·96	1·07	1·10	1·31	1·46	1·61	1·68
,, 16	10 A.M.	,,	·81	·95	1·07	1·10	1·30	1·45	1·60	1·68

FIG. 1.



Platform placed on the natural ground for Rows 5 and 6.

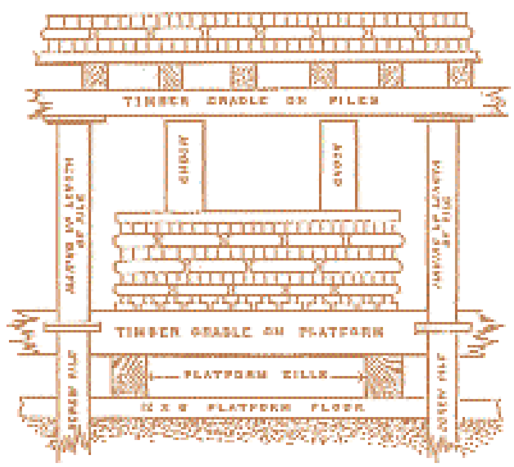
The cradle to support the test load was arranged as shown in woodcuts, Figs. 1 and 2. The load consisted of 402 tons of rail and pig iron. The piles and platform began to yield under a load of 200 tons, or 25 tons on each pile. A gradual subsidence took place after each tide as the load was increased. During the last thirty days the sinkage was so slight as to be scarcely observable. The platform was placed upon the natural formation.

* A new staff man.

Date.	Time.	Weight Applied.	Sinkage. A.	Sinkage. B.	Sinkage. C.	Sinkage. D.	Sinkage. A.	Sinkage. B.	Sinkage. C.	Sinkage. D.
1874		Tons. cwt.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Nov. 16	Cradle fixed.		Row 7.				Row 8.			
,, 17	9 A.M.	22 7	·13	·07	·04	·00	·05	·04	·12	·04
,, 17	5 P.M.	88 13	·30	·20	·14	·07	·10	·15	·28	·12
,, 18	10 A.M.	97 7	·35	·24	·17	·11	·13	·18	·20	·15
,, 18	2 P.M.	123 8	·37	·26	·20	·11	·16	·19	·27	·17
,, 18	5 P.M.	172 4	·42	·31	·26	·19	·19	·22	·31	·23
,, 19	11 A.M.	236 19	·45	·34	·29	·22	·18	·25	·35	·28
,, 20	8 A.M.	,,	·46	·36	·32	·26	·21	·27	·37	·30
,, 21	10.30 A.M.	,,	No perceptible sinkage.							
,, 22	,,	,,								
,, 23	10 A.M.	,,	·48	·37	·34	·27	·21	·28	·38	·31
,, 24	3.30 P.M.	,,	·49	·39	·36	·29	·22	·28	·40	·33
,, 25	2 P.M.	,,	·49	·39	·30	·30	·23	·29	·41	·32
,, 26	5 P.M.	,,	·51	·41	·38	·31	·23	·31	·41	·35
,, 27	2 P.M.	,,	·50	·41	·38	·32	·24	·31	·42	·35
Dec. 1	12 mid.	,,	·50	·43	·40	·34	·25	·33	·44	·37
,, 6*	..	..	..	..	..	..	..	..	..	..

* No perceptible sinkage having taken place during the last week under a load of, say, 237 tons, the arrangements shown in Fig. 2 were adopted to ascertain the load that could be supported by the piles working independently of the platform. A layer of stones and gravel 2 feet thick was deposited under the platform.

Fig. 2.



Stone, 2 feet thick, deposited under this platform for Rows 7 and 8.

The piles began to yield under a load of 60 tons, the pile being then 15 feet in the ground. After the piles in the 7th row had subsided 1 inch, and those in the 8th row ¾ inch, the respective loads became united, that is the load on the top cradle was transmitted through vertical chocks to the cradle below, thereby distributing the whole of the load of 306 tons, so that it was supported by the piles and platform working together.

L 2

Date.	Time.	Weight Applied.	Sinkage. A.	B.	C.	D.	Sinkage. A.	B.	C.	D.
		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1874	Cradle fixed.		Row 7.				Row 8.			
			Sinkage after ten hours' standing.							
			Platforms.							
Dec. 6	..	306	·62	·53	·53	·47	·40	·48	·56	·49
			Screw piles.							
„ 6	..	„	·17	·20	·19	·21	·18	·19	·16	·20
			Platforms.							
„ 7	10.30 A.M.	400	·65	·58	·59	·51	·40	·48	·60	·55
			Screw piles.							
„ 7	„	„	·22	·29	·34	·30	·28	·31	·28	·30
„ 8	„	„	No perceptible sinkage.							
			Platforms.							
„ 9	„	„	·64	·56	·58	·52	·37	·47	·60	·54
			Screw piles.							
„ 9	„	„	·21	·27	·35	·31	·22	·32	·28	·30

NOTES.—The load in the first instance was applied direct upon the platform, which had an area of 840 square feet.

	Row 7.	Row 8.
	Feet.	Feet.
Under a load of 400 tons the average sinkage of the screw-piles was	·29	·28
Ditto of the platforms	·58	·51
Ditto of the two combined	·43	·39

Date.	Time.	Weight Applied.	Sinkage. A.	B.	C.	D.	Sinkage. A.	B.	C.	D.
		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1874 Dec. 30	Cradle fixed.		Row 9.				Row 10.			
1875 Jan. 7	9 A.M.	300	·13	·14	·14	·16	·15	·15	·09	·18
„ 16	10 A.M.	„	Sinkage scarcely observable.							
„ 18	„	„*	·20	·20	·19	·23	·22	·21	·22	·21
„ 26	„	„	·18	·17	·18	·18	·27	·21	·22	·18

NOTES.—* Strong wind at the time of taking levels.

This platform has a layer of stone 2 feet thick under it, and is 36 feet broad and 24 feet long.

Date.	Time.	Weight Applied.	Sinkage.				Sinkage.			
			A.	B.	C.	D.	A.	B.	C.	D.
1875		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Feb. 4	Cradle fixed.		Row 11.				Row 12.			
„ 15	Noon	300	·25	·25	·25	·25	·24	·30	·26	·21
„ 22	..	„	·30	·29	·30	·28	·28	·35	·32	·26
March 8	..	„	·28	·27	·27	·28	·21	·33	·30	·24

NOTES.—This platform is 36 feet across, and 24 feet in length, composed of whole balks of timber 12 inches square. It rests on a cockle-shell layer. No stones were put under it.

Date.	Time.	Weight Applied.	Sinkage.				Sinkage.			
			A.	B.	C.	D.	A.	B.	C.	D.
1875		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
March 12	Cradle fixed.		Row 13.				Row 14.			
„ 18	..	300	·13	·11	·09	·12	·15	·10	·15	·12
April 7	..	„	·15	·17	·17	·19	·21	·22	·21	·20
„ 10	..	„	·16	·17	·17	·18	·21	·22	·20	·19

NOTES.—This platform rests upon a bed of cockle-shells. It is 36 feet across and 24 feet in length, and is composed of whole balks of timber 12 inches square.

Date.	Time.	Weight Applied.	Sinkage.				Sinkage.			
			A.	B.	C.	D.	A.	B.	C.	D.
1875		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
April 13	Cradle fixed.		Row 15.				Row 16.			
„ 15			Sinkage after four days' standing.							
„ 19	..	300	·13	·14	·20	·18	·14	·20	·16	·19
„ 23	..	„	·15	·17	·21	·20	·16	·22	·18	·21
„ 26	..	„	·17	·17	·23	·22	·17	·22	·19	·25
„ 30	..	„	·19	·19	·25	·24	·19	·24	·22	·25
May 4	..	„	·21	·22	·27	·27	·21	·27	·24	·27
„ 8	..	„	·21	·21	·27	·27	·21	·27	·24	·27

NOTES.—This platform is 36 feet across and 24 feet in length. Half balks of timber 12 inches by 6 inches are used for the floor. The platform is bedded on a cockle-shell layer, at least 12 inches thick.

Date.	Time.	Weight Applied.	Sinkage.				Sinkage.			
			A.	B.	C.	D.	A.	B.	C.	D.
1874		Tons. cwt.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Nov. 28	Cradle fixed.		Row 17.				Row 18.			
Dec. 3	..	68 10	·05	·04	·05	·05	·07	·07	·08	·07
,, 4	..	98 18	·04	·04	·05	·07	·08	·08	·11	·08
,, 6	..	144 14	·06	·06	·07	·06	·11	·11	·11	·08
,, 7	..	151 17	·08	·06	·07	·08	·12	·14	·11	·08
,, 8	..	232 4	·10	·08	·10	·09	·13	·16	·11	·12
,, 9	..	248 19	·09	·09	·09	·09	·17	·19	·14	·12
,, 11	..	320 6	·13	·13	·13	·14	·22	·25	·18	·15
,, 12	..	349 13	·16	·16	·15	·16	·25	·25	·18	·18
,, 14	..	478 2	·15	·18	·17	·16	·27	·27	·21	·20
,, 15	..	520 0	·20	·20	·22	·28	·32	·32	·28	·24
,, 16	..	552 12	·23	·28	·24	·24	·35	·35	·29	·25
,, 17	..	641 18	·20	·27	·30	·29	·38	·39	·34	·29
,, 18	..	642 0	·28	·33	·35	·31	·44	·44	·37	·33
,, 19	..	,,	·31	·30	·35	·33	·45	·45	·37	·33
,, 21	..	,,	·32	·38	·38	·35	·47	·50	·39	·34
,, 22	..	,,	·34	·39	·38	·37	·49	·51	·41	·36
,, 23	..	,,*	·34	·41	·41	·39	·51	·53	·42	·36
,, 24	..	,,	·34	·42	·42	·40	·51	·52	·43	·36
,, 26	..	,,	·37	·48	·44	·42	·53	·55	·45	·38
,, 28	..	,,	·37	·45	·45	·48	·54	·57	·46	·38
,, 29	..	,,†	·33	·46	·47	·39	·55	·55	·43	·35
,, 30	..	,,	·37	·45	·45	·43	·53	·57	·46	·39

NOTES.—* Strong wind blowing when the levels were taken.

† These levels were taken by the assistant of S. Don Rafael Clemente, government engineer.

The load was applied direct upon the piles, and transmitted through the piles and discs to the platform.

The platform, 50 feet across by 84 feet in length, is composed of whole balks of timber 12 inches square. No stones were put under it.

Date.	Time.	Weight Applied.	Sinkage.				Sinkage.			
			A.	B.	C.	D.	A.	B.	C.	D.
1876		Tons. cwt.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Jan. 25	Cradle fixed.		Row 19.				Row 20.			
,, 26	1.30 P.M.	42 2	·02	·01	·00	·00	·00	·00	·00	·01
,, 27	,,	71 7	·02	·02	·01	·00	·03	·04	·00	·03
,, 28	,,	108 0	·03	·06	·03	·03	·06	·05	·08	·06
,, 29	,,	153 0	·06	·09	·09	·06	·11	·10	·07	·08
,, 30	3.30 P.M.	233 15	·09	·14	·17	·15	·17	·19	·17	·18
Feb. 1	1.30 P.M.	283 0	·12	·19	·28	·27	·31	·34	·32	·37
,, 2	,,	318 0	·42	·49	·45	·35	·45	·49	·43	·44
,, 3	,,	359 0	·40	·53	·51	·45	·52	·40	·48	·52
,, 4	,,	410 0	·54	·57	·55	·52	·57	·53	·52	·59
,, 5	,,	,,	·58	·57	·54	·52	·56	·58	·52	·59
,, 8	,,	,,	·50	·60	·59	·56	·58	·56	·56	·62
,, 16	--	,,	·64	·68	·67	·67	·65	·64	·66	·76
,, 22	--	,,	·66	·70	·69	·70	·68	·65	·68	·75
March 6	--	,,*	·75	·79	·81	·81	·75	·75	·77	·86
,, 7	Sunday	,,	·73	·78	·77	·77	·75	·73	·70	·84
,, 8	--	,,	·73	·80	·79	·78	·76	·74	·70	·85

NOTES.—* Strong wind and rain when the levels were taken.

The load was applied direct upon the piles, and transmitted through the piles and discs to the platform. The piles were left standing up 4 to 6 inches above the discs. They are 27 feet 6 inches in the ground. The whole of the load was supported by the piles until they sank about ·40 foot, after which they acted with the platform. Therefore the weight supported by the piles is as follows:—

Total area of screw blades is 19·63 × 8 = 157 square feet ∴ $\frac{283 \text{ tons}}{157 \text{ square feet}}$ = 1·8 ton per square foot.

The platform, 36 feet long by 24 feet broad, is composed of whole balks of timber 12 inches square. No stones were put under it.

Date.		Time.	Weight Applied.		Sinkage.				Sinkage.			
					A.	B.	C.	D.	A.	B.	C.	D.
1875			Tons,	cwt.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
May	11	Cradle fixed.			Row 21.				Row 22.			
,,	12	On twenty-four hours	107	8	Nil.				Nil.			
,,	17	..	311	0	·10	·10	0·12	0·11	0·19	0·21	0·21	0·23
,,	22	..*	444	0	·33	·35	0·37	0·35	0·61	0·68	0·75	0·70
,,	24	..†	,,		·41	·42	0·47	0·45	0·70	0·75	0·84	0·79
,,	28	..	477	5	·57	·62	0·71	0·76	0·80	0·85	0·92	0·82
,,	31	..	485	0	·68	·68	0·79	0·85	0·88	0·89	0·96	0·96
June	7	Sinkage after standing twelve days.										
,,	7	..	485	0	·73	·79	0·91	0·97	0·94	0·98	1·06	1·06
,,	11	..	,,		·77	·83	0·94	1·01	0·97	1·01	1·07	1·09
,,	14	..	,,		·80	·86	0·98	1·04	1·00	1·04	1·10	1·16
,,	21	..‡	,,		·82	·90	1·01	1·09	0·97	1·09	1·13	1·14
,,	26	..	,,		·84	·92	1·06	1·11	1·05	1·11	1·16	1·18
July	3	..	,,		·91	·97	0·97	1·18	1·10	1·15	1·21	1·26
,,	5	..	,,		·92	·96	1·14	1·19	1·11	1·16	1·28	1·23

NOTES.—* The test load was not equally distributed.
† New staff man.
‡ Strong wind blowing.
The whole of the load was supported by the platform.
The platform sank only 0·36 feet in forty days under a load of 485 tons.
The platform was 36 feet long by 24 feet broad, composed of whole balks of timber 12 inches square. No stones were put under it. It rests on a bed of cockle-shells.

Date.		Time.	Weight Applied.		Sinkage.				Sinkage.			
					A.	B.	C.	D.	A.	B.	C.	D.
1875			Tons,	cwt.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
July	4	Cradle fixed.			Row 23.				Row 24.			
,,	5	On twenty-four hours	96	6	Nil.				Nil.			
,,	12	..	446	0	3·12	3·12	3·10	3·08	3·11	3·05	2·99	2·98
,,	16	..	,,		3·30	3·22	3·19	3·26	3·25	3·17	3·21	3·18
,,	23	..*	485	0	3·51	3·44	3·42	3·48	3·64	3·58	3·52	3·51
,,	26	..	,,		3·57	3·49	3·41	3·57	3·69	3·62	3·59	3·60
,,	30	..†	,,		3·64	3·62	3·78	3·66	3·76	3·69	3·69	3·71
Aug.	2	..	,,		3·72	3·70	3·68	3·73	3·81	3·70	3·73	3·72
,,	6	..	,,		3·86	3·76	3·70	3·79	3·88	3·83	3·79	3·81
,,	9	..	,,		3·89	3·75	3·76	3·82	3·91	3·80	3·80	3·80
,,	21	..	,,		4·00	3·88	3·85	3·89	3·98	3·87	3·79	3·81

NOTES.—* Load completed this morning.
† Commencement of spring tides.
This platform is composed of whole balks of timber 12 inches square, and is the first on the curved portion of the pier. It is about 36 feet long by 24 feet wide.
After a load of 485 tons had rested on the platform for eighteen days the sinkage was 2·47 feet. The platform was placed upon the natural ground.

Date.	Time.	Weight Applied.	Sinkage.				Sinkage.			
			A.	B.	C.	D.	A.	B.	C.	D.
1875.		Tons. cwt.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Aug. 18	Cradle fixed.		Row 25.				Row 26.			
,, 21	..	92 0	Nil.				Nil.			
,, 30	..	146 15	0·50	0·46	0·44	0·60	0·20	0·20	0·24	0·21
Sept. 4	..	300 0	2·22	2·11	2·51	2·98	1·55	1·47	2·97	3·22
,, 6	..	300 0*	2·25	2·18	2·58	2·69	1·63	2·60	3·03	3·14
,, 13	..	300 0	2·27	2·22	2·65	2·76	1·74	2·81	3·16	3·41
,, 20	Sinkage after two days' standing.									
,, 20	..	385 0	5·00	5·01	5·17	4·64	5·90	5·20	4·18	3·58
,, 27	..	385 0	5·78	5·27	5·18	4·94	6·21	5·29	4·30	3·60
Oct. 5	..	425 0	5·55	5·44	5·40	5·17	6·17	5·42	4·46	3·98
,, 12	..	425 0	5·86	5·57	5·68	5·29	6·06	5·48	4·62	4·15
,, 18	..	,,	5·86	5·50	5·70	5·27	6·28	5·42	4·64	4·37

NOTES.—* Strong wind blowing when the levels were taken.

This platform is composed of whole balks of timber 12 inches square. It is about 86 feet long by 24 feet wide. The platform was placed upon the natural bed of the river. During the night of the 1st of September, 1875, the platform settled down nearly 2 feet, the sudden subsidence probably arising from the cockle-shell stratum on which the platform was placed giving way.

Date.	Time.	Weight Applied.	Sinkage.				Sinkage.			
			A.	B.	C.	D.	A.	B.	C.	D.
1875		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Oct. 18	Cradle fixed.		Row 27.				Row 28.			
,, 25	..	40	0·04	0·25	0·06	0·08	0·28	0·20	0·02	0·07
Nov. 1	..	235	0·39	0·25	0·25	0·27	0·28	0·21	0·11	0·14
,, 15	..	425	1·02	1·18	1·17	1·47	0·72	0·61	0·58	0·58
,, 22	..	465	1·22	1·56	1·62	1·88	1·16	0·76	0·58	1·02
,, 29	..	,,	1·27	1·61	1·68	1·90	1·17	0·92	0·64	1·03
Dec. 6	..	,,	1·34	1·74	1·81	2·00	1·09	0·90	0·72	0·96
,, 13	..	,,	1·54	1·65	2·01	2·12	1·11	0·96	0·73	0·99
,, 20	..	,,	1·50	1·84	1·99	2·09	1·08	1·07	0·76	1·01
,, 27	..	500	1·62	1·87	1·93	2·18	1·14	1·14	0·88	1·02

NOTES.—The platform is 50 feet long by 30 feet wide. It was sunk by rubble stone to the bed of the river, after which a timber cradle was arranged upon it, and the load was applied.

Date.	Time.	Weight Applied.	Sinkage. A.	Sinkage. B.	Sinkage. C.	Sinkage. D.	Sinkage. A.	Sinkage. B.	Sinkage. C.	Sinkage. D.
		Tons. cwt.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1875 Dec. 31	Cradle fixed.		Row 29.				Row 30.			
" 31	..	109 9	Nil.				Nil.			
1876 Jan. 8	..	240 0	0·48	0·89	0·82	0·38	0·46	0·48	0·40	0·27
" 11	..	395 0	0·98	0·80	0·69	0·69	0·75	0·75	0·70	0·66
" 11	..	500 0	1·47	1·18	1·08	0·97	1·38	1·21	0·98	0·96
" 24	..	500 0	1·51	1·29	1·13	1·08	1·51	1·33	1·25	1·09
" 31	..	..	1·52	1·29	1·11	1·05	1·49	1·30	1·23	1·07

Date.	Time.	Weight Applied.	Sinkage. A.	Sinkage. B.	Sinkage. C.	Sinkage. D.	Sinkage. A.	Sinkage. B.	Sinkage. C.	Sinkage. D.
		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1876 Jan.	Cradle fixed.		Row 31.				Row 32.			
" 20	..	450	..	..	..	..	..	..	..	..
" 31	..	500	·12	·15	·18	·17	·18	·22	·19	·16
Feb. 5	..	..	·28	·28	·32	·32	·24	·31	·30	·31
" 14	..	..	·39	·44	·48	·46	·38	·50	·40	·47
" 24	..	..	·46	·50	·56	·56	·50	·57	·55	·57

Date.	Time.	Weight Applied.	Sinkage. A.	Sinkage. B.	Sinkage. C.	Sinkage. D.	Sinkage. A.	Sinkage. B.	Sinkage. C.	Sinkage. D.
		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1876 April 5	Cradle fixed.		Row 33.				Row 34.			
" 6	350 rails.		Nil.				Nil.			
" 11	..	500	1·69	1·49	1·48	1·57	1·47	1·31	0·98	0·82
" 17	..	..	1·88	1·71	1·66	1·80	1·58	1·40	1·08	0·92
" 24	..	..	2·33	2·12	2·18	2·20	2·07	1·94	1·50	1·43
May 1	..	..	2·50	2·29	2·85	2·17	2·23	2·03	1·71	1·52

Date.	Time.	Weight Applied.	Sinkage.				Sinkage.			
			A.	B.	C.	D.	A.	B.	C.	D.
		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1876 Feb. 23	Cradle fixed.		Row 35.				Row 36.			
" "	..	80	Nil.				Nil.			
" 26	..	462	0·75	0·72	0·74	0·77	0·73	0·62	0·50	0·69
March 8	..	500	1·42	1·16	1·08	1·99	1·11	0·90	0·83	0·79
" 17	..	"	1·52	1·21	1·22	2·09	1·18	1·04	0·98	0·90
April 8	..	"	1·68	1·27	1·35	2·18	1·35	1·11	1·07	0·97

Date.	Time.	Weight Applied.	Sinkage.				Sinkage.			
			A.	B.	C.	D.	A.	B.	C.	D.
		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1875 Oct. 22	Cradle fixed.		Row 37.				Row 38.			
" "	..	112	Nil.				Nil.			
" 25	..	112	..	0·03	0·04	0·04	0·03	0·02	..	0·01
Nov. 1	..	112	..	0·01	0·01	0·06	0·03	0·02	..	0·04
" 8	..	130	..	0·06	0·09	0·10	0·05	0·05	0·04	0·04
" 15	..	163	..	0·04	0·11	0·16	0·08	0·10	0·08	0·13
" 22	..	482	0·41	0·47	0·48	0·44	0·52	0·52	0·41	0·45
" 29	..	500	0·87	0·83	0·85	0·65	0·88	1·04	0·91	0·84
Dec. 6	..	"	1·07	1·08	0·98	0·88	0·87	1·16	1·08	0·91
" 13	..	"	1·17	1·11	1·05	0·92	1·22	1·19	1·08	1·01
" 20	..	"	1·20	1·25	1·16	0·98	1·44	1·29	1·12	1·08
" 27	..	"	1·23	1·23	1·15	1·11	1·37	1·30	1·14	1·04
1876 Jan. 3	..	"	1·26	1·27	1·19	1·07	1·44	1·35	1·20	1·08

Date.	Time.	Weight Applied.	Sinkage.				Sinkage.			
			A.	B.	C.	D.	A.	B.	C.	D.
		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1876 Jan. 11	Cradle fixed.		Row 39.				Row 40.			
" 12	..	183	Nil.				Nil.			
" 17	..	420	1·08	0·81	0·53	0·52	0·56	0·60	0·60	0·34
" 24	..	495	1·12	0·69	0·84	0·51	1·02	0·90	0·77	0·63
" 31	..	500	1·22	1·11	0·96	0·83	1·21	1·02	0·90	0·71
Feb. 5	..	"	1·28	1·14	0·90	0·84	1·29	1·05	1·00	0·75

Date.	Time.	Weight Applied.	Sinkage. A.	Sinkage. B.	Sinkage. C.	Sinkage. D.	Sinkage. A.	Sinkage. B.	Sinkage. C.	Sinkage. D.
		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1876 Feb. 5	Cradle fixed.		Row 41.				Row 42.			
„ 5	744 rails.		Nil.				Nil.			
„ 9	..	470	·30	·30	·37	·64	·34	·36	·33	·32

Date.	Time.	Weight Applied.	Sinkage. A.	Sinkage. B.	Sinkage. C.	Sinkage. D.	Sinkage. A.	Sinkage. B.	Sinkage. C.	Sinkage. D.
		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1876 March 8	Cradle fixed.		Row 43.				Row 44.			
„ „	342 rails.		Nil.				Nil.			
„ 17	..	500	·89	·88	·82	·88	·93	·70	·83	·90
April 3	..	„	·96	·87	·81	·87	·97	·72	·81	·93

Date.	Time.	Weight Applied.	Sinkage. A.	Sinkage. B.	Sinkage. C.	Sinkage. D.	Sinkage. A.	Sinkage. B.	Sinkage. C.	Sinkage. D.
		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1876 Mar. 25	Cradle fixed.		Row 45.				Row 46.			
April 6	..	500	Nil.				Nil.			
„ 11	..	500	·01	·05	·04	·04	·01	·05	·03	·00
„ 29	..	500	·42	·49	·46	·47	·46	·47	·43	·46

Date.	Time.	Weight Applied.	Sinkage. A.	Sinkage. B.	Sinkage. C.	Sinkage. D.	Sinkage. A.	Sinkage. B.	Sinkage. C.	Sinkage. D.
		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1876 May 10	Cradle fixed.		Row 47.				Row 48.			
„ 10	..	500	Nil.				Nil.			
„ 15	..	500	·03	·07	·06	·01	·03	·03	·04	·07
„ 22	..	500	·07	·07	·08	·08	·05	·06	·10	·09

Date.	Time.	Weight Applied.	Sinkage.				Sinkage.			
			A.	B.	C.	D.	A.	B.	C.	D.
		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1876 May 22	Cradle fixed.		Row 49.				Row 50.			
„ 22	..	250	Nil.				Nil.			
„ 29	..	500	·62	·60	·62	·62	·51	·56	·56	·52
June 5	..	..	·62	·62	·67	·68	·58	·60	·55	·55

Date.	Time.	Weight Applied.	Sinkage.				Sinkage.			
			A.	B.	C.	D.	A.	B.	C.	D.
		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1876 June 12	Cradle fixed.		Row 51.				Row 52.			
„ 13	..	500	Nil.				Nil.			
„ 19	..	..	·18	·26	·32	·28	·10	·17	·20	·22

Date.	Time.	Weight Applied.	Sinkage.				Sinkage.			
			A.	B.	C.	D.	A.	B.	C.	D.
		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1876 June 25	Cradle fixed.		Row 53.				Row 54.			
„ 26	..	475	Nil.				Nil.			
July 4	..	500	·20	·12	·20	·27	·28	·17	·20	·13
„ 10	..	..	·17	·12	·15	·27	·20	·15	·19	·13

Date.	Time.	Weight Applied.	Sinkage.				Sinkage.			
			A.	B.	C.	D.	A.	B.	C.	D.
		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1876 July 3	Cradle fixed.		Row 55.				Row 56.			
„ 4	..	480	Nil.				Nil.			
			Sinkage after eight days' standing.							
„ 10	..	..	·18	·11	·11	·03	·11	·13	·09	·10
„ 16	..	500	·14	·20	·11	·18	·16	·16	·12	·09

Date.	Time.	Weight Applied.	Sinkage.				Sinkage.			
			A.	B.	C.	D.	A.	B.	C.	D.
		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1876 May 26	Cradle fixed.		Row 57.				Row 58.			
,, 28	..	450	Nil.				Nil.			
,, 29	..	500	·36	·51	·46	0·83	·45	·46	·43	·81
June 5	..	,,	·56	·75	·68	1·03	·59	·61	·70	·52
,, 13	..	,,	·69	·90	·76	1·18	·69	·79	·85	·67
,, 20	..	,,	·74	·91	·80	1·25	·77	·81	·90	·69

Date.	Time.	Weight Applied.	Sinkage.				Sinkage.			
			A.	B.	C.	D.	A.	B.	C.	D.
		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1876 May 10	Cradle fixed.		Row 59.				Row 60.			
,, 10	..	470	Nil.				Nil.			
,, 15	..		Sinkage after four days' standing.							
,, 16	..	500	·17	·20	·28	·37	·14	·16	·11	·58
,, 22	..	,,	·16	·17	·29	·41	·12	·18	·21	·61
,, 29	..	,,	·15	·27	·36	·58	·17	·24	·31	·69

Date.	Time.	Weight Applied.	Sinkage.				Sinkage.			
			A.	B.	C.	D.	A.	B.	C.	D.
		Tons.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1876 April 24	Cradle fixed.		Row 61.				Row 62.			
,, 24	..	490	Nil.				Nil.			
,, 29	..	,,	·51	·62	·57	·82	·49	·56	·62	·69
May 8	..	500	·48	·78	·68	·91	·47	·68	·71	·98

Mr. G. B. Bruce said the system of shipping ore by gravitation had been adopted by Mr. Harrison, Past-President Inst. C.E., at the Tyne Docks.[1] Going into the matter of how to carry out the intention of the company, of shipping a large quantity of ore at Huelva, he took into consideration the various methods adopted in England, and thought, on the whole, the plan followed by Mr. Harrison was the best. It had been a matter of deliberation whether it would not be preferable to carry the pier along at a low level, and to have some hydraulic apparatus at the end to lift and tip the wagons. He came to the conclusion that that would be a slow process, and not one which would be so satisfactory as to incur the greater expense of making the end of the pier at a sufficient height to allow of the wagons being run down by gravitation and be tipped, and then on an incline back to the station-yard, which was barely above high-water level. The pier had a peculiar feature in it. After extending from the shore for a considerable distance at right angles, it turned round, and the shipping part of the pier was in a line with the waterway, so that the ships lay in the direction of the current. This might have been managed by constructing the pier with a T-head; but that would have involved turntables, which would have been a slow and unsatisfactory process. The great difficulty was with the foundations, which were worse than was expected when the pier was designed. It could have been overcome by putting in a larger number of screw piles, and perhaps by going down to a greater depth. That would have cost a great deal more; and, on the whole, he considered it would not have been more satisfactory than the plan ultimately adopted. The mud was about 80 feet deep. Mr. Dixon had some borings made, he believed, which went down deeper than that. The plan followed by the contractor was this. He first completed the ironwork. Each pile was screwed down to its exact depth, irrespective of whether the bottom was hard or soft, and then the platforms were fixed round the pier. The platforms were weighted with rails and pig-iron, at the shore end with 300 tons per platform, and further on with 500 tons. They sank under that pressure quite clear of the ironwork, the distances varying from 1 foot to 5 feet. When that was done, the cast-iron discs in two pieces were put round the piles, underneath a collar upon the pile, and in that way the whole structure could not settle without the weight being transmitted to the timber platform. There was bearing power enough in the screws alone to hold the structure

[1] *Vide Minutes of Proceedings* Inst. C.E., vol. xviii., p. 490.

without any weight on it; and then the platforms were put in to give sufficient stability to the structure when the trains were upon it. Although some of the platforms sank considerably at first, yet they never sank afterwards, and he had not heard of the structure having given way in the least; he believed it was strong and solid. There was one point which might perhaps be called in question. The road was carried upon timber, and not upon iron. It was a question whether perhaps it might not with advantage have been iron. It was a good deal cheaper to put timber; and considering that there were different elevations, different unequal heights, and so on, it was much handier to deal with timber than with iron for that purpose; and covered as it was with 8 inches of ballast, he did not think that there was the least fear of accident from fire. But Spain being a hot country, and timber being dry in that climate, it was thought desirable to have a pipe along it which was fed by a cistern at one end, kept constantly full in case of accident. The ore shipped was extremely hard, and therefore the spouts, which had a curve in them that could not be avoided, were lined with steel to avoid cutting. The couplings for the wagons were self-acting, an American patent, but one easy to work, and which answered remarkably well. While the pier was being built some experiments were made for him by Mr. Kirkaldy upon the strength of timber of whole balks, 12 feet between the bearings, which seemed to him to differ in the results from the experiments mentioned in books usually taken as authorities. All the timber was pitch pine, excepting where it was between wind and water on the shipping deck and the 3-inch planking, which were creosoted Memel. The experiments made by Mr. Kirkaldy when reduced to the capacity of a piece 12 inches long and 1 inch square in the case of the pitch pine, the average weight per cubic foot of which was 48 lbs., showed a breaking transverse strain of 430 lbs., loaded in the middle. He had not been able to find an example of pitch pine anywhere, except in an old book of Templeton's, where it was given as 916 lbs. It had a permanent set with 240 lbs. The average power to resist crushing of a piece 10 inches in diameter and 50 inches long was 4,680 lbs. per square inch. With regard to Baltic red wood, 12 inches long between the bearings by 1 inch square, the average breaking weight was 271 lbs., and there was a permanent set at 144 lbs. Templeton gave the bearing capacity as 556 lbs., and Beardmore and Molesworth 446 lbs. as against the actual experiment here, 271 lbs. The power of Baltic red wood to resist crushing was an average of 2,445 lbs. per square inch as against what was given by Beardmore and Molesworth of 5,400 lbs. per square inch.

Mr. JOHN DIXON said, any one who stood on that pier could not but witness with pleasure the working of the trucks on the reverse gradients. The quantity of ore which that system gave facilities for shipping was almost unlimited. He believed about 700 tons were shipped at the first experimental trial, the men being unaccustomed to their work, in about four hours, and 1,000 tons could now be shipped before twelve o'clock, at each of the four spouts; so that the Rio Tinto Company need have no fear that, great as was the productive power of their mines, there would be any difficulty in getting all their ore shipped. With reference to the railway, although there was no gradient exceeding 1 in 75 in going up to the mines, there was no reverse gradient against a load descending from the mines; and as there were passing stations at about every 6½ miles, the return traffic could be worked with facility. There were one or two points in the construction of the pier to which it might be interesting to direct attention. One was the device of Mr. Gibson of adopting about low-water mark a ball-and-socket joint—an exceedingly simple thing, merely two flanges kept apart about 0·4 inch, and a slight curve given to the spigot. This afforded facilities for rectifying the line, and the joint being afterwards plugged with cement, became exceedingly solid and stable. Another point of interest was the screws which had been adopted. They were intended to be about 4 feet in diameter, but when the soft nature of the ground was discovered it was deemed advisable to increase the diameter to 5 feet. A 5-feet screw of ordinary construction was rather awkward to ship when fixed to the shaft, and the device was adopted of casting the screws loose and of threading them on to the end of the shaft, where they were held by a bolt the inside head of which was counter-sunk in the pile, so that it offered no resistance to the borer or other tool passed down. This not only facilitated the shipment, but it reduced both the freight and the amount of breakage. The system of bracing was another thing which led to exceedingly good results. All the tie-bolts in the structure were passed through the columns, so that there was a firm substance to screw the bolts up against, and the whole structure was put into rigid tension by which the greatest amount of strength was secured with the smallest quantity of material. He thought that a work on which such a large sum of money had been expended should have had an iron floor, especially in such a climate. The Author had alluded to the manual labour employed in the work. With such a number of piles to screw, it might reasonably be imagined that he ought to have adopted something more scientific than the old practice of hand-screwing. That did occur to him, and an elaborate apparatus for carrying out the screwing by steam was provided, but, as frequently happened, it was found, as soon as work was commenced, that the conditions were different to those for which the apparatus had been provided, and fresh conditions arose. Piles had to be increased in size and sunk to a greater depth. So that, after all, he could not but think that in an ordinary way it was difficult to beat the old-fashioned plan of putting several men to work and turning the piles by manual labour. An objection might be raised to the under-scouring of the timber platforms sunk on the bed of the river. However, that plan was not adopted until the engineers had satisfied themselves that the ground, though soft, was so tenacious that there was no danger of under-scouring.

Mr. A. C. Pain assumed from the free use of timber underneath the pier that the teredo navalis and other marine worms were not present.

Mr. John Robinson said it had been shown how a good bearing surface on a bad foundation had been obtained in a simple and economical manner. The method adopted at the deep-water end was novel; first constructing the pitch pine foundations on the surface of the water, then of the pier weighting them to sink them to the bottom, and afterwards, by means of divers, fixing bearing girders to the piles to transmit the weight on to the platform. That was a practical method of laying a foundation in deep water, which might be repeated in similar cases. In situations where timber was liable to be attacked by sea worms, or white ants, iron joists and plates might be substituted. Where the soft strata extended to an unknown depth it would be desirable to make an experiment by weighting a pile as it went down at every 5 feet, and noting each time the weight it would bear for the purpose of ascertaining at what rate the bearing power increased with the depth, and in order to judge the best depth at which to stop. It would probably be found in a structure of that kind, where platforms were used, that it was only necessary to screw the piles down to a depth sufficient to steady the superstructure laterally, and that all beyond that was not worth the cost. For bridge work that kind of foundation on soft stuff would commend itself to engineers, who carried out works abroad, for the ease and rapidity with which it would be laid. The tables on pitch pine appended to the Paper would be valuable, because little that was reliable had been published relating to this wood.

Sir James Ramsden remarked that it would be interesting to know what was the relative cost of high and of low level structures. This seemed an expensive structure, when there was only provision to load four vessels at the same time at the end of the pier. Looking at the delicate nature of the foundation, it appeared to him that a less expensive structure would have been more satisfactory under the circumstances. It must also be remembered that this was the terminus of a mineral railway, and that the mineral might be exhausted. Therefore the less costly the structure, the sooner would a profitable result be attained. Looking at the perfection of hydraulic and steam machinery for raising and shipping, he thought a less costly structure might have answered the purpose.

Mr. Bruce observed that the low level line was to be used for the Huelva and Seville railway, which would bring ordinary goods. The structure was not merely a mineral railway pier, but a pier for a railway which would bring all kinds of goods to Huelva, and would take all kinds of goods back from Huelva to the rest of Spain. There was little doubt that Huelva would become the chief shipping port before long for that part of Spain instead of Cadiz. Therefore it was not a mere pier for mineral traffic. The low level line was used for ordinary traffic, and the high level for mineral traffic.

Mr. Gibson, in reply, said the Tharsis pier had been standing for several years. There was not the slightest indication of the presence of any worms in the timber, although the timber had been placed in the mud when the works were started. Considering the special and great amount of work that had to be regularly done he thought the expenditure that had been incurred was fully justified. The resources of the mines, according to the testimony of scientific referees were sufficient to supply the chemical trades for more than a century, while the mines were also capable of being worked for the production of copper, and, if need be, of iron also. Judging from the company's contracts, 300,000 tons of ore, at least, would have to be shipped annually. By the pier as built, this could not only be done at a much smaller cost than by a cheaper structure; but the facilities enabled the company to load at a low cost per ton, and by the quick despatch of steamers they obtained the most favourable freights. In addition to this, the lower floor of the pier had been let to the Madrid Alicante and Zaragossa Railway Company, and there was reason to anticipate a fair return from the dues on the import and export which that company, with its 1,400 miles of line, would have to pass over the pier.

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