(*Paper No. 2601.*)

"The Arauco Railway and Bio-Bio Bridge."

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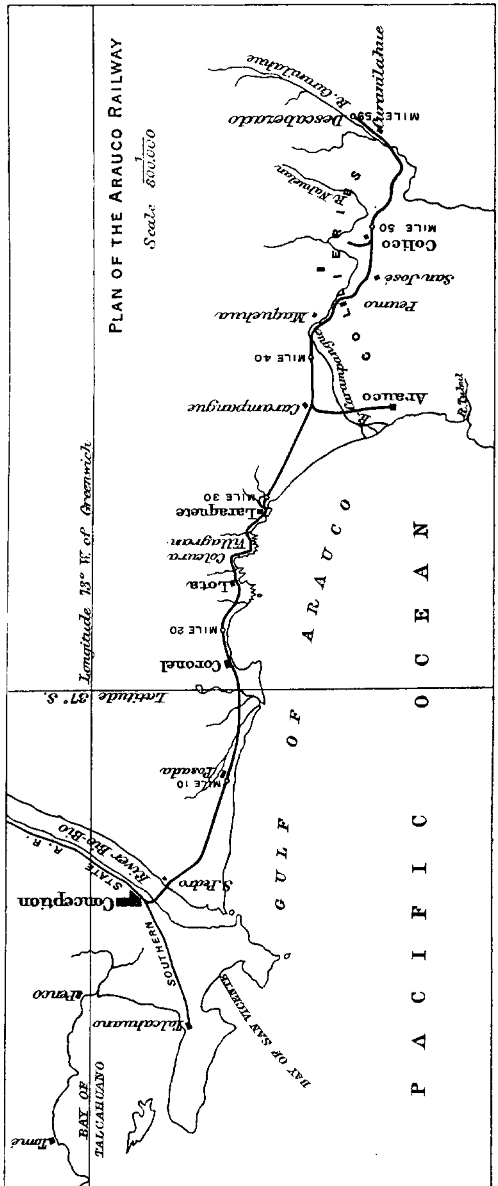
The Arauco Railway is situated in the south of Chili, in the provinces of Concepcion and Lebu. From its junction with the State Railway in the city of Concepcion it follows a southerly direction along the sea coast for 30 miles; then, turning inland, it runs through the Arauco Company's coal properties, and ends at a spot called Descabezado, 59 miles from Concepcion (*Fig. 1*).

The construction of the railway was commenced in November 1886, and the main line was opened to traffic throughout on the 1st of April 1890. A branch line, 5 miles long, has since been built from mile 37 on the main line to the city of Arauco, and was inaugurated in April 1891.

The main object of the construction of this railway was the development of the Arauco Company's coal properties, which extend from mile 41 to some distance beyond the present end of the line at mile 59. The staple article of transport is of course the company's coal, but there is besides a considerable amount of general goods and passenger traffic. Almost immediately after leaving Concepcion, the line meets the River Bio-Bio, which it crosses by means of an iron bridge 6,118 feet long, a full description of which will be given further on. After crossing the river, the line runs over easy ground to the port of Coronel (mile $17\frac{1}{2}$), and afterwards through some rough country to Lota, mile 23. From Lota to Laraquete (mile 30) the line follows the face of very steep cliffs, where exceedingly heavy work occurs. This section includes nine tunnels and many very deep cuttings. From Laraquete to the end of the main line the earthworks are tolerably heavy, and numerous timber bridges and viaducts occur, some of which are 60 feet high.

The Arauco Railway is built to the standard gauge of the Chilian State railways, 1 metre 68 centimetres, equal to 5 feet $6\frac{1}{8}$ inches. The width at formation-level is generally about 15 feet. The rails

Fig. 1.



Map of the Arauco Railway.

are of the Vignoles pattern, and weigh 50 lbs. to the yard. The sleepers are of native timber. The limiting radius of curve is 660 feet. The maximum gradient is about 1 in 90, but there is no great length of it, and the line is generally very easy, with long stretches of level and gradients under 1 in 150. The rocks traversed south of the Bio-Bio river are almost exclusively micaceous schist, clay, and sandstone, belonging to the coal formation. The schist is hard, and contains numerous quartz veins. To the north of the river the formation changes, and the tunnel forming the northern approach to the Bio-Bio bridge runs through gneiss. All these rocks disintegrate rapidly by exposure to the atmosphere, and the tunnels require, therefore, to be lined throughout. The only iron bridges are the Bio-Bio bridge and another of a single 81 feet span near Laraquete. All the remaining bridges are of timber, the piles or trestles being of native timber, and the stringers of Oregon pine. The usual type of trestle bridge consists of 20 feet spans, with four longitudinals 16 inches by 12 inches of Oregon pine. The native timber makes excellent pillars, but it is not so reliable under tensile strain. It is generally of a very enduring nature.

The total number of tunnels is twelve, and their aggregate length 2,300 yards, out of which 720 yards were driven by means of compressed-air machinery, and the remaining 1,580 yards by hand. All these tunnels gave a good deal of trouble, owing to the treacherous nature of the rock. Their cost, including lining over nine-tenths of their total length, has been £44 *5s. 2d.* per lineal yard. The lining is generally of brick in the arch and stone in the walling, but in some places of either material throughout. The thickness varies from 18 inches to 24 inches, and 3 feet in bad places.

The rolling-stock is of English manufacture; it is built with central couplings, which are used on all the Chilian State railways. The locomotives are of four different types, weighing 16, 20, 35, and 42 tons respectively. The three heavier types are six-wheel coupled engines. Their rigid wheel-base does not exceed 9 feet. The passenger carriages are of the American type, on bogie trucks. The coal-wagons are four-wheeled, weighing about 5 tons, and carrying 10 to 11 tons of coal. Recently some American tubular frame bogie-cars have been sent out, weighing about 9 tons, and intended to carry 24 tons.

The total cost of the Arauco Railway, 64 miles in length, including the branch line to Arauco city, has been £571,900, distributed as follows:—

	£
Earthworks	119,200
Tunnels	101,800
Bio-Bio bridge, including general expenses	74,500
Other bridges and culverts	18,000
Permanent way	58,100
Buildings	46,900
Land and expropriation	13,100
Fencing	4,400
Telegraph	900
Rolling stock	47,900
General expenses, comprising freights, insurance, commissions, agencies, landing-charges, carriage, general expenses, salaries, house-expenses, law-costs, surveys and preliminary expenses for all parts of the railway except the Bio-Bio Bridge	87,100
Total	£571,900

Or £8,936 per mile.

The Bio-Bio Bridge.

The Bio-Bio river, which flows past the city of Concepcion, is the widest on the west coast of South America. It is also one of the shallowest during the greater part of the year, as the average depth of lowest summer water does not exceed 18 inches. But it rises very rapidly when the rainy season begins, and attains, in exceptional years, a maximum height of 9 feet above summer water-level. It rains very heavily in this part of Chili; the annual rainfall is generally between 50 and 60 inches. In 1883 it amounted to 65 inches, of which 53 inches fell in five months, from May to October. The bed of the river is composed of heavy, coarse, black sand, reaching to a very great depth. Borings made for coal-prospecting in the banks not far from the site of the bridge have gone through 150 feet of sand before touching rock, and it is probable that the depth in the river valley is still greater. The borings for the bridge were not carried down beyond 50 feet, because it was ascertained that the sand possessed the requisite bearing-power at a much lesser depth. This body of sand is intersected at varying depths by beds of clay and gravel, generally not more than a few inches, but in some places as much as 2 feet in thickness. The average speed of the current is generally from 3 to 3½ miles per hour, but during freshets attains 6 to 6½ miles. The deepest channels are constantly varying in position. The greatest depth of scour is about 12 feet below the level of summer water-level. The mouth of the river is only about 5 miles below the site of the bridge; but the effect of the tides at the bridge is barely perceptible.

The preliminary borings and experiments led to the following conclusions:—

I. That at a depth of less than 20 feet the bearing-power of the sand was at least equal to $7\frac{3}{4}$ tons per square foot, which was the greatest load that could conveniently be placed upon the experimental piles.

II. That screw-piles penetrated this sand with extreme difficulty, and that blades of the required diameter could not be expected, with ordinary means, to reach a greater depth than 12 or 14 feet, which was hardly sufficient for safety against scour.

III. That, judging from the great facility with which some experimental disk-piles were driven to a depth of 28 feet into the sand by means of a small hydraulic jet, there was every probability of reaching that depth with disks of 3 feet, and even 3 feet 6 inches in diameter, by using more powerful appliances.

The system of concrete piers in wrought-iron cylinders, sunk by machine diggers, was at one time suggested; but, apart from the many obvious uncertainties attached to this process under the circumstances, it was principally feared that it might prove a very slow one. The period available for construction was very short, and it was considered that the system of foundation most likely to combine rapidity of construction with the necessary bearing-surface and penetration would be the disk-footed piles invented by Sir James Brunlees, Past President Inst. C.E., sunk by means of the hydraulic jet. The clear waterway between piers was, after some discussion with the Chilian Government, fixed at 82 feet (25 metres), and upon this leading dimension the bridge was designed. The bridge is 6,118 feet long, or 1·16 mile. It consists of sixty-two spans of "Warren riveted" girders (similar in shape to some designed by Sir Alexander Rendel, K.C.I.E., for the Indian State narrow-gauge railways), of 81 feet 8 inches clear opening, resting on sixty-one piers of cast-iron disk-piles, and a brick abutment at each end. Each pier is composed of six piles, divided into two rows of three, 15 feet apart between centres along line of bridge, the three piles in each row being 6 feet apart from centre to centre. These piles are connected by longitudinal and transverse bracing, and each row bears a stout box-girder, on which the ends of the longitudinal girders are supported. The longitudinal girders are 6 feet apart between centre lines. The short longitudinal girders which rest over the piers are fixed at both ends to the cross-bearing box-girders. The main girders are fixed at one end, and rest on rollers at the other. The top boom of each girder carries a balk of timber, upon which are bolted cross sleepers, 2 feet apart between centres. Upon these are spiked the rails and guard-rails. The gauge being 5 feet $6\frac{1}{8}$ inches, the centre of the rail falls well over the longitudinal timbers. The two middle piles of each pier are 15 inches in outer diameter and $1\frac{5}{8}$ inch thick. Their disk-feet are 3 feet 6 inches in diameter. The four outer piles are 12 inches outer diameter and 1 inch thick, with disks 3 feet in diameter. The maximum possible pressure at the foot of the disks, under a train of the heaviest locomotives, amounts to 4·93 tons per square foot on the middle piles, and 3·38 tons on the outer ones. The tested bearing-power of the sand at much less depth than the disks have reached was 7·75 tons per square foot.

The normal level of the bottom of the disk-feet is 55 feet 3 inches below rail-level, and about 28 feet 6 inches below the average level of the river-bed. A good many disks, especially the 3-foot 6-inch ones, have not reached this depth, but all are many feet below the level of possible scour. The highest flood-level ever known to have been reached by the Bio-Bio river is 6 feet 6 inches below the bottom of the longitudinal girders of the bridge.

The weights of the ironwork in the bridge are as follows:—

	Tons.	Tons.
Piers.		
Cast-iron piles, packing-plates and bolts	1,235	
Wrought-iron bracing	230	
		1,465
Superstructure.		
Cross-bearing girders	89	
Roller-boxes and rollers	42	
Longitudinal pier-girders	205	
Longitudinal main girders	1,485	
Handrailing	67	
		1,888
Total		3,353

The weight of each pair of longitudinal main girders with their bracing is therefore 23 tons 19 cwt. The total weight of iron in the superstructure is 30 tons 9 cwt. per span. The average weight of iron in a pier is 23 tons 16 cwt. 2 qrs.

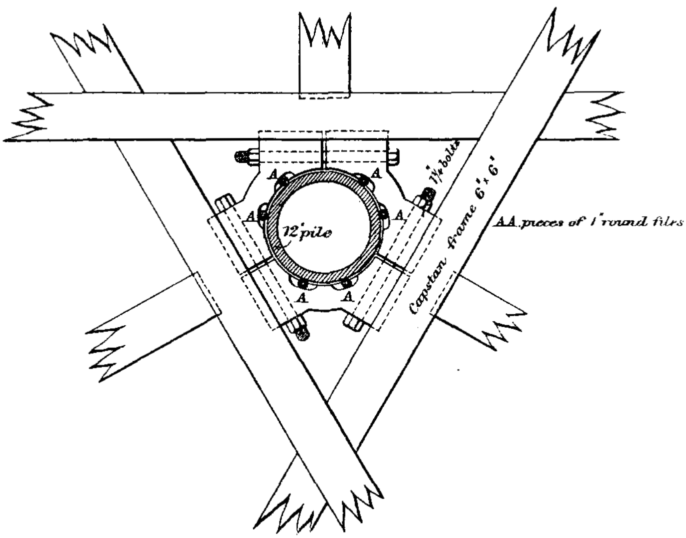
Pile-Sinking.

The disk-feet of the piles were of the well-known shape illustrated in Fig. A, Plate 13, vol. xxvii. of the Minutes of Proceedings of this Institution. They were put down by the water-jet system described in the same volume, and were rotated by steam-power. The pumping-machinery on the southern bank of the river consisted of two Tangye pumps delivering into a 5-inch main, from which the water was taken through 3-inch hose to 3-inch wrought-iron pipes running down the centre of the cast-iron piles, and discharging generally about 8 inches below the disk. The water delivered amounted to about 10,000 gallons per hour, and was sufficient to sink two piles at a time. On the northern bank a duplex Worthington pump was used, capable of delivering about the same quantity.

The piles were rotated by means of steam-winches having double cylinders, 7 inches by 12 inches stroke, fed from semi-portable boilers of from 16 to 18 HP., working at 80 to 90 lbs. pressure. These winches drove, from a 15-inch drum, an endless wire rope 2½-inch circumference which wound several times round a capstan 8 feet in diameter fixed on the cast-iron pile. The arms and frame of the capstan were of timber bolted on to a cast-iron collar or grip, made in three segments. Each of these segments had two wedge-shaped recesses, into which were dropped pieces of 1-inch round files (*Fig. 2*); when the pull came on the capstan, these got jammed between the pile and the narrowing wall of the recess, and served to grip the pile very firmly. This form of grip answered very well, and seldom slipped. When the pile was very wet, a spadeful of sand thrown into the recesses would stop any slipping at once. Yet the strain at the periphery of the pile was sometimes enormous when a pile was driving through stiff ground, and a sudden jerk would come from the winch. Under such circumstances the 2½-inch wire rope frequently parted, and on two occasions the eight 1-inch bolts connecting two of the 12-inch pile lengths, were sheared through by a sudden pull. The lower part of all columns driven to the normal depth, consisted of the disk-foot, section 2 feet 6 inches high, and three 10-foot lengths. This lower part was driven down until the top flange of the uppermost 10-foot length remained 2 feet 6 inches above an assumed line of level of average summer waters, in those piers where the ends of the main girders rested on rollers, and 2 feet 11¼ inches above the same level in those piers where the ends of the main-girders were fixed directly to the cross bearing girders. From the lower portion, the columns were continued upwards by an intermediate length, normally 5 feet 9 inches long, and a capital length 5 feet long, upon which the transverse bearing girders were bolted.

The steam-winches and boilers, after the first four piers were driven from the shore, were always established on timber frames bolted to the lower parts of the six columns of a driven pier, and, from that position, served to drive four piers ahead without

Fig. 2.

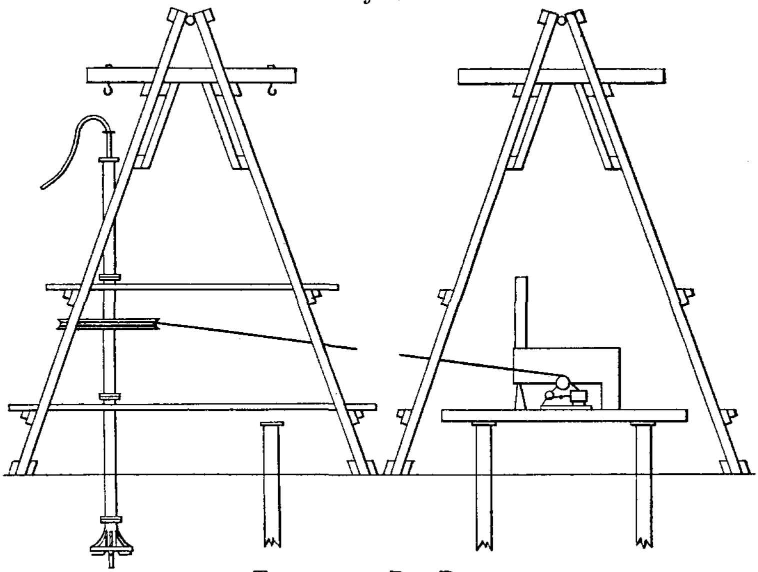


GRIP FOR PILE-DRIVING.

Scale ⅛ inch = 1 foot.

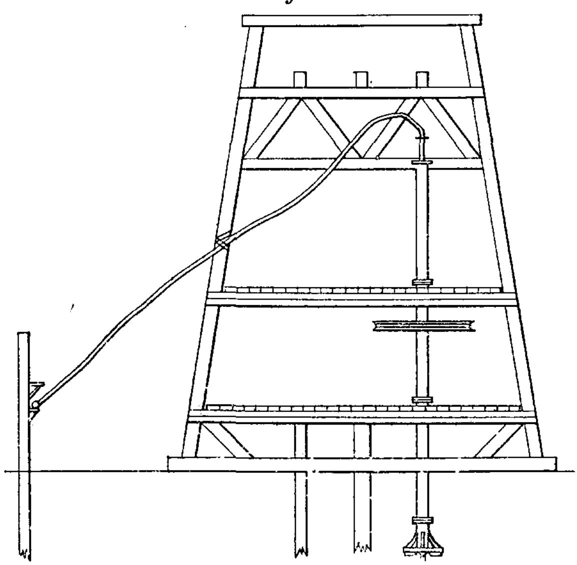
shifting by means of varying lengths of wire rope. The water was delivered alongside the piers through a 5-inch main, supported on timber piles about 25 feet from and parallel with the line of the bridge, and was conveyed to the foot of the disks, through 3-inch hose and 3-inch wrought-iron pipes let down through the centre of the piles. The hole in the pile foot was 6 inches in diameter. The platforms from which the piles were slung into position, guided and driven, were bolted to movable trestles of the form shown in *Figs. 3* and *4*. These trestles were built of Oregon pine, and, after a pier was completed, were let

Fig. 3.



TRESTLES FOR PILE-DRIVING.
Scale $\frac{1}{8}$ inch = 1 foot.

Fig. 4.



TRESTLE FOR PILE-DRIVING.
Scale $\frac{1}{8}$ inch = 1 foot.

down and floated away to the next position. The two halves were hinged at the top by means of a 3-inch pipe slipped through staples. This system worked very well, and resulted in a considerable saving of time and expense, over what would have been entailed by the use of a fixed scaffolding for each pier. The foot of the frames soon settled into the sand, and bore up very well against the pull of the driving rope. Nine trestles of this description sufficed for the whole of the work.

The piles being slung into position, the first step was to turn on the water jet, and let them down, without turning, through the superficial layer of quicksand. In a short time their own weight thus carried them down 2 or 3 feet. This served to anchor the whole system to a great extent and resist any displacement from the pull of the rope. Next the capstan was fixed to one of the centre piles, the rope wound round, and the winch set going. The average time of rotation for sinking a pile to the average depth attained was about 18 hours. Particulars of the speed and penetration will be found in the Appendix.

The pile-sinking began on the 28th of June, 1888, and ended on the 3rd of October, 1889, occupying, therefore, four hundred and sixty-two days. But, out of this time one hundred and eleven days were occupied in sinking the first and second pier. The actual time employed in sinking these two piers only amounted to forty-four working days, so that sixty-seven days were lost at the outset. This delay was due principally to the exceptional severity of the rainy season of 1888, and also in some measure, to the imperfection of the early methods employed. After the first two piers were driven (on the 17th of October, 1888), the work continued regularly until the end with but slight interruptions. From that date onward, work was carried on by day and by night, with the help of the Wells light, burning paraffin oil. Until the 12th of February, 1889, pile-sinking was carried on upon only one pier at a time. After that date two piers were kept going, and from the 1st of March, three piers were worked simultaneously. Between the 17th of October, 1888, and the 12th of February, 1889, thirteen piers were sunk singly, in one hundred and eighteen days, averaging 9·07 days per pier. Between the 12th of February and the 3rd of October, 1889, two hundred and thirty-three days, the remaining forty-six piers were driven, averaging 5·06 days per pier. Of these two hundred and thirty-three days, fifty-three were lost through holidays or stormy weather, so that the average number of working days occupied in driving each pier was really 3·91, of which 2·09 were taken up in shifting scaffoldings and machinery, laying out piles, setting platforms and blowing down, and 1·82 in actual pile-driving. The rate of progress would have been much quicker, had the bed of the river been exclusively composed of black sand. The clay bands and occasional patches of gravel traversed, absorbed more than half the time employed in driving. A clay stratum was struck in most piers close to the finishing depth, and the last few inches often took two or three hours to drive. A good many piles stopped short of the full depth, and resisted every effort to move them. For these columns a shorter intermediate length was cast. A few of the 15-inch piles were stopped 10 feet short of the full depth, in extremely tough ground. While the piles were going through pure black sand, their rate of progress was very rapid, often as much as 7 or 8 feet per hour. Very often, when the disk had reached a depth of over 12 feet, the water, being unable to get away under the disk, would return up the interior of the pile, and run over the top, charged with 25 to 30 per cent. of black sand, thus making an excavation under the foot of the pile which materially assisted the descent. The piles ran in guides on the platforms above and below the capstan, and no very great trouble was experienced in keeping them straight; in fact, much less than is generally met with in driving screw-piles.

The number of accidents was very small. A troublesome one occurred in the first pier from the southern bank; the bolts of the second joint from the bottom of one of the 12-inch columns sheared off when very near the full depth, leaving the top part loose. The disk-foot and bottom length were thus left buried beneath 10 feet of sand and 8 feet of water. The extraction of these pieces caused an immense amount of trouble. The flange of the top length was grasped by four steel rails provided with strong steel projecting pieces, water jets were applied to the upper surface of the disk-foot, and the rails were hauled up by four 20-ton jacks bearing on the other piles of the pier, and on an extra one sunk for the purpose. The upward progress of the pile was extremely slow, but after many slips it was eventually extracted and replaced by a sound column. The lifting force exerted was probably about 50 tons.

Superstructure.

The girders were shipped from England in a comparatively small number of pieces, and were riveted together on the southern bank of the river, whence they were carried and dropped into their places by a travelling steam crane. The first main girder was placed in position on the 2nd of February, and the last on the 19th of November, 1889. The time actually required between the placing of each span, for riveting the bracing, fixing the timber superstructure and laying the rails was about $2\frac{1}{2}$ days, but these operations constantly overtook the pile-sinking, and were frequently stopped in consequence. In performing this work, which consisted of three trips per span, one with a pair of the small over-pier girders, and one with each of the next main girders, the steam-crane travelled altogether 224 miles.

The bridge was tested under the directions of the Chilian Government Engineer, Mr. Dutillieux. Six spans were selected by him for trial under (*a*) quiescent load, and two others for trial under (*b*) running goods trains, and (*c*) running passenger train respectively.

The train for the A and B trials was composed of a 35-ton engine on a 15-foot 4-inch wheel-base, and ten loaded four-wheel wagons weighing about $18\frac{3}{4}$ tons each on 8-foot wheel-bases. This was the greatest weight that could be applied with the company's rolling stock, the car-springs were nearly down. The average load from the front part of this train was 1·13 ton per foot run, or $92\frac{1}{3}$ tons on the span. The goods train was run at a speed of 20 miles per hour. The passenger train was represented in the trial by a 42-ton engine on a 27-foot wheel-base, and nine loaded four-wheel wagons, weighing 9 tons each, on 8-foot wheel-bases. It was run at 31 miles per hour. The measured deflections in all these tests were about 18 per cent. below the theoretical deflections calculated on assumed moduli of elasticity of 20 tons per square millimetre in tension, and 16 tons in compression (equivalent to 12,900 and 10,300 tons per square inch respectively), for girders supported at both ends. This discrepancy might to a small extent be accounted for by the bolting down of one end of the main girders, which, however, does not constitute a fixed end in the fullest sense of the term, and by the rigidity of the timber longitudinals. But by far the greater part of the margin is no doubt due to the good quality of the iron. No permanent set was observed. It had probably all been taken out by the travelling-crane.

The communication is accompanied by a series of drawings from which the cuts in the text have been engraved.

APPENDIX.

I.—Notes on Pile-Driving.

There were sixty piers composed of six piles each, and one pier composed of nine piles. (This arrangement was necessary in order to establish the abutments at a safe distance from the edge of the river bank.) These sixty-one piers contained one hundred and twenty-three piles, of 15 inches outer diameter, and two hundred and forty-six piles of 12 inches outer diameter. The one hundred and twenty-three 15-inch piles penetrated in the aggregate 2,986 feet into the sand. The average penetration of the 15-inch piles was thus 24·28 feet. This penetration was the result of two thousand three hundred and sixty-eight hours' rotation of the columns. The average speed of penetration for the 15-inch piles was thus 1·261 foot per hour.

The two hundred and forty-six 12-inch piles penetrated 6,837 feet. The average depth of sand reached by the 12-inch piles was thus 27·80 feet. This penetration was the result of four thousand two hundred and seventy-nine hours' rotation, the average speed of penetration for the 12-inch piles was therefore 1·598 foot per hour.

In twenty-two piers out of the sixty-one, all piles of both kinds reached the regulation depth, about 55 feet below rail-level, and penetrated into the sand on the average 28 feet 6 inches. In these twenty-two piers, the forty-four 15-inch piles took eight hundred and forty hours' driving, and the eighty-eight 12-inch piles one thousand two hundred and seventy. The average penetration-speed in these twenty-two piers, which may be taken as a standard of the work on account of the uniform nature of the soil traversed, and the uniform depth attained, was 1·493 foot per hour for the 15-inch piles, and 1·975 foot per hour for the 12-inch piles. The penetration-speed of the 15-inch piles was thus 0·756 of the speed of the 12-inch piles. The area of the disk-foot of the 12-inch piles is about 0·735 of the area of the 15-inch pile-feet, so that the speed of penetration appears to have been approximately in inverse ratio to the area of the disk-foot. The amount of water supplied per hour was the same in both cases, but the 15-inch piles required greater power and a slower rate of rotation than the 12-inch piles. The winches had to run more frequently in double purchase when driving the larger piles. In these twenty-two piers, the average time of driving each 15-inch pile was 19·09 hours, and for each 12-inch pile 14·43 hours.

Supply of Water and Motive Power.

The usual amount of water supplied to each pile was 5,000 gallons per hour at 45 lbs. pressure in the main. This quantity was amply sufficient for the 12-inch piles, and no appreciable advantage was observed to arise from an increased supply in driving them. With the 15-inch piles, however, the speed of penetration was somewhat accelerated by an increased delivery, but not to an indefinite extent, and for this class of pile the maximum useful effect was attained from a supply considerably smaller than the maximum available quantity, which was 10,000 gallons per hour when only one pier was at work. The actual work performed under the disk-foot, whatever might be its nature, appeared to depend greatly upon the head of water inside the pile. In the 12-inch piles the water generally filled the pile nearly to the top and very frequently overflowed. In the 15-inch piles this result was more rarely attained. The extra quantity of water required to place the larger pile in similar conditions to the smaller one in this respect, would depend mainly upon the relative contents of the cylinders, and, to a smaller extent, upon the relative surface of ground opened up by the disks. Neglecting the latter element, the contents of the 15-inch piles were about 40 per cent. greater than the 12-inch piles. In practice about that amount of increase seemed to satisfy the requirements of the case.

The water was delivered from the main at 45 lbs. pressure per square inch. The maximum pressure from head of water inside the pile, when full depth was being reached, would amount to 18 lbs. per square inch. The motive power for the rotation of the piles consisted of double cylinder steam-winches with cylinders, 7 inches diameter by 12 inches stroke, supplied from boilers of from 16 to 18 HP. working up to 90 lbs. pressure. The highest speed of rotation of the piles was about 13 revolutions per minute, but they usually revolved at 10 turns per minute with the winch in single purchase. The capstans were from 7 to 8 feet in diameter, and polygonal in figure.

The conditions which govern the work performed by the water-jet are so complex, and probably vary so much in respect of the quality of the sand and other strata traversed, that it would be rash to lay down empirical formulas based upon this single case. This consideration is equally applicable to the amount of motive power required for the rotation of the piles. However, the Author believes that the capabilities of the hydraulic-jet system have been tested to the utmost in the Bio-Bio bridge, and that considering the nature of the stuff traversed, the largest size of disk has been used which could conveniently have been driven down by this means. The rotating-power has proved amply sufficient for all purposes, the water-supply but slightly deficient for a portion of the work. The Author therefore considers that the quantities, both of motive power and of water used at the Bio-Bio bridge, may be fairly regarded as maxima for almost any case in which the adoption of the water-jet system may be technically or economically advisable.

II.—Details of Cost of the Bio-Bio Bridge.

	£	s.	d.
The total cost of the bridge was . . .	74,500	0	0
The iron piers cost	40,578	0	0
The superstruction	33,498	0	0
The two brick abutments	424	0	0
The total cost of the bridge per span was	1,201	12	3
The average total cost per foot run of bridge was	12	3	5½
The average cost of each iron pier complete was	659	16	0
The materials of each pier	251	15	0
Ditto delivered in San Pedro, and erected	408	1	0
The average cost of sinking the six piles of each pier was	377	10	2

	£	s.	d.
Considering the length of time respectively employed in sinking either class of pile, the proportionate average cost of sinking a 15-inch pile was	67	5	0
Sinking a 12-inch pile	60	15	0
The total cost of the wrought-iron girders, ready erected, was	29,486	0	0
The timber superstructure	2,921	0	0
The handrailing	1,091	0	0
The average cost of each complete span of superstructure was	540	5	10
The average cost of the complete superstructure per foot run of bridge . . .	5	9	5
The cost of the wrought-iron girders per foot run of bridge amounted to . . .	4	16	4
(Of which £3 14*s.* 9*d.* represents the value of the iron work delivered in San Pedro, and £1 1*s.* 7*d.* the cost of erection.)			
The timber superstructure cost per lineal foot	0	9	6
The handrailing per lineal foot . . .	0	3	7

The cast-iron piles, together with wrought-iron packing-plates and nuts for same, cost £10 3*s.* 11*d.* per ton delivered in San Pedro.

The wrought-iron girders cost £12 11*s.* 2*d.* per ton delivered in San Pedro. They cost £9 15*s.* in England.

The following general statement of cost may, perhaps, present some interest:—

No. 1.

		£	£
Materials	Value of materials of bridge	31,108	
	Freight and purchasing-charges on same .	9,890	
	Brick abutments	424	
			41,422
Erection	Tools, stores, appliances, plant, and buildings	14,513	
	Freight and charges on same	609	
	Labour in erection	16,004	
	General expenses	1,952	
			33,078
	Total		74,500

	£	s.	d.
Cost of materials per lineal foot of bridge . .	6	15	4½
„ erection per lineal foot of bridge. . .	5	8	1
	£12	3	5½

No. 2.

	£	£
(A.) *Piles and Pile-sinking—*		
Value of cast-iron piles	12,590	
Plant, tools, and stores for pile-sinking	10,325	
Coal	1,551	
Labour in pile-sinking	9,975	
Proportion of general expenses	1,366	
		35,807
(B.) *Erection of upper columns and pier-bracing—*		
Value of wrought-iron pier-bracing	2,893	
Plant, tools, and stores for erection	437	
Labour in erection	1,245	
Proportion of general expenses	196	
		4,771
(C.) *Girders—*		
Value of girders	22,872	
Plant, tools, and stores for erection	2,421	
Coal	388	
Labour in erection	3,415	
Proportion of general expenses	390	
		29,486
(D.) *Timber superstructure—*		
Value of timber superstructure	1,660	
Labour in erection	1,261	
		2,921
(E.) *Handrailing—*		
Value of handrailing	983	
Labour in erection	108	
		1,091
(F.) Brick abutments		424
		£74,500

No. 3.

DETAILED COST OF PLANT, TOOLS, AND STORES FOR PILE-SINKING.

	£
1. Launches, boats, &c.	417
2. Pumps, pumping-plant, pipes, &c.	2,834
3. Scaffolding	1,412
4. Lifting-tackle	863
5. Steam-winches and turning-tackle	1,273
6. Wells light	252
7. Oilskin suits and tarpaulings	211
8. Proportion of cost of buildings and of general tools, stores, and appliances	3,063
	£10,325