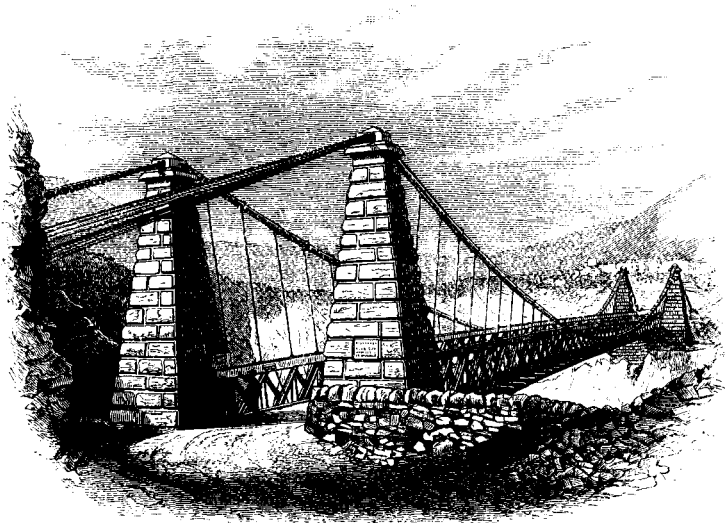


(*Paper No. 1826.*)

“The Kawarau Suspension Bridge, N.Z.”

By HARRY PASLEY HIGGINSON, M. Inst. C.E.

THE lake county of the Middle (South) Island in New Zealand embraces a mountainous district divided by lakes, rocky gorges,



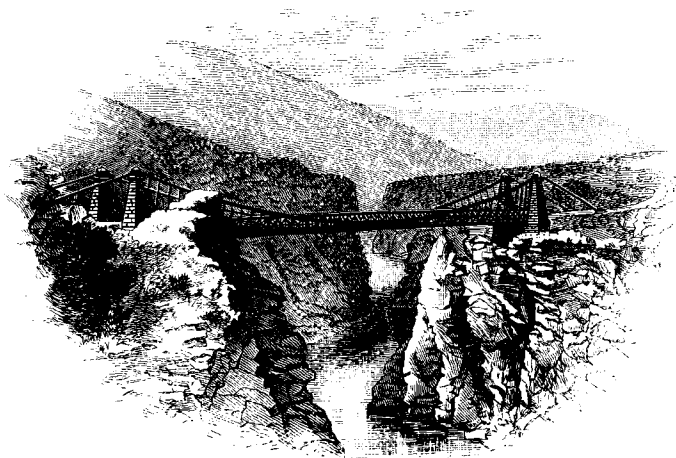
THE KAWARAU SUSPENSION BRIDGE, N.Z.

and rivers subject to floods. Owing to its auriferous character it has for many years been settled by a scattered population, who have latterly brought a considerable area under cultivation. The construction of roads in a country of this description has naturally been costly, entailing the erection of heavy bridge works over rivers which till lately have been crossed by ferry-boats and punts.

The suspension bridge over the river Kawarau, together with about 4 miles of new road, was undertaken by the Lake County Council to improve a portion of the main coach-road between Cromwell and Queenstown on lake Wakatipu, which had always

proved a great obstacle to traffic, owing to the steep gradients and the necessity for maintaining an expensive ferry service over the river. This new portion of the road embraced some heavy rock cuttings, one of which was 50 feet in depth through a projecting spur of the hills; also a bridge 120 feet in length over the river Arrow, another of 60-feet span over the Swiftburn, and other minor works, in addition to the bridge which is the subject of this Paper.

The Kawarau bridge spans the river at a point where it discharges the water of lake Wakatipu, combined with the Shotover and Arrow rivers. It here runs through a deep and rocky gorge for many miles, and is subject to heavy floods. The span is 300



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feet, the platform being 140 above ordinary water-level. The width of the platform is 12 feet between the girders, which is found to be sufficient for a single line of traffic. The versed sine of the cables is one-thirteenth of the span; those at the centre are drawn together 6 feet, forming horizontal as well as vertical curves, so generally adopted in American practice, and which undoubtedly gives great lateral stability to the platform. It also affords greater width between the anchorages, thereby improving the approaches. The violent winds which are frequent in this gorge have but a slight effect upon the bridge. The anchorage tunnels on the north side were driven upon the line of the back stays into a perpendicular face of rock, the roadway being turned under the back

stays and carried up the face of the cliff clear of the anchorages. Upon the south side, owing to the dip of the rock, vertical shafts were adopted, the cables being passed round a curved iron plate, bedded upon a radially-dressed ashlar bearing. The details of the anchorages were the same on both sides (Plate 7).

The four towers were constructed of ashlar masonry, in 18-inch courses, set in Portland cement mortar, some of the stones being upwards of 2 tons in weight. The towers are 3 feet square at the top and 9 feet square at the base. The caps were cut out of single blocks of the hardest stone. Considerable difficulty was experienced in procuring stone sufficiently good for the work, as being a quartzose schist it was very variable in quality.

The cables, which were constructed by the Warrington Wire-Rope Company, are composed of twenty-eight galvanized steel wire ropes $4\frac{1}{2}$ inches in circumference. Each rope consisted of six strands of seven wires each, with a core of hemp. These ropes were arranged in four cables, two upon each side of the bridge. Before shipment from England portions of the wire were tested by Mr. David Kirkaldy, the average result giving a breaking strain of 86 tons per square inch of metal. When twisted into cable form it is estimated that the wire is weakened about 10 per cent., which leaves the ultimate breaking strain at 78 tons per square inch. The factor of safety when the bridge is fully loaded is 4.4. The ropes were originally specified to be $4\frac{1}{8}$ inches in circumference to stand a breaking strain of 67 tons each, but at the suggestion of the manufacturers the size was increased to $4\frac{1}{2}$ inches. The result of the tests proves that the size originally specified would have had ample strength, the factor of safety having been taken at 4, which was considered a sufficient margin.

The wrought- and cast-ironwork was constructed in the colony.

The timber used is the locally termed "red beech" (*Fagus fusca*), which possesses every qualification for bridge-building purposes, being durable, and having a transverse strength equal to English oak. The brace blocks and filling blocks, or keys at joints in the chords, were of Australian ironbark.

In the erection of the cables the ropes were hung over, stretched, and adjusted to correct length separately, a correction being allowed for variation in temperature; the whole was completed in six working days. The following mode was adopted:—

One end of the rope was first passed round an anchor pulley and tightly served with fine wire; it was then fixed into its permanent place in the vertical shaft, hauled across, and the other end passed

round the corresponding anchor pulley fixed into its permanent place upon the opposite side; an ordinary block and tackle was then attached to the free end, and by the help of a double-purchase winch the rope was hauled taut till the deflection in the centre of the span was exactly 6 feet, and left in that position for twelve hours, the strain amounting to nearly 3 tons. It was then lowered, or rather let out, for a length corresponding to the difference between what was necessary for a 6-feet deflection and the permanent deflection of 23·08 feet, when it was fixed by the attachment of clips tightly screwed up.

The anchorages and towers not being in a direct line, owing to the horizontal curve formed by the cables, a temporary staging was erected at the outer side of the towers upon that side of the river where the hauling was effected. The ropes were passed over this stage, which corresponded in height with the saddle-plate upon the towers, next were all stretched side by side, permanently fixed in the anchorage, and then one by one lifted by an ordinary derrick crane and placed in their permanent positions.

By this process the length of the rope was measured while sustaining a strain which entirely removed all tendency to twist or kink, a tendency inseparable from ropes that have been long coiled up. In order also to ensure the rope being tight round the anchor-pulley before being clipped, the weight of one of the tightly-strained adjoining ropes was added to the one being fastened by simply clipping them together. When the full weight of the structure came upon the ropes they all hung correctly in their respective positions and appeared to be equally strained.

It was thought by the Author that the strain applied would have been sufficient to fully stretch the ropes, and that no further elongation would take place from the effect of the permanent load. When however the bridge was completed, the intended camber of 12 inches was found to have been reduced to 9 inches, which for the sake of appearance is ample. This camber has been permanently retained, subject of course to variations in temperature. Before the completion of the work it was found impossible to keep the vertical shafts free from water; they were therefore subsequently filled with Portland cement concrete.

The locality was not conducive to cheap work, being in the centre of the Otago gold-fields, where wages are generally from 30 to 50 per cent. higher than elsewhere. The cost of hauling the material also formed a considerable item, there being 175 miles of railway, 25 miles of water, and 12 miles of road over which it had to be conveyed. The actual cost of the bridge, ascertained from

careful accounts kept during the progress of the work, was as follows:—

Excavation in foundations, shafts, and tunnels	£. 416
Masonry in cement mortar	2,074
Concrete	67
Timber fixed in place "	785
Ironwork " "	635
Steel-wire cables fixed in place	1,110
Painting	136
Plant	150
Total actual cost	<u>5,373</u>

This sum does not include anything for contractor's profit or for engineering management.

The scale of wages paid on the work was: carpenters per diem, 15s.; masons, 15s. to 20s.; and labourers, 10s. to 13s. 4d. The Portland cement cost 45s. per cask delivered.

The designing and carrying out of the work was entrusted to the Author, who was ably assisted by Mr. A. R. W. Fulton, Assoc. M. Inst. C.E., and Mr. Walter C. Edwards, Stud. Inst. C.E., who were in immediate charge.

It may be remarked, in conclusion, that for local reasons, the work was laid out, and the designs and specifications were made, within sixteen days from the date when the Author received his instructions. The designs did not suffer from this hurry, as was proved by the fact that the only departure from the contract plans was necessitated by the sudden dip of the rock upon the south side of the river, the consequence of which was that vertical anchor-shafts had to be adopted in lieu of tunnels as used upon the north side.

The works were completed and the road was opened for traffic upon the 30th of December 1880.

ABSTRACT OF PARTICULARS.

Span from centre to centre of the towers	300 feet.
Versed sine, $\frac{1}{8}$ of span, or	23·08 "
Width of platform between the girders	12 "
Dead weight of the structure	110 tons.
Live load (at 100 lbs. per square foot)	160 "
Total load possible	270 "
Material of which the cables were composed	Steel wire, galvanised.
Sectional area of metal in the cables	25·9 sq. inches.
Ultimate strength of the cables	2,016 tons.
" strain on the cables per square inch of metal	78 "
Maximum possible strain on the cables	459 "
" " " per square inch of metal	17·7 "
Factor of safety	4·4

The Paper is illustrated by one tracing, from which Plate 7 has been engraved, and by two photographs, from which the woodcuts have been produced.

