# LIGHT RAILWAY CONSTRUCTION IN NATAL.

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## PIETERMARITZBURG TO GREYTOWN.

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THE Pietermaritzburg to Greytown railway, at present in course of construction, is of an aggregate length of 68 miles, or half as long again as the wagon road, and is being built as a light line; that is to say economy in first cost is the main consideration. The gauge is 3 feet 6 inches, curve of minimum radius 300 feet, and maximum grade 1 in 30.

Old material, taken from the main line, is used in the permanent way; the rails are 45 lbs. per yard, carried in flat cast iron chairs fastened to the sleepers by trenails and dogspikes.

On curves of less than 500 feet radius, new Karri (W. Australia) sleepers are used, 14 to a rail of 30 feet. On straights and curves of greater radius than 500 feet, creosoted sleepers are put in, 13 to a rail.

The first section dealt with in this paper, is about 19 miles in length, and includes the bridge over the Umgeni River and some of the heaviest cuttings.

The route was governed by the proximity of a high steep range of hills about 8 miles from Pietermaritzburg, and after several trial lines had been run, the one adopted was that passing through the lowest neck, although very heavy work was required immediately beyond, owing to the existence of many streams close together.

At the outset the line descends into the Dorp Spruit Valley, crossing the stream at an angle, and then begins to ascend along one of the spurs of the above-named range until its highest point is attained, when the side of the main range is followed until at a distance of 8½ miles, and an elevation of 2767 feet, a plateau is reached on which a horse-shoe curve is formed, making the ascent to the neck practicable; the greatest altitude being 2819 feet, or a climb from the Dorp Spruit Valley of 856 feet in 6¾ miles. The summit gained, the next obstacle of importance was the Umgeni River, the approaches to which are very steep on each side. An easy trial line was run down the valley, immediately to the right of the adopted line, but was not thought to meet the needs of the people.

The one adopted crosses the river on the top of a whinstone dyke, which, acting as a dam, causes a long reach of water on the upper side, and falls about 40 feet deep on the lower.

The route was finally pegged out at intervals of 100 feet, and the levels of the pegs being taken, sections were prepared and estimates made out. The estimate for the first 19 miles was about £7,600.

The labour employed was Kaffir and coolie (Indian), and the wages paid averaged 30/- a month.

Work was commenced at the end of January, 1898, the contract time of completion of earthworks being thirteen months.

The line was opened for traffic on May 10th, 1899, from Pietermaritzburg to Albert Falls, about 19 miles.

The country traversed is purely agricultural, but there are also indications of coal near Greytown. The market for this district is Pietermaritzburg, and hence the heaviest traffic may be expected from Greytown to Pietermaritzburg. Thus we find the several grades on the Pietermaritzberg side of the summit.

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## Earthworks.

The cuttings were taken out 14 feet wide at the bottom, most of the slopes standing 1 to 1, the earth was run into the banks, which were carried up to the full height and width, at one tip, by means of barrows. According to specification, the contractor had to run spoil to a maximum distance of 300 feet out of the cutting, giving a maximum lead to bank of 600 feet. The average price for moving all kinds of spoil, exclusive of rock, was 1/1 per cubic yard.

On the Pietermaritzburg half of the work, the ground gone through varied little, consisting for the most part of stiff clay and soft shales, but on the other side of the summit cutting a curious boulder formation was met with. This consisted of soft clay and large boulders, and caused great expense to the contractors, as most of the stones were too small to blast economically, but took a great deal of time in hauling out of the cuttings, especially in wet weather. The price paid for moving this class of material was 2/- per cubic yard.

Where banks were tipped in sidelong ground of considerable steepness, the ground was benched. These benches were not less than 6 feet wide and were dug at about 10 feet centres. No trouble was experienced with the earthworks till the side of the main range was reached, and the cuttings at the end of the horse-shoe loop opened up. Fig 1, plate 1, gives a rough topographical plan of the country at this point. Figs. 2, 3, and 4 shew longitudinal and cross sections of the cuttings.

From these several figures, it will be observed that the line doubles upon itself, and, at this particular point, altough the difference in elevation is about 59 feet, the horizontal distance of the two lines from one another is only 117 feet. In the wet season the ground was little better than a bog, and no work was done till the winter set in.

The gullet of the lower cutting was then opened up at the Pietermaritzburg end, and a hard black shale was immediately met with, overlying a bed of whinstone. As there was every indication that the ground was solid throughout, work was commenced all along the lower cutting, and also on the one above. From this latter a portion of the spoil was dumped on the ground between the two cuttings, as shewn in Fig. 4. As the lower cut progressed, small mud rushes were occasionally met with, and on July 2nd, a small crack appeared between the two cuttings, and another one up the hill above the upper cutting.

The remedy suggested by the Engineer in Charge was—to remove the heap of spoil, to batter the top side of the lower cut, till it reached the outer edge of the upper one ; and to batter the top side of the upper one till it stood. At the same time, the hill above the upper cutting was trenched, the object being to relieve the weight above the cuttings. However, hardly had the contractor begun to move the heap of spoil than the ground shewed signs of moving, and on July 16th, a slip of some 3,000 yards came down into the lower cutting. All the available boys were put on to clear the fallen earth and then the cause of the trouble was exposed.

The shale first met with ended suddenly against a vertical wall of whinstone about 10 feet thick. Beyond this was brown shale intermixed with a soft blue clay, and very steeply inclined, and on this, which was as greasy as soap, the earth above had slid. All the fallen earth was cleared and the cutting trimmed to about $1\frac{1}{2}$ to 1. A dry stone wall was built in between the cuts as shewn in Fig. 4, and filled in behind with earth, to afford a toe to the formation above. After the rains of December and January, a spring broke out under this wall, and a large stream poured down the batter into the cut, which soon became a bog. As the watershed is only some 600 feet above the cutting, this spring created a surprise. Examination revealed the fact, that although the water in the pan, shewn in Fig. 1, sank rapidly, it did not flow away through the natural outlet, and the conclusion was that the water in the pan leaked away through a fissure in the ground, and emanated in the cutting in the form of a spring. From the sections of the cuts, it is apparent that the ground has been subjected to great upheavals. As the dry season set in no trouble was caused, and as the line was handed over to the Maintenance Department in June, nothing was done to prevent a recurrence of the spring. The pan could not be drained as it is used for watering stock in the dry weather. The cutting was well drained and the permanent way maintained with ashes.

Whilst the work was going on here, it was noticed by the author that the inclined shale reappeared some 200 feet further on, but as the ground was not very steeply inclined no special precautions were taken to avoid a slip, with the result, that a large amount of spoil from one of the upper cuttings was dumped on the ground between, as Plate II. Fig. 1 shews. In fact, all along the hillside, the question of spoil was a serious one. As there was no place to dump from the upper cuttings without endangering the line below.

This cutting was of a very loose shale, and inspection of the dumping ground gave no cause for alarm. However, hardly had the rails been laid, when the ground began to slip, spewing up under the lower line. The extent of the slip is shewn in Plate II.

At one place (marked "bog" in the plan), the slip came down very fast. A large gang of boys was put on to clear the fallen earth, but it was a week before any headway was made. The stuff taken out was an extremely hard sticky clay, and entailed great trouble in moving.

Over the whole face of slip the stuff was only cleared away to a distance of 7 feet from the centre line, and the way restored. At the time of writing this paper, no further trouble was experienced, notwithstanding some three weeks continuous rain in January, 1899. It is difficult to account for the springs all along the hillside, in the most unlikely places. In the case of this slip, a large hill immediately above should have acted as a watershed, yet the slip over its whole area was in a wet greasy bed of shale.

A third slip occurred after the December rains, some 300 feet further on, resulting in the cracking of a wing wall of a culvert. On Plate II, this point is marked as "slip No. 3"; it will be observed that there are two culverts immediately opposite one another; between these a drain had been cut about 5 feet wide and 3 feet deep, down to a hard shale bottom. The slip came forward into the drain, carrying with it the toe of the bank behind the upper culvert. At one time it seemed as if the whole bank would go.

The culvert was built on a hard shale bottom, the wing walls being 2 feet in thickness, and set in cement mortar; notwithstanding, the wing was cracked from top to bottom. To test the ground, a drain was cut above the upper toe of the bank, when, at a depth of about 18 inches, a fairly strong spring was tapped; this was cut off and drained through the culvert.

The ground in front of the wing was now excavated in the form of a triangle, the shale being gone into about 18 inches; concrete foundations were put in and the old wing, originally at right angles with culvert, was pulled down and built at a skew angle. This was completed on January 5th, 1899.

It was decided to pitch the drain between the two culverts, as the shale, though very hard, used to weather, and at the same time to build a concrete toe to prevent further slip. Plate I, Fig. 5, shews a section of this pitching and concrete. As the excavation was being taken out, wet weather set in, and on the 21st January, the shoring was pushed out and more stuff came down, again cracking the wing wall of the culvert, but not badly. To prevent further pushing over of the wing an excavation was made immediately in front and filled with concrete, but before this had time to set, a tremendous storm came down, and the wall in question moved 3 inches.

Owing to the continuous rain, it was not till the 11th February, that the concrete toe was put in from culvert to culvert, a distance of 80 feet; near the upper one, it was carried some 4 feet into the shale, to act as a buttress to the damaged wing: the drain was then pitched. The broken wing was not rebuilt; the cracks were filled with cement: it has stood well since.

## Culverts.

The rainy season in Natal generally lasts from September to March, and during that time the country is subject to very heavy thunderstorms, and as there are no trees to act as retarding agents, a large body of water comes down the gullies in a very short time: hence, most of the culverts are large. If possible, flood levels in the dongas (gullies) were formed, and the area of culvert thus fixed; where this was not practicable the drainage area was roughly determined, and the size of culvert thus arrived at.

The culverts were of three kinds, arched, box, and open, and the masonry employed was for the most part flat bedded whinstone rubble, with freestone for arches. Cement mortar, 1 to 4 was used throughout the masonry work, the cement being supplied by the Department; the quantity used was about 1 cask to 2½ cubic yards of masonry.

Arches were put in under, banks of 10 feet in height and over, and box culverts under those of less than 10 feet. The covers to these latter were: old rails, corrugated plates, or stone.

At the inlets, wing walls were always built, but at the outlet in the majority of cases, the main walls were carried straight out and stepped down at the same rate as the banks thus ensuring economy in masonry.

The method of putting in a culvert was as follows:—The centre lines of the culvert having been pegged out and sections taken, a foundation plan of approximate dimensions was sent to the contractor who excavated to the depth shewn. If the bottom was approved by the engineer, the working plan was completed and masonry commenced, if not, sinking was continued till a good bottom was reached, levels were then taken and the plan prepared. This system was in many instances expensive, causing loss of time both to contractors and engineers, as bottoms had sometimes to stand open three or four days, during which time a thunderstorm would cause the sides to fall in; but when underground streams were met with it was imperative. These streams were generally found in the boulder and clay formation. The ground was opened up until the water was reached, which was generally at a depth of from 6 to 10 feet. In many cases the water made its appearance at one side of the excavation and disappeared at the other; then a deep trench was cut at the mouth of the culvert, and at right angles to it, and driven each way till the water was met with; this trench was filled with concrete and the water thus driven up into the mouth of the culvert. The main excavation having been carried down about 18 inches below water level, and the clay pockets between the boulders picked out, the bottom was inspected, and if satisfactory, about 2 feet of concrete was put in and the masonry built on this.

At 10¾ miles, two streams joined and flowed in a direction closely allied to that of the centre line of the railway for about 150 feet. There were two proposals, one to put the culvert in at junction of the streams, and cut an outlet through very rocky ground; the other, to put it about 80 feet farther in and cut an inlet. The latter plan was adopted. Plate I. Fig. 6, shews the plan of streams and position of culvert.

The upper stream flows underground, so to intercept it a trench was cut across the valley till the water was reached, when a concrete wall was built in, thus forcing the water up into an intercepting drain leading to the inlet of culvert. At the same time, in case any water should follow the old course, the bed of the stream under the bank was filled with boulders, and a weep hole 12 × 9 feet left in the concrete foundations of the culvert. Figs. 7 and 8 shew respectively longitudinal and cross sections of the floor of culvert.

When an arched culvert was completed and passed by the Engineer, the earth was built up on each side and well rammed to the height of the extrados of the arch, after which the Contractor was at liberty to tip the bank over the culvert at full height.

A great drawback to the progress of the work was the absence of good building stone along the route; most of it had to be brought some 5 miles in bullock waggons.

Some of the culverts were situated in places unapproachable by waggons, and in some instances, stone, sand and cement, had to be carried some 300 yards. Sand also was scarce, and all found had to be well washed before it was accepted.

The cost of culvert masonry was about 32/- per cubic yard. All culverts were dry backed by 12 inches of stone.

Along the latter half of the route the ground is more or less flat and long runs are to be had before the bottom of the valley is reached. Where this length was more than 1,000 feet, a pipe was put in to act as a relieving drain.

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## Bridges.

The first bridge met with is that over the Dorp Spruit, at 2¾ miles. The line crosses the spruit (creek) at an angle, but the faces of the abutments are square with the line and the wing walls parallel to it. Thus the abutments project into the stream cornerwise.

The masonry, all of which had to be brought 5 miles, in waggons, is of whinstone with bed-stones of sandstone, 5 × 3 feet × 1 foot 6 inches.

A good shale foundation was met with about 5 feet below the water level, on this 2 feet of concrete was put, and the masonry commenced. The contract price for this kind of work was—per cubic yard—concrete, 23/-; masonry, 33/-. Owing to the lead of 5 miles on the stone, the cost of masonry was increased to 38/-.

The superstructure is of the ordinary lattice girder type and was lately removed from the main line, as being too light for the increased weight of engines; it is 100 feet clear span. The erection of the girders was an easy matter. During the winter there was very little water in the spruit, so sleeper stacks were built between the abutments, and on these were 12 inch baulks carrying a 3 inch deal floor.

The sections of the girder were wedged up into position and rivetted together. The girders were built with a camber of 2½ inches, and all old and loose rivets were cut out and replaced, but, nevertheless, when the wedges were knocked out and the girders lowered into position, the camber decreased to a bare ⅝ inch. This was due to the original rivetting which was very faulty, in many instances ⅝ rivets were used in ¾ inch holes.

At $12\frac{1}{2}$ miles there is a 40 feet span plate girder bridge. The abutments are of sandstone which was found on the spot, the wings being square with the face of abutment, as at Dorp Spruit. No difficulty was experienced in building, as there was no water in the creek during the winter.

The girders were built on the bank and launched into position by means of a derrick.

At 19 miles is the Albert Bridge over the Umgeni River. This consists of thirteen 40 feet spans of the same type as that at $12\frac{1}{2}$ miles. The bridge is built in the rapids immediately above the falls, and on a whinstone dyke running across the river. All the foundations are on solid rock, the only difficulty being the velocity of the water, which however at most pier sites was only about 2 feet deep, whilst the foundations were being put in.

The rainy season ended in April, 1898, and early in May a start was made on No. 1 abutment, which was on dry land. No 1 pier offered no difficulty, but the work not being satisfactory the sub-contractors were obliged to throw up the work, and considerable delay ensued. A fresh start was made in July, when, in order to prevent delays from possible floods, it was decided that the piers should only be built high enough to be above flood level, and then completed at leisure. The water was now very low, and piers 2 and 3 were put in and built up about 6 feet; a tram line was then laid down and fastened to the upstream cutwaters of the piers, already built, and to projecting pieces of rock; this enabled the work to proceed more expeditiously.

Some trouble was experienced with pier No. 4, which stood right in a very rapid water way, the bed rock at the upstream nose running sheer down, and affording no room for sandbags. Figs. 9 and 10, whilst shewing the type of pier used, shew the position of this pier, and the cofferdam employed. Pieces of timber having been fixed in position to projecting pieces of rock, sheet iron was worked outwards from each end, and the force of the water being thus broken, sandbags were packed between the iron and face of the rock, and on the top of these, concrete in sacks. A small leakage was led away by spouting. The bottom was then cleaned and the concrete put in. The other bottoms offered little difficulty, and on December 9th, the concrete of pier No. 12 was put in. Immediately work was commenced behind and the piers were rapidly carried up to bedstone level. Owing to rains up country, the river rose some 3 feet about the middle of the month, and work was discontinued for some ten days.

Abutment II. was built on dry ground. The masonry was completed on January 6th, 1899. Throughout the whole bridge, no bedstone varied more than $\frac{3}{8}$ inch from true bed level and the noses of the piers, both up and down stream, were in dead line.

Formation level is 7 feet 6 inches above the highest known flood level, and about 12 feet above winter level of water.

The foundations were in every case levelled up with concrete, 1 cement, 2 sand, 4 sandstone.

The masonry was of sandstone, all of which was hauled some 5 miles on bullock waggons.