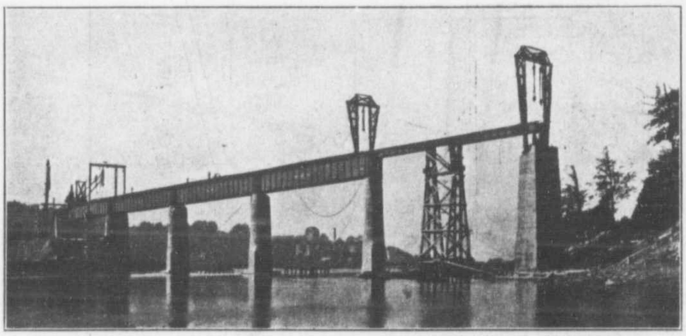
basis a virtual 0.60 per cent. profile for east-bound traffic, for a minimum speed of 10 miles per hour, the train load assumed being 1,631 tons. The only exception was a one per cent. helper grade for the first 6 miles east-bound from Goderich. In extreme cases the above limitations may have been exceeded, depending, perhaps, on an increased acceleration to overcome some of the higher summits.

In order that the effect in such cases could be determined, the diagram had to be abandoned and the usual theoretical rule substituted. This led the writer to compare the data obtained by experiment with the results obtained by theory in expectation of being able to modify the 0.60 per cent. and 10 mile per hour requirement to embrace the new conditions, but he was unable to do so with the class of locomotives expected to be put in operation on the division. This requirement had, therefore, to be departed from in some cases, reducing the speed at summits to six miles per hour and even lower. The velocity heads shown on speed diagram are substantially those given in table 118 of Wellington's "Railway Location," and are derived from the formula for finding force of gravity in falling bodies, $h = v^2/2g$, to which is added 6.14 per cent. for the rotative energy stored in the wheels. As stated elsewhere, the writer is inclined to attach very little importance to the so-called potential energy stored in the wheels of a moving train and doubts if such force has any value in addition to the momentum of a train in its ascent or descent upon a grade. It is evident that the greatest speed of the wheel is at its point of contact with the rail, and is no greater than the speed of the train, the centrifugal force in the wheel itself being dependent on and maintained uniformly with the momentum of the train throughout its entire movement. On this account and for other reasons the factor for potential energy has invariably been omitted from formulas for velocity grades, the result being a closer approximation to velocities obtained from actual experiments.

The distance from Guelph to Goderich is 80 miles, and with the exception of 20 miles at the Goderich end the location presented but few difficult engineering problems. The location of the last 20 miles, however, was repeatedly revised, leaving no doubt as to the final location being the most favorable.



Lower Maitland Bridge during construction, Guelph & Goderich Ry.

The average quantity of earthwork in the first 60 miles was 18,300 cubic yards per mile, that of the last 20 miles 42,000 cubic yards per mile approximately. No rock had been encountered throughout the whole line. The classifications specified were "solid rock," "loose rock" and "common excavation," the latter embracing all materials which could not be classed as loose rock. To avoid disputes and simplify questions arising from the calculations of overhaul the usual clause was annulled and a fixed amount included in the contractor's tender to cover the cost of all overhaul, such amount being previously determined by estimating the extra cost of removing from the line excavation the quantity in gutters of sufficient width to permit of the additional widening being done by train haul. Earthwork was paid for by quantities measured in excavation. The rate of shrinkage observed in embankments was from 5 to 8 per cent., the material being almost uniformly a clayey gravel where observations for shrinkage were made.

The structures are absolutely of a permanent character and are built entirely of concrete, the only exception being the upstream cutwaters of the piers of large bridges at two places, there are no wooden bridges or culverts on the whole line. Concrete pipe culverts were used up to 24 inches in diameter, and concrete arch culverts from 5 feet to 10 feet in diameter, also concrete rail culverts up to 10 feet clear span in low embankments. For greater spans than 10 feet in low embankments, I-beam spans with concrete abutments were used. The proportions of concrete used were for piers and abutments, the 1:4:7, and for arch culverts and foundations under water 1:3:5. There was no difficulty in procuring good gravel for concrete, and frequent tests were made in order that the correct proportion of sand could be added before mixing.

In the designing of piers and abutments the standard designs of the Canadian Pacific Railway were adhered to as closely as circumstances would permit. The graceful form of the piers of the larger structures was evolved from the application of the Gothic shape cutwaters, it being found a circular end above the cutwater base permitted a shorter base than would be required if the radii of the cutwater had to be struck from the corners of a rectangular pier of equal dimensions at the bridge seat. According to Cresy's experiments this form of cutwater is as near as practicable the one that offers the least resistance to the current, in addition to being a more massive form of concrete work where exposed to the erosion of grit and ice.

There are altogether twenty-nine bridges with steel superstructures and, although four of them are of considerable magnitude, there are no lattice spans — plate girders being used exclusively up to 110 feet in