The angle at the circumference subtended by the arc (AF) must be calculated, and a delicate theodolite having been planted at (A), this angle is to be laid off from the tangent. The telescope will then point in the proper direction for the first stake in the curve, and its proper distance from (A) being set off by means of the chain, its position will be determined at once.

The angles at the circumference subtended by (AF) + 100 feet, (AF) + 200 feet, (AF) + 300 feet, (AF) + 400 feet, &c., being also calculated, and laid off in succession, will respectively give the proper direction for the ensuing stakes (G), (H), (I), &c., which are at the same time to be placed successively at uniform distances of 100 feet by means of the chain. It is scarcely necessary to observe, that the difference between an arc of 100 feet and its chord, on any curve which usually occurs on railways, is too small to cause any perceptible error in practice, even in a very long distance; but should curves occur of unusually short radii, it is easy to calculate the proper chord, and set it off from each stake to the next, instead of 100 feet, the length of the arc.

When the inequalities of the ground prevent a distant view from any three stations to lay down the entire curve from them, any stake which has already been placed in a commanding position will answer as a station for the theodolite.

By this method the operation of laying down a circular curve of any radius is made exactly analogous to that of laying down a straight line with the assistance of the telescopic sights of a theodolite.

It is stated that by this method the curve is laid down with accuracy at the first operation; that any accidental error in the position of a single stake, affects that stake only; and it has been found in practice that the progressively increasing errors of the old method are entirely avoided.

Mr. Gravatt observed that a well-made theodolite* was a convenient instrument for setting out curves for railways, and that it had been used by him and by his assistants for this purpose for several years. The common theodolite was not, however, in practice universally applicable without some further contrivances for accommodating it to this peculiar service. Mr. Gravatt.

He stated that the circular arc (used, he believed, almost universally

* Part of the curves of the north division of the Birmingham and Gloucester Railway were set out with the theodolite, by Captain Vetch, in 1836. And in 1837, that gentleman suggested to Capt. W. S. Moorsom, the use of the parabolic curve as being theoretically the best for railways and of practical utility in sharp curves.

on railways) was not the true curve for a line of rails; as might be proved by considering that a straight line of road required both rails to be at the same level, when viewed in the cross section, whilst on a curved road the outside rail required to be raised, in order to resist the tendency of the engine and carriages to fly off the rails in going round the curve.

Where a straight line was joined on to a circular arc, the before-mentioned condition would require an instantaneous and vertical rise of one of the rails, which was a condition that could not be fulfilled.

In curves of contrary flexure, if composed of circular arcs, the difficulty was increased; for the outer rail, which ought to be the highest, suddenly became the inner and the lowest, so that an instantaneous elevation of one rail, and a corresponding depression of the other was required; if the curves were of the same radius, the alteration would be of double the extent to that required when passing on to the same arc from a straight line.

Therefore as the outside rail must be in all cases the highest, the circular arc, which required the manifestly false condition of an instantaneous elevation, could not be the true curve.

He had several years since demonstrated that the true curve was one, which commenced with an infinite radius, decreased in a regular manner, in advancing on the curve, when the radius might be constant for some time, and then increased again to infinity, before it joined either a straight line or another curve of contrary flexure.

He had fixed upon the elastic curve, which complied with all the conditions required, but other curves were also applicable.

His late assistant, Mr. W. Froude, had found that arcs of a cubic parabola, whilst they complied with the necessary conditions, were extremely convenient in practice; the equation and its fluxions, or differential co-efficients, being very simple and easy of application.

Mr. Froude had also applied other properties of that curve, so that with the assistance of a few calculated tables, the process of setting out a true curve was rendered as easy in practice as setting out a circular arc. With any curve there was considerable practical difficulty in finding the direction of the tangents, the radii of curvature, and the position of the curves upon the ground.

Mr. Gravatt used what he termed a skeleton plan, of several stakes driven into the ground nearly in the course of the intended line, expressing their position by columns of figures with reference to two co-ordinates; thus obtaining a numerical accuracy far greater than that of any drawn plan.

By using a table of sines and co-sines, a few hours' calculation would save many days' labour in the field, besides ensuring an accuracy not otherwise to be obtained.

No. 553. "Description of Lieutenant D. Rankine's Spring Contractor." By Wm. John Macquorn Rankine, Assoc. Inst. C. E.

Spring Contractor for Railway Carriages.

This paper describes a contrivance for suiting the action of the springs of railway carriages to variable loads, so as to give the proper ease of motion to a carriage when heavily laden, and at the same time to be sufficiently flexible for light loads. Its effect is to make the strength and stiffness of the spring increase in proportion to the load placed upon it. Each extremity of the spring, instead of supporting a shackle or roller, as in the usual construction, carries a small convex plate of cast iron. The form and position of this plate are so adjusted, that when the carriage is unloaded, it bears on the extreme end of the spring, thus allowing it to exert the greatest amount of flexibility; but as the plate is convex, the more the load increases, and the further the ends of the spring descend, the nearer does the point of bearing of the plate upon the spring, approach to the centre or fulcrum, so that the convex plate or contractor tends to diminish the virtual length of the spring in proportion to the load, the result of which is to increase the strength of the spring, in the inverse ratio of its virtual length, and its stiffness in the inverse ratio of the cube of the same quantity.

The author then gives, in a tabular form, the details and the results of some experiments made on springs of this description, which are similar to those now in use on the Edinburgh and Dalkeith Railway. The springs were 4 feet long, each consisting of ten plates, each $\frac{1}{2}$ inch thick, and $2\frac{1}{2}$ inches broad. The contractors were cast with a radius of $12\frac{1}{4}$ inches, and so constructed as not to act until the load on each spring exceeded 10 cwt., and with a load of 30 cwt. they should have contracted the distance between the bearing points to 3 feet 4 inches instead of 4 feet; by this means the strength of the spring was increased in the ratio of 6 to 5, and its stiffness in the ratio of 216 to 125.*

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* Since this communication was made, contractors of greater length and increased radius of curvature have been applied, so as to produce a contraction of 6 inches at each end of the spring when fully loaded, which increases the strength in the ratio of 4:3, and the stiffness in that of 64:27. The details of the construction of these contractors, with a drawing of them, as applied to the springs of the carriages on the Edinburgh and Dalkeith Railway, are given in the addendum to the original paper.