METHODS FOR THE COMPUTATION FROM DIAGRAMS OF PRELIMINARY AND FINAL ESTIMATES OF RAILWAY EARTHWORK, WITH DIAGRAMS. PART I-TEXT

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METHODS

FOR THE

COMPUTATION FROM DIAGRAMS

OF

PRELIMINARY AND FINAL ESTIMATES

OF

RAILWAY EARTHWORK,

WITH DIAGRAMS

GIVING QUANTITIES ON INSPECTION TO THE NEAREST CUBIC YARD, FOR BOTH REGULAR AND IRREGULAR SECTIONS, DIRECT FROM ORDINARY FIELD-NOTES.

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PART I.—TEXT.

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PREFACE.

THE nearest approach to this somewhat novel method of computing earthwork is found in the methods often used for graphically computing bridge-strains, and occasionally for preliminary estimates; both being based on Analytical Geometry. But there is the important difference in this case that no *construction* is required, or scaling of distances, the quantities being merely read off, as if from a table. Inaccuracy and delay are thus avoided, and the method becomes adapted to numerous and exact computations.

The best description, in fact, which can be made of the diagrams is, that they are a series of CONDENSED TABLES; the only difference being that quantities are read off from lines instead of Arabic numerals, which, with a little practice, is equally convenient. The diagrams might be replaced by tables of the ordinary form, except for three reasons:

First. The tables would be of vast extent; larger, indeed, than all those which have ever been made for earthwork computation put together.

Second. It would be impracticable to secure accuracy in such extensive tables; whereas, in constructing a diagram, any error of importance becomes immediately evident.

Third. Even if the tables were accurately constructed, they would be too bulky for practical use.

These objections are self-evident, if the first be granted. To illustrate that point, let us take a single diagram, Plate I. It extends to about 29 feet centre-heights, with a range in horizontal dimensions of 32 feet. Then to tabulate it, to tenths of each dimension, would require $290 \times 320 = 89{,}600$ quantities, equal to 155 pages of Trautwine's tables, or ten times as extensive a series of tables as all those given in that volume, which are for 12 different road-beds, and extend to 60 feet centre-heights instead of 30 feet. Moreover, every *point* on Plate I. represents a tabular quantity, and this fact enables the range of the diagram to be readily quadrupled, which cannot be conveniently done with tables.

This statement sufficiently illustrates the peculiar advantage of diagrams; that their conciseness and ease of construction enable results to be reached which are otherwise quite unattainable. The only plausible objection which can be made *against* their use, is a lack of decimal precision; and it is so frequently urged as to require some notice, though quite unjustified by facts.

The diagrams for construction estimates read to the nearest cubic yard, in all cases, or to half-feet of sectional area. Now, the unavoidable irregularities of construction render this limit abundantly accurate even if the field-notes were absolutely correct, and the method of computation perfect. As a matter of fact, they are never so. In the field-work, half-tenths are habitually neglected, and there are other sources of error. In computation, nine-tenths of railway estimates are made by averaging end-areas, which is widely erroneous, and the remaining tenth by the "Method of Level Sections," involving errors greatly in excess of the "error of observation," and tending always to deficiency. In fact, it may safely be asserted that no

theoretically perfect earthwork estimate of any extent has ever been made, because the labor ordinarily required is quite incommensurate with the importance of the result. By the aid of diagrams, however, an estimate may be made with a theoretical nicety now rarely if ever attempted; or, if preferred, we may rest content with any degree of approximation; but, in either case, quantities are determined directly from the notes, with little or no computation. When such a result is rendered possible, a minute compensating error may safely be left to take care of itself—although it may prove a fatal objection to that numerous class who condemn "theoretical refinements," but carry out "end-area" solidities, with great care, to decimals of a yard.

It is not supposed that all the diagrams given will be of equal value in practice. The Diagram of Cross-Sections and of Triangular Prisms will probably be of most general convenience; especially the latter, from its very general application to all varieties of earthwork. Diagrams of Cross-Sections for double-track road-beds are not included among the plates, because levels over the road-bed angles are commonly taken with wide road-beds, and the section is then best computed from the Diagram of Triangular Prisms. The Diagrams of Cross-Sections may be applied, however, to all road-beds of the three most common slopes, by the simple process of paragraph 105, so that only a single plate for each side-slope is absolutely required. Only a single diagram for computation by the method of Henck's "Field-book for Engineers" is included, on account of the comparatively rare use of the method. The single diagram given is applicable to all road-beds having $1\frac{1}{2}$ to 1 side-slopes by the process of paragraph 109.

The Diagram of Prismoidal Correction can be used to determine corrections either by the "Method of Level Sec-

tions" or by what has been here termed the "Method of Centre-Heights," and it also offers a concise and theoretically perfect method, which is something of a novelty, and is due to Prof. Charles A. Smith, of Washington University. For the benefit of those interested in exact computation, a comparison of these methods is given in Appendix A, not on account of the intrinsic importance of their discrepancies, but to bring out the fact, which the writer regards as of some importance, that the "Method of Level Sections" has an injurious effect on an estimate as compared with a simpler process; and that the same holds true of some elaborate rules for computing irregular earthwork which have been recommended and possibly used. The practical effect of such methods is mainly visible in a very general verdict that they "don't pay," and in the consequent almost universal use of simple "end-area" solidities. The fact that more correct results can be reached with so little labor as to be unobjectionable to every one is at least not generally recognized, and is thought to be here first demonstrated. To reduce this labor to its lowest terms a little table has been added, in Appendix B, for the reason there stated. The simple expedient of determining separate corrections at any time, to be deducted in the sum total, is not known to have been previously suggested, though it greatly simplifies exact computation.

The methods given for preliminary estimates are entirely new, except that Trautwine's diagrams and tables* subserve the same purpose indirectly as the diagram for a uniform surface-slope. They are especially designed for use with an odometer, to enable the volume of an entire cut with either uniform or double surface-slopes to be determined at once. The method of correcting for curvature

* "A New Method of calculating the Cubic Contents of Excavations and Embankments by the Aid of Diagrams." By John C. Trautwine, C. E.

is also new. All the diagrams proper are of course original, but, except as has been mentioned, they are based on methods in general use, and their only purpose is to eliminate multiplication and division from the process, and reduce it to simple addition. They have been constructed with great care, and, it is thought, will prove trustworthy. They are at least absolutely free from important error. It may be proper to add that the numerical illustrations throughout this volume are given as actually taken off from the originals of the plates, and are a fair test as they stand of the accuracy which can be habitually attained with ordinary care. None of them were previously computed, nor have any legitimate errors of observation been corrected.

In the Preliminary Explanation and elsewhere it has been preferred to err on the side of fullness, as will readily be seen. But little familiarity with the ordinary rules for measurement or with mathematics has been assumed, and none whatever with Analytical Geometry.

The writer takes pleasure in acknowledging his indebtedness to his friend Prof. CHARLES A. SMITH, of Washington University, not only for the equation on which the Diagram of Prismoidal Correction is founded (equation 15) and the suggestion to construct a diagram from it, but also for a number of valuable suggestions during an extensive correspondence; including, especially, that of multiplying all areas by the factor $\frac{100}{54}$ to give solidities at once instead of sectional areas.

A. M. W.

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