from which it will be seen that the volume may be obtained by having the slope stake distances of the two end sections (W and W_2), the centre cuts (d and d_2) the roadbed width (b), and slopes (s), thus eliminating the determination of the middle area from the calculation.

(2) Mean areas, which custom has established as the one to be ordinarily used, because of its simplicity, is merely, volume $= L \frac{A+A_2}{2}$ .....(10)

where A and A_2 are the two end areas, the error involved in this formula is $+\frac{1}{6}L\,(h-h_2)^2\,s$. Where h and h_2 are the two centre heights, and s=slope of earth work, it is evidently = zero when $h=h_2$ and increases with their difference.

(3) Middle area volume is given by

Volume $= L+A_1$ .....(11)

Where A_1 = area of section midway between the ends of the prismoid.

The error involved in this formula is $+\frac{1}{72}L(h-h_2)^2s$, being one-half as much as in the formula for mean areas, and also disappearing.

When $h=h_2$—and although equation (11) is more accurate than equation (10), it is not used, because once the middle area has been determined, the prismoidal formula is easily applied and still more accurate. There is another reason why formula (10) is not objectionable, that, in general, the profile of a line is convex in cuts, and concave in fills, and any system of sections, no matter how carefully taken will, as an average, need a little allowance for this rotundity between sections.

At points where the cut changes to a fill there should be two grade pegs determined (see Fig. 76) and cross-sections taken at these points, this makes the first volumes in cut and fill always pyramidal, there is no necessity for a centre grade peg, unless the distance from one grade peg to the other is excessive.

Borrow pits should be carefully cross-sectioned from some well defined base line before excavation is permitted, and, if at all possible, it should be made imperative that these pits before being abandoned should be left in good shape for final cross-sections and for drainage; undrained borrow pits are unsightly, a menace to health, and difficult, often, of measurement. There is another matter in this connection which should be well attended to, *i e.*, proper referencing of alignment hubs; this may be done by cross lines fixed by hubs, trees, etc., or by right-angled lines and steel tape measurements, but in whatever way accomplished, considerable judgment is required to place the references out of harm's way and at the same time reasonably available; in side-hill cross-sections made after excavation great precision is required in this respect to prevent serious error.

Article 29.—Methods of Payment and Classification of Materials, etc.

There are occasional instances of railway companies of some financial strength and progressive growth carrying on construction under their own management, with their own plant and by day labor, but such instances are not frequent, and in general we may look to responsible contractors for the rapid execution of this kind of work requiring experience, undertaking risk, and with considerable capital as plant continually wearing out. Occasionally such work is taken by contractors at so much per mile, within limits of curvature, grades, style and locality, but as the element of risk is great the price is correspondingly high. Only approximate estimates are furnished, and the experienced judgment of the contractor to size up the class of material to be met with is his chief reliance. Such contracts are apt to be made when the railway company and the contractors are more or less identical.

Again, at times, contracts are taken in which such as timber, stone and iron are specified as to quality and price *pro rata*, but the excavation is unclassified and an average price per cubic yard is given, the contractor again taking chances, and being, by this method, unable to alter the location, his risk is great and price high enough, on the whole, to cover the risk; this has led to what is, at present, the general method of letting contracts for excavation, namely, to define certain classes of material as rigidly as possible and fix prices for each class, the usual divisions are solid rock, loose rock, hard-pan and other cemented material, and earth. As the dividing lines between these classes are purely arbitrary they need to be defined for all possible contingencies, which is a difficult matter. An engineer is always, although in the employ of the railway company, more or less an arbitrator, and he should endeavor to be just to all; theoretically he should always live up to the strict letter of the contract, and ordinarily this is the only course to pursue, but there are cases in which contractors, in their eagerness to obtain contracts, take them at too low prices, or they may strike some very difficult cuts which will not classify very highly if the specifications are adhered to, and in such cases it is usual to allow percentage classifications based on a fair cost of doing the work, *e.g.*, a heavy cutting composed of a mass of small boulders closely cemented together would only classify as hard pan, but often must be excavated entirely by drilling and blasting, and in such a case percentages, at least of rock, would be quite justifiable.

This idea of *helping out* a contractor, however, is a very pernicious one, and should only be done for good cause, where the recipient is worthy of it by his economical handling of the work, and with full knowledge and consent of the railway company. The vigilant watch and full knowledge of the various classes of material met with in excavation and the most economical methods of handling them, form one of the most important duties that a railway engineer has to perform, needing, moreover, a knowledge of men as well as ways and means. The calculation of quantities in structures should be made very minutely and in detail, as the prices are so much higher per unit than those of excavation; but the method to be used will depend on the terms of the contract and the individuality of the engineer. In some cases payment is made on bills of timber furnished, and on general plans of masonry, while in others the actual timber used and the masonry as built are the basis of payment. In the case of timber this latter method should include payment, as timber delivered, for all pieces cut off either from piles or timber, so long as the material used was as per bill given.

Quantities of earthwork should always be measured in excavation, for no one can determine accurately the shrinkage of fills, especially as only a portion of it takes place while construction is in progress, and continues for a year or two depending on the method of forming the bank. The total shrinkage is fairly well known, being about 5 per cent. for sand, 10 per cent. for clay, and 15 or 20 per cent. for loam; while rock expands 50 to 75 per cent., depending on the size of the pieces, and such figures modified according to the age of the bank will be sufficiently accurate for monthly estimates, but not for final ones. It is more laborious, often, to measure irregular borrow pits, but by insisting on these pits being shaped up before being left, the extra labor is not so very great and is the only really reliable way, the chief value of embankment quantities being to aid in a proper dis-