APPLIED GEOLOGY IN MUNICIPAL ENGINEERING.*

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FEW municipal engineers of to-day can fail, after much experience, to realize the importance of practical geology in the construction of their works. The success of underground water supplies, whether attained by knowledge, trial and error, or by a stroke of luck, is admittedly dependent in each case upon the local geology. In works of sewerage, again, the cost may be largely influenced by the nature of the geological materials met with in the trenches and tunnels, producing as they may do difficulties and expense in excavation, timbering, dealing with ground-water, and modification in the design and construction of the permanent work. The same general principles apply to all deep excavations or foundations that may be carried out by the municipal engineer, whether in the construction of new roads with deep cuttings; sea, river, and retaining walls; bridges, reservoirs, sewage tanks, or large buildings. The geology of building stones, road-metals, and similar materials, though in a lesser degree, is of importance in all those branches of municipal work in which they are constantly employed.

One of the most striking factors that has forced applied geology upon the attention of the engineer has been the number of disputes which have arisen between contractors and municipal authorities concerned almost solely with the "nature of the ground" encountered during construction of public works. A few of these cases have been taken to the courts, some to arbitration, while others have been privately settled. In most instances the cause of the dispute has been due to some misunderstanding as to the "nature of the ground," or, in other words, the geology of the excavations; and almost invariably the ultimate result has been costly.

Frequently this kind of trouble has been the result of providing intending contractors with inadequate or misleading descriptions of the strata, obtained from trial holes or borings. Another cause has been the enforcing under the contract of a type of construction unsuited to the kind of ground unexpectedly encountered in the trenches or foundations.

Quite outside the question of legal disputes, however, serious difficulties have arisen, and heavy expense has been incurred by locating works in bad ground, either through lack of previous geological investigations or by wrong deductions from haphazard exploration, when such troubles might have been avoided in the original location or largely anticipated by investigation with practical geological knowledge.

It is a remarkable fact that this branch of engineering, common as it is to all classes of the profession, and on which so much frequently depends, is so strangely ignored in our own engineering literature, and until recently so little considered in the scientific training of civil engineers. Thus we find in our engineering text-books the most minute mathematical investigations of structures, more or less without relation to the varying geological materials on or in which they may be placed.

As a minor example, retaining walls, the dimensions of which, other things being equal, depend entirely upon the geology, water-bearing nature, and dip of the materials to be supported, are subjected to detailed mathematical analysis which may, in the drawing office, be slavishly applied to practice by arithmetical and graphical calculations, without any knowledge of the ground in which the walls are to be built.

To a limited extent the design of tunnel and sewer sections, for example, in "good" and "bad" ground, are considered in text-books; but no account is given of the many types of material met with underground, under varying conditions; nor of the principles of the occurrence of underground water, the great variation in cost, and the difficulties of construction under different geological conditions. Under "earthwork" we find the usual tables of slopes, prismoidal formulæ, and the like, but practically nothing on the highly important subject of "slips," or treatment of soft, unstable, or "bad" ground.

It may be argued, and rightly, that these are matters of actual practice and experience; but this does not excuse the failure of these treatises to impress the student with the great variation in cost and difficulties of engineering construction in different deposits, and the fact that efficiency and economy in construction might be as much the result of geological knowledge and investigation as of skill and experience in calculation and design. In some degree this void in the engineering text-books is due to the extreme complexity and variation in the physical properties of the geological deposits, which render them incapable of mathematical analysis.

Another inconsistency is sometimes to be seen in the letting of large contracts, where we may have items in the schedule of quantities amounting to only a few shillings, yet the contractor may be wholly ignorant of the character of the ground in which the works are to be constructed, and may in consequence under-estimate by several thousand pounds the cost of excavation.

The causes which have contributed to the scant consideration of practical geology among engineers are not easy to determine. Probably the chief of these is the fact that, whatever geological difficulties do arise during construction, it is always possible to complete engineering works, whether economically or not, without geological knowledge, and the engineer is not likely to be blamed by his employers for what turns up unexpectedly below ground.

Secondly, there is a pessimism among certain engineers, some of whom, though they may be experienced in excavation work, have little time for geology, and see only a comparatively heterogeneous mass of deposits underground in no cort of order, and to be classified broadly into two types—"rock" and "muck." There is also the optimist, who expects the geologist by surface indications alone to prophesy precisely what will be met with in almost every yard of his proposed trench, and in consequence loses faith in the accuracy and practical application of the science.

Thirdly, we have scant consideration of the subject in the engineering and geological text-books. The former have already been discussed. The latter, while containing all the necessary elements for the study of the subject, rarely present the applied or practical side of the science, except on the very broadest lines, and include matter that is unnecessary to learn, and which has rarely any direct bearing upon engineering questions.

In the writer's opinion, every civil engineer should be familiar first with the elements of geology, i.e., the principles of stratification, and formation of rocks and deposits, and the various structures occurring in them as the result of formation, change, weathering, or earth movements. He should be able to recognize and describe correctly all the common solid rocks and unconsolidated

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