Development and Application of Soil Engineering in Michigan

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● THE history of soil engineering in Michigan dates from the early days of the state highway department. This agency had been in existence since 1905, but it was the new legislation enacted in 1919 which stimulated rapid growth in organization and activities. This legislation included a $50-million bond issue, money from which became available by July 1919 at the rate of $10 million a year. It was the extensive mileage of new construction at this time which produced serious problems in soil engineering.

In 1926, the highway commissioner's report to the governor stated: "So many questions were continually arising for solution for which no solution was had, that late in 1924 it was decided to provide one engineer whose time should be wholly occupied with these new problems. An engineer with the title of 'engineer on special assignments' was therefore appointed for this work." It was under the direction of this new position that soil engineering studies were started.

The first department activity related to soil engineering was the sand and gravel inventory carried on in cooperation with the state geological survey during the summers of 1924 and 1925. The geological survey supplied personnel, office and techniques; the highway department paid the cost.

During the summer of 1925, an extensive pavement-condition survey and soil-classification survey was initiated. Regarding the personnel for this work, the above-mentioned commissioner's report states: "The character of the soil is shown by a survey made by men trained in this work." Note especially that men trained in soil technology were employed. This fact, plus an open administrative mind, served effectively to start the department on a productive engineering study and incidently to accelerate the development of soil engineering as a new discipline in the field of civil engineering.

Another factor which strongly influenced soil engineering technology as it developed in Michigan will be recognized in the following quotation from the department's 1925-26 report: "It was the thought of the department heads that the (construction) work done previously should constitute a great outdoors laboratory which should show much more truly the performance of different designs under various conditions than could any setup of the more or less artificial conditions necessary to an experimental road. This information was all at hand — it only remained to collect and classify it." And so the research in soil engineering became a field project rather than a laboratory project. During the summers of 1925 and 1926, 500 mi. of soil-classification maps and pavement-condition maps were prepared and the laborious job of correlating the data started. By 1928, the rural portion of the 2,000 mi. of portland-cement-concrete pavement in the state had been mapped and subgrade soils classified.

This extensive research program of field mapping served from the beginning to uncover considerable information on the relationship between pavement behavior and the various soil profiles as identified and mapped. This relationship was apparent to field personnel long before results were available from statistical studies carried on in the office.

During this early period of department history, certain instances of spectacular highway structural behavior occurred with sufficient regularity to act as a powerful stimulant to the rapid development of soil-engineering techniques. The need for working out solutions in the correction of peat-swamp embankment failures, in the correction of frost heaves so serious that they had to be lighted by flares at night to warn traffic, and in the correction of conditions which led to the failure of a new bridge structure were a few of the experiences which proved quite disturbing to the young highway organization. The practical application of soil-engineering skills to design and construction problems therefore got underway by the time the research program was a year old.

The first soil-classification survey for design purposes was made in 1926 on the relocation between Cheboygan and Mackinaw City. Information uncovered by this survey resulted in the adoption of a special cross-section designed to intercept seepage and to obtain a pavement grade of adequate height above water table to prevent frost damage. Probably one of the greatest of the dividends which accrued from mapping soils and pavements along 1,600 mi. of roadway was the intensive training and extensive knowledge acquired by the field men. This mapping program formed the best possible training ground for developing wide experience in the use of various soil textures as highway-construction materials. It served to teach the influence of environment on the behavior of these soil textures as construction materials. Finally, it served to point out certain limitations of routine laboratory tests as a source of general design information. From the beginning, therefore, laboratory testing became a supplement to field studies — a means for obtaining quantitative data for some specific design problem or a means for checking field judgment.

The period from 1925 to 1929 was a time during which the techniques of soil engineering were developed to the point where expansion of these specialized services seemed desirable. Expansion consisted mainly of building a field organization by attracting highway engineers sufficiently experienced to recognize the importance of soil as a construction material. These men were assigned to various sections of the state and then given only technical guidance and training from the headquarters office. Under this system, full advantage was taken of individual initiative, with the result that this period marked a rapid development of soil-engineering techniques and in the application of these techniques. These field men were left free to develop their special bents and to specialize in problems most important to their respective sections. Their special studies and reports became subject matter for group discussions and group field-inspection trips with the result that new and successful techniques were quickly given statewide application.

Aside from selecting the best qualified personnel available for the job, certain other developments were necessary to assist the soil surveyors in improving their efficiency and also to assist design engineers in the use of soil-survey reports. The first step in this direction was the development of a legend of soil descriptions which would apply throughout the state. The technique for doing this was borrowed directly from soil science and consisted of devoting a full page of the legend to each soil so that the soil profile could be both illustrated and described. Information of special significance to engineers was added. At first, all the soils in the state had not been identified and described. Therefore, when an occasional new soil profile was encountered during the course of field mapping, it was described, sampled and named. This information was then given to the Soil Science Department, Michigan State College, where ultimately it was correlated and new names assigned. Gradually, through the efforts of soil scientists, the soils of the state have been identified and described until the comprehensive legend as shown in the 1952 edition of the Michigan Field Manual of Soil Engineering was evolved.

A further development which served to stimulate the application of soil engineering techniques to all highway road projects was the tabulation of routine subgrade design recommendations for all the soils recognized in the state. This tabulation greatly increased the efficiency of the soil engineering personnel by permitting the field engineers to concentrate in their reports on items peculiar to each individual project and relieving them of the need to write long and detailed discussions covering all routine items. Likewise, the designer could, with the aid of this tabulation, obtain most of his needed information without waiting for an opportunity to discuss the project with the soil engineer. The final step in this direction was the publication of the Field Manual of Soil Engineering, now in its third edition.

The period of development in soil engineering services included, also, development in methods of operation. The present soil-engineering practice in Michigan will be described under the headings of (1) Selling the Service, (2) Personnel, (3) Organization, (4) Operations, (5) Tools of the Trade, (6) Advantages Accruing from Long Experience.

SELLING THE SERVICE

Salesmanship is a skill not always considered too seriously by the practicing engineer, especially within an organization such as a state highway department. Efforts in this direction by the Michigan soil-engineering section have consisted mainly of working toward building a reputation as a reliable source of technical information made freely available without carrying with it an inference of ignorance on the part of the receiver, without appearing to encroach on the receiver's field of responsibility, without jealous regard for authorship on the part of the giver, and without entertaining a notion that one's importance will be enhanced if he can keep his "trade secrets" to himself.

Soil engineering has been developed as a service function. Soil engineers, therefore, investigate, analyze, report and recommend but leave action to the design engineer, construction engineer, or to any group who has the responsibility of putting recommendations into effect. This program of investigation has encouraged a constant development in the field of soil-engineering methods. Bringing the results of this development to other engineers has been greatly facilitated by taking active part in technical short courses, department meetings, regional and national conferences. In this manner has reputation been built and the effectiveness of the soil-engineering section developed.

PERSONNEL

In building the soil engineering organization, a serious attempt has been made to find men who by natural bent, personality and training would be happy in soil-engineering work and who, for the same reasons, would have a future in the department. At the beginning, men were selected mainly from a group who had established themselves as successful employees of the Construction Division. These men for the most part had been in contact with construction projects long enough to have gained an appreciation of the need for more and better information regarding soils and foundations. Early training on the new job consisted mainly of teaching the art of classifying soil profiles in the field. This training was simplified by making each man responsible only for one of the eight districts into which the state is divided for general highway administrative purposes. The number of soils with which the new man had to become acquainted were, therefore, limited. The process of training consisted mainly of working with him in mapping the first two or three projects. Subsequent projects which he mapped alone were carefully checked and discussed in the field where the soil profile in its natural environment was available for reference in the correction of errors in judgment and in settling differences of opinion.

Soil engineering has developed sufficient reputation as a challenge to the student with the result that it continues to attract young engineers of ability. In recent years, with the scarcity of experienced engineers, an adequate staff has been maintained by recruiting recent graduates as engineering trainees. As these trainees mature and acquire the necessary experience to carry on as district soil engineers, the older hands are graduated out to better positions, generally within but sometimes outside the department. This system has been criticized as being wasteful in that much time is constantly being devoted to the training of new employees. There is compensation for this extra training work in that a less static personnel becomes more attractive to promising young men. The movement of personnel to better positions is also an important factor in maintaining high morale. In addition, since the soil is an important construction material, engineers trained in soil engineering find the experience of value in other divisions of the Department.

Building an effective organization requires that considerable thought be given to a training program. In addition to time spent with individual men in the execution of their regular duties, the program includes bringing the group together for short courses in laboratory techniques, for special lectures covering new developments in soil classification, for conferences where each can discuss his special problems with others in the same field, and finally, for special field tours in the study of related sciences such as pedology, geology, agronomy and for the study of special problems such as erosion control, slope protection, borrow restoration. The success of these educational ventures requires that advantage be taken of the best talent available. For instance, one of the finest experiences of this kind made available to the soil-engineering group in Michigan has been an annual geology tour under the direction of the head of the Department of Geology, Michigan State College. Each tour has covered glacial geology of a small portion of the state, and each year a different section has been covered until the entire state has been studied in this manner. In the meantime, the personnel roster has changed sufficiently to warrant starting the cycle over again.

ORGANIZATION OF FUNCTIONS AND PERSONNEL

The soil engineering services of the department are organized as one of five sections in the Testing and Research Division. Since this is a service division supplying technical information and recommendations to all other divisions, the soil-engineering group is free to work with any other division wherever their special training may be needed. The arrangement encourages an objective approach to problems. It creates an atmosphere in which recommendations can be made without prejudice on the basis of facts uncovered in the course of study.

A schematic chart is shown in Figure 1 to indicate the functional services of the soil section to other divisions of the state highway department.

The headquarters office for the soil-engineering section in Lansing exercises general supervision over field work. The eight district offices are the actual operating centers for most of the soil engineering work. Supervision of these offices from Lansing is limited mainly to technical problems and does not include the planning of daily work. An important function of the headquarters staff is to serve in a consulting capacity regarding the use of soil engineering information in the execution of other highway operations. This work includes the interpretation of soil-survey data and pointing out its significance in design, construction, maintenance and research. The staff in the Lansing office is limited to the chief and one assistant.

While the bulk of the field work is carried on directly out of the district offices, there are some special services supervised from the Lansing headquarters office. For instance, foundation borings for bridge design, information borings for swamp treatment, and check borings for borrow studies involve the use of three hydraulic boring rigs and two continuous flight auger drill rigs. The need for this expensive equipment in one district is not great enough to justify equipping each district office to do its own boring work. This operation is therefore directed from the Lansing office. So also are two inspectors specializing in compaction control who circulate over the state trouble shooting and training other inspectors in the art of making the necessary field tests. The electrical-resistivity-survey party works out of its own special headquarters near the central laboratory at the University of Michigan and travels mainly in response to requests from the various district offices.

The soil-engineering activities in the district offices are carried out by one district soil engineer and one assistant. The assistant, for the most part, is an engineer or engineering geologist in training. Maintaining an assistant in training is important to assure a supply of trained personnel to take the place of older engineers stepping into more responsible positions.

The soil-engineering service includes, in addition to the Lansing office and the district offices, one central laboratory which serves the entire state. These limited laboratory facilities satisfy the needs adequately because soil-engineering practice in Michigan is principally a field operation rather than a laboratory function. The laboratory serves as a source of check information on field judgment and as a means of obtaining quantitative test data for use in the solution of an occasional design problem. The laboratory testing program splits naturally into two functions. First, the routine testing to determine gradation, Atterburg limits, compaction characteristics, etc. These tests were used extensively to obtain design data, but since the addition of clay binder has been greatly limited in the construction of base courses, these tests are now run mainly to obtain general information regarding the nature of the soil sampled or to aid in the interpretation of other test

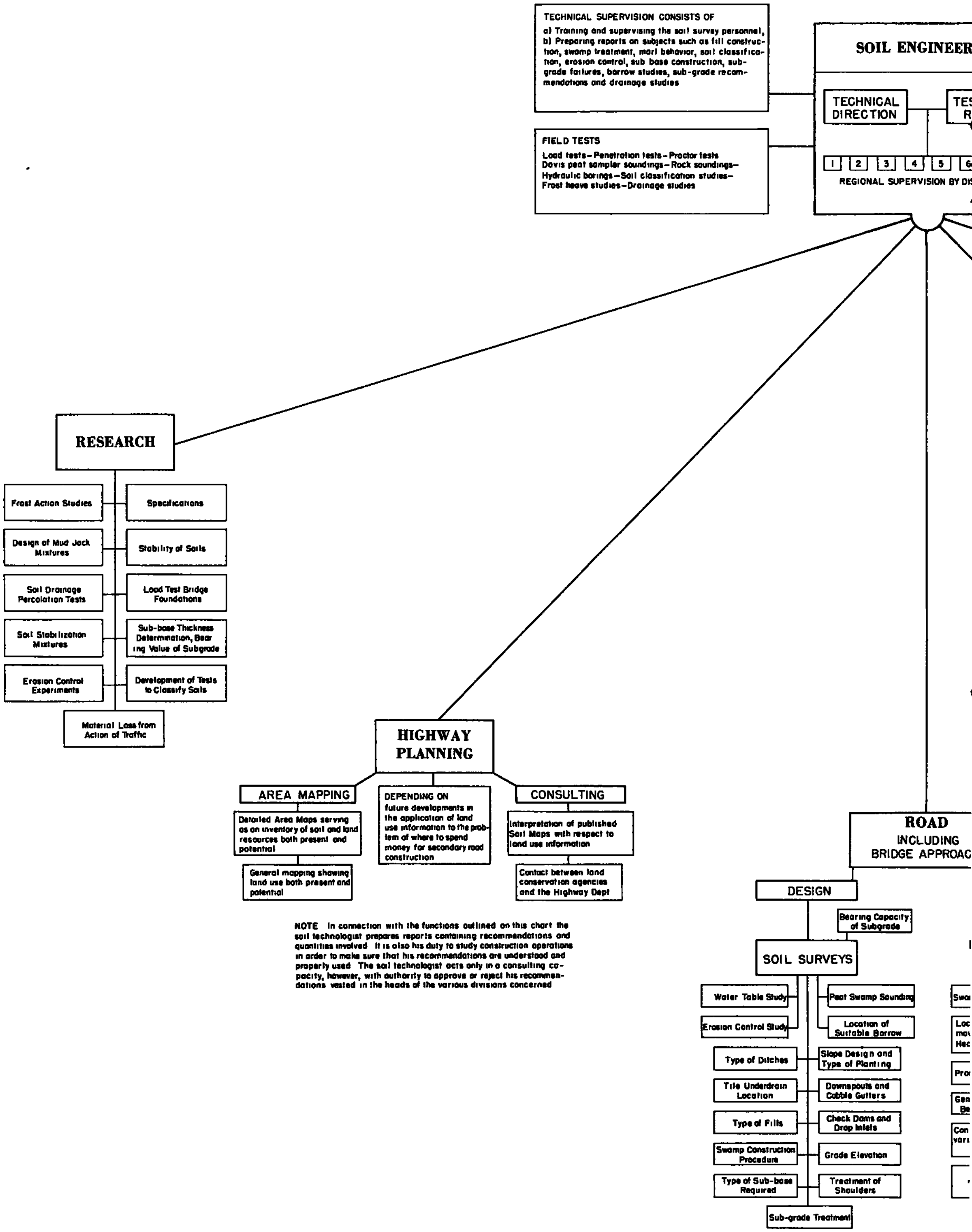
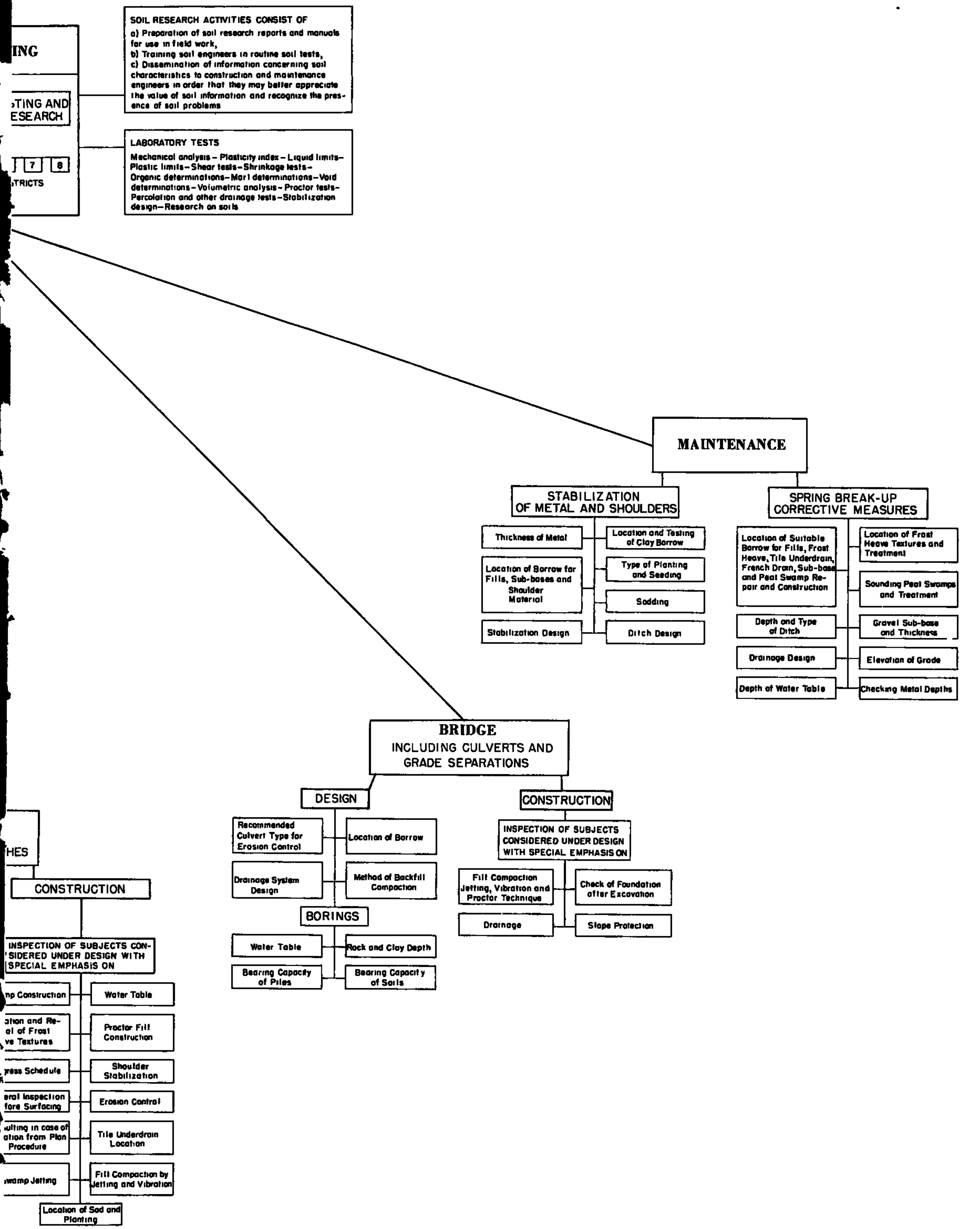


Figure 1. The functions



of soil engineering.

results in the field of soil mechanics. A second laboratory function involves the field of soil mechanics and tests conducted to study the stability of various soil formations. Actually, conducting the tests is the simplest part of this laboratory function. It is the use of test data in the development of definite design recommendations which requires experience and training. For this purpose, a staff member of the Civil Engineering Department, University of Michigan, is retained as a consultant.

Mention has been made of the special services which are administered directly out of the Lansing office. The operation of these various services requires men with a variety of highly developed skills. The operator of a hydraulic boring crew, for instance, must be able to describe soil textures as well as to describe the conditions under which they exist in their natural position. He must be handy with equipment as well as be skilled in handling people. Not only must he be able to get the most out of a pickup crew on a rather disagreeable job, but he must know how to obtain the cooperation of property owners in gaining permission to enter privately owned property to make borings.

The personnel in charge of the electrical-resistivity surveys are trained in geology, pedology, soil engineering and electronics. This survey technique is useless unless it is backed by well-trained and experienced technicians who recognize the limitations of methods used and also who can make accurate interpretations of data obtained.

The employee who is in charge of swamp fill jetting operations must be familiar with the diesel powered pumping equipment. He must also know enough about the effect of water under pressure on the behavior of embankment materials to recognize danger signals and thus protect the men from sudden slides.

OPERATIONS

The foundation upon which all other soil-engineering operations are based in Michigan is the soil-classification survey. The results of this survey is shown on a strip map which is the means by which most of the soil engineering information for each project is transmitted to the Design Division. The soil classification survey serves as a record of subgrade conditions for future reference, it serves as a basis for comparing one project with another, it serves as a means by which soil information may be handed down from one generation of engineers to the next, as a means by which boring and laboratory data (point information) may take on area significance, the means by which both the soil textures and the environments under which they occur are recorded, a means by which future maintenance experience may influence new construction practice.

The technique for making strip-map records of soil information is the result of evolution and includes contributions from many of the other natural sciences. Many of the early specialists in soil classification were trained as geologists which, no doubt, influenced mapping methods. Field mapping for the purpose of classifying the soil of the United States was started by the U.S. Department of Agriculture at the turn of the century. This work has been a continuing operation with the result that there has been a 50-yr. development in classification technique and a large volume of published soil survey reports for areas all over the United States. The techniques developed have become international through the influence of the International Congress of Soil Science and through the wide travels of soil scientists throughout the world.

The highway-engineering profession from the first was quick to recognize the value of the information obtained by soil scientists, but it has been slow to adapt the soil survey techniques for the purpose of recording soil-engineering information. The area concept of soil information has been difficult for engineers to grasp, since their traditional methods for foundation study has been to dig holes and test the materials encountered either at the site or in the laboratory and then to base foundation treatment or design provision on the results of these tests. Recent development in the identification of land forms from aerial photographs has helped greatly to make engineers more area conscious with the result that there is now considerable activity in the development of engineering soil-survey maps from these photographs.

County soil-survey maps and airphotos are excellent aids to soil engineering field work. On the other hand, the scales used in preparing these maps are inadequate for showing the detail necessary for highway design purposes. The soil-survey strip maps, as made in this state, use the same scale as is used in drawing highway plans (1 in. = 100 ft.). This has the advantage of permitting the same degree of detail as the plan portion of the road plans and also of permitting the soil map to be traced directly onto the plan sheets. County soil-survey reports are used mainly as source of general information regarding soils to be encountered and as an aid in sizing up the area to be mapped before actually doing the detailed mapping. Many of the county reports were prepared before an adequate legend was available. The value of these older reports is obtained mainly by reading the descriptions of the soils mapped. The soil names may be incorrect, but the descriptions will serve to suggest the soils to be encountered in making a detailed highway soil survey.

In classifying the soil profile, it is necessary for the soil engineer to study the terrain carefully, to observe the topography, drainage, vegetative cover, surface texture and even land use. He must take advantage of every opportunity to examine the soil profile by studying cut sections, building excavations, tile trenches, and also by the use of soil auger and tile spade. The soil engineer records his findings on the strip map in the form of soil boundaries, soil type names, sounding notes, unusual drainage conditions, and any other information which he thinks may be of interest to the engineer who will be preparing plans for construction. After this field map is finished, the soil engineer may collect samples from some of the main profiles identified for more-accurate information regarding soil properties. Continuous sampling along the centerline is never done. In other words, the soils are classified first, and then such sampling is done as may be necessary to supplement the field survey. One of the functions of the soil survey is to provide the design engineer with information regarding the location and character of construction materials. This involves an inventory of borrow resources in the general neighborhood of the project and also information on which to plan selective grading in order to finish grading operations with the granular soils on top. This is an important consideration in a region of substantial frost penetration, in a region where pavement pumping is a problem, or for a road which must carry heavy truck traffic. In transmitting his soil survey, the engineer writes a brief report in which are highlighted points of special significance to the design or construction engineer.

In the process of making this soil survey, the soil engineer acquires an intimate knowledge of the project under study. He has many opportunities to capitalize on this knowledge of the job as he checks plans in the field before construction and then again later when he works with the construction project engineer in the solution of problems as construction operations progress. Close cooperation between the construction engineer and the soil engineer during the construction phase of the project is an important factor contributing to the quality of the finished product. It is during this stage that the fine points of foundation design are effected. Some of the items involved are the exact stationing of frost-heave excavation, the exact location of special drainage, the detailed control of peat-swamp treatment, the close control of embankment construction, both as to the selection of fill materials and regarding the compaction of these materials.

While surveys and construction occupy the bulk of the district soil engineer's time, there are many odd jobs for the slack periods. Of these, the spring breakup is one of the most important. This involves actually mapping the breakups on a map which also shows the soil classification. Three or four years' record on the same map becomes very valuable as a basis for developing improvement programs, gravel-retirement programs or maintenance-betterment programs. In addition to information on soils and road conditions, the maps are prepared showing the recommendations for correcting the failures. These field records serve as a basis for estimating quantities, preparing proposals, and controlling construction operations.

There are a number of special projects on which soil engineers work with other members of the department in assembling information. An example of these is the gravel-pit survey completed through cooperation with the material section. All the known gravel pits in the state were visited, described, and the information tabulated for distribution to engineers, contractors and material producers.

TOOLS OF THE TRADE

The most-important tool in the soil engineer's kit, the one which will do more than any other in increasing his efficiency, is an adequate soil-classification system. To serve this need properly, the classification system must permit classifying the soil in the field without continuous resort to sampling and testing. The system must be capable of supplying almost all of the necessary design information as soon as the field work is done. Only by this means can a small organization be spread over large construction program.

A second important tool is a soil-engineering manual in which soil-engineering techniques are properly organized and described. This manual contains the descriptions of the soil series recognized in the state. In order that this descriptive legend be useable, it must include a chart in which the soils are arranged in accordance with topographic, textural, drainage, and geologic features which can be recognized in the field. This chart serves the field man as a guide to the soil descriptions which should be studied in connection with any classification problem encountered in the field soil survey.

The hand tools for making soil surveys are simple. One of the most effective is the tile spade. Wherever it can be used, it is superior to a soil auger, because it permits examining the soil with less destruction of the natural soil structure and soil colors. The soil auger's advantage lies in the fact that greater depths can be reached in less time and with less effort. The field man therefore is inclined to use the tile spade as far as he can easily reach and then go on with the soil auger. To do an adequate job of sampling the soil profile, it is necessary to dig a larger hole than can be done with an auger. Small test pits are suggested for this purpose, in order that the horizons of the soil profile may be properly described and so sufficient quantities of each horizon may be collected for testing. In regions containing marsh deposits, the Davis peat sampler is a convenient hand tool for sampling the marsh material at any depth and for determining the depth of unstable materials. It works well in soft clay and peat but cannot be used in sand and gravel. Therefore, marsh deposits containing layers of sand and gravel will require power drill rigs for obtaining an accurate picture of subsurface conditions.

ADVANTAGES WHICH ACCRUE FROM LONG EXPERIENCE

During the 27 yr. since soil mapping for highway use was started in Michigan, most of the highway system has been mapped. Reconstruction along the existing highway routes therefore involves mainly extending soil boundaries, making new maps of alignment relocations, and generally bringing the old maps up to date.

This backlog of maps serves as an excellent source of soil information for any location in the state.

There are other advantages which accrue from long experience. It takes time, for instance, to sell soil engineering to a state-wide industry. This is especially true when that industry includes private enterprise and two or three levels of government. The years of soil-engineering operation in Michigan have permitted the techniques used to become accepted on the county level, the state level, the national level in Michigan, and on the contractor level. This assures maximum use of soil-engineering information as it is submitted for the entire highway-construction program. Even equipment operators on earth-moving jobs associate their own excavating and embankment building experience with soil names such as Miami Loam or Fox Sandy Loam. These names over the years have become a form of shorthand for disseminating a great range of soil-engineering experience throughout the highway industry.