Preparation of Soil Strip Maps for Michigan State Highway Projects

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This paper describes present methods and procedures used in preparing pedological soil strip maps for proposed highways in Michigan. It includes an explanation of the organization, education, and training of personnel who perform this work and discusses the responsibilities and types of work performed by Michigan district soils engineers. The types of information collected in soil surveys and their relation to the planning, location, and design of highways are discussed. Examples of soil type descriptions, pedological soil strip maps, design charts, and a resistivity-survey profile are also included.

● SOIL MAPPING in Michigan for highway purposes is done by the Department's own soils engineers, using the pedological method of soil classification, supplemented by point investigations where deemed necessary. This system has been used for the past 35 years. Information regarding the application of each soils series for highway design and construction, as acquired from experience, is available in the Department's "Field Manual of Soil Engineering" (Fourth Edition).

For the purposes of this paper, it is not deemed necessary to trace the history or explain the theory of the pedologic system of soil classification. This system with or without modifications is now being used by many highway organizations. Instead, this discussion concentrates on the organization and training of the personnel who perform the work and on detailed description of preparing a pedological soil strip map in the field.

PERSONNEL ORGANIZATION AND TRAINING

Michigan has ten highway districts, varying in size from 2 to 13 counties, with 427 to 1,356 miles of state trunkline highway. At present, in each district there is one district soils engineer with one or two assistant soils engineers, depending on the work load. These men are responsible for all of the soils engineering work in their particular district. In general, this consists of: reconnaissance soil appraisals for route location; soil surveys, peat and rock soundings for design purposes; and location and investigation of borrow sources (not including sources of produced aggregates). During the construction stage, it is also the soils engineer's responsibility to investigate the following: subgrade for potential frost heave and differential heave areas, seepage zones, and water tables; quality of sand subbase; quality of compaction; the methods of treatment of peat swamps; and to recognize and assist in the solution of embankment and structure foundation problems. Also, it is his responsibility to provide soils information which may be necessary for maintenance of the highway system.

The central soils office correlates this information; acts as liaison between route location, design, construction, and maintenance; establishes policies; and offers advice and administrative assistance. Scheduling and performing the routine work is the responsibility of the individual soils engineer. The special point or area investigations, which are not performed by the district soils engineers, are foundation borings, resistivity, and seismic surveys. The foundation boring work is the responsibility of the central soils office, and resistivity and seismic surveys are carried out by the central testing laboratory.

There are 26 engineers in the soils division including men in the central office and in the field at the district level. Twenty-one have degrees in civil engineering, three have degrees in geology, and two have degrees in soil science and long experience in highway engineering. Of the 26 engineers, 13 are registered professional engineers. In addition to the engineers, there are four technicians who assist in the district work. These men are former foundation boring crew chiefs.

In general, the policy is to obtain men with civil engineering degrees and then train them for the soils mapping work. Usually, they are assigned to a district which will have one or two experienced soils engineers. They assist in mapping four or five projects along with the district soils engineer, and from the experience gained in this manner can start making soil surveys on their own. In case they run into soils with which they are not familiar, they can call on the district soils engineer for assistance in mapping these areas. An invaluable aid in gaining soil mapping experience is to map a project, and then during the construction stage, to study the exposed profiles and correlate them with the original.

Each summer in a selected area of the state, soils classification tours are conducted by the Soil Science Department of the College of Agriculture of Michigan State University, primarily for local county extension agents, agriculture teachers, and the local United States Department of Agriculture (USDA) soils mappers. These tours are also attended by the highway soils engineers and aid in their training and knowledge of pedological classification. If geology tours are held, they are usually attended by the local soils engineers to aid them in landform identification and the associated soils.

PREPARATION OF A PEDOLOGICAL SOIL STRIP MAP

To illustrate the soil mapping procedure as used in Michigan, the various stages through which a project is followed by the soils engineer are discussed. The first use of soil mapping is in connection with the planning office and its long-range program studies. The soils engineer is consulted as to whether there may be any soils factors influencing the cost of the job and affecting long-range budgeting. In this stage, these factors consist primarily of long or deep swamp deposits which cannot be avoided, bedrock, extensive areas of soft lacustrine clays requiring special treatment, and longer than average haul distances for borrow materials.

The next stage in which soil information is used is during the route location study. During this study, the route location division makes use of the existing USDA county soil maps and the state geology maps in trying to avoid swamp sections and to use borrow sources. Where necessary, these are often supplemented by more detailed soil classification or peat soundings obtained in the field by the soils engineer. This study for route location may cover an extensive area, and therefore is not made in the detail which is used after the final line has been selected.

After the final location has been established and the line staked by the survey crew, the complete detailed soil survey is made. It is made at this time so that the design office will have full use of all necessary soils information in selecting the preliminary design and grade. The special point or area investigations will be made at a somewhat later date.

The base which is used for the soils map will vary, depending on what is available for the project. For projects on which aerial surveys have been made, aerial mosaics will be available using a scale of 1 in. to 200 ft. These are often used as base maps. The photographs are obtained by special line flights. The aerial base map is a positive print on photographic paper. Advantages of the aerial photos are (a) topographic features are readily determined and the soils survey can easily be made if the survey stakes have been removed, (b) soil boundaries are easier to define, and (c) drainage characteristics are more apparent. The main disadvantage is the smaller scale of the photo; they are somewhat bulky to use in the field. Also, the scale is smaller than that used by the design office in the preparation of plans and the information cannot be traced directly. The soil boundaries as shown on the aerial photo are transposed to the plan sheet, using the stationing shown on the aerial photo.

Where the aerial photographs are not available, the most common base sheets are 8½- by 11-in. cross-section paper using a scale of 1 in. to 100 ft. The plan sheet may be used as a base map if the survey has already been plotted.

Once the base map has been selected, the soils engineer is ready to prepare the soils map. Before beginning the detailed field survey, several sources of information are studied. One of these is the state surface geology map. With this, he can readily determine which geologic landforms and associated soils may be encountered. If the USDA county soils map is available, this is also studied. Ordinarily, this does not cover enough detail for highway mapping purposes; however, it does assist in narrowing down the number of anticipated soils series. Also available are small-scale aerial mosaics of the entire state, although at present Michigan does not use them to any great extent in making soils surveys. They may be studied, however, as an indication of what to expect. The major use of these available aerial mosaics by the soils engineer is during the stage of borrow study and location.

After this available information has been studied, the soils engineer is ready to begin the detailed soil survey. Tools used for this purpose consist of a tile spade, orchard or bucket auger, and a soil auger. As he progresses with the soils survey, he constantly observes the topography, the landform, the vegetation, and the agricultural use of the land. Each of these provide valuable tips in soil mapping. He then proceeds to examine the soil profile. This is done by exposing the profile in a cut section or side hill, or by boring a hole. As the material is removed, it is laid out in the form of a soil profile and he notes the texture, color, consistency, and the depths at which the various horizons are encountered. From the information which has already been gained by studying the county soils map and the geologic landforms, he can now anticipate perhaps five or six different soil series. Then by using the soil profiles in the Department's "Field Manual of Soil Engineering" and studying the exposed profile, he can identify the soil series which he is examining (Fig. 1).

As the pedological system shows area significance, it is not necessary to bore holes at certain specified intervals or to specified depths. Conditions at the site determine the spacing and depth of the borings. Only enough profiles are exposed to determine the soils series which is being mapped and its boundaries. This is dependent on the

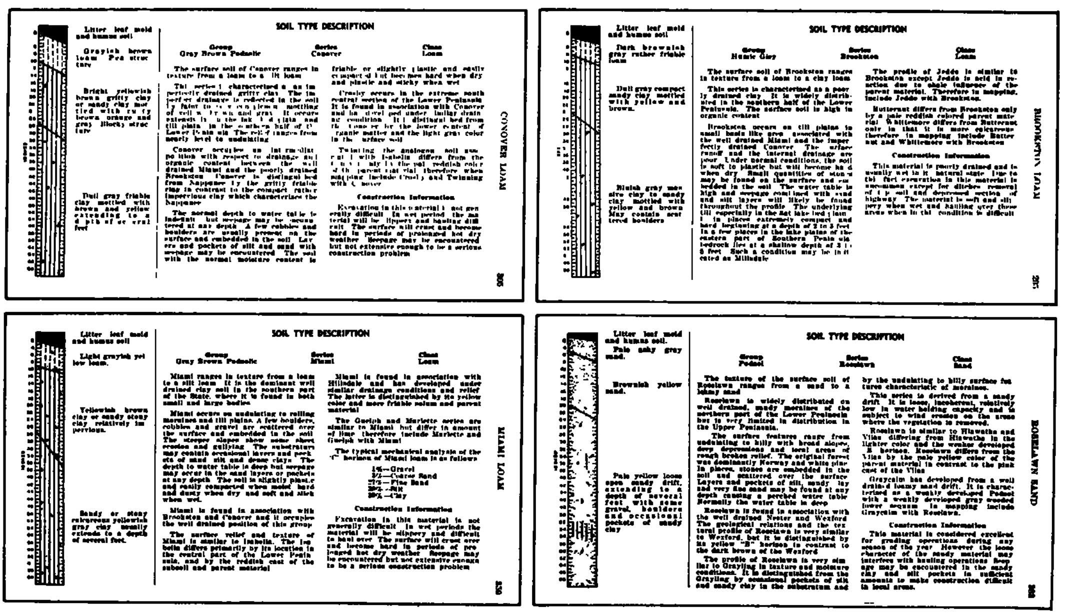


Figure 1. Soil series profiles from "Field Manual of Soil Engineering" (Fourth Edition).

judgment and experience of the soils engineer. Soil boundaries are quite often recognized by changes in topography, changes in vegetation, or changes in the color or feel of the natural ground (Fig. 2). The entire area within the proposed right-of-way is mapped.

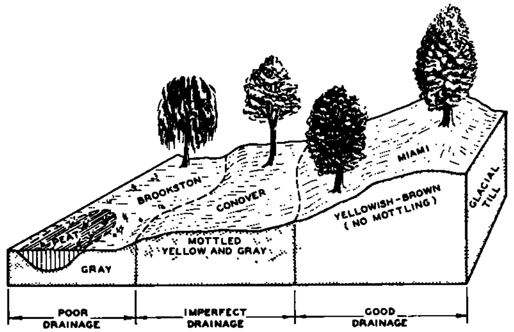


Figure 2. The drainage and relief characteristics of a soil catena.

At each boring, the soils engineer will record the depth of topsoil. However, when the final soils map is submitted, the topsoil depths may be submitted either for each boring or as an average depth for an entire soils series within its boundaries. Depending on the soils series mapped, the soils engineer may obtain the depth to water table, underlying clay, or bedrock. When water tables are mapped, he not only shows the existing water table but also the expected high water table which can be determined by the color and the amount of mottling in the soil. Water tables are taken at intervals of 200 to 400 ft. As the field soil survey progresses and boundaries are mapped, the soils engineer notes where point investigations will be required. Mapping in this manner the experienced soils engineer can map from two to five miles per day.

On the map which is being made the soils engineer will show the boundaries between soil series by dashed lines and denote the name of the soil series. Also, on this map he shows depth of the topsoil and the depth to the water table, underlying clay, and bedrock if encountered (Fig. 3).

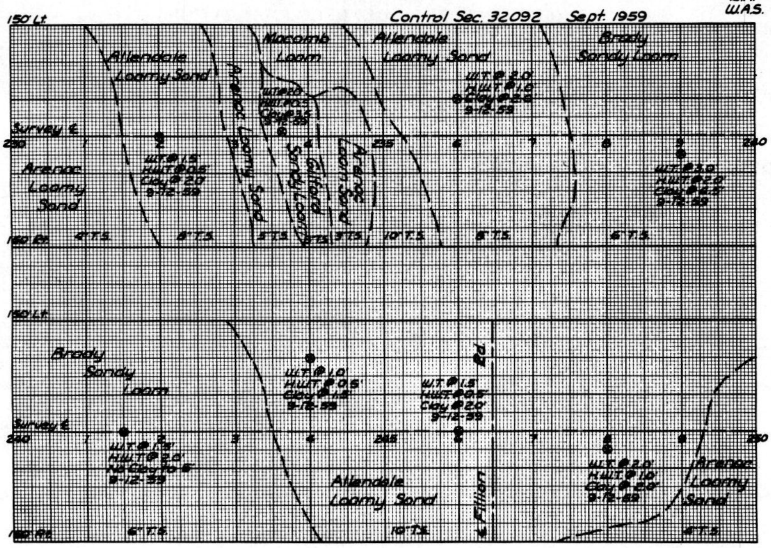
DESIGN RECOMMENDATIONS

The soils strip map, along with recommendations pertinent to the project, are transmitted to the engineer of soils in the Lansing central office. Recommendations for design purposes are usually not made in detail. These are provided in the Department's "Field Manual of Soil Engineering" and particularly its soils design chart which has recommendations concerning the engineering properties for highway design of each soils series. The design chart is the result of intensive correlation of experience and performance of each soils series since the pedological system was adopted in Michigan. It is revised periodically to conform with new policies and specifications. The recommendations can be applied for each soils series no matter where it is mapped in the state, and the only recommendations which need be submitted with the soils strip map are those which vary from the recommendations given in the design chart (Fig. 4). The Department does not recognize all of the soils series which are mapped by the USDA in the state. Many soils which have only slight differences in texture, drainage, pH values, etc., are grouped together under one series. However, the 141 series mapped by the Highway Department have the same names and essentially the same profile descriptions as those adopted by the USDA. Although 141 series may seem like a large number with which to be familiar, it must be recognized that many series are found in only certain parts of the state and that with the information available and the soils engineer's experience, the anticipated number of soils series on a particular project can be narrowed down to 10 to 12.

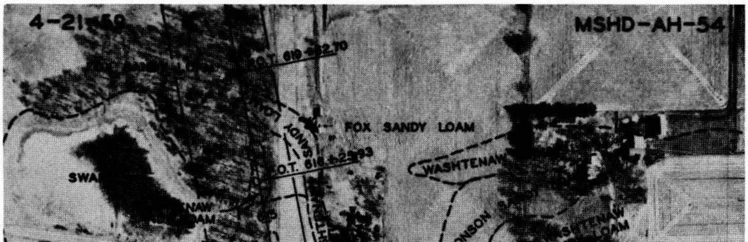
POINT INVESTIGATIONS

As previously mentioned, the district soils engineer ordinarily does not make extensive point investigations during the preparation of the detailed soils strip map. However, while the project is still in the preliminary design stage, he will return for these investigations.

The type of investigation which occupies the majority of his time is peat sounding. He refers to the soil survey for these areas and boundaries. Soundings are taken at



On cross-section paper



On aerial survey

Figure 3. Soil strip map: (a) on cross-section paper and (b) on aerial survey.

50- to 100-ft intervals along the line and at not less than 50-ft intervals across the grading section. The soundings are usually made by hand with the Davis Peat Sampler. As

DESIGN CHART
SOIL ENGINEERING DATA AND RECOMMENDATIONS

SERIES	CHARACTERISTICS: Brief Description of Typical Profile	CHARACTERISTICS: Adapted to Winter Grading (1)	CHARACTERISTICS: Normal Depth to Water Table (2)	TREATMENT – GRADE: Recommended Location of Plan Grade with Respect to Natural Ground (3)	GRADE: Recommended Protection of Slopes (4)	GRADE: Estimated Percent of Boulders (Rock Excavation) (5)	GRADE: Estimated Depth of Topsoil (ft.) (6)	GRADE: Subbase Recommended (See Specs 2 11) (See note e) (7)	GRADE: Selected Subbase Recommended (See Specs 2 11) (8)	GRADE: Est. Lineal Ft. Per 1000 Ft. of Cut below Natural Ground Elevation – Frost Heave Excavation, Per Roadbed (m) (9)	Edge Drains, Per Roadbed (m) (10)	Bank Drains: Use only if cut is deeper than (11)	Bank Drains: Lin. Ft. per 1000' (11)	EMBANKMENT: Suitable Borrow (12)	EMBANKMENT: Recommended Method of Restoring Borrow Pits where Restoration is Necessary (See Specs 2.08 03-k) (13)	EMBANKMENT: Percent of Shrinkage (14)	RESOURCES: Porous Material Grade A (See Specs. 7 02.03-g) (15)	RESOURCES: Possible Source of Gravel (16)	RESOURCES: Source of Topsoil (See Specs. 2.08.03-e) (17)	REMARKS
Brookston	Poorly drained clay	No	Shallow (g)	Fill 4—5 (n)	Seed (n)	0 0	7—1 0	Yes		300 (a)	600 (a)			No		25—35	No	No	Excellent	
Conover	Imperfectly drained clay	No	Indefinite(f)	Remarks	T S. (c)	0 0	6—9	Yes		300	600			Ltd.	F S.&M. (c)	25—35	No	No	Excellent	(3) Controlled by surface drainage
Miami	Gently rolling clay uplands	No	Deep	Anywhere	T S. (c)	0 1	4—7	Yes		300	600			Yes	F S.&M. (c)	25—35	No	No	Good	
Roselawn	Well drained sand rolling to hilly topography	Excellent	Deep	Anywhere	F S.&M.(c)	0 0	1—4	No (k)	Yes	200	300			Yes	Plant (b)	10—30	Yes	No	No	

GENERAL NOTES

(a) These answers apply only where standards of vertical alignment require cut sections in variance with recommendations in column 3.

(b) Plant collected stock. (See specification 7 21-a-4)

(c) The method of treatment by T S. (Topsoil and Seed) and by F S.&M. (Fertilize Seed and Mulch) where recommended, should be used on all 1 on 4 slopes or flatter and, also on 1 on 2 slopes through shallow cuts and fills. The 1 on 2 slopes through deeper cut and fill areas should be sodded.

(d) A fill will always be required due to the wet condition of the soil and the possibility of overflow

(e) Fine grading difficult due to stoniness.

(f) Indefinite: No true water table. Possible seepage water at any depth.

(g) Shallow: Indicating that at times this series will be under water but after the water has receded there is no apparent water table.

(h) Additional excavation required for transition from cut to fill and in shallow cut and fill areas, as per sketch in Field Manual of Soil Engineering, page 94.

(k) Subbase recommended if grade line is in "B" horizon (upper 3' of soil profile)

(m) Lineal feet of cut to be measured along a line below plan grade determined by the maximum depth of frost heave excavation so specified. (See Specs 2.08.03-b).

(n) The higher grade heights are a minimum standard for primary trunklines expressways and interstate routes

(p) Extremely variable due to its origin.

(s) These answers apply when the grade line is in cut or when the embankment is constructed of material from the same series.

Figure 4. Excerpt from the design chart, "Field Manual of Soil Engineering" (Fourth Edition).

the peat soundings are taken the depths at which changes in classification occur are recorded. Experience has shown that in many swamps, sand layers may be encountered which cannot be penetrated by hand tools, thus giving an impression of a true bottom. To prevent this, in swamps more than 500 ft long, supplemental borings are made at intervals of 200 to 300 ft to determine whether the swamp may have a false bottom. This is done by two special crews which operate out of the central office, using lightweight hydraulic boring equipment.

Rock soundings are also the responsibility of the district soils engineer. Where

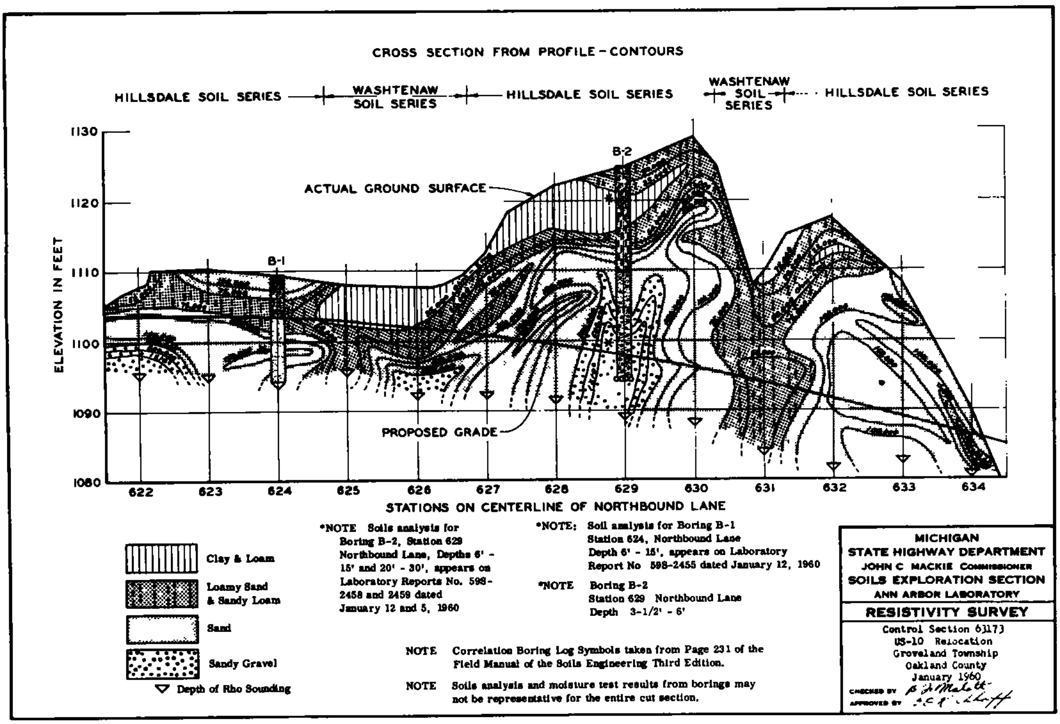


Figure 5. Typical resistivity survey.

possible, these are made with a truck-mounted power auger. At every station, at centerline, and at the ditch lines these borings are made to a depth of 4 ft below the proposed plan and ditch grades. In inaccessible areas, a Barco Hammer driving 1-in. steel rods is used. Rock soundings are often made with seismic or resistivity apparatus.

Resistivity and seismic surveys are used extensively in Michigan for area investigation. In all cuts more than 10 to 12 ft deep, resistivity surveys are made. Seismic apparatus is used primarily where it is anticipated bedrock may be encountered. These surveys are made by a special section which operates from the central testing laboratory. Wherever correlation borings are made, samples are submitted for mechanical analysis and Atterberg limits. This information is shown on the resistivity report (Fig. 5).

The foundation borings for larger culverts and bridges are not the responsibility of the district soils engineer. Foundation borings are made by special boring crews from the Lansing office.

Another responsibility of the district soils engineer, involving soil mapping but for which a formal strip map is not prepared, is that of borrow survey and location. In Michigan, with the exception of a very few projects, the only borrow materials the contractor is required to furnish are the processed aggregates. It is the district construction engineer's responsibility to locate all needed embankment material, swamp backfill, sand subbase, material for culvert backfill, sewer pipe edge drains, etc. This is delegated to the district soils engineer.

In making a borrow study, the district soils engineer relies on the available aerial mosaics, the USDA county soil maps, and the surface geology maps. In counties which do not have soil maps it has been found that the local offices of the Soil Conservation Service often may have a large part of the county mapped for individual farmers who participate in the program, and therefore they can be a valuable source of information. With this available information, the soils engineer begins his location study for the various materials needed. With his knowledge of pedological classification and its resources, the amount of field reconnaissance necessary can be held to a minimum.

Potential borrow areas are noted when the detailed soils strip map is prepared for the project. The soils engineer usually investigates these borrow areas by hand auger borings to determine the feasibility of using the material. If it appears to be a possible source, these borings are then supplemented by power auger borings or a resistivity survey. In granular materials, samples are ordinarily taken and submitted to the laboratory for analysis and specification gradation.

The only detailed map prepared by the soils engineer is for his own use in determining the amount of borrow material. This consists of an area soils and topographic map showing prominent topographic features, soil boundaries, and the locations at which borings were made. However, when the information is submitted to design so that overhaul and other quantities can be estimated, this map is not submitted. The information which design receives gives the location and use of the material, the amount available, and the amount of work necessary to prepare and to restore the pit.

CONCLUSIONS

In Michigan one of the advantages of the pedological system is that it has been developed over a long period of years and is backed by extensive field correlation, experience, and performance. The qualities peculiar to each soils series are summed up in its name and are easily recognized by design and construction engineers and contractors. Also, by mentioning a soils series the one name brings to mind the geology, topography, texture, and drainage characteristic of the particular soil. Thus, a poorly drained soil can be recognized at any time of the year. The soils series name also expresses a three-dimensional concept in that it not only describes depth but also area significance along and on either side of a survey line. As one man can map from two to five miles per day, the system can be applied not only to major highways but also to all reconstruction projects on a highway program. One of the major differences between the pedological system and other methods of soil classification is that in the pedological system, laboratory investigation and testing supplement field investigations, whereas in the other systems the field investigations furnish the information for the laboratory classification.

The reliability of the information depends to some extent on the experience and ability of the soils engineer who prepares the soils strip map and on the amount of detail shown. As has been mentioned, the Michigan Design Chart is a result of years of correlation and experience. Errors which might result from incorrect interpretations of this chart are usually prevented by a close liaison between the central soils office and the design and construction offices.