Use of Pedologic Map in a Highway Soil Survey

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This paper briefly explains the method of producing soil strip maps based on the pedologic (agricultural) system of soil classification and the interpretation of aerial photographs, for proposed highways in Illinois. It discusses the types of information presented in the engineering soil reports that accompany the strip maps and the way in which they are used for highway soil surveys. Examples of the strip maps and the methods of presenting engineering soil data are included.

● PEDOLOGIC MAPS in Illinois date back to 1911, and have been prepared and published by the University of Illinois Agricultural Experiment Station at various intervals since that time. Highway engineers have long felt that this information, properly correlated, could be useful in the planning stages of highway design and construction, but the variation in quality of the maps over the long period was an obstacle not easily overcome.

In 1950 the cooperative research program of the Illinois Division of Highways and the University of Illinois Engineering Experiment Station was expanded to include "Soil Exploration and Mapping." In 1952, the United States Department of Commerce, Bureau of Public Roads, joined as a co-sponsor of the project. The project was undertaken by the University of Illinois to furnish the Illinois Division of Highways information for planning detailed soil surveys and for use in location and design of highways.

After project personnel had prepared soil maps and reports for several counties, the policy of using pedologic soil-type classification in preparing maps for strips four miles wide along the right-of-way of highways where work is contemplated, rather than on a county basis, was adopted.

The soil mapping project in Illinois has been previously reported by others (2, 8), but a brief summary seems required to provide a better understanding of the mapping units and the engineering reports prior to discussing their actual use. The difference in nomenclature of the agricultural and engineering fields is a common cause for misunderstanding unless resolved whenever representatives of the two groups meet to exchange ideas. In the following discussion, it is indicated when a "highway" survey or report is referred to rather than a survey or report prepared by other agencies.

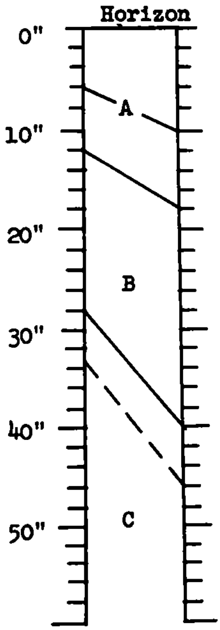
PEDOLOGIC PRINCIPLES

Although the pedologic system of soil classification is widely used, its methods are unfamiliar to many civil engineers and a brief description of it and its basis seems appropriate. An understanding of the pedologic system of classification should be valuable to the highway engineer, because many published soil reports and maps using this system are available. In addition, the data on the engineering characteristics determined for a map unit occurring in one area may later be used in other locations for which pedologic information is available.

Under any given set of conditions of soil formation it may be expected that a certain type of soil profile will develop. This profile is typical of all areas where that particular set of conditions prevails. A soil profile may, therefore, be considered as a geologic entity and classified just as other geologic features are classified. This is the basis of the science of pedology.

The profile studied by the pedologist is exposed in a vertical section from the ground surface to a depth of 40 in. or more (Fig. 1). Normally the profile will consist of three

Soil No. and Name - 148 Proctor SL County McHenry



Profile Description

Surface	Brown to very dark brown silt loam
Subsurface	Dark brown to dark yellow brown silt loam
Subsoil	Dark yellow brown clay loam mottled with yellow brown silty clay loam
Substratum	Silty, sandy or mixed silty, sandy or gravelly glacial outwash.

Topography	Slope 1 to 4%
Parent Material	Water-laid or wind-laid silty sediments of Wisconsin age.
Surface Drainage	Moderate
Underdrainage	Moderately rapid

Estimated Engineering Properties and Problems

Horizon	A	B	C
AASHO Class	A-4, A-6	A-6, A-7-6	A-2-4, A-3 or A-4
Group Index	8-10	15-20	0-8
LL %	30-40	40-60	NP-40
PI %	10-20	20-40	NP-15
Max dry dens, pcf	90-102	95-102	110-120
Opt w, %	20-25	20-24	15-18

Remarks: Subgrade performance fair to good. Occasional pockets of frost heaving material may be encountered. A 5-6 inch layer of silty material will be found between subsoil and substratum. Sometimes a sticky sandy clay loam or gravelly clay loam 8-12 inches thick occurs below the substratum. Loose sandy or gravelly outwash material lies below this sticky layer.

Figure 1. Typical soil type data sheet.

or more distinct layers or horizons which lie roughly parallel to the surface. Soils having similar profile characteristics are grouped together and given a soil series name for the purpose of identification. The name is usually chosen from the geographic area in which the series was first identified. The system is based only on the in-

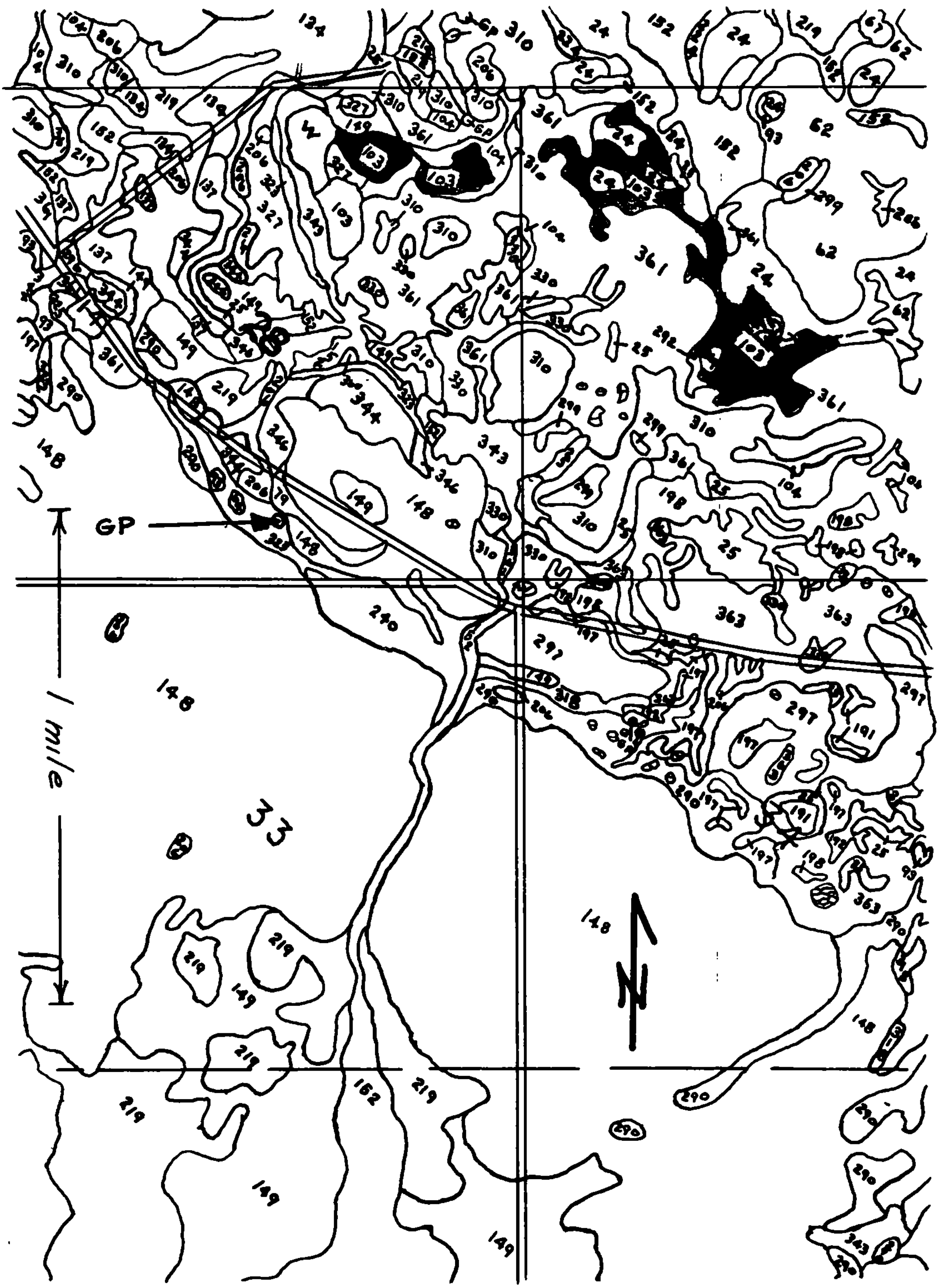


Figure 2. Portion of McHenry County pedologic map. Number 93: Rodman gravelly loam, parent material—coarse gravel; Number 103: Houghton muck, parent material—silty sediments; Number 152: Drummer silty clay loam, parent material—water deposited sediments; Number 198: Elburn silt loam, parent material—loess.

herent properties of the soil materials typically found in the profile and is not dependent on their agricultural characteristics.

Due to many variations in the surface texture of soils having otherwise similar profiles, an almost infinite number of soil series would be possible. By combining the textural name of the surface horizon with the soil series, a soil type is identified within each larger soil series. This soil type is the basic pedologic mapping unit. "Peotone silt loam" is an example of a typical soil type name. Peotone identifies the soil series and silt loam indicates the texture of the surface horizon. The textural characteristics are based on a classification system which has been adopted by the United States Department of Agriculture and which differs slightly from those commonly used in highway engineering work.

If all of the counties in Illinois had been mapped on the basis of present-day nomenclature and criteria, it would be possible to relate engineering properties of the soils directly to the pedologic classification by means of physical tests and some field experience (4). Unfortunately this is not the case. Of the 102 counties in Illinois, only 76 have agricultural maps in published form, and of these only 25, the reports published since 1933, use the present mapping technique and consistent nomenclature. The need for a method of up-dating the older maps and preparing strip maps in other areas was thoroughly studied and a procedure based on airphoto interpretation was developed.

MAP PREPARATION BY AIRPHOTO INTERPRETATION

Airphoto interpretation may be defined as the method of obtaining information from photographs and by logic and reasoning determining the effect on a particular problem (11). It is a specialized art that requires deductive and inductive reasoning ability combined with broad technical knowledge in several sciences. In the type of investigations being considered, the sciences will include not only engineering but also geology and pedology.

Varying types of soil may be formed from the same parent material under the varying effects of other soil-forming factors such as natural vegetative cover and degree of surface slope. The soil type names are assigned to these different profiles on the basis previously discussed. The preparation of pedologic soil type maps for engineering use now consists of outlining, on aerial photographs, the boundaries of the different soil types present in the strip being studied. This is done by means of stereoscopic examination and interpretation of the strip.

Inasmuch as the soil-forming factors of climate and time of exposure of the parent material may be assumed to be uniform in the small area being studied for any one map, they are not usually considered in the study of the airphotos. The character of the parent material is determined from available geological and agricultural information. Thus the soil type boundaries in the area being studied may be delineated on the airphoto primarily by denoting changes in vegetative cover, color, and slope characteristics within the region derived from the same parent material and the proper soil type name assigned on the basis of these characteristics.

Information on parent material, natural vegetative cover, slope, etc., is available, for most of the soil types encountered, in the publication, "Illinois Soil Type Descriptions" (9). A very complete presentation of airphoto interpretation techniques has been published by the Civil Aeronautics Administration (4).

For the Illinois soil strip mapping, actual soil boundaries were delineated on aerial photographs by the use of airphoto interpretation techniques and transferred to a base map using a scale of 2½ in. = 1 mi (Fig. 2). Various other aids, such as soil association maps were used, but there was no ground control. It was anticipated that the maps would not be as accurate in detail as those prepared by pedologists in the field. The present technique reproduces the aerial photographs directly (Fig. 3) and has an approximate scale of 1 in. = 800 ft. The additional detail available to the engineer in the field has proved to be quite helpful.

Inasmuch as only limited distribution is required for these maps, they are reproduced by a blue-print process. The airphotos, with the soil boundaries indicated, are assembled in mosaic fashion along the appropriate strips and are then photographed.

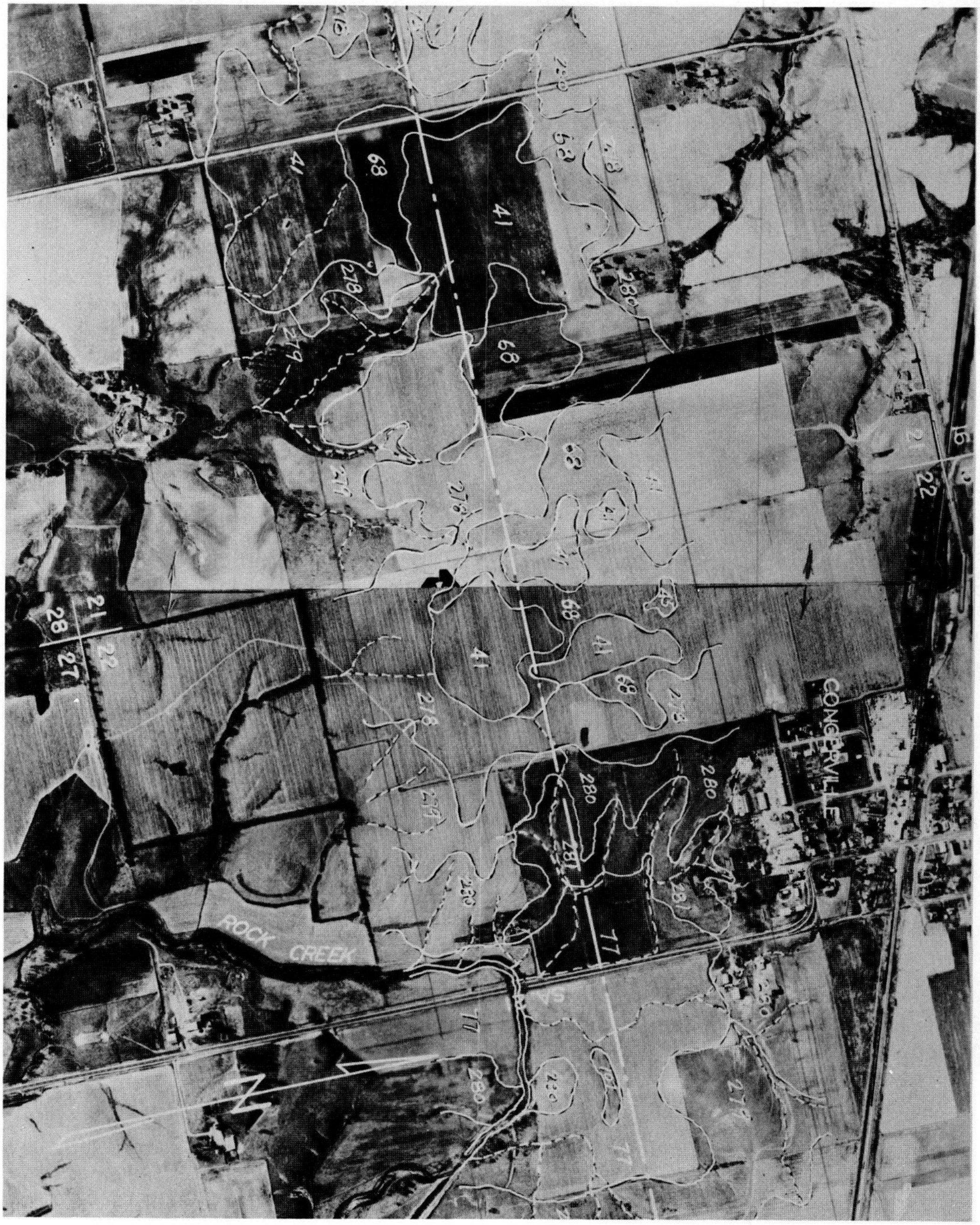


Figure 3. Airphoto on which soil type boundaries have been outlined. Number 41: Muscatine silt loam, parent material—loess; Number 68: Sable silty clay loam, parent material—loess; Number 77: Huntsville silt loam, parent material—water-laid sediments; Number 278: Stronghurst silt loam, parent material—deep loess.

The negative is then used to make contact blue-prints. The quality of the prints obtained provides satisfactory reproduction of the airphoto details.

ENGINEERING SOILS REPORT ACCOMPANYING THE STRIP MAP

Of course the strip map alone would be of little value, and an engineering report is prepared to present the pertinent information required for the highway engineer to intelligently interpret the map. Such information includes geologic background of the area, correlation between pedologic description and engineering classification and comments on construction problems likely to be encountered with some of the soil types present.

The first item usually presented in the report is a description of the physiography and topography of the area, and this is followed by a discussion of the geology of the area considering both surface and bedrock formations. This information is gathered from various publications of the Illinois State Geological Survey and the Geological Society of America. Much of Illinois has been covered by glaciation and possesses the variability in surface topography and material usually associated with this type of area. Loess deposits have later covered large areas adjacent to the major rivers and vary in depth from a few inches to over 25 ft in some locations along the Mississippi and Illinois Rivers.

A brief description of the pedologic classification system used and the mapping units involved is presented in the body of the report and a more complete discussion is attached as an appendix. The pedologic soil types possessing similar engineering characteristics are grouped according to a classification system developed by Thornburn and Bissett (8). This system considers the plasticity of both subsurface and subsoil in conjunction with the permeability characteristics of the substratum. This is a broad classification which does not indicate all of the significant differences but can be useful in the preliminary study of an area. It is anticipated that this grouping may be dropped from future reports, because it requires acquaintance with a classification system that is rather limited in use.

A note on the occurrence of granular materials is included as such information is quite valuable in consideration of availability of construction material. Although the Illinois Division of Highways does not furnish the borrow pits required for construction, information of this type is necessary for the preparation of cost estimates and in other planning phases. Soil type 93, Rodman gravelly loam, for example, indicated "0-10 inches of gravelly loam material over calcareous coarse gravel." In section 28 (Fig. 2) this soil type occurs. The gravel pit (GP) indicated near the southern boundary of the section is probably operating in this type of material.

The possible construction problems associated with the various soil types are discussed both from the viewpoint of design and that of construction. In areas where the depth of loess is such that cuts are likely to encounter un-weathered loess, note is made of the erosion problem and specific design recommendations are made. The difficulty of compacting loessial soils is mentioned, if the area is one in which material of this nature is likely to be used for embankments, and the need for careful control of the moisture content explained. These are just two examples of the types of information presented in the section of construction problems.

A bibliography of pertinent references is usually the last item in the body of the engineering report accompanying the map. This lists the publications used in preparing the report and is a handy guide in the event that further information is required on one particular phase of the report. Items indicated by an asterisk in the "references" in this paper are some of the common sources referred to in the engineering reports and were not necessarily used herein.

APPENDIX TO THE ENGINEERING SOILS REPORT

The most important items presented in the appendix to the reports are the descriptions of the pedologic soil types (Fig. 1). These descriptions indicate the profile characteristics, topography, parent material and drainage characteristics for each soil type encountered. The estimated engineering properties of each horizon are presented and remarks are given as to probable subgrade performance and any special probem likely to be associated with each profile. The engineering properties are either based on actual test data or estimated from agricultural data. Statistical analyses of the Atterberg limits (liquid limit, plastic limit and plasticity index) and some of the chemical and physical properties commonly contained in agricultural soils reports indicate that there is a very close relationship between the Atterberg limits and these latter soil properties (6).

Also included as an appendix is a description of the pedologic classification system used. This system has been briefly described earlier in this paper. The appendix to the engineering report also contains considerable information on the Thornburn-Bissett engineering group classification system which has been used as a basis for a map similar to the one now being prepared on the pedologic system. As mentioned previously, this classification system was too broad to be of use to the highway engineers except in a general study of an area.

TRAINING HIGHWAY PERSONNEL

In June of 1958 a program consisting of several conferences and field-trips was conducted to familiarize the division of highways soils engineers with the soil mapping and sampling techniques of agronomists. At the same time, the agronomists had an opportunity to become acquainted with engineering problems and techniques. As a result of this exchange of ideas, the highway soils engineers became more aware of the capabilities of existing agricultural soils maps and more confident of their own ability to use these maps to better advantage.

The response to this initial program was such that a second one was held in 1959. This meeting emphasized soil conditions in the southern portion of the state because the first program primarily considered the northern portion. Once again representatives of the Agronomy and Civil Engineering Departments of the University of Illinois met with the highway engineers and discussed the pedologic classification and mapping system, as normally used, as well as the strip map technique used in preparing maps and reports for use by the divison of highways. The close cooperation of the groups involved made both of these programs quite successful.

This cooperation has continued in subsequent operations. A general working arrangement was made so that the maps and reports provided by the project staff were also checked for accuracy and adequacy by the engineers as they were being used to aid in the preparation of the detailed soil surveys for the highway projects. In this manner the staff was kept informed of the usefulness of their work and could make any changes that seemed necessary. It is the opinion of the project staff, and its advisory committee, that the procedure for preparing reports and strip maps based primarily on airphoto interpretation has progressed to the stage that it may be considered operational rather than experimental. The maps and reports prepared by the methods just described can, and are, being used in the Illinois Division of Highways as aids in the preparation of highway soil surveys.

APPLICATION TO A SPECIFIC HIGHWAY PROJECT

The following discussion presents, in general terms, the use of the report on "Engineering Soils of Part of McHenry County" (1), and its companion strip map in preparing the detailed highway soil survey and report for FA Route 20, Section 28R, in McHenry County. No attempt will be made to give the station limits of areas involved, the specific recommendations for base or subbase thickness, or special construction procedures outlined. Most of these items depend to a large extent on local policy and procedure, a discussion of which would tend to detract from the subject of the use of pedologic strip maps.

Preliminary Analysis

In the first step of the preliminary analysis, the centerline of the proposed improvement was drawn on the strip map and checked to see if it crossed any undesirable areas. Inasmuch as the map provided, used color to indicate the various soil types, this was a quick procedure. The highly organic areas, for example, were indicated in black and were easily identified (Fig. 2). The following remarks are taken from the pedologic data sheet for soil type 103, Houghton muck. "Depth of muck may vary from 3-12 feet or more. Adjustment of highway line to bypass these areas advisable. Otherwise complete replacement of muck by selected material or use of some other corrective measures necessary." In the specific case involved, nearly all of these areas had been avoided and no line change was deemed necessary. Replacement of this material was recommended however. Although the present system of outlining the areas directly on the airphoto does not require coloring (Fig. 3), it is still easy to determine the soil type numbers that are troublesome and a quick study of the proposed centerline will indicate their existence and the areas may be marked in color. By having such a graphic picture of the undesirable areas, the design engineer can plan alternate routes for consideration before too much other work is completed that would require costly revision if the line were to be moved at a later date.

Prior to beginning the field boring and sampling program, the field crew made a study of the strip map in order to become familiar with the terrain involved. A review of the profiles and the remarks on problems associated with each type gave then an indication of the soils that they would encounter, of those areas in which they could expect uniform conditions for a fairly large distance, and of those areas in which they could expect a large degree of variability. Certain areas were picked where more extensive borings were indicated to be necessary to determine more accurately depth and extent of unsuitable material so that reasonable estimates of quantities for removal and replacement could be made.

In glaciated areas such as this, it is not always possible to pinpoint the actual locations for the field borings, but a general idea may be obtained as to the amount of work necessary and the field work scheduled on this basis. It is especially helpful to be able to spot highly organic or other soft areas in advance because quite often the work may be scheduled so that borings can be made in these areas during the winter months when the ground is frozen and the more stable areas can be checked later. Such procedure is common practice in the areas in Illinois where peat deposits are numerous. By being familiar with the area, the field crews can often pick up some of the changes that are marked only by subtle changes in appearance, or have been masked by construction or farming operations.

Soil Profile and Description

The soil profile included with the highway soil survey report is normally drawn by connecting the similar horizons indicated by plotting the logs of the individual field borings. In relatively uniform areas this is a rather simple procedure but in many areas the question of determining whether the soil exposed in two adjacent borings is the same, indicates a transitional area, or belongs to two distinct profiles, is rather difficult to answer with any degree of assurance. Often there is a tendency to simplify the profile by assuming that a particular horizon is continuous if there is perhaps only a slight change in the field description of the center of three borings, when actually a distinct difference in engineering properties exists. The presence of a change would be indicated on the strip map and laboratory tests could be made to verify this. The use of the pedologic profile descriptions also provides information as to those areas that are likely to contain pockets of different materials and this information is included on the highway soil profile. Often this will also explain an apparent discrepancy in borings through an area which had been assumed to be uniform. For example, the pedologic data sheet for Proctor silt loam (Fig. 1) indicates the variability that may be expected in this soil type and states that: "Occasional pockets of frost heaving material may be encountered." By presenting information of this nature, the pedologic strip map serves as a valuable supplement to the engineers' experience when preparing the highway soil profile.

Laboratory Analysis

As mentioned earlier, the strip map occasionally indicated the need for additional laboratory tests but the general result was a reduction in the number of tests required. The pedologic map was a great help in assisting the engineer in "pairing up" field samples. Of course some testing of two or more samples from the same horizon is advisable to determine variability within a particular soil type, but otherwise it is possible to eliminate some testing by identifying two soils as being the same type although existing in separate areas, or being separated by a discontinuous profile. It was hoped that definite information could be presented on the number of tests that had been eliminated by the use of the strip map but a "post-mortem" analysis provided rather inconclusive evidence. The increased accuracy of the finished report was perhaps the more valuable result of the assistance afforded by the pedologic maps. If careful notes are made during the actual preparation of a highway soil survey with the aid of pedologic strip maps, it may be possible to determine actual savings realized, but the greatest good seems to lie in the additional information provided the engineer.

Soil Survey Report

The final step in the highway soil survey was the preparation of a soils report containing recommendations for base and subbase thickness, as well as discussions and recommendations concerning other items to be considered during the design and construction stages. Areas were indicated in which removal of unsuitable material and replacement with granular material or select borrow was recommended. Material that could be excavated from cuts and used in embankments was indicated as well as that cut material that was unsuitable for use as embankment and had to be wasted. The remarks for 152, Drummer silty clay loam indicate that "A and B horizon material should not be used as subgrade." This particular material would not likely be available from a cut, but might be included in a proposed borrow pit. Possible adverse moisture conditions that might be encountered were mentioned so that they could be considered in the planning of construction operations and so that the necessary drainage could be considered during the design of the highway through the area.

Such items are determined by the experienced engineer based on the field examination and subsequent tests and guided by certain established policies and procedures. The engineering soils report accompanying the pedologic strip map serves to supplement the experience of the engineer and provide him with additional information for his consideration during the preparation of his report. Drainage classification is one of the items to be considered during the determination of base and subbase thickness and the soil type descriptions provide information on permeability and topography which, when combined with knowledge of surface drainage being planned, make a much more accurate classification possible.

CONCLUSION

The use of pedologic soil strip maps, when accompanied by a report on the engineering properties and characteristics of the soil types, can be an invaluable aid to the highway soils engineer. Although claims that the use of these maps will result in less field sampling or less laboratory testing would be hard to either prove or disprove, it is unquestionable that they do make possible a more intelligent interpretation of such data as are obtained. This in turn provides a better basis for highway design and construction, resulting in more economical highway transportation.

The joint conference, field-trip meetings between the highway soils engineers and the Agronomy and Civil Engineering Departments of the University of Illinois have been quite beneficial in promoting better mutual understanding which has already increased the use of the available pedological soils maps in Illinois. Highway engineers are now taking advantage of not only the published agricultural soil reports but also much of the unpublished information available through such sources as the Soil Conservation Service and various departments of the University of Illinois.

Although this report contains little material of a statistical or numerical nature, such as most engineers seem to best understand and appreciate, it is hoped that it will encourage others to investigate the use of pedologic maps in their own area, if they are not already being used, and to exchange ideas with others interested in this technique. More efficient use of engineering man-power and better service to the motoring public are sure to result.

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