Commonwealth of Kentucky
Department of Highways

AN ENGINEERING SOIL SURVEY OF FAYETTE COUNTY, KENTUCKY

by

R. C. Deen
Research Engineer

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INTRODUCTION

The need for soils data in the site selection, design, construction and maintenance of any major structure is generally appreciated by the engineer. The "rule of thumb" methods often used in developing smaller structures can prove unsatisfactory, or even disastrous, when applied to larger projects.

Probably the most pressing need is for use in preliminary surveying -- maps and/or surveys giving the areal distribution of local soils and their engineering characteristics. Were such information available, together with the topographic maps now obtainable for many areas, much preliminary work for structures could be accomplished without the engineer's ever having to leave his office.

Agricultural scientists have developed a soil classification and mapping system that could be of great use to engineers. Belcher, et. al. (2)*, appreciating this possibility, in 1943 published a report giving engineering significance to the pedological classification of Indiana soils. Since that time much work has been done toward translating

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* Numbers in parentheses refer to the References at end of this report.

and developing the data made available by the sciences of geology, physiography and pedology, and air photo interpretation into terms familiar to the engineer. Many states are now preparing soil surveys and maps, using the principles of pedology and air photo interpretation, for use by their engineers.

Engineering soil surveys and maps can be used in four major ways by engineers: 1) to make soil-reconnaissance surveys, 2) to locate sand and gravel deposits, 3) to organize and check field surveys, and 4) to correlate pavement and structural performances with soil type. In soil-reconnaissance surveys, the maps may be used for preliminary site selection by taking advantage of favorable soil and drainage conditions and avoiding the undesirable situations -- the soils maps making it possible to note the areas where these conditions prevail before ever going into the field. Sand and gravel deposits can be located readily if it is known what soil types are associated with or developed from them.

Soil maps can be used to a great advantage in organizing and checking field sampling. Since a soil type will have the same engineering properties wherever it is mapped, it is unnecessary to sample at regularly spaced intervals. One or two check samples could be obtained from each soil type area, allowing more time and effort to be spent in problem areas.

The intelligent use of engineering soil surveys and maps can reduce the time required in making surveys for engineering locations, and the association of engineering performance with the soil type name provides a convenient means of cataloging and filing of soils information.

METHODS

As a first step in obtaining a soil map of Kentucky, an engineering soil survey of Fayette County was made. Since there was available a sufficiently reliable pedological soil survey and map of the county, no actual mapping or delineation of soil areas was required for this study. The problem became, therefore, one of determining the engineering test constants and giving engineering significance to the pedological soil classifications. The work consisted of field sampling, laboratory testing, analysis and correlation of data, and finally, preparing the material in a form suitable for use by the engineer.

The first step in the solution of the problem was to answer the question, "How many samples of each horizon of each soil series would be required to give significant results?" To obtain an answer, the question was approached from a statistical viewpoint.

If the thesis that the peological properties of a given soil are similar wherever the soil is mapped is correct and can be applied to engineering properties also, then the engineering test constants for a given horizon of a given soil should fall within a more or less narrow range, determinable from considering test results from a few samples taken at random. This range of values for a given engineering property could be assigned to the particular soil horizon in question, and no matter how many times this horizon is sampled in the many different locations it may be mapped, it could be confidently assumed that the soil is sufficiently uniform for the test value to fall within the range established.

The number of samples required to give such a significant range varies, of course, with the accuracy desired and with the variability of the particular engineering test constant under consideration.

The limits first established for this project were such that the test results on a given sample out of a hundred might deviate from the mean by not more than ten percent. The selection of these particular limits is not to be considered the establishment of a satisfactory range; it merely served as a starting point in determining the number of samples required. Assuming that the engineering test constants fall into a normal distribution about their respective means, this statement of accuracy desired can be represented by the general equation

$$z\sigma' = E\bar{X}' \qquad (1)$$

where $z = \dfrac{X - \bar{X}'}{\sigma'}$

σ' = standard deviation of the universe,

E = allowable error expressed as a decimal,

$\bar{X}'$ = mean of the universe, and

X = any value of the universe.

The above equation can also be stated in the following terms:

$$z\frac{\sigma}{\sqrt{N}} = E\bar{X} \qquad (2)$$

where σ = standard deviation of a group of samples,

N = number of items in the group of samples,

$\bar{X}$ = mean of a group of samples,

$\sigma' = \sigma/\sqrt{N}$, and

$\bar{X}' \approx \bar{X}$.

In arriving at Equation 2, two assumptions were made. The first was that the engineering test constants for a given soil series assume or are closely approximated by a normal or Gaussian distribution. This is not an unreasonable assumption to make. For example, if the liquid limit were determined for a very large number of samples of the C horizon of the Maury series, as many results would be expected to fall above the mean as would fall below, and these results would be concentrated about the mean. The second of the assumptions was that the mean of the universe was approximated by the mean of a group of samples. This assumption was based on the method of maximum likelihood; that is, the sample statistic is the maximum likelihood estimate of the corresponding universe parameter. This is usually the case and this method is favored by many statisticians (4).

In Equation 2, letting $z = 2.57$ satisfies the requirement that ninety-nine of one hundred sample results be within the desired range about the mean. Letting $E = 0.10$ establishes this range as plus or minus ten percent of the mean. Using the values of σ and X obtained from a group of samples, the number of samples, N, required can then be calculated.

By making a preliminary field sampling and laboratory testing of one soil series, it was estimated that three samples from each horizon of each soil series would be needed to meet the requirements established in all cases except that of the plastic limit and plasticity index. The number of samples required for these test values was as high as thirty, seemingly an unreasonably large figure. Calculations indicated that test results from three samples, however, would show only a twenty percent deviation from the mean of the universe for these two test constants. On the basis of this preliminary study, it was decided to attempt to obtain samples of each horizon of each of the soil series from three different locations in the county.

The sample sites were located by reference to the pedological soil map and were selected in such a way as to distribute the sites in each soil series over the county. An attempt was made to place the sites near the centers of the large areas of a soil series in order to obtain typical samples and not fall in the transition zones between the series.

No unusual methods of sampling were used. Most of the samples were obtained by a four-inch, Iwan post hole auger; and this proved to be a quite satisfactory method except in the very wettest horizons. In these cases, sampling was delayed until the dry season. Samples were obtained to depths of 15 feet with the auger, and others were obtained from test pits. In all instances depth, color, texture, moisture conditions, and any other features that might be of interest or use in identification or classification were noted and recorded. A 20- to 30-pound disturbed sample was taken from each of the major horizons at every location and sent to the laboratory for testing.

Once in the laboratory the samples were prepared for the determination of engineering soils constants by the following methods:

Soil Preparation	ASTM Designation: D 421-39
Mechanical Analysis	ASTM Designation: D 422-39
Liquid Limit	ASTM Designation: D 423-39
Plastic Limit & Plasticity Index	ASTM Designation: D 424-39
Specific Gravity	ASTM Designation: D 854-45T
Moisture-Density Relations	ASTM Designation: D 698-42T
Laboratory CBR	Kentucky Modified Procedure

A small portion of the minus one micron material was recovered by sedimentation and decantation from 17 selected soil samples. These fractions, representing the near-colloid portion of the soil and consisting predominately of clay-type minerals, were leached with acid or otherwise treated to remove x-ray scattering and masking impurities and subsequently conditioned with ethylene glycol preparatory to analysis or identification by x-ray diffraction.

The diffractometer was a Hayes instrument using Cu radiation, 14 centimeter diameter twin cameras, and wedge-type powder mounts. Patterns were recorded on film and the lines measured on a plain vernier scale.

In order to be of value to the engineer, data obtained from an investigation such as this must be presented in a form that is quickly and easily read and understood. In an attempt to satisfy this requirement it was decided to give first a pictorial representation of each soil with a brief, general written description of each of the major horizons.

This was followed by a table of typical engineering test constants. Rather than give the mean of the test constants as obtained by laboratory testing, it was felt that some significant range should be reported. With this in mind, the 90 percent confidence limits for each test constant were calculated and the values recorded in the table. Since the number of samples was small in each case, it was decided to base these confidence limits upon a "t" or "Student's" distribution rather than the normal distribution as was done on page 5. With small sample sizes, the "t" distribution will give better estimates of the universe parameter. The confidence limits were calculated by the procedure given by Duncan (4) from the limited data obtained during this investigation. These data are so determined, however, that regardless of the number of times the particular soil is sampled in the future the engineering test constants will fall within these limits 90 percent of the time. These ranges, then, do have some significance, since a given horizon of a soil may be represented by a more or less narrow range of values for a certain property.

The three classifications (textural, HRB, the group index) given in the table are not subject to the abovementioned analysis, but are the actual designations given each sample. The table is followed by a general discussion of some features and properties of the soil that might affect the engineering treatment of that soil.

This description of each soil -- a pictorial view of the profile with description, a range of values with statistical significance for certain engineering test constants, and a general discussion of other items of interest -- could be used with the agricultural soil survey of the county and with the topographic maps of the area and be of great value to the engineer in planning and carrying to completion the soils portion of his engineering work.

SOILS OF FAYETTE COUNTY

The pedological soil map of Fayette County published in 1931 is one of the five highest rated county maps of Kentucky. Its soil boundaries are accurately delineated, and modern nomenclature is used except in a few instances.

There are 17 soil series and 28 soil types recognized and used in Fayette County. All but three of these series, accounting for 99-7/10 percent of the total area of the county, were sampled during the present investigation. One hundred twenty-six samples from 47 locations were obtained from the remaining 14 soil series. No attempt was made to obtain a sample from each soil type; however, 18 of the 28 types are represented.

Most of the soils of the county are residual, developing for the most part from limestones or calcareous shales. These soils are relatively plastic, as shown by laboratory tests; but nonetheless they are very well drained, there being practically no poorly drained areas in the county. This well drained condition is possible because the joints, cracks and solution channels of the bedrock allow the water to escape quite rapidly and because the soils develop a fragmentary structure which results in a relatively permeable unit. When this natural structure is destroyed in engineering construction, the soils become plastic and react in much the same manner as other clay-like materials.

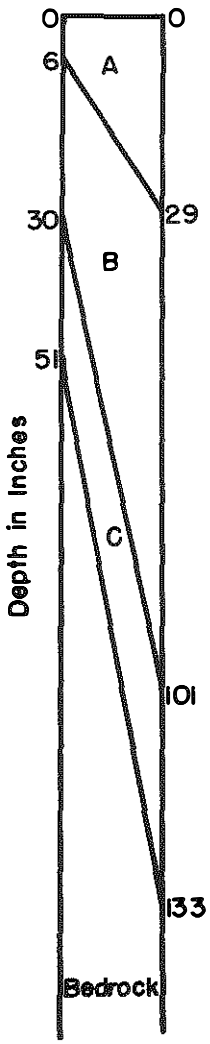
Soils formed in alluvium cover less than six percent of the area of the county. The alluvium has been derived from limestone uplands.

The topography is so gentle over the county that in most cases rock excavation is of no concern in highway construction. However, because of the solution channels, bedrock properties do become a point of concern in connection with foundations for large buildings.

The data for selected soil series recorded in tabular form in the Appendix were collected during the sampling and testing of the Fayette County soils. These data have been reviewed and reorganized and are presented in the following few pages in a form suitable for field use. Following the tabulation of data, a geological and pedological map of Fayette County are included in the Appendix .

HAGERSTOWN

PROFILE



DESCRIPTION

Horizon A - Grayish-brown or dark brown silty clay or clay silt - friable.

Horizon B - Light brown to reddish-brown silty clay or clay silt - friable when dry, plastic and sticky when wet - common black concretions.

Horizon C - Light reddish-brown to yellowish-brown clay or silty clay - firm and slightly compact, brittle when damp.

Bedrock - Massive, hard limestone.

HAGERSTOWN

Engineering Test Constants	Horizon A	Horizon B	Horizon C
% Sand - 2.0-0.05mm	5-20	13-20	9-34
% Silt - 0.05-0.005mm	50-59	31-67	30-33
% Clay - -0.005mm	26-40	19-50	34-60
% Colloids - -0.001mm	7-19	6-24	17-35
Liquid Limit, %	32-39	36-45	40-56
Plasticity Index, %	10-14	16-20	14-28
Max. Dry Density, PCF	100-102	97-104	87-104
Opt. Moisture Content, %	20-24	20-26	22-30
Laboratory CBR, %	3-12	5-12	2-3
Textural Classification (Miss. River Comm)	Silty Clay or Clay Silt	Silty Clay or Clay Silt	Clay or Silty Clay
HRB Classification	A-6	A-7-6;A-6	A-7-6;A-6
Group Index	8-9	11-12	8-18
Clay Minerals	--	--	Illite

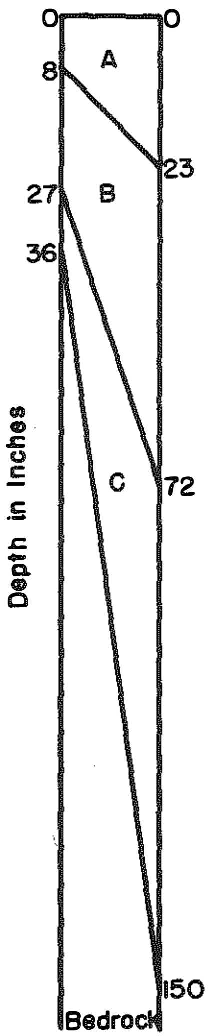
Topography: Level to gently rolling terrain.

Drainage: Well drained. Surface and internal drainage good.

Distribution: Limestone areas in Pennsylvania, Maryland, West Virginia, Virginia, Kentucky, and Indiana.

LORADALE

PROFILE



DESCRIPTION

Horizon A - Dark grayish-brown to dark reddish-brown clay silt or, occasionally, silty clay - friable.

Horizon B - Dark brown to reddish-brown silty clay or clay silt - sticky and plastic when wet, firm when moist, hard when dry - a few small round dark concretions near top of horizon increasing to many small and medium round concretions, giving way to abundant splotches of soft irregularly shaped concretionary material mottled yellowish-brown to brownish-gray in lower portion of horizon.

Horizon C - Light olive brown to yellowish-brown clay - very sticky and very plastic when wet, very firm when moist, very hard when dry - a few small round dark concretions and some soft, black, irregularly shaped concretionary material - mottles of brownish-gray or light olive gray common.

Bedrock - Interbedded high-grade, medium phosphatic limestones and calcareous shales.

LORADALE

Engineering Test Constants	Horizon A	Horizon B	Horizon C
% Sand - 2.0-0.05mm	9-15	17-34	14-24
% Silt - 0.05-0.005mm	56-63	30-48	26-29
% Clay --0.005mm	25-32	31-41	49-58
% Colloids --0.001mm	7-11	12-19	31-35
Liquid Limit, %	33-39	33-41	51-59
Plasticity Index, %	11-15	12-21	18-32
Max. Dry Density, PCF	97-104	96-106	84-91
Opt. Moisture Content, %	20-22	21-25	28-33
Laboratory CBR, %	5-10	2-18	4-8
Textural Classification (Miss. River Comm)	Clay Silt or Silty Clay	Silty Clay or Clay Silt	Clay
HRB Classification	A-6;A-7-6	A-6; A-7-6 A-7-5	A-7-5 A-7-6
Group Index	8-10	8-14	14-20
Clay Minerals	--	--	Illite

Topography: Moderately rolling topography exhibiting in some areas a slight Karst configuration. Soil develops on gently sloping ridge tops and hillsides with slopes of 3 to 15 percent, occurring most commonly on the gentler slopes.

Drainage: Well drained; runoff medium to rapid; internal drainage medium.

Distribution: Extensive in the Inner Blue Grass Region of Kentucky and the Central Basin Area of Tennessee. Closely associated with Mercer soils.