ENGINEERING CHARACTERISTICS OF SOILS
OF FAYETTE AND UNION COUNTIES, INDIANA,
PERTINENT TO RESIDENTIAL HOUSING

by

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III. INTRODUCTION

The investigation of foundation soils for structures is often carried out in great detail where high cost and heavy loads are involved. Many advances in techniques for such investigations have been made and reported (Hvorslev, 1949). However, soil investigation for light commercial and residential structures has often been neglected. The low cost of each structure does not warrant expensive investigative work. Still, the accumulated cost of failure due to problem soils is great (Henry, 1960, and Herron, 1960). There is a need, therefore, to obtain and make available preliminary subsurface investigation data covering broad areas. This would allow obvious adverse situations, such as flooding, frost action, failure of foundations due to swelling and shrinkage of soils, and failure of septic tanks, to be avoided.

The purpose of this study is to investigate the feasibility of obtaining preliminary soils data for residential housing over a large area with a minimum of expense. The available reports were reviewed and field and laboratory studies made. Methods of transferring this information to maps that can be easily read and reproduced have been devised (Hunter and Krebs, 1961).

The area selected for study is Fayette and Union Counties, Indiana. Although there is not a large amount of construction activity in this area, the soils are similar to several places where such activity is great. These soils include both residual and transported materials. One of the chief advantages of working in these counties is the availability of a modern and recent soil survey report (U.S.D.A., 1960). This includes a detailed map of the area and the description of each type of soil material. Unlike some of the more modern soil survey reports, no engineering data has been included in this volume. Interpretation of many of the common pedologic expressions and descriptions in engineering terms is a continuous problem. Its solution in this case was enhanced by being able to conduct field work and discussions with agronomists who contributed to the report and engineers who specialize in the interpretation of such reports. Another advantage of working in these counties is the availability of a report of an investigation of the engineering characteristics of soils of Indiana, conducted by the Engineering Experiment Station, Purdue University (Belcher, Greg, and Woods, 1943). This report is based on investigations connected with highway engineering problems. A proper interpretation of the above two reports and correlation of them with engineering data gathered in the laboratory are among the objectives of this study.

IV. EARTH MATERIALS IN FAYETTE AND UNION COUNTIES, INDIANA

The greater portion of Fayette and Union Counties is covered with glacial deposits from which the present pedologic soil horizons are derived. Over a period of several thousand years, a succession of continental ice sheets moved in a southerly direction through Fayette and Union Counties. As these sheets moved, many valleys were filled, hills leveled, and new hills and valleys formed. Glaciers of three ages, Kansan, Illinoian and Wisconsin, deposited till in the two counties (Wayne, 1956). Materials of Kansan age were completely covered by drift of Illinoian age. Later much of the Illinoian deposits were covered by glacial till of the Tazewell substages of the Wisconsin age. The resultant till plains are exposed to weathering and most of the existing soils of the two counties are derived therefrom. Soils formed from till of Illinoian age are old soils and in many cases they are leached free of carbonates to depths of 10 or more feet, indicating long-term weathering. Soils of the Wisconsin glaciers are relatively younger and are leached of free lime to depths of only 40 or 55 inches. In the northern part of Posey Township, the soil is leached free of lime to the depth of only 12 to 30 inches, indicating that the soil is still younger (U.S.D.A., 1960).

Till of the Tazewell substage of the Wisconsin glacial age has considerably influenced soil-forming conditions in Fayette and Union counties. As the ice melted during summers it caused flood water to cover large areas of what is now the Whitewater River valley, depositing comminuted rock in that area. These deposits became mud flats and dried out in cool seasons. The debris was then blown by winds on to the uplands and deposited as loess. This loess, now mostly modified by weathering, varies in thickness from one to five feet or more and covers nearly 60 percent of Fayette and Union Counties. In some rolling to steep areas, geological erosion removed loess as fast as it was laid down, and in such places the soils have formed in glacial till only. Soils that have formed in glacial till are gritty and gravelly, whereas soils formed in loess are smooth and silty.

Another type of soil formed in these counties is that derived from out-wash. The out-wash materials originated by sedimentation from glacial meltwater and occur in terraces as "high bottoms". The derived soils contain considerable amounts of gravel. Less coarse in texture are the soils associated with recent flood plain or "first bottom" positions; these alluvial soils undergo frequent flooding and fresh additions of alluvium.

Bedrock of the Ordovician system underlies soil mantle throughout Fayette and Union Counties, except a small portion west of Fayette County. The Ordovician system consists of alternate layers of slab-like limestones and a very dense argillaceous shale. On weathering, the shale between the layers of limestone disintegrates into a highly plastic clay, resulting in dangerous situations from the standpoint of foundation problems and slides (Belcher, Gregg, and Woods, 1943). Soils associated with the beds of flaggy limestone and limey shale have formed in place and are generally shallow. Fortunately, they occupy a small area in Fayette and Union Counties.

V. PEDOLOGIC CLASSIFICATION OF FAYETTE AND UNION COUNTY SOILS

Pedological classification suggests that the soils in Fayette and Union Counties fall into several general groups: 1) Gray-Brown Podzolic soils, 2) Planosols, 3) Humic Gley soils, 4) Brown Forest soils, 5) Regosols, 6) Rendzinas, and 7) Alluvial soils. These groups have further been subdivided into topographic and drainage classes such as "nearly level" and "somewhat poorly drained". With further subdivisions based on gelogic material such as "highly calcareous loam to light clay loam glacial till of Wisconsin age, leached to depths of 13 to 42 inches," the individual soil series are identified. Thus, 31 soil series are identified for Fayette and Union Counties. These are shown in Tables 1 to 4.

Gray-Brown Podzolic soils, given in Table 1, are a group of soils having a comparatively thin organic covering and organic-mineral layers over a grayish-brown leached layer which rests upon an illuvial brown horizon, developed under deciduous forest in a temperate moist climate (U.S.D.A., 1938). Nearly 80 percent of the area of Fayette and Union Counties is covered by this group of soils. Members of this group vary widely one from the other in drainage condition. With well-drained soils, water percolates rapidly through the soil pores to reach the water table, which occurs relatively far below the surface. With somewhat poorly drained soils, percolation is very slow or the water table is relatively close to the surface. Soils of the same drainage condition are categorized on the basis of geologic parent materials and soils

TABLE 1

Gray-Brown Podzolic Soils in Fayette and Union Counties, Indiana*

Parent Material	Nearly level to strongly sloping		Nearly level to gently sloping	Nearly level
	Well drained to excessively drained	Well drained	Moderately well drained	Somewhat poorly drained
1. Loess 10-72 in. thick, over calcareous loam to clay loam glacial till of Illinoian[1] age; strongly leached to depths of 10 or more feet.	Cincinnati	-	-	-
2. Loess 18-40 in. thick, over highly calcareous loam to light clay loam glacial till of Wisconsin[2] age, leached to depths of 42-60 or more inches.	-	Russel	Xenia	Fincastle
3. Highly calcareous loam to light clay loam glacial till of Wisconsin age; leached to depths of 13-42 inches.	-	Miami	Celina	Crosby
4. Loess, 36-65 in. thick, over loamy glacial till of Wisconsin age; generally calcareous at depths of 36 or more inches.	-	Manlove	Birkbeck	Reesville
5. Loess and loamy glacial till of Wisconsin age over limestone of Ordovician period[3]; generally leached.	-	Wynn	-	-

TABLE 1 (cont'd)

Parent Material	Nearly level to strongly sloping		Nearly level to gently sloping	Nearly level
	Well drained to excessively drained	Well drained	Moderately well drained	Somewhat poorly drained
6. Medium-textured glacial drift of Wisconsin age, 18-42 in. thick, over limestone terraces.	-	Milton	-	-
7. Stratified sand, silt and some clay of Wisconsin age; calcareous at depths of 42-60 in.	-	Martinsville	-	Whitaker
8. Silty and loamy outwash, 42 or more inches thick, over highly calcareous gravel and sand.	Ockley	-	-	-
9. Silty and loamy outwash, 24-42 inches thick, over highly calcareous gravel and sand.	Fox	-	-	Homer

* Reproduced from "Soil Survey Report of Fayette and Union Counties, Indiana - 1960"

1 274,000 to 330,000 years (Thornburn, 1960)

2 8,000 to 28,000 years

3 381 to 448 millions of years.

TABLE 2

Planosols in Fayette and Union County, Indiana*

Parent Material	Nearly level Somewhat poorly drained	Level Poorly drained
1. Loess, 10 to 72 inches thick, over calcareous loam to clay loam glacial till of Illinoian age; strongly leached to depths of 10 or more ft.	Avonburg	-
2. Loess, 18 to 40 inches thick, over highly calcareous loam to light clay loam glacial till of Wisconsin age; leached to depths of 42 to 60 or more inches.	-	Delman

* Reproduced from "Soil Survey Report of Fayette and Union Counties, Indiana - 1960"

TABLE 3

Humic Gley Soils in Fayette and Union County, Indiana*

Parent Material	Nearly level to slightly depressed	Nearly level to depressed	
	Poorly drained	Very poorly drained	Very poorly drained to ponded
1. Loess, 18 to 40 inches thick, over highly calcareous loam of Wisconsin age; leached to depths of 42 to 60 or more in.	Cope	Brookston	Kokomo
2. Highly calcareous loam to light clay loam glacial till of Wisconsin age; leached to depths of 13 to 42 inches.	-	Brookston	Kokomo
3. Stratified sand, silt, and some clay of Wisconsin age; calcareous at depths of 42 to 60 inches.	Westland	-	-
4. Medium-textured, neutral to alkaline alluvium, chiefly from glacial drift of Wisconsin age.	-	Sloan	-

* Reproduced from "Soil Survey Report of Fayette and Union Counties, Indiana - 1960"

TABLE 4

Brown Forest Soils, Regosols, Rendzinas, and Alluvial Soils
in Fayette and Union County, Indiana*

Parent Material	Brown Forest Soils	Regosols	Rendzinas
	Nearly level	Steep to very steep	Steep
	Well drained to excessively drained	Excessively drained	Excessively drained
1. Highly calcareous loam to light clay loam glacial till of Wisconsin age; leached to depths of 13 to 42 inches.	-	Hennepin	-
2. Soft, marly and flaggy limestone of Ordovician period.	-	-	Fairmount
3. Loamy outwash, 12 to 36 in. thick, over highly calcareous gravel and sand.	Nineveh	-	-
4. Loamy outwash, less than 18 inches thick, over highly calcareous gravel and sand.	Rodman	-	-

Parent Material	Alluvial Soils		
	Nearly level	Nearly level to slightly depressed	Nearly level to depressed sloughs and meander channels
	Well drained	Moderately well drained	Somewhat poorly drained
5. Medium-textured, neutral to alkaline alluvium, chiefly from glacial drift of Wisconsin age.	Genesee Ross	Eel	Shoals

* Reproduced from "Soil Survey Report of Fayette and Union Counties, Indiana - 1960"

derived from the same geologic materials are subdivided on the basis of drainage condition. In the latter case, the group of series is called a "catena" (U.S.D.A., 1951).

Planosol soils, given in Table 2, are a group of soils having leached 'A' horizons and strongly illuviated, cemented or compacted 'B' horizons. In Fayette and Union Counties, planosols have been formed under forests and occupy a very small area.

Humic Gley soils, given in Table 3, are dark colored soils formed in low areas where the drainage condition, in the static sense, is very poor most of the time. About five per cent of the area of the two counties are covered by this group of soils.

Brown Forest soils, given in Table 4, are somewhat leached, but have not developed eluvial and illuvial horizons to any extent. The topography of the soils is nearly level, and the drainage condition is described as well drained to excessively drained. The soils have been formed on loamy outwash with excellent engineering properties. Although this group of soils occupies a very small area in these two counties, it is in this area that much urbanization has occurred.

Regosols, given in Table 4, are made up of deep, unconsolidated or soft rocky deposits in which no clearly expressed pedologic soil characteristics have developed (U.S.D.A., 1960). In Fayette and Union Counties such soil is excessively drained and has topography that is very steep. Nearly four per cent of the area of these counties is covered by regosols.

Rendzinas, given in Table 4, are a group of soils with dark gray or black surface layers overlying soft, light-gray or white highly calcareous material (U.S.D.A., 1938). In Fayette and Union Counties, they developed from soft and flaggy limestone, and generally have fairly steep slopes.

The term "alluvial soils", given in Table 4, applies only to the more recently deposited water-laid materials that have been very little changed by environment (U.S.D.A., 1938). The characteristics of these soils depend entirely on the nature of the materials from which they are derived and the manner in which they have been deposited. The alluvial soils of Fayette and Union Counties have been formed from neutral to calcareous materials washed from timbered areas of glacial drift of Wisconsin age. The topography of these soils varies from nearly level to depressed sloughs and meander channels, and the drainage condition varies from well-drained to somewhat poorly drained.

The assignment of engineering properties to certain Indiana soils has been done employing the pedologic names. Purdue University has a continuing program of characterizing pedologic soils of the various counties in Indiana that have been mapped. This has been aimed at highway engineering problems and the suitability of soils for performance as subgrade material. Purdue University, the Bureau of Public Roads, the Soil Conservation Service, and the Indiana State Highway Department have entered into a co-operative agreement to provide engineering test data on the important soil series that occur within a county (Miles and Spencer, 1961). Hence, the soil survey reports that are to be published in the future by the Soil Conservation Service will contain engineering soil test data combined with the land-use information normally given.

A similar program aimed at estimating the engineering properties of the soils of Illinois has been conducted by the University of Illinois (Thornburn, 1960). Three soil series evaluated by the Illinois study occur in Fayette and Union Counties. Again, this work is oriented toward highway engineering.

VI. MATERIALS AND METHODS

Field investigation was conducted during October 16 and 17, 1961, with the aid of soil scientists and engineers from Virginia Polytechnic Institute, Purdue University, U.S.D.A. Soil Conservation Service and the Federal Housing Administration. Although the work was restricted for the most part to Fayette and Union Counties, special problems occurring in the suburbs of Indianapolis were given attention. The newly built housing colonies skirting Connersville, county seat of Fayette County, and Indianapolis were visited, and inquiries were made with residents regarding difficulties arising from soil conditions. Excavations made for the foundations of new houses were inspected and soil profiles studied with reference to the agricultural Soil Survey Report.

Soil samples were most often gathered with a four inch bucket-type auger, but in a few instances they were taken from exposures adjacent to gravel and borrow pits. In these cases the exposures were cut into to reach relatively undisturbed material. The soil series sampled are given in Table 5. The samples were taken from the 'B' horizons, as determined by agricultural field scientists. The samples were collected and transported in cloth bags.

The soil samples were kept in cloth bags for nearly one month and then air dried for ten days in the laboratory. Lumps were broken down by hand and by using a rubber-tipped pestle. The portion of each sample passing through a No. 10 sieve was subjected to the following tests:

TABLE 5

Soil Series Sampled

Soil	Horizon Sampled	Remarks
1. Concinnati silt	B	Taken from old road cut in southern Fayette County, Indiana; soil indurated in place.
2. Crosby silt loam	B	Taken from cultivated land in northwestern Fayette County, Indiana.
3. Fox loam	B	Taken from gravel pit near Connersville, Indiana.
4. Fox loam	B	Soil sample occurred as a thin plastic lens in gravel outwash near Connersville, Indiana.
5. Manlove silt loam	B	Taken from cultivated land where modified loess was at least six feet deep, northern Fayette County, Indiana.
6. Russel silt loam	B	Taken from a borrow pit near Connersville, Indiana.
7. Xenia silt loam	B	Taken from cultivated land near Connersville, Indiana.
8. Brookston silt loam	B	Sampled in Miami County, Indiana, at a basement excavation holding water.
9. Crosby silt loam	B	Sampled in a residential area near Indianapolis, Indiana.
10. Wisconsin till	5' Depth	Sampled in Miami County, Indiana, near a housing area where the overlying soil, Miami series, had been removed.

1) Liquid limit and plastic limit

2) Particle-size distribution

3) PVC and swell index.

The liquid limit and plastic limit tests were conducted primarily to identify and classify the soil according to the Unified Soil Classification System (FHA No. 373, 1959). The test procedures followed were those given by Lambe (Lambe, 1960). The soils were sieved through a No. 40 sieve and were cured at approximately the liquid limit for 24 hours before testing for Atterberg limits. After determining the liquid limit and plastic limit of the soil, the corresponding plasticity index and flow index were calculated.

Since all the soil samples are fine grained, the hydrometer test was conducted to determine particle size distribution. The deflocculating agent used was calgon at the rate of 1.6 grams per 50 grams of soil. The test procedure followed was that given by Lambe. The test results were applied to classification and the calculation of the activity ratio of each soil.

To determine the swell properties of the soils the PVC meter was used. This PVC meter was developed recently by Lambe (FHA, 1960) to determine the potential volume change of clay soils. The "swell index" is the value of the pressure in pounds per square foot developed at the end of two hours of testing. The corresponding value of PVC can be directly read from the rating curve "swell index versus potential volume change" given by Lambe. The test procedure followed was according to that outlined by him. The soil tested was passed through a No. 10 sieve and air dried before conducting the test.

The swell property of a soil depends upon 1) percentage and type of clay mineral present, 2) soil structure, 3) relative water content, 4) initial density, 5) load condition, and 6) time. The last four factors are variables, the first two being constant for any particular soil. To find a good correlation of test results and to obtain a relative idea of potential volume change, every soil has to be subjected to test under similar conditions such as relative water content, initial density, load condition, and time.

The PVC test may be conducted at any one of three relative water contents, dry, moist, and wet, defined as follows:

Dry = W_{50} = water content at 50 per cent relative humidity

Moist = W_{100} = water content at 100 per cent relative humidity

Wet = W_p = plastic limit

Dry, moist, and wet samples are chosen to represent approximately an air-dried water content, a very low field water content and a very high field water content, respectively. The samples are tested at water contents which are thought to cover the range of water contents from which a field sample might swell.

To have relatively the same density during the tests, the soils are compacted dynamically by a 5.5 pound hammer (Standard AASHO hammer) falling through 12 inches. Since it requires more effort to compact dry samples to the same density as wet samples, the compacting effort is increased with decreasing water content as shown in Table 6.

TABLE 6

Compactive Effort Used With Varying Water Contents

Water Content	Nominal Compactive Effort	No. of Layers	Blows per Layer	Compactive Energy (ft.lbs.per cu.ft.)
Dry	Modified AASHO	3	7-7-8	55,000
Moist	½ Modified AASHO	3	4	31,000
*Wet	Standard AASHO	1	5	13,000

* The plastic limit approximates optimum water content for Standard AASHO compaction. After Lambe (FHA, 1960).

After mounting the test specimen in the test device, an initial load of 200 lbs. per sq.ft. is applied. After the application of the initial load, distilled water is added through vertical holes located at the top of the compaction ring of the PVC meter. This procedure is adopted to minimize the amount of air entrapped in the soil and to ensure that the soil sample has access to water over its entire top and bottom surfaces. The dial reading of the proving ring is taken at the end of two hours, and the corresponding pressure developed is calculated. This pressure is the "swell index". The dial readings at known intervals of time may be taken and a plot of pressure versus log time may be drawn. Swell index is used in PVC classification of soil, using as categories 1) non-critical, 2) marginal, 3) critical, and 4) very critical. A numerical PVC classification system is given in Table 7.

TABLE 7

Numerical PVC Classification System

Swell Index - lbs/sq.ft.	PVC Rating	Category
Less than 1,700	Less than 2	Non-critical
1700 - 3200	2 - 4	Marginal
3200 - 4700	4 - 6	Critical
More than 4,700	More than 6	Very critical

VII. RESULTS

The data obtained from liquid limit and plastic limit tests are given in Table 8. Plasticity index and flow index have been calculated and noted in the table. These results combined with the results of particle size analysis, given in Table 9, were used in the classification of the soils according to both the Unified and AASHO Classification systems. Xenia silt loam and Crosby silt loam #2 samples are classified as clay of high plasticity (CH) and the Fox samples as sandy clay (SC). The rest of the soils come within the clay of low plasticity (CL) class.

Before conducting the particle size analysis by the hydrometer method, no attempt was made to remove the minute pieces of organic matter or the free carbonates present in the soil. The free carbonates and organic matter might have prevented the deflocculant agent from functioning thoroughly.

The activity ratios of the soils tested are given in Table 10. According to Skempton's classification (Grim, 1962), Fox loam #1 and Manlove silt loam soils lie in the group of inactive soils, those with an activity ratio of less than 0.5. Fox loam #2, Russel silt loam, Crosby silt loam #1, Cincinnati silt, Brookston silt loam and Wisconsin till lie in a second group of inactive soils, those with an activity ratio of between 0.5 and 0.75. Xenia silt loam and Crosby silt loam #2 lie in the group of normally active soils, those with an activity ratio of between 0.75 and 1.25, despite the fact that these samples are CH.

TABLE 8

Atterburg Limits and Classification of Soil Samples from Indiana

Soil	Horizon	Liquid Limit L.L.%	Plastic Limit P.L.%	Plasticity Index P.I.%	Flow Index I_f	Classification Group Symbol Unified	AASHO
Soils from Fayette and Union Counties:							
1. Cincinnati silt	B	41.5	23.0	18.5	25.2	CL	A-7
2. Crosby silt loam #1	B	42.0	19.3	22.7	9.6	CL	A-7
3. Fox loam #1	B	28.9	18.2	10.7	13.0	SC	A-6
4. Fox loam #2	B	40.5	22.6	17.9	11.6	SC	A-7
5. Manlove silt loam	B	24.6	16.7	7.8	6.0	CL	A-4
6. Russel silt loam	B	34.0	17.3	16.6	11.8	CL	A-6
7. Xenia silt loam	B	51.5	22.5	29.0	17.0	CH	A-7
Soils from Miami County:							
8. Brookston silt loam	B	37.0	18.5	18.4	7.0	CL	A-6
9. Crosby silt loam #2	B	57.5	23.2	34.3	23.2	CH	A-7
10. Wisconsin till	B	21.0	13.6	7.5	5.0	CL	A-4

TABLE 9

Particle Size Distribution of Soil Samples from Indiana

Soil	Horizon	Percent Greater Than 0.074 mm	Percent Between 0.074 mm. and 0.002 mm.	Percent Finer Than 0.002 mm.
Soils from Fayette and Union Counties:				
1. Cincinnati silt	B	20.2	52.5	27.3
2. Crosby silt loam #1	B	19.5	43.5	37.0
3. Fox loam #1	B	65.4	11.4	23.2
4. Fox loam #2	B	62.0	10.3	27.7
5. Manlove silt loam	B	20.2	57.3	22.5
6. Russel silt loam	B	42.5	28.2	29.3
7. Xenia silt loam	B	7.4	57.4	35.2
Soils from Miami County:				
8. Brookston silt loam #2	B	28.2	41.0	30.8
9. Crosby silt loam	B	12.0	49.0	39.0
10. Wisconsin till	B	50.0	34.8	15.2

TABLE 10

Activity Ratio and PVC Ratings of Soil Samples from Indiana

Soil	Horizon	Activity Ratio	Plasticity Index P.I.%	PVC Test Results Swell Index psf	PVC Value	PVC Rating
Soils from Fayette and Union Counties:						
1. Cincinnati silt	B	0.67	18.5	661	0.61	Noncritical
2. Crosby silt loam #1	B	0.61	22.7	1155	1.30	Noncritical
3. Fox loam #1	B	0.46	10.7	647	0.60	Noncritical
4. Fox loam #2	B	0.64	17.9	634	0.56	Noncritical
5. Manlove silt loam	B	0.34	7.8	722	0.70	Noncritical
6. Russel silt loam	B	0.56	16.6	1155	1.30	Noncritical
7. Xenia silt loam	B	0.82	29.0	2000 (1545)*	2.40 (1.60)	Marginal (Noncritical)
Soils from Miami County:						
8. Brookston silt loam	B	0.60	18.4	900 (716)*	0.91 (0.70)	Noncritical (Noncritical)
9. Crosby silt loam #2	B	0.88	34.3	1420	1.60	Noncritical
10. Wisconsin till	B	0.50	7.5	408	0.30	Noncritical

* The values within parentheses refer to the second test results.

The PVC test results are given in Table 10 along with the PVC values as obtained from the rating curve "swell index versus potential volume change" given by Lambe (FHA, 1960). None of the soils lie in the critical range, including the OH samples. Hence, none of the soils are of a high-swelling nature.

Lambe suggests that a relation exists between swell index and plasticity index (FHA, 1960), but results obtained in this study do not show any such correlation. For example, Xenia silt loam has a plasticity index of 29.00 and a swell index of 2000 lbs. per sq. ft., whereas Crosby silt loam #2 has a higher plasticity index, 34.3, and a lower swell index, 1420 lbs. per sq. ft. Lambe states (FHA, 1960 - p. 35) "the reliability of the correlation for soils which do not fall close to the A-line is not known." But he has not stated how close to the A-line is meant. The ten soils tested lie within about five per cent of the A-line.

Slightly erroneous values of swell index of soils might be obtained due to personal factors such as 1) improper tightening of top bolts, 2) improper compaction, 3) the time taken to fill up the container with distilled water, and 4) improper cleaning of the porous plates. Every precaution was taken to eliminate errors due to the above factors while conducting the tests.

There is a slight eccentricity at the point of application of swell pressure on to the proving ring in the PVC meter used for conducting the tests. This probably did not introduce appreciable error.

The proving ring used gives more accurate values for higher dial readings. For small loadings, the published calibration curve may give erroneous pressure. To eliminate errors due to this factor, the proving ring of the PVC meter was re-calibrated in the Wood Testing Laboratory of the Virginia Polytechnic Institute, applying small pressures only. These re-calibrated values were used to calculate the swell index.

With a view toward checking whether the PVC meter tests give consistent results or not, two soils, Xenia silt loam and Brookston silt loam, were subjected to PVC test for the second time. The difference between the first test results and the second test results was about 25 per cent.

VIII. DISCUSSION

Problems of Residential Housing Relating to Soil Character

A detailed study of the problems of residential housing is necessary to rate a soil according to its usefulness. Primary among these problems are 1) Foundation stability, 2) Sewage disposal, 3) Flooding, 4) Seepage of water and high water table, 5) Failure of slopes, 6) Shallow depth to bedrock, and 7) Maintenance of access roads. These problems depend on the geologic, hydrologic and topographic positions of the soil and the character of the soil material proper.

For a foundation to be stable, the soil on which it is built should have a high bearing strength, low volume change, low compressibility, and a low potential for frost heave. A high load sustaining power of a soil reduces the cost of construction of a foundation by allowing for decreased footing size. Low compressibility reduces the possibility of settlement. Uniform settlement may not fail a structure, but differential settlement, due to a soil with a heterogeneous nature, may lead to cracks in the foundation, superstructure, or veneer. Volume changes of soil, due to wetting or drying, change the pressure condition on the foundation. Such pressure changes, especially when they are differential, may cause considerable damage.

Disposal of sewage through municipal sewerage, when it is available, is an ideal method of handling an important problem. But the cost of laying conduits to a house to connect the main sewers of a town may be prohibitive in some cases, especially when the residences are in suburban areas. The septic tank or sewage lagoon method of sewage disposal may be far more economical. The sewage lagoon method is favorable and economical when storage areas are available near a stream. The beds of these reservoirs must be impervious to prevent the loss of liquids through the bottom as seepage. Low berms have to be constructed with relatively impervious soil. Sewage lagoons must also be some distance from residential houses and well screened with vegetation. Lagoons are most suitable in rural areas and lose their usefulness as urban areas are approached. Drainage condition and permeability are important among the factors that govern the suitability of soil for disposal of sewage by septic tank absorption fields. Permeable layers must extend horizontally and vertically for the efficient absorption of effluent by the soil. High water table areas and poorly drained soil series are a problem to septic tanks. In steep slopes, the effluent may tend to pond at the foot of the slopes and create an unhealthy situation. The limiting slope, for safe performance of sewage disposal by individual system of the absorption field type, is often taken as being 25 percent (Krebs and Hunter, 1961).

Another problem, which seems obvious in its implications, but is often neglected just the same, is flooding of residential areas. Frequent flooding of housing areas weakens the stability or integrity of the structures. Most structural foundation materials, if subjected to alternate soaking and drying such as soaking in flood seasons and drying in the summer and early part of the winter, lose strength and durability. Construction timber, in particular, deteriorates easily. In addition, road materials are affected adversely under such conditions. Access to residences may be put temporarily out of use or permanently destroyed during seasons of high water table or flooding. Electrical and telephone service may be interrupted. Finally, individual sewage disposal systems will fail under such conditions.

Even though it may not occur as a flood, water is an enemy of the home owner. Seepage water and a high water table cause warping of timber and the deterioration of masonry and roadway subgrade materials. Working individual sewage disposal systems cannot be provided in such areas as they fail to perform satisfactorily. Usually, areas of seepage water and high water table are swampy and marshy, and as such, these areas are unhealthy and not especially suitable for habitation. In areas where there is frost susceptible soil, a high water table provides a source of water for frost action. Frost action affects deleteriously the subgrade materials of access roads and the foundation of light structures. In winter, due to the freezing of water in the pores of soils, the soils heave, exerting pressures on the foundation. Again, in the spring, the frozen layers melt, and the soil softens and settles. Due to this phenomenon, differential settlement of foundations may occur, leading to cracks in the structure.

It sometimes happens that the slopes on which homes are built fail so as to cause a complete loss of the residence. The most common force which destroys the stability of a slope is gravity, including the weight of the soil mass and that of the superimposed load. The weight of small residential houses may not appreciably add to the superimposed loads, as the weight of such buildings is many times equal to or even less than the weight of the soil excavated for foundations and basements. The weight of the additional soil mass placed for grading and the embankment for an access road may play an important part in destroying the stability of a slope. Most slides occur during or soon after a rain. The shearing strength, the resisting force of the soil, may be decreased by excess moisture content. Also, seepage force may add to the forces tending to cause failure. In any case, removal of the soil material at the toe of a slope is a dangerous practice. If a soil or rock deposit is stratified, and the layers are parallel or nearly parallel to a sloping ground surface, there is every possibility of sliding of these stratified layers. If the stratified layers are sloping in a direction opposite to the ground surface, there is less possibility of sliding. Creep is a slow motion of the upper strata of a generally unloaded soil, soil rock, or rock mass with respect to the underlying strata. This usually affects the first few feet below the ground surface. Thick clay deposits may creep even on mildly sloping terrain. Tilted trees, electric, and telephone poles are indicative of the presence of creep in a soil mass. Sewage disposal by an individual system of the absorption field type may tend to accelerate such creep and sometimes lead to a land slide. Erosion of soil is great on steep slopes where the velocity of flowing rain water is high. The shear failure of slopes, sliding of stratified layers, creep, and erosion affect such structures as houses, access roads, sewage conduits, and water mains. They affect landscaping also. In addition, the cost of construction and maintenance of houses, access roads, and other auxiliary structures on steep slopes tends to be higher than that on flat terraces.

Depth to bedrock may have an important bearing on the suitability of a site for residential structures. Shallow bed rock depths are desirable from the standpoint of foundation bearing, but other problems, such as installing water mains, sewerage conduits, and access roads cost more because of the rock excavation involved. Also, differential settlement may result when a foundation is placed partially on rock. The placing and proper functioning of an individual sewage disposal system is yet another problem in shallow bedrock region. Hence, the advantage of the high load sustaining power of bedrock is often more than outweighed by the many disadvantages of its occurrences.

The stability, durability and life of access roads is important to housing developments. It depends on strength, drainage, ease of compaction, and permanency of compaction and strength of the subgrade materials. The cost of providing a good pavement, as in the case of highways, for these access roads is prohibitively high. Ordinary pavements of low cost are usually provided. If the soil of the subgrade is of a high-swelling nature or is frost susceptible, the pavement will be damaged early and requires maintenance at high cost.

Soils of Fayette and Union Counties, Indiana, With Reference to Residential Housing

The most important items presented in the Soil Survey Report of Fayette and Union Counties, Indiana, are the descriptions of the pedologic soil types. These descriptions indicate the profile characteristics, topography, parent material and drainage characteristics for each soil. The characteristics are discussed here in general with reference to the problems of residential housing referred to above.

As previously mentioned, the soils of Fayette and Union Counties were formed from glacial drift, loess, alluvium and weathered products of limestone and shale. Glacial drift may contain numerous beds of pervious sand and gravel, but may also contain considerable quantities of impervious clay or clayey silt. Because glacial drift is made up of many different kinds of materials, heavy structures built in glacial zones may be endangered by the possibility of differential settlement; but the design of foundations for light structures in glacial zones generally does not present difficulties (Krynine and Judd, 1957). Any high permeability of underlying material of glacial drift is advantageous for individual sewage systems of the absorption field type and for the subgrades of access roads. Because of its hydro-consolidation properties, loess in general may be a dangerous foundation material, even for small structures, when it is brought into contact with water. In Fayette and Union Counties, loess is found as a shallow, weathered veneer over calcareous loam glacial till of Illinoian or Wisconsin age, and therefore foundations are not troubled by loess.

Alluvium is in many respects similar to glacial drift. Alluvial deposits are heterogeneous and also may be stratified. These soil materials may be found forming terraces or as floodplains forming relatively level deposits. Usually the floodplains are subjected to frequent flooding if the alluvium is recent. In steep areas, soils that overlie beds of flaggy limestone and shale have been formed in place from weathered products of these materials. On weathering, the shale between the limestone strata disintegrates, forming highly plastic clays. These thin layers of clays may cause sliding of the overlying rock and soil mass.

In the Soil Survey Report of Fayette and Union Counties, the drainage condition and permeability of each soil is described. For the study of soil in relation to sewage disposal, this information is valuable. Several drainage-condition classes have been defined in relation to hydrologic conditions as 1) very poorly drained, 2) poorly drained, 3) somewhat poorly drained, 4) moderately well drained, 5) well drained, and 6) excessively drained. As the nomenclature indicates, the very poorly drained, poorly drained and somewhat poorly drained soils are unfavorable for the disposal of sewage by absorption field systems. The other drainage-condition classes tend to be favorable. The permeability characteristics of the soils is given as 1) very rapid, 2) rapid, 3) moderately rapid, 4) moderately slow, and 5) slow. The soils of slow or moderately slow permeability are unfavorable for the disposal of sewage by the absorption field type of system.

The study of the profile characteristics, topography, parent material, and drainage characteristics of each soil type given in the Soil Survey Report allows one to group the soil areas of Fayette and Union Counties into eight general units as follows:

1. Uplands on glacial till plains.
2. Disserted ridge tops in uplands and on hillsides around deep valleys or drainage ways.
3. Upland swales and depressions.
4. High alluvial terraces.
5. Low alluvial and outwash terraces, and areas adjacent to the valleys of streams and drainage ways.
6. Slopes bordering deeply entrenched streams.
7. Bottom lands.
8. Unclassified.

These units have been developed on the basis of five criteria:

1. The units are recognizable by terrain reconnaissance procedures and topography.
2. Each unit contains soil types with similar parent materials, and, as far as possible, soil types of the same pedologic "great soil group."
3. There is a significant difference in engineering considerations among the units.
4. Each unit contains soil types of the same general characteristics and engineering considerations

pertaining to the problems of residential housing.

5. These units can be recognized by observing the general morphology of the land.

The Bureau of Soil Mechanics of the New York State Department of Public Works has set up almost similar criteria for grouping of areas for mapping for the design and construction of highways in New York State (HRB Bulletin No. 299, 1961). Each of the units established for this study, the pedologic soil types they contain in Fayette and Union Counties, and the features of importance to residential housing are discussed below.

1. Uplands on the glacial till plains.

The uplands can be easily distinguished from high or low terraces, bottom lands, and steep slopes. Ten soils of Fayette and Union Counties fall into this unit, which covers nearly 66 percent of the total area. The parent material of these soils is loess over calcareous loam to clay loam or loamy glacial till. All the soils except Avonburg and Delmar belong to the Gray-Brown Podzolic soil group. Avonburg and Delmar soils belong to the Planosol soil group. Drainage properties vary from well-drained soil, such as the Russel series, to poorly drained soil, such as Delmar. Problems of residential housing in these areas are minor, as these areas are typically level or moderately sloping lands at higher elevations. There are no problems of slope failures, erosion, water table and flooding. Since the top soil for nearly three to four feet deep contains loess, frost problems can be expected, especially for access roads. Poorly drained soils and somewhat poorly drained soils may create a problem for the disposal of sewage by absorption fields.

The individual soil series found in the uplands and their suitability for residential housing are as follows:

Avonburg - The use of this soil area as a residential area is limited by a somewhat poor drainage condition.

Delmar - The use of this soil area as a residential area is restricted by the poor drainage and low permeability characteristics of the nearly level soil.

Crosby - The use of this soil area for residences is limited by its somewhat poor drainage characteristics, but the drainage condition can often be improved by artificial drainage, as is being done by agriculturists.

Fincastle - Nearly 65 percent of Fayette and Union Counties is covered by this soil. Its use is restricted by its somewhat poor drainage condition.

Birkbeck - This soil has good drainage and permeability characteristics. Shallow foundations, however, may be affected by frost action. Except for this, there is no other serious problem for residential housing. Slight erosion and seepage may be expected during wet seasons.

Manlove - This soil has good drainage and permeability characteristics similar to the Birkbeck series. Shallow foundations may be affected by frost action. The soil is very silty, being modified loess, but the water table is not high.

Reesville - The use of this area for residences is restricted by its somewhat poor drainage characteristics. Also, frost action is dangerous with this soil.

Russel - In some areas, this soil is nearly level and in other places, slopes may be as much as 25 percent. Nearly 45 percent of Fayette and Union Counties is covered with Russel soil, out of which only a small percentage is steeply sloping. The soil has good drainage characteristics. Foundations, taken deep, will not be affected by frost action. Accordingly, in general, the areas occupied by this soil, except when the slope exceeds 18 percent, are good sites for residential housing.

Wynn - This soil is similar to Russel soil, but it is underlain by bedrock at shallow depths. The bedrock is gray limestone or calcareous unconsolidated clay shale of the Ordovician period. The slopes may vary from 2 to 25 percent. Due to the stratification of limestone and clay shale, sliding of the stratified layers may be expected. Wynn occupies very small areas mainly in the southwestern part of Fayette County. It is one of the most unsuitable soils for residential housing because of the bedrock at shallow depths and the possibility of sliding. Wynn should not be mistaken for Russel, which is good for residential housing.

Xenia - This soil is of high plasticity and its PVC rating classification is marginal. However, it has good drainage and permeability characteristics. Areas are generally good for residential housing. Foundations, taken deeper than frost penetration as fixed by the local building code, may not be affected by frost action.

2. Dissected ridge tops in uplands and on hillsides around deep valleys or drainage ways.

The Cincinnati and Miami soil series fall into this unit. These are Gray-Brown Podzolic soils. The parent material of Cincinnati soil is loess 10 to 72 inches thick over calcareous loam to clay loam glacial till, and that of Miami soil is highly calcareous loam to light clay loam glacial till. Both are well drained and moderately permeable soils. Erosion is a main problem. Another important problem is frost action in wet seasons, especially in Cincinnati soil areas, as they contain a high percentage of silt. Areas of slopes greater than 18 percent may be unsuitable as erosion is severe, and seepage also may occur in deep cuts. The water table may be expected to surface in deep cuts. Cincinnati and Miami soils occupy 6.2 percent of Fayette and Union Counties, out of which nearly one-half has slopes greater than 18 percent.

3. Upland, swales and depressions.

Brookston, Cope, and Kokomo soils occur in shallow depressions in upland areas of glacial till. The parent materials of these soils is loess 18 to 40 inches thick over highly calcareous loam to light clay loam. These soils are in the Humic Gley great soil group. The upper surface soils contain appreciable organic matter. The water table may be expected to be at or near the surface in wet seasons. The soils are poorly drained and of slow permeability. Problems of residential housing are many in these areas; high water table in the spring, severe frost action in the winter, and failing individual sewage disposal systems throughout the year. Delmar, which is classified in the first unit, may also be classified under this unit as it also occurs in depressions on uplands and has associated characteristics.

4. High alluvial terraces.

These soils are of the river terraces and former glacial channels, generally 5 to 10 feet or more above bottom lands, and slightly lower than adjacent glacial till plains. They are predominantly well drained to excessively drained soils in silty and loamy materials over stratified gravel and sand. Fox, Homer, Ockley, Martinsville and Westland come under this group and cover 6.9 percent of Fayette and Union counties. Except for Westland, all are soils of the Gray-Brown Podzolic group. Westland is in the Humic Gley great soil group. The water table may be close to the surface in low level areas, but internal drainage is generally good. At the foot of slopes and at the junctions of two sloping areas, the water table may be at the surface and seepage may be encountered, especially in the Homer type soils, during wet seasons. Frost action is a problem in Homer and Westland soils, because of the silty nature of the surface soils and high water table. Most of the urbanization in Fayette County is in regions of Fox and Ockley soils along the Whitewater River valley. High quality granular material will usually be found at depths below five feet.

The Rodman soils can also be grouped under high alluvial terraces. This soil lies between Ockley soils on the higher terraces and Fox soils on the lower terraces. It has formed from stratified, loose, gravelly calcareous glacial drift that contains much limestone. Its slope varies from 12 to as much as 50 percent. Hence, steep slope is the chief problem of residential housing in the Rodman soil region. Fortunately, a very small area, 0.6 percent of Fayette and Union Counties, is covered by this soil.

5. Low alluvial and outwash terraces, and areas adjacent to the valleys of streams and drainage ways.

These are areas on low terraces and plains between the lower flood plains and the higher terraced Fox soils. Two soils, Nineveh and Whitaker, are found in this unit. Both of them are outwash materials containing stratified sand, silt and a small amount of clay, over highly calcareous gravel and sand. Whitaker is Gray Brown Podzolic soil and somewhat poorly drained. Nineveh is a Brown Forest soil and well drained. The water table is high at times. Only 0.4 percent area of Fayette and Union Counties is covered with these soils, whose main problems are water table and nearness to potential flood areas.

Another soil that lies on terraces slightly higher than bottom lands is the Milton series. This is a medium-textured glacial drift of 18 to 42 inches thick over limestone and calcareous shale of the Ordovician period. The surface slope is 2 to 6 percent and the top soil erodes easily. The porous limestone at shallow depth, its strong slope, and its nearness to flood plains limit the use of this soil for residential housing.

Yet another soil that lies adjacent to valleys of streams and drainageways is the Fairmount series. This soil has formed from weathered products of soft, marshy, and flaggy limestone. Only a thin layer of soil material can be found over the parent material, because of great erosion. Steep slope and interbedded clay and limestone stratification may lead to slope failure. Slope failure, shallow bedrock depth, and nearness to streams are problems which make this soil area unfavorable for residential housing.

6. Slopes bordering deeply entrenched streams.

This unit consists of Hennepin soil. Because of steep slope, weathered soil materials have been washed away almost as fast as they have accumulated. Consequently, the soil has only a thin weathered zone. Hennepin soils' parent material is highly calcareous loam to clay loam glacial till. The soil can be easily recognized by its steep slope, which varies from 25 to 50 percent, and by its position adjacent to large streams. The steep slope associated with this soil is its main problem for residential housing.

7. Bottom lands.

Bottom lands occur in drainageways and on flood plains of streams. They are subject to intermittent flooding. The parent material is medium textured alluvium, chiefly from glacial drift of Wisconsin age. The alluvial soil series Eel, Genessee, Ross, and Shoals are grouped in this unit. Sloan, a Humic Gley soil which occurs in marshy and seepy areas of bottom lands may also be grouped in this unit. Sloan soil areas are likely to be flooded from November to June. Such floods leave deposits of fresh alluvium on the soils.

The alluvial soils of bottom lands have formed from material recently deposited, and so have little or no pedologic development. Frequent or infrequent flooding is a major problem of these bottom lands and, hence, they are unsuitable for residential housing.

8. Unclassified.

In the Soil Survey Report, areas such as borrow pits, lake-beach, made land and river wash are left as unclassified according to soil type. In lieu of information to the contrary, one is safe by assuming that these areas are unsuited for residential housing.

The rating of the suitability of each of the pedologic soil types in Fayette and Union Counties for residential housing is given in Table 11. This rating is based on the information available in the Soil Survey Report and on considerations discussed above. The survey report is prepared by Agricultural soil scientists and surveyors, but not by

TABLE 11

Engineering Suitability Ratings of Agricultural Soil Survey Mapping Units in Fayette and Union Counties, Indiana

Map Symbol	Soil Name	Suitability for Foundation	Suitability for Access Road	Suitability for Sewage Disposal
AvA	Avonburg silt loam -0 to 2 per cent slope	Good	Good	NS*
AvB_2	Avonburg silt loam -2 to 6 per cent slope -eroded	Good	Good	NS
BbA	Birkbeck silt loam -0 to 2 per cent slope	Good	Good	Good
BbB_1	Birkbeck silt loam -2 to 6 per cent slope -slightly eroded	Good	Good	Good
BbB_2	Birkbeck silt loam -2 to 6 per cent slope -moderately eroded	Good	Good	Good
Bp	Borrow pit	N.S.	N.S.	N.S.
Br	Brookston silt loam	Fair	Fair	N.S.
By	Brookston silty clay loam	Fair	Fair	N.S.
CcB_1	Cincinnati silt loam -2 to 6 per cent slope -slightly eroded	Fair	Fair	Good
CcB_2	Cincinnati silt loam -2 to 6 per cent slope -moderately eroded	Fair	Fair	Good
CcC_1	Cincinnati silt loam -6 to 12 per cent slope -slightly eroded	Fair	Fair	Good

*N.S. - Not suitable.

TABLE 11 (cont'd)

Map Symbol	Soil Name	Suitability for Foundation	Suitability for Access Road	Suitability for Sewage Disposal
CcC_2	Cincinnati silt loam -6 to 12 per cent slopes -moderately eroded	Fair	Fair	Good
CcD_1	Cincinnati silt loam -12 to 18 per cent slopes -slightly eroded	Fair	Fair	Good
CcD_2	Cincinnati silt loam -12 to 18 per cent slopes -moderately eroded	Fair	Fair	Good
CcE_1	Cincinnati silt loam -18 to 25 per cent slopes -slightly eroded	Poor	Poor	Poor
CcE_2	Cincinnati silt loam -18 to 25 per cent slopes -moderately eroded	Poor	Poor	Poor
CcF_2	Cincinnati silt loam -25 to 45 per cent slopes -eroded	NS	NS	NS
CnC_3	Cincinnati soils -6 to 12 per cent slopes -severely eroded	Fair	Fair	Good
CnD_3	Cincinnati soils -12 to 18 per cent slopes -severely eroded	Fair	Fair	Good
CnE_3	Cincinnati soils -18 to 25 per cent slopes -severely eroded	Poor	Poor	Poor
Co	Cope silt loam	Poor	Poor	NS
Cp	Cope silty clay loam	Fair	Fair	NS
CrA	Crosby silt loam -0 to 2 per cent slopes	Good	Good	NS

TABLE B1 (cont'd)

Map Symbol	Soil Name	Suitability for Foundation	Suitability for Access Road	Suitability for Sewage Disposal
CrB_1	Crosby silt loam -2 to 6 per cent slopes -slightly eroded	Good	Good	NS
CrB_2	Crosby silt loam -2 to 6 per cent slopes -moderately eroded	Good	Good	NS
De	Delmar silt loam	Fair	Fair	NS
Ee	Eel loam	NS	NS	NS
Es	Eel silt loam	NS	NS	NS
FaB	Fairmount silty clay loam -2 to 6 per cent slopes	Fair	Fair	Poor
FaC	Fairmount silty clay loam -6 to 12 per cent slopes	Poor	Poor	Poor
FaD	Fairmount silty clay loam -12 to 18 per cent slopes	Poor	Poor	Poor
FaE	Fairmount silty clay loam -18 to 25 per cent slopes	Poor	Poor	Poor
FaF	Fairmount silty clay loam -25 to 35 per cent slopes	NS	NS	NS
FaG	Fairmount silty clay loam -35 to 50 per cent slopes	NS	NS	NS
FcA	Fincastle silt loam -0 to 2 per cent slopes	Good	Good	NS
FcB_1	Fincastle silt loam -2 to 6 per cent slopes -slightly eroded	Good	Good	NS
FcB_2	Fincastle and Crosby silt loam -2 to 6 per cent slopes -eroded	Good	Good	NS

TABLE 11 (cont'd)

Map Symbol	Soil Name	Suitability for Foundation	Suitability for Access Road	Suitability for Sewage Disposal
FeA	Fincastle and Crosby silt loam -0 to 2 per cent slopes	Good	Good	NS
FeB	Fincastle and Crosby silt loam -2 to 6 per cent slopes	Good	Good	NS
FeB_2	Fincastle and Crosby silt loam -2 to 6 per cent slopes -eroded	Good	Good	NS
FmA	Fox loam -0 to 2 per cent slopes	Fair	Fair	Good
FmB_1	Fox loam -2 to 6 per cent slopes -slightly eroded	Fair	Fair	Good
FmB_2	Fox loam -2 to 6 per cent slopes -moderately eroded	Fair	Fair	Good
FmC_2	Fox loam -6 to 12 per cent slopes -moderately eroded	Poor	Poor	Good
FnA	Fox silt loam -0 to 2 per cent slopes	Fair	Fair	Good
FnB_1	Fox silt loam -2 to 6 per cent slopes -slightly eroded	Fair	Fair	Good
FnB_2	Fox silt loam -2 to 6 per cent slopes -moderately eroded	Fair	Fair	Fair
FnC_2	Fox silt loam -6 to 12 per cent slopes -moderately eroded	Poor	Poor	Fair
FnD_1	Fox silt loam -12 to 18 per cent slopes -slightly eroded	Poor	Poor	Fair

TABLE 11 (cont'd)

Map Symbol	Soil Name	Suitability for Foundation	Suitability for Access Road	Suitability for Sewage Disposal
FnD_2	Fox silt loam -12 to 18 per cent slopes -moderately eroded	Poor	Poor	Fair
FoB_2	Fox silt loam, kames -2 to 6 per cent slopes -moderately eroded	Fair	Fair	Good
FoC_2	Fox silt loam, kames -6 to 12 per cent slopes -moderately eroded	Fair	Fair	Fair
FpC_3	Fox soils -6 to 12 per cent slopes -severely eroded	Fair	Fair	Fair
FrC_3	Fox soils, kames -6 to 12 per cent slopes -severely eroded	Fair	Fair	Good
FsD_2	Fox and Rodman loams -12 to 18 per cent slopes -moderately eroded	Poor	Poor	Fair
FtD_2	Fox and Rodman loams, kames -12 to 18 per cent slopes -moderately eroded	Poor	Poor	Fair
FtE_2	Fox and Rodman loams, kames -18 to 25 per cent slopes -moderately eroded	Poor	Poor	Fair
FvD_3	Fox and Rodman soils -12 to 18 per cent slopes -severely eroded	Poor	Poor	Fair
FxD_3	Fox and Rodman soils, kames -12 to 18 per cent slopes -severely eroded	Poor	Poor	Fair
Ge	Genesee fine sandy loam	NS	NS	NS
Gg	Genesee gravelly loam	NS	NS	NS

TABLE 11 (cont'd)

Map Symbol	Soil Name	Suitability for Foundation	Suitability for Access Road	Suitability for Sewage Disposal
Gm	Genesee loam	NS	NS	NS
Go	Genesee loam, high bottom	NS	NS	NS
Gs	Genesee silt loam	NS	NS	NS
Gt	Genesee silt loam, high bottom	NS	NS	NS
Gv	Gravel pits	NS	NS	NS
HeF_1	Hennepin loam -25 to 35 per cent slopes -slightly eroded	NS	NS	NS
HeF_2	Hennepin loam -25 to 35 per cent slopes -moderately eroded	NS	NS	NS
HeG_1	Hennepin loam -35 to 50 per cent slopes -slightly eroded	NS	NS	NS
HeG_2	Hennepin loam -35 to 50 per cent slopes -moderately eroded	NS	NS	NS
Ho	Homer silt loam	NS	NS	NS
Ko	Kokomo silty clay loam	Poor	Poor	NS
La	Lake beach	NS	NS	NS
Ma	Made land	NS	NS	NS
MbA	Manlove silt loam -0 to 2 per cent slopes	Fair	Fair	Good
MbB1	Manlove silt loam -2 to 6 per cent slopes -slightly eroded	Fair	Fair	Good

TABLE 11 (cont'd)

Map Symbol	Soil Name	Suitability for Foundation	Suitability for Access Road	Suitability for Sewage Disposal
MbB_2	Manlove silt loam -2 to 6 per cent slopes -moderately eroded	Fair	Fair	Good
MoA	Martinsville silt loam -0 to 2 per cent slopes	Poor	Poor	Good
MoB_1	Martinsville silt loam -2 to 6 per cent slopes -slightly eroded	Poor	Poor	Fair
MoB_2	Martinsville silt loam -2 to 6 per cent slopes -moderately eroded	Poor	Poor	Fair
MoC_2	Martinsville silt loam -6 to 12 per cent slopes -moderately eroded	Poor	Poor	Fair
MoD_2	Martinsville silt loam -12 to 18 per cent slopes -moderately eroded	Poor	Poor	Fair
MmA	Miami silt loam -0 to 2 per cent slopes	Fair	Fair	Fair
MmB_1	Miami silt loam -2 to 6 per cent slopes -slightly eroded	Fair	Fair	Fair
MmB_2	Miami silt loam -2 to 6 per cent slopes -moderately eroded	Fair	Fair	Fair
MmC_1	Miami silt loam -6 to 12 per cent slopes -slightly eroded	Fair	Fair	Fair
MmC_2	Miami silt loam -6 to 12 per cent slopes -moderately eroded	Fair	Fair	Fair

TABLE 11 (cont'd)

Map Symbol	Soil Name	Suitability for Foundation	Suitability for Access Road	Suitability for Sewage Disposal
MmD_1	Miami silt loam -12 to 18 per cent slopes -slightly eroded	Poor	Poor	Fair
MmD_2	Miami silt loam -12 to 18 per cent slopes -moderately eroded	Poor	Poor	Fair
MmE_1	Miami silt loam -18 to 25 per cent slopes -slightly eroded	Poor	Poor	Poor
MmE_2	Miami silt loam -18 to 25 per cent slopes -moderately eroded	Poor	Poor	Poor
MsB_3	Miami soils -2 to 6 per cent slopes -severely eroded	Fair	Fair	Fair
MsC_3	Miami soils -6 to 12 per cent slopes -severely eroded	Fair	Fair	Fair
MsD_3	Miami soils -12 to 18 per cent slopes -severely eroded	Poor	Poor	Fair
MsE_3	Miami soils -18 to 25 per cent slopes -severely eroded	Poor	Poor	Poor
MtB_1	Milton silt loam -2 to 6 per cent slopes -slightly eroded	Poor	Poor	Poor
MtB_2	Milton silt loam -2 to 6 per cent slopes -moderately eroded	Poor	Poor	Poor
Nn	Nineveh loam	NS	NS	NS

TABLE 11 (cont'd)

Map Symbol	Soil Name	Suitability for Foundation	Suitability for Access Road	Suitability for Sewage Disposal
OcA	Ockley silt loam -0 to 2 per cent slopes	Fair	Fair	Good
OcB_1	Ockley silt loam -2 to 6 per cent slopes -slightly eroded	Fair	Fair	Good
OcB_2	Ockley silt loam -2 to 6 per cent slopes -moderately eroded	Fair	Fair	Good
OcC_2	Ockley silt loam -6 to 12 per cent slopes -moderately eroded	Fair	Fair	Good
OkB_3	Ockley soils -2 to 6 per cent slopes -severely eroded	Fair	Fair	Good
OkC_3	Ockley soils -6 to 12 per cent slopes -severely eroded	Fair	Fair	Good
ReA	Reesville silt loam -0 to 2 per cent slopes	Good	Good	NS
ReA_2	Reesville silt loam -0 to 2 per cent slopes -moderately eroded	Good	Good	NS
ReB_2	Reesville silt loam -2 to 6 per cent slopes -moderately eroded	Good	Good	Poor
RgD_2	Rodman gravelly loam -12 to 18 per cent slopes -moderately eroded	Poor	Poor	Poor
RgE_1	Rodman gravelly loam -18 to 25 per cent slopes -slightly eroded	Poor	Poor	Poor

TABLE 11 (cont'd)

Map Symbol	Soil Name	Suitability for Foundation	Suitability for Access Road	Suitability for Sewage Disposal
RgE2	Rodman gravelly loam -18 to 25 per cent slopes -moderately eroded	Poor	Poor	Poor
RgF2	Rodman gravelly loam -25 to 50 per cent slopes -eroded	NS	NS	NS
Ro	Ross silt loam	NS	NS	NS
RsA	Russel silt loam -0 to 2 per cent slopes	Good	Good	Good
RsB1 & B2	Russel silt loam -2 to 6 per cent slopes -slightly eroded	Good	Good	Good
RsC1	Russel silt loam -6 to 12 per cent slopes -slightly eroded	Good	Good	Good
RsC2	Russel silt loam -6 to 12 per cent slopes -moderately eroded	Good	Good	Good
RsD1	Russel silt loam -12 to 18 per cent slopes -slightly eroded	Fair	Fair	Good
RsD2	Russel silt loam -12 to 18 per cent slopes -moderately eroded	Fair	Fair	Fair
RsE1	Russel silt loam -18 to 25 per cent slopes -slightly eroded	Poor	Poor	Poor
RsE2	Russel silt loam -18 to 25 per cent slopes -moderately eroded	Poor	Poor	Poor

TABLE 11 (cont'd)

Map Symbol	Soil Name	Suitability for Foundation	Suitability for Access Road	Suitability for Sewage Disposal
RtB3	Russel soils -2 to 6 per cent slopes -severely eroded	Good	Good	Good
RtC3	Russel soils -6 to 12 per cent slopes -severely eroded	Good	Good	Good
RtD3	Russel soils -12 to 18 per cent slopes -severely eroded	Fair	Fair	Fair
RtE3	Russel soils -18 to 25 per cent slopes -severely eroded	Poor	Poor	Poor
RuA	Russel and Miami silt loams -0 to 2 per cent slopes	Good	Good	Good
RuB1	Russel and Miami silt loams -2 to 6 per cent slopes -slightly eroded	Good	Good	Good
RuB2	Russel and Miami silt loams -2 to 6 per cent slopes -moderately eroded	Good	Good	Good
RuC1	Russel and Miami silt loams -6 to 12 percent slopes -slightly eroded	Good	Good	Good
RuC2	Russel and Miami silt loams -6 to 12 per cent slopes -moderately eroded	Good	Good	Good
RvB3	Russel and Miami soils -2 to 6 per cent slopes -severely eroded	Good	Good	Good
RvC3	Russel and Miami soils -6 to 12 per cent slopes -severely eroded	Good	Good	Good

TABLE 11 (cont'd)

Map Symbol	Soil Name	Suitability for Foundation	Suitability for Access Road	Suitability for Sewage Disposal
Rw	Riverwash	NS	NS	NS
Sh	Shoals silt loam	NS	NS	NS
Sn	Sloan silt loam	NS	NS	NS
We	Westland silt loam	Poor	Poor	NS
WhA	Whitaker silt loam -0 to 2 per cent slopes	NS	NS	NS
WhB	Whitaker silt loam -2 to 6 per cent slopes	NS	NS	NS
WnB1	Wynn silt loam -2 to 6 per cent slopes -slightly eroded	Fair	Fair	Fair
WnB2	Wynn silt loam -2 to 6 per cent slopes -moderately eroded	Fair	Fair	Fair
WnC2	Wynn silt loam -6 to 12 per cent slopes -moderately eroded	Fair	Fair	Fair
WnD2	Wynn silt loam -12 to 25 per cent slopes -moderately eroded	Poor	Poor	Poor
WyC3	Wynn soils -6 to 12 per cent slopes -severely eroded	Fair	Fair	Fair
XeA	Xenia silt loam -0 to 2 per cent slopes	Good	Good	Good
XeB1	Xenia silt loam -2 to 6 per cent slopes -slightly eroded	Good	Good	Good

TABLE 11 (cont'd)

Map Symbol	Soil Name	Suitability for Foundation	Suitability for Access Road	Suitability for Sewage Disposal
XeB2	Xenia silt loam -2 to 6 percent slopes -moderately eroded	Good	Good	Good
XnA	Xenia and Celina silt loams -0 to 2 percent slopes	Good	Good	Good
XnB1	Xenia and Celina silt loams -2 to 6 percent slopes -slightly eroded	Good	Good	Good
XnB2	Xenia and Celina silt loams -2 to 6 percent slopes -moderately eroded	Good	Good	Good

civil engineers. The information in the Soil Survey Report is collected with the main purpose of helping and guiding agriculturists. The characteristics of the soils, given to aid farmers, are here interpreted in terms of engineering properties and a rating of the soils is thus prepared. Errors might have resulted by misinterpretation. Also, the information on the soils available in the Soil Survey Report refers to soil material to a depth of about 5 to 6 feet. When a residential foundation is deeper than this, the characteristics of the soils encountered may not necessarily be the same as that of the overlying soil, and the rating given herein may not hold entirely true. Further, the information available from the Soil Survey Report and the soil maps may not be accurate in every detail. Even though careful work is performed by those who conduct the soil surveys in the field, and every attempt is made to make the maps as accurate as possible, some error must be expected. The ratings in this study may best be used primarily in planning more detailed investigations to determine the nature and characteristics of soils at the proposed residential housing project area. However, as reconnaissance information it allows the direct use by engineers of the published soil survey maps or the preparation of engineering soil maps employing the boundary demarcations shown in the agricultural soil survey.

IX. CONCLUSIONS

Soil investigation for light commercial and residential structures has often been neglected, resulting in great loss and inconvenience to the residents. There is a need, therefore, to obtain and make available preliminary subsurface investigation data to avoid adverse situations such as flooding, failure of foundations, and failure of septic tank disposal fields. The purpose of this study is to investigate the feasibility of obtaining preliminary soils data and to prepare a rating of suitability of soils for residential housing. The Soil Survey Report of Fayette and Union Counties, prepared by the United States Department of Agriculture Soil Conservation Service, is mainly used for this purpose. The common pedologic description of each soil is interpreted and discussed in terms of engineering characteristics.

The greater portion of Fayette and Union Counties is covered with glacial deposits of three ages, Kansan, Illinoian and Wisconsin. Loess, mostly modified by weathering, caps these deposits with a thickness of one to five feet or more in more than half the area. Soil is also derived from glacial outwash. Bedrock of the Ordovician system underlies the soil mantle throughout the counties, except in a small portion west of Fayette County. The pedologic classification suggests that most of the soils in Fayette and Union Counties fall into the great soil group "Gray Brown Podzolic Soils".

Field and laboratory investigations and the study of the Soil Survey Report reveal that most of the soils in Fayette and Union Counties are fine-grained and contain a high percentage of silt, which makes them frost susceptible. None of the soils are of a high-swelling type. Nearly 70 percent of Fayette and Union Counties may be rated as suitable for residential housing from the standpoint of favorable foundation conditions.

Reasonably accurate engineering soil maps for guidance in the determination of the suitability of a site for residential housing can be prepared directly from Survey Reports and maps prepared by agricultural soil scientists. The maps may be best used in planning more detailed investigation to determine the nature and characteristics of soils at the proposed residential housing project area.

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ENGINEERING CHARACTERISTICS OF SOILS OF FAYETTE AND UNION COUNTIES, INDIANA, PERTINENT TO RESIDENTIAL HOUSING

Abstract

There is a need to obtain and make available preliminary subsurface investigation data applicable for light commercial and residential structures. Foremost among problems that this would alleviate are flooding, foundation failures due to adverse soil conditions, and improper location of absorption field disposal systems. This study investigates the feasibility of obtaining such preliminary soils data from available reports and maps and rates the suitability of soils in Fayette and Union counties, Indiana, for residential housing on the basis of published soil survey reports and maps and field laboratory study.

The greater portion of Fayette and Union counties is covered with glacial deposits, thinly capped with loess, mostly modified by weathering. Bedrock of the Ordovician system underlies soil mantle throughout the two counties, except in a small area west of Fayette County. Most of the soils fall into the great soil group "Gray Brown Podzolic soils". With a few exceptions, all the soils are fine-grained and contain a high percentage of silt. None of the soils are of a high-swelling type.

The soils are grouped by terrain reconnaissance procedures and topography, and these groups or units are discussed in detail with reference to the problems of residential housing. This study reveals,

neglecting frost action, that nearly 70 percent of Fayette and Union counties is suitable for residential housing. The ratings given may best be used primarily in planning more detailed investigations of soil nature and characteristics at the proposed housing project area.