REGIONAL APPROACH TO HIGHWAY SOILS CONSIDERATIONS IN INDIANA

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It is hypothesized that a regional or physiographic subdivision approach can be effectively used in preliminary studies and investigations generally to predict the environment and to formulate the major soils problems to be considered in the design of a highway facility. Both generalized and specific quantifications of significant factors influencing a regional approach to highway soils considerations have been proposed. Available data from physiography, geology, pedology, remote sensing, and engineering soils mapping were used in the general approach. Data were compiled from completed Indiana State Highway Commission projects and roadway soil surveys performed by consultants, and statistical methods were applied to some of these data in the specific approach. If the findings and conclusions of this study are to be of practical consequence, they must be interpreted in terms of the present standards, policies, and procedures concerning roadway soil surveys used by the Indiana State Highway Commission. The physiographic subdivision approach is capable of contributing significantly and economically in the preliminary stages of planning, route location, and design of highway facilities in Indiana. Within the soil parent material areas in Indiana, the classes and severity ratings of highway soils problems can probably be generalized with confidence. This was accomplished for the Calumet Lacustrine Plain, a subsection of the Northern Lake and Moraine Region. The same procedure can be applied to the other physiographic units to provide similar information of practical value to the Indiana State Highway Commission.

• AMONG the factors to be considered in the planning, location, design, and construction of highway facilities are the soil and rock conditions within the corridor of the proposed route. These conditions are inherently complex and will need to be studied in detail before certain design and construction decisions are reached. However, there is considerable logic in deriving a generalized description of them prior to assessing details. This can be accomplished by examination of the factors of origin, parent material, topographic expression, and climatic environment. If the engineer has experience on projects where these general factors were similar, even though geographically removed from the route under study, he has a valid basis for the transfer of that experience. In other words, he can anticipate the likely challenges of the new project. A recognition of these interrelations and a concise recording of them will allow even an inexperienced engineer to exercise valuable insight. All of this occurs at the preliminary stage of investigation and is intended to enhance the interpretation of detailed physical studies, as opposed to replacing the studies.

As suggested above, the descriptors that appear most significant in a generalized assessment of route conditions are the geologic origin and complexity of the parent materials, the topographic expression, and the general texture of the soil, particularly clay content. The topographic expression is conveniently characterized by the branch

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of geology known as physiography or regional geomorphology, which defines units of unique landform combinations based on factors of structure, process, and stage. Therein lies the basis for the regional or physiographic subdivision approach. The physiographic units of Indiana adopted for this study are based on those defined by Malott (13), as shown in Figure 1. A further subdivision to the landform or an engineering soil parent material area level is needed to characterize the geologic origin and complexity of the soil parent materials and to afford a measure of the soil distribution throughout the physiographic region. Soil and landform maps (1, 25) were used for this purpose. The general texture of the soils is described by various soil index properties, which must be determined by physical tests.

PURPOSE

The objective of this paper is to show that a regional or physiographic subdivision approach may be effectively used in preliminary studies and investigations to predict the general soil and rock environment and to provide significant insight into the kinds of problems to be anticipated in the design and construction of a highway facility. A future goal is to indicate how the approach can be integrated into the present Indiana State Highway Commission's standards, policies, and procedures for performance of roadway soil surveys. In addition to the generalizations possible at the physiographic unit level, variability of soil characteristics was assessed for significant landforms within one unit. The purpose was to ascertain the variability of soil conditions within a landform and to frame correlative equations for selected soil characteristics for the landform unit.

That class of soils considerations peculiarly related to pavement design and construction has been omitted from this study because of its specialized nature and the complex and highly relevant soil-structure interaction effects.

GENERAL BACKGROUND

Physiography

As stated by Witczak (26):

> In the simple view, physiography permits subdivision into areas of contrasting or distinctive topographic expression. Such division is effected by an examination of three geomorphic control factors, viz., structure, process, and stage [22].
>
> Structure is a comprehensive term defined [by Thornbury, 22] as ". . . all those ways in which earth materials out of which landforms are carved differ from one another in their physical and chemical attributes." In a sense, structure expresses the type and arrangement of parent materials.
>
> Process describes the factors of origination and modification primarily responsible for the landscape. Processes may act constructively or destructively and may originate above the earth surface (e.g., wind, water, ice) or below it (viz., diatrophism or vulcanism). Thus process may be interpreted as origin.
>
> The operation of process upon structure in the development of the landscape involves various evolutionary phases or stages. Thus, this term conveys the notion of time of aging under ambient climate conditions, or the factor of age.
>
> In summation, the topographic expression is a function of the geologic parent material, the geomorphic processes acting, and the time and climate of action. These factors are highly relevant to landscape classification for engineering purposes, although they are probably not sufficiently quantified.

A physiographic unit is characterized by a mode of topographic expression that is different from those of adjacent units. However, certain variations from the modal pattern occur, and these variants are included as a matter of necessity. It is, therefore, logical that the physiographic subdivision becomes more "homogeneous" as the division becomes more limited in size. Malott (13) recognized this about 50 years ago when he outlined the basic physiographic subdivisions of Indiana and described them in considerable detail.

The state of Indiana lies physiographically within the Central Plains Province of North America as determined by Atwood (3). In the classical scheme of Fenneman (8), the maximum extent of glaciation is the boundary between the Till Plains Section of the Central Lowland Province and the Highland Rim and Bluegrass Section of the Interior Low Plateau Province to the south. Approximately the northern fourth of the state lies within the Eastern Lake Section of the Central Lowland Province.

Wayne (22) states that Indiana can generally be divided into 3 broad physiographic divisions trending in an east-west direction across the state. The central division, comprising about one-third of the state area, is a depositional plain of low relief, underlaid largely by thick glacial till and modified only slightly by postglacial stream erosion. It is called either the Central Drift Plain or the Tipton Till Plain.

The northern division is called the Northern Lake and Moraine Region and comprises slightly less than one-fourth of the state area. It is divided into 5 subdivisions, as shown in Figure 1. The northern division is characterized by greater relief than the central division, being very hilly in some areas; but even in those areas, the uplands are interrupted by lowlands and plains of little relief. Landforms in this division are mostly of glacial origin. A large variety of depositional forms are present, including end moraines, outwash plains, kames, lake plains, valley trains, and kettles; also present are many related postglacial features such as lakes, sand dunes, and peat bogs.

The roughest topography in Indiana is formed in the southern division, which is divided into 7 subdivisions (Fig. 1). Landforms in this division are primarily the result of normal degradational processes, such as weathering, stream erosion, and mass movement. The middle part of the southern division was not glaciated, and the topography strongly reflects the nature of the parent bedrocks. The units on either side were glaciated, but the influences of glaciation were minor, and the physiography is largely bedrock controlled. An exception in part is the Wabash Lowland where many lacustrine areas, valley trains, and outwash plains have developed as a result of glacial activity.

Geology

Most of the surface of Indiana has been glaciated to varying degrees by the various continental glacial advances. The south central portion of the state was not affected by the sculpturing effects of the ice sheet; thus, the topography, drainage, and soils have been formed through the weathering of the Paleozoic sediments. Wayne (25) shows the various glacial formations and landforms throughout the state. The lacustrine deposits resulting from Illinoian and Wisconsin glacial stages are mapped in some detail by Thornbury (29). A map of the thickness of drift north of the Wisconsin glacial boundary has been prepared by Wayne (24).

An excellent and thorough account of the bedrock geology and stratigraphy is presented by Cummings (7). The various bedrock formations along with their areal extent and several typical bedrock cross sections are shown by Parvis (16). Bedrock physiographic units as shown by Wayne (24) were originally developed by Malott (13). The bedrock physiographic units in southern Indiana generally have north-south boundaries that conform to the physiographic subdivisions previously discussed. It can be clearly seen, by comparison, that the east-west boundaries for the bedrock units extend much farther north, reflecting the subsurface geology. It can also be seen that the northern bedrock physiographic units have lateral limits very much modified from the previously discussed physiographic units. The dominant lithologies of the various bedrock physiographic units are given by Wayne (24). The formations and geologic age of these consolidated deposits are detailed by Cummings (7) and by McGregor (14).

Pedology

The pedologic approach to classification and distribution of Indiana soils (4, 6, 10, 19, 23, 27) and maps of the pedologic soil associations and soil series descriptions (1) are given in various reports. The Soil Conservation Service (SCS) has prepared the following 4 tabulations of soil indexes and interpretative ratings of those soils for various related fields of interest and practical applications: brief description of soils of

Indiana and their estimated physical and chemical properties, interpretation of the soils in Indiana for rural and urban development, interpretations of engineering properties of major soils in Indiana, nonagricultural (urban), interpretation of engineering properties of major soils in Indiana for agriculture. In addition, modern SCS county soil surveys contain simple engineering soil data.

Remote Sensing

Aerial photographic interpretation has been the dominant tool in the preparation of county engineering soils maps. These maps are available for many counties in Indiana, and have been summarized by McKittrick (15). Several other reports were very useful in this research (4, 9, 15, 17). Other excellent reports have been prepared as a part of the Joint Highway Research Project for air-photo interpretation of some major parent material regions in Indiana. These have also been summarized by McKittrick (15).

Engineering Soils

The mapping of soils and rocks depends most strongly in its form on the scale and the perspective and objective of the mapper. All maps are generalizations, and the smaller the scale is the greater is the degree of generalization. All mapping needs to be based on descriptors that are relatively simple and easy to determine. The descriptions chosen by the engineer are those that are both convenient and highly useful for framing the general nature of design and construction problems. Such maps provide valuable insight for preliminary studies such as locating a route and setting up a boring program for any given project. On occasion they may substitute for field studies, e.g., where the latter do not appear economically justifiable.

An outstanding effort to map and describe the soils of Indiana, drawing heavily on available pedologic data, was made by Belcher, Gregg, and Woods (4). This work led to a map of the engineering soil parent materials of Indiana (5).

As previously mentioned, certain county engineering soils maps have been prepared through interpretation of black and white aerial photography, usually supplemented by limited boring, sampling, and testing. As might be expected, the county maps give more detail because of the larger scale.

GENERALIZED QUANTIFICATION OF SIGNIFICANT FACTORS INFLUENCING REGIONAL APPROACH

Several original procedures were used generally to quantify the distribution of soil parent material areas or landforms within each physiographic region. Other related factors were also investigated.

A first and obvious step in generalized quantification was to compare the state physiographic regions with other state maps depicting topography, geology, pedologic units, engineering soil parent material areas, and thickness of drift. All of these maps were readily available. The comparisons are described in some detail below.

Topography

The topographic map by Logan (12) has a 100-ft contour interval and a scale of approximately 1:500,000 or about $1\frac{1}{4}$ in. to 10 miles. It is the largest scale state topographic map known to the authors. Because topography is considered to be a major factor, it was analyzed for each physiographic subdivision in a number of ways; e.g., the frequency distribution of elevation was defined. Areas within defined elevation intervals were planimetered, and curves of terrain elevation interval versus percentage of physiographic region were prepared. The curve obtained for the Calumet Lacustrine Plain is shown in Figure 2. Curves obtained for this phase of the study were typically of 3 types.

1. A high peak or mean value for percentage of physiographic region and a narrow range for terrain elevation interval characterize this group. Slight local relief and minor topographic expression are generally implied, i.e., almost level to gently undulating terrain.

2. Such curves have a moderate to high peak or mean value for percentage of physiographic region and a moderate to wide range for terrain elevation interval. Moderate variations in local relief and moderate topographic expression, viz., gently undulating to rolling terrain, are indicated.

3. A small to moderate peak or mean value for percentage of physiographic region and a wide range for terrain elevation interval characterize these curves. Large variations in local relief and major topographic expression are implied, i.e., rolling to rough terrain.

Thickness of Drift North of Wisconsin Glacial Boundary

The thickness of drift map was prepared by Wayne (24). The scale of this map is 1:500,000, or approximately 1¼ in. to 10 miles, and a contour interval of 50 ft is used. The thickness of unconsolidated deposits in Indiana south of the Wisconsin glacial boundary has not been mapped to the present time. Because depth to bedrock or thickness of drift is an important factor for many engineering projects, a frequency distribution of depth was developed for each physiographic region. Areas between defined depth intervals were planimetered and distribution curves drawn. These curves show the drift depth interval versus percentage of physiographic region. The curve obtained for the Calumet Lacustrine Plain is shown in Figure 3. Curves obtained for this phase of the study were typically of 2 types.

1. These curves showed an approximate normal distribution, with low percentages for extreme values and a peak at about the distribution mean. Such curves generally indicate the bedrock is well covered and will be encountered infrequently in an average project.

2. These distributions are skewed to the left; i.e., the curve peaks near the left extreme instead of near the mean value. Because the left extreme is the drift depth interval of 0 to 50 ft, bedrock may be encountered more than occasionally on an average project. The probability of encountering bedrock on a project is dependent on the actual percentage for the 0- to 50-ft interval and to a lesser extent on the percentage for the 50- to 100-ft interval.

Engineering Soil Parent Material Areas

A map of the engineering soil parent material areas was issued in 1943 (5) and revised in 1950. The scale is approximately ¾ in. equals 10 miles. The physiographic subdivisions were outlined on this map, and the area of each engineering soil parent material occurring within a physiographic region was planimetered. This information has been plotted and is shown in Figure 4 for the Calumet Lacustrine Plain.

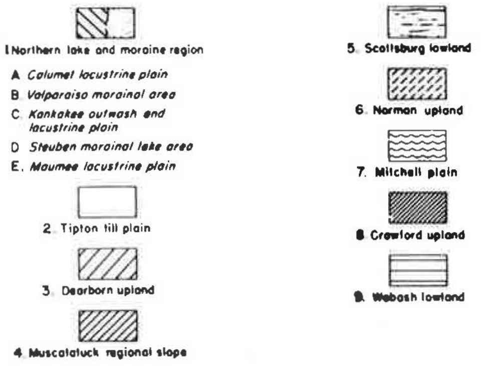
Glacial Geology

The map of the glacial geology of Indiana was prepared by Wayne (25) in 1958. The scale is 1:1,000,000 or approximately ⅝ in. equals 10 miles. It shows the predominant soil areas of glacial origin for the glaciated part of the state. Again frequency distribution bar graphs were plotted, and the information for the Calumet Lacustrine Plain is shown in Figure 5.

Pedology

A map of Indiana soils (1) shows soil regions (parent material areas) and associations of soil series within the regions. In many areas of the state, the boundaries for the soil regions correspond to the boundaries given by Belcher, Gregg, and Woods (4), who emphasize the probable utility of such mapping for engineering purposes. The four tables prepared by the Soil Conservation Service are helpful in interpreting the pedologic mapping for engineering applications. The physiographic subdivisions were transferred to the state pedologic map, and the area of each series association within a physiographic region was planimetered. This information is shown in Figure 6 for the Calumet Lacustrine Plain.

Figure 1. Physiographic regions based on topography.



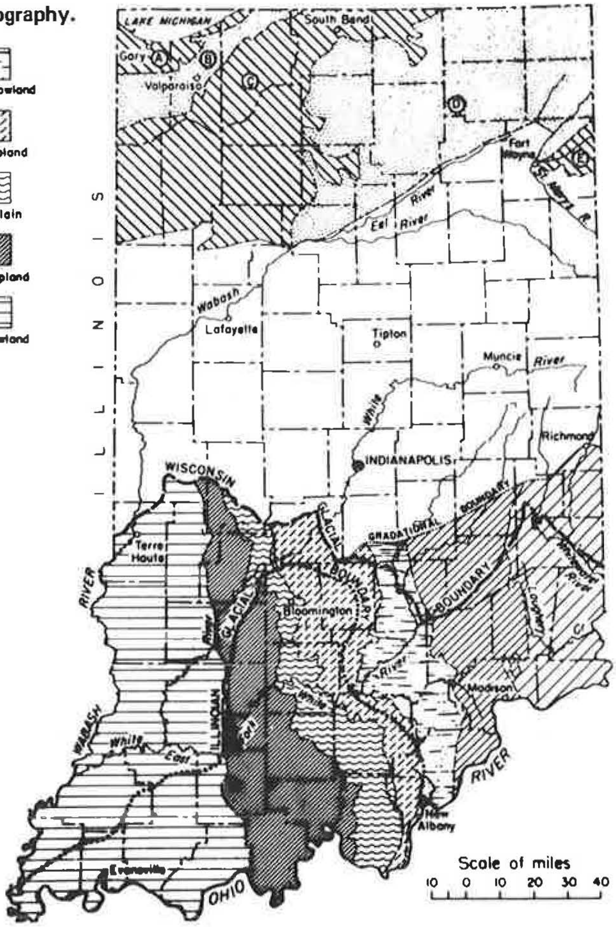


Figure 2. Terrain elevation interval for Calumet Lacustrine Plain.

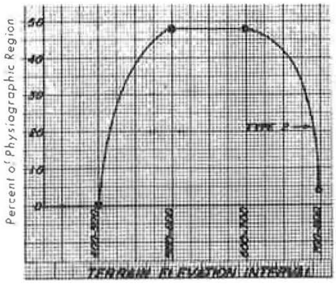


Figure 3. Drift depth interval for Calumet Lacustrine Plain.

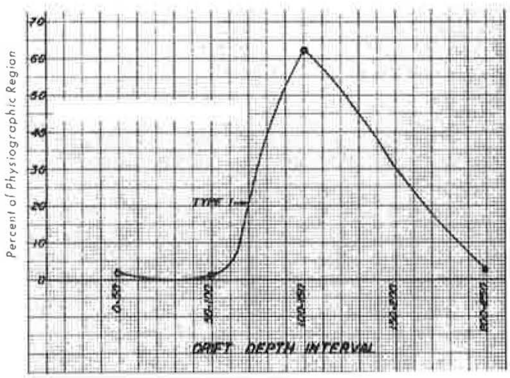


Figure 4. Engineering soil parent material in Calumet Lacustrine Plain.

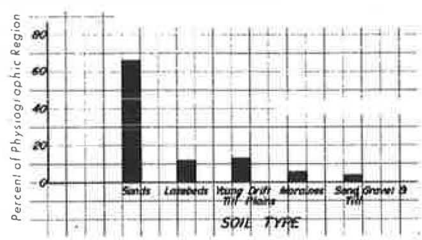


Figure 5. Glacial soils in Calumet Lacustrine Plain.

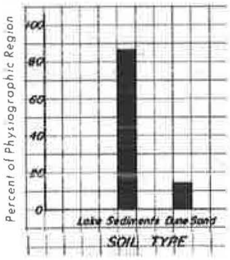
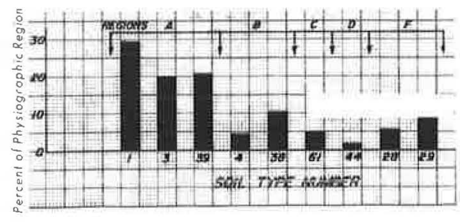


Figure 6. Soil regions and series association numbers for Calumet Lacustrine Plain.



Earthwork Quantities by Physiographic Regions

A further generalized quantification involved tabulating the earthwork quantities for Indiana highway projects within each physiographic region for Interstate, primary, and secondary roads. Only those relatively recent projects for which data were readily available were used. A portion of the plotted data for the Interstate projects is shown in Figure 7. These data serve as indicators of topographic variation or roughness of terrain. However, they are also a function of the standard requirements for alignment, grade, and geometry of roadway cross section for the various classes of projects. An earthwork factor was defined as E, percent = [special borrow per mile/(special borrow per mile + excavation per mile)] × 100. The earthwork factor for the Calumet Lacustrine Plain was 96 percent for Interstate highways.

Aggregate Availability and Use Data

Rock quarry and sand and gravel pit data were also prepared for each physiographic region. The data may be used as indicators of (a) the occurrence of valley train and outwash plain sediments and (b) the occurrence of carbonate bedrock at relatively shallow depths.

Slope Instability

A survey of highway slope failures was conducted and analyzed with respect to the physiographic subdivisions (Table 1). The "normalization" of failures (square miles per failure) with respect to subdivision area is a convenient but approximate technique. The data given in Table 1 do indicate, however, that the parent materials and other environmental factors are more conducive to slope instability in some subdivisions than in others.

Other Aspects

At this point, let us consider the relative uniformity that is exhibited by the various physiographic subdivisions with respect to factors considered for generalization.

The relative percentages of significant soil parent material areas in the physiographic regions can be viewed as a first measure of uniformity. The logic of this premise can be illustrated by the following example. Consider the circumstance of a small number of significant soil parent material areas or landforms in a physiographic region (Figs. 4 and 5). "Significant" areas are those comprising more than 5 percent of the total physiographic region. Where the relative percentages are high, only a few soil parent material areas are present, and those are presumably repeating in a common or dominant pattern. This situation is viewed as a relatively uniform one. Such a first approximation of uniformity is shown by data given in Table 1, where 4 general ratings have been established.

A second degree of measure of uniformity within a physiographic region involves the soil series associations encountered within the soil parent material areas or landforms. Consider the data shown in Figure 6. A small number of significant associations within a soil parent material area are interpreted to mean a high degree of uniformity.

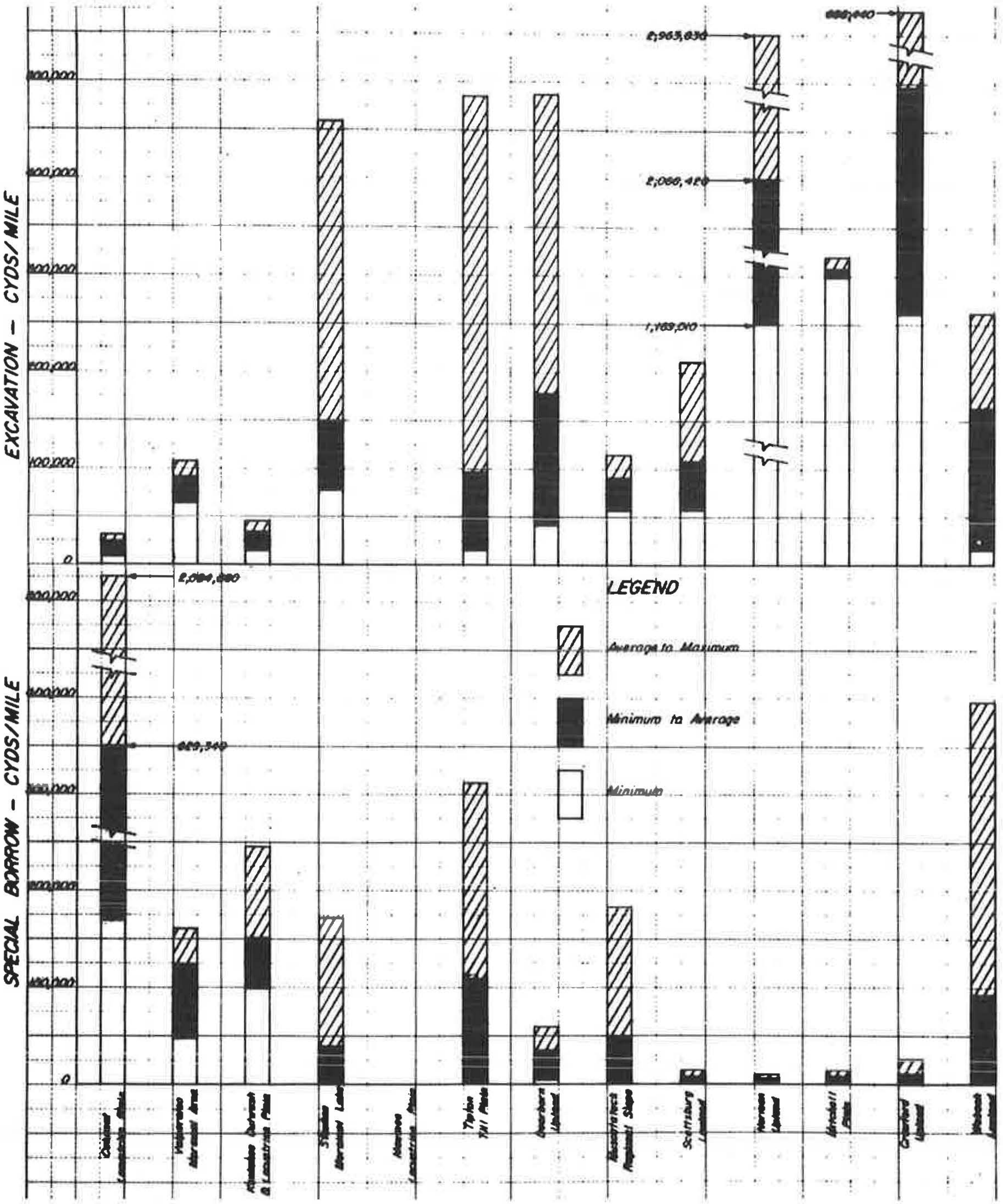
SPECIFIC QUANTIFICATION OF SIGNIFICANT FACTORS INFLUENCING REGIONAL APPROACH

As stated previously, the significant factors influencing a regional approach to highway soils considerations are the geologic origin and complexity of parent materials (or landforms), the topography, and the texture of the parent materials (particularly the percentage of the clay fraction). This section presents an approach for handling these factors in some detail.

Distribution of Interstate Mileage Within Physiographic Regions, Landforms, and Soil Types

The Interstate highway mileage within each landform or numbered soil area was determined as a percentage of the total Interstate mileage within the physiographic region.

Figure 7. Earthwork quantities by physiographic regions for Interstate projects.



These data tend to answer the question, What landforms, soil types, or soil type numbers do existing or designed highways traverse? With this information, one can speculate as to the nature of the soils considerations and whether their magnitudes could be lessened by relocating routes to more desirable landforms. Economics is the criterion, and both initial cost and maintenance costs should be included. The information is included in detail in the original study (18).

Roadway Soil Survey Data for Cuts by Physiographic Region

One can make some very effective inferences about the nature of the terrain, the adequacy of standard design backslopes, and the amount of rock excavation required on a given project if one has a summary of the cut information for other projects in the same region. Therefore, a detailed study was made of the proposed cuts in the roadway soil surveys. Numerous cut statistics have been developed and included in the original study (18). The inferences that can be made are that (a) fewer cuts and shallower depth of cuts indicate more level terrain; (b) shallower average depth of cuts implies more stable backslopes; and (c) frequency of rock cuts is uniquely related to the physiographic region. The bedrock information is especially useful south of the Wisconsin glacial boundary, where thickness-of-drift maps are not applicable.

Specific Terrain Quantification Factors for Physiographic Regions

Several terrain descriptors were determined for the terrain elevation interval curves: coefficient of variation, V, in percent, and topographic coefficient, T, in percent, defined for the purpose of this study. These values were calculated for the curves obtained for each physiographic region and are given in Table 1. The significance and usefulness of these results are given in Table 2. The limits set for these values can be used to predict the general soil origin.

Typical Profiles and Physical Properties of Soils for Significant Landforms Within Physiographic Regions

Some degree of uniformity or frequency of occurrence for the soil types encountered within each significant landform within a physiographic region was demonstrated by typical profiles that were developed for the Calumet Lacustrine Plain. The data for the physical properties of the soils composing each significant landform were subjected to statistical methods and procedures in an attempt to characterize each significant layer or stratum within each typical profile. In addition to a typical profile, some pertinent relations and regression equations have been developed.

Typical Profiles—Typical profiles were prepared for each of the 3 significant landforms or soil parent material areas, as defined by the map of engineering soil parent material areas in Indiana, in the Calumet Lacustrine Plain. "Significant" has been defined as more than 5 percent of the physiographic region area. Thus, typical profiles were prepared for the dune sand, lake-bed, and ground moraine (Wisconsin) areas, which constitute about 66, 12, and 13 percent respectively of the approximate 279 square miles.

One needs to make use of all conveniently available sources to avoid erroneous conclusions. For example, consider the large area shown as dune sand on the map of engineering soil parent material areas in Indiana (5). If we consider this information, along with that on the map of Indiana soils (1), the impression is gained that sand is the engineering material. (Pockets, layers, and lenses of peat, marl, and other organic soils are expected in the depressions between the sand dunes.) However, the entire soil parent material area shown as dune sand is underlaid by a deep deposit of lacustrine sediments from glacial Lake Chicago, consisting of compressible fine-grained soils. This fact would be evident from the map of glacial geology of Indiana (25). The consolidation of these underlying deposits due to superimposed loading might well control the design of many facilities.

An important part of the typical profile is the statistical soil classification, which is based on average values for the pertinent physical characteristics used in the textural

Table 1. Measures of regional uniformity for physiographic regions.

Physiographic Region	Slope Failure Number	Slope Failure Square Mile per Failure	Rating[a]	Coefficient of Variation (percent)	Topographic Coefficient (percent)
Northern Lake and Moraine Region					
Calumet Lacustrine Plain	0	–	II	22.5	9.6
Valparaiso Morainal Area	1	619	I to II	17.4	7.8
Kankakee Outwash and Lacustrine Plain	0	–	IV	23.6	10.6
Steuben Morainal Lake Area	2	1,842	III	23.8	8.3
Maumee Lacustrine Plain	0	–	I	0	100.0
Tipton Till Plain	1	13,435	II to III	22.8	3.7
Dearborn Upland	16	114	III to IV	29.8	2.4
Muscatatuck Regional Slope	0	–	III	25.8	3.1
Scottsburg Lowland	4	373	IV	25.3	5.0
Norman Upland	2	617	III to IV	26.5	2.9
Mitchell Plain	2	647	III	19.3	5.2
Crawford Upland	10	243	II to III	27.2	3.1
Wabash Lowland	3	1,646	IV	26.0	7.2
Total	41				

[a]For first degree of uniformity for soil parent material areas within each physiographic region: I = very uniform, 1 to 2 significant landforms; II = uniform, 2 to 3 significant landforms; III = slightly uniform, 3 to 4 significant landforms; and IV = complex, 5 or more significant landforms.

Table 2. Terrain quantification factors for physiographic regions.

Coefficient V[a]	Coefficient T[b]	Topography	Physiographic Regions V	Physiographic Regions T	Origin
<5	>25	Level to gently undulating	1E	1E	Lacustrine
≥5 ≤25	≤25 ≥ 5	Gently undulating to undulating	1A, 1B, 1C, 1D, 2, 7	1A, 1B, 1C, 1D, 5, 7, 9	Glacial
>25	<5	Undulating to rolling	3, 4, 5, 6, 8, 9	2, 3, 4, 6, 8	Residual

[a]Coefficient of variation, $V = S(100)/\bar{x}$ where S = standard deviation and $\bar{x}$ = mean value, from terrain elevation interval curves.
[b]Topographic coefficient, T = maximum ordinate/number of contour interval from terrain elevation interval curves.

Table 3. Statistical soil classification of dune sand landform of Calumet Lacustrine Plain.

Item	Passing Sieve (percent) No. 40	Passing Sieve (percent) No. 200	Sand (percent)	Silt (percent)	Clay (percent)	Liquid Limit	Plasticity Index	Classification Textural	Classification AASHO
Dune Sand, Stratum A									
Average value									
Method 1	85.7	5.9	94.1	4.0	1.9	N. P.	N. P.	Sand	A-3(0)
Method 2	91.1	3.5	96.5	2.4	1.1	N. P.	N. P.	Sand	A-3(0)
Method 3	91.5	3.2	96.8	2.4	0.8	N. P.	N. P.	Sand	A-3(0)
Standard deviation									
Method 1	19.3	6.3	6.3	4.5	3.4	N. P.	N. P.		
Method 2	14.7	5.0	5.0	3.4	2.6	N. P.	N. P.		
Method 3	14.1	4.6	4.6	3.3	2.2	N. P.	N. P.		
Maximum value	100	20	100	19	13	N. P.	N. P.		
Minimum value	1	0	80	0	0	N. P.	N. P.		
Range	99	20	20	19	13	N. P.	N. P.		
Lakebed, Stratum B									
Average value									
Method 1		87.6	12.4	58.6	29.0	28.4	12.5	Silty clay loam	A-6(9)
Method 2		87.1	12.9	54.7	32.4	28.4	12.5	Silty clay	A-6(9)
Method 3		87.8	12.2	55.0	32.8	28.4	12.5	Silty clay	A-6(9)
Standard Deviation									
Method 1		11.9	11.9	11.8	14.3	4.4	4.1		
Method 2		12.4	12.4	11.6	14.3	4.2	4.0		
Method 3		11.8	11.8	10.3	12.9	4.0	3.7		
Maximum value		100	34	80	55	38	21		
Minimum value		66	0	42	6	21	7		
Range		34	34	38	49	17	14		

and in the AASHO classification systems. These values were obtained from roadway soil surveys performed for the Indiana State Highway Commission. Three different methods were used in determining the statistical soil classification.

Physical Properties—Physical properties of the soils in each significant landform were subjected to statistical methods and procedures in an attempt to characterize each significant layer or stratum within each typical profile. Because economy is a major factor in the performance of any roadway soil survey, sufficient data were not always available. In areas where it was intuitively obvious that the proposed conditions would pose no challenge to the existing foundation soils, detailed information was not requested or supplied. This was the case for several of the strata involved in the typical profiles developed for this study.

The data compiled and the relations determined are given in Table 3 and shown in Figures 8, 9, 10, and 11 for the dune sand landform of the Calumet Lacustrine Plain. Development of similar information for landforms in other physiographic regions would be most useful but would be a major undertaking. All such summaries should be continually updated as more information becomes available.

Ratings of Highway Soils Considerations for Landforms Within Physiographic Regions

Ratings of highway soil considerations for landforms within physiographic regions in Indiana are given in Table 4 for the Calumet Lacustrine Plain. The authors consider that information of this type is potentially quite valuable for practicing soils engineers who are inexperienced in this geographical location. The usefulness of these data (shown for the entire state in the earlier study, 18) could be expanded if other practicing soils engineers who are experienced in this locale were to offer constructive criticisms and if their thoughts and experiences were to be reflected in a modified presentation. These ratings are primarily useful in the preliminary studies of highway planning, route location, and design. One must always keep in mind that (a) these ratings are generalizations within a landform and (b) they reflect the present standards, policies, and procedures used by the Indiana State Highway Commission for the design and construction of highway facilities. It is emphasized that detailed information is needed at a specific location before final decisions are made. The information in this study may influence but does not replace a detailed investigation. Only if a partial study of a project were to reveal conditions extremely similar to those developed within this investigation and if sufficient data were available in this study to lead to statistically sound conclusions may a complete detailed study be judged unwarranted for that particular project. This decision should always be made by a competent, experienced soils engineer.

CONCLUSIONS AND RECOMMENDATIONS

1. The physiographic subdivision approach outlined in this study can lead to meaningful and worthwhile implications and conclusions for use in the preliminary stages of planning, route location, and design of highway facilities in the state of Indiana.

2. To increase the usefulness of this approach, a further subdivision of the physiographic units (Fig. 1) is recommended. The landforms or engineering soil parent material areas (5) seem to define areas within which one can indeed generalize as to the class and severity of highway soil problems with which one must cope.

3. The significant factors influencing a regional approach to highway soils considerations are the geologic origin and complexity of parent materials (landforms), the topography, and the general texture of the parent materials (particularly the magnitude of the clay fraction).

4. Methods and procedures presented for a generalized quantification of significant factors influencing a regional approach provide a useful means for generally quantifying the factors of geologic origin and complexity of parent materials (landforms) and topography. Data developed in this phase of the study, and related to the frequency of occurrence of landforms, are the basis for what has been defined as the first dimension or degree for the measure of uniformity within physiographic regions.

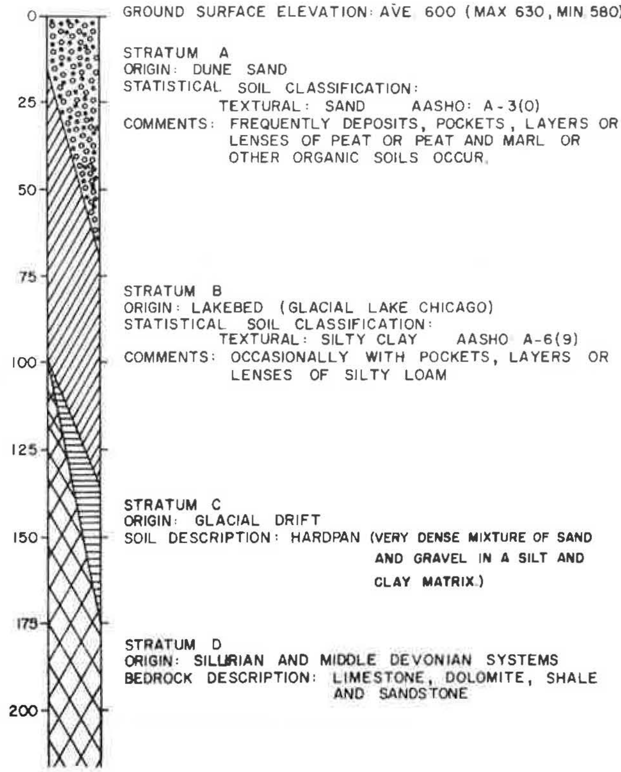


Figure 8. Typical profile of dune sand landform of Calumet Lacustrine Plain.

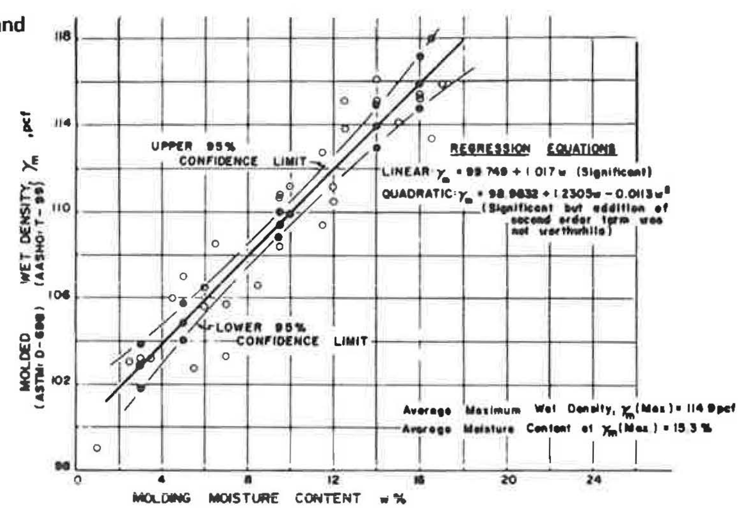


Figure 9. Molded wet density and molding moisture content, stratum A.

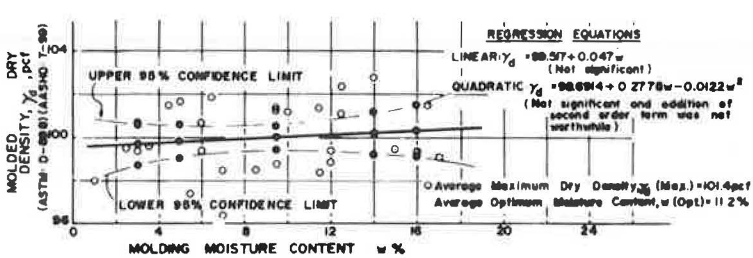


Figure 10. Molded dry density and molding moisture content, stratum A.

Figure 11. CBR and molded dry density, stratum A.

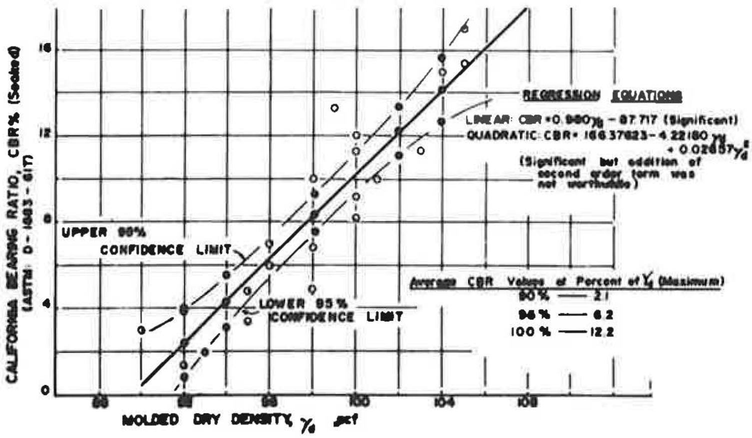


Table 4. Ratings of highway soils considerations for landforms of the Calumet Lacustrine Plain.

Soil Consideration	Dunes[a]	Lacustrine[b]	Depressions and Stream Channels[c]	Ground Moraine[d]
Cut design				
Soil backslope instability	L	M	H	L
Rock backslope instability	—	—	—	—
Groundwater control	L	L	L	L
Erosion potential	H	M	H	M
Surface drainage	H	M	H	M
Sinkholes and solution channels	—	—	—	—
Natural slope and river bank instability	L	M	H	M
Embankment design				
Soil sideslope instability	L	L	H	L
Rock sideslope instability	—	—	—	—
Soil type, compaction, and placement methods	L	M	H	L
Rock type, compaction, and placement methods	—	—	—	—
Erosion potential	H	M	H	M
Surface drainage	H	M	H	M
Embankment foundations				
Inadequate shear strength potential	L	M-L	H	M
Excessive settlement potential	L	M-H	H	M
Groundwater control	L	L	L	L
Organic deposit occurrences	L	L	H	L
Localized areas of unstable soils	L	M	H	M
Liquefaction potential	L	—	—	—
Sinkholes and solution channels	—	—	—	—
Surface drainage	L	H	H	M
Design and camber of culverts and conduits	L	M-H	H	M
Subgrades				
Support characteristics	H	L	L	M
Frost action potential	L	M	L	M
Pumping potential	L	H	H	M
Shrink and swell potential	L	H	H	M
Structure design with footings				
Instability potential	L	M	H	M
Excessive settlement potential	L	M-H	H	M
Scour potential	H	M-L	H	M
Structure design with piles				
Instability potential	L	L-L	M	L
Excessive settlement potential	L	L-M	M	L
Negative skin friction potential	L	M-H	H	M
Predetermination of pile lengths	L	H-H	H	M
Scour potential	H	M-L	H	M
Retaining structure				
Determination of lateral earth pressure	L	H	H	M

Note: L = low, M = medium, and H = high, and indicate little, average, and high likelihood respectively that major problems deserving detailed consideration will develop.

[a]Wisconsin, sand. [b]Wisconsin, sand and silty clay. [c]Recent-Wisconsin, peat and muck-marl. [d]Wisconsin, clay and silty clay.

5. The methods and procedures presented for the specific quantification of significant factors influencing a regional approach provide a useful means for specifically quantifying the 3 significant factors mentioned above. Data developed in this phase of the study, and related to the frequency of occurrence of soil types within landforms, are the basis for what has been defined as the second dimension or degree for the measure of uniformity within physiographic regions. The typical profiles and regression equations for pertinent relations, which were developed for landforms within the Calumet Lacustrine Plain physiographic region, could constitute a very valuable cataloging of soils experiences. If these relations were developed for the significant landforms within each physiographic region, they could lead to greater economy in the performance of soil and foundation investigations or at least a redistribution or concentration of any efforts to the known so-called problem landforms.

6. The authors consider the information given in Table 4 to have the greatest potential value for soils engineers inexperienced in this geographical location. The principal usefulness of these ratings is in preliminary studies related to highway planning, route location, and design. This usefulness would be expanded severalfold by the constructive criticism of other experienced soils engineers in this locality.

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Any statements and conclusions made in this study represent the personal views of the authors based on their experience and should not be interpreted necessarily to represent the views of other personnel of the Indiana State Highway Commission.

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