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DESIGN OF FLEXIBLE SURFACES IN MICHIGAN

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SYNOPSIS

A discussion of Michigan's basis for design describing how design criteria have been developed around a system of soil profile classification is presented. Traffic volumes control wearing course design, and soil, drainage, and climate are important factors controlling foundation design. The relations between laboratory test results and the soil classification based on field study of soil profiles is also discussed.

The soil survey provides most of the soil engineering design information. In addition to this it supplies area meaning by which to test results; it yields information concerning the natural environment of the samples collected; and it suggests the influence which changes in this environment will have on the significance of test results. Information obtained both from laboratory tests and from field identification of soils is complementary in providing a soil engineering background for the design of flexible surfaced roads.

In considering design of flexible highway surfaces it is natural and desirable that a great deal of attention should be devoted to the development of tests for determining the thickness of sub-base, base and surfacing. A number of sampling and testing methods have been developed for this purpose, some of which are the California bearing ratio test, North Dakota cone test, Florida sand test, and various shear tests. Each of these are intended to yield information for specific design problems after the location has been selected and grades established. As yet, however, there is no complete agreement or general acceptance of any method of rational foundation design for flexible surfaces.

In Michigan, field studies rather than laboratory studies have been emphasized as a basis for design. These studies combined with long experience in the evaluation of soil, geology, climate, water, and certain laboratory tests as factors in foundation design, serve to determine the practices to be followed. This method has been successful for two reasons. First, highway wheel loads have remained fairly constant, so that experience of 15 years ago is still applicable insofar as the effect of this factor on foundation stability is concerned. Second, most of the important design controls are conditions which can best be determined by sight, feel and judgment in the field when the soil survey is made. For example, the texture of the soil determines whether or not a granular sub-base is to be used. The position of the water table is an important grade elevation control. Materials which heave sufficiently to be classified as frost heaving are easily recognized for the purpose of removal. Seepage areas and wet pockets requiring special drainage attention are not difficult to determine and correct. Suitable construction materials are easily located and identified without the aid of special testing procedures. Experience and good judgment then combine to develop design methods which consider information such as that listed above.

TABLE 1

Pavement Type	24-hr Traffic Count
Bituminous Concrete on Gravel	500 to 1000
Bituminous-Aggregate Mix on Gravel	200 to 500
Bituminous Surface Treatment on Gravel	50 to 200
Gravel.	50 or less

The entire area of Michigan has been thoroughly worked over by ice during the various great glacial periods. The resulting glacial deposits are comparatively young so that weathering forces have not had an opportunity to eliminate textural irregularities to the extent found in older glacial deposits. Soil materials, therefore, may involve many changes both vertically and horizontally in short distances. The natural drainage systems are also very immature causing sudden variations in soil-moisture relationships. Constant variations in soil material, drainage, and climate combine to form an infinite number of foundation conditions. Visualizing the combined effects of these variations as a series of points on a curve the information from a single test would determine only one point. To accurately produce the entire curve would require an unreasonable amount of sampling and testing. For this reason conventional sampling and testing methods are impractical as a means to present the entire foundation picture. The objective in this State, therefore, has been to develop soil survey methods which would yield most of the needed design data without relying on continuous sampling and laboratory testing. In this way it has been possible to make a wide application of soil and foundation knowledge to problems in highway design.

The system of soil classification used by this State is that developed by soil scientists and adopted by the Soil Survey Division, U. S. Department of Agriculture for making county soil surveys throughout the United States. The legend was developed by isolating, describing, and naming the various soil profile developments considering principally the weathered portion of the earth's crust. The Michigan Highway Department soil surveys, therefore, include identification of these soil profiles by name. Michigan construction and maintenance experience has been correlated or associated with these profile names. This past experience becomes available to the design engineer when he is given the names and limits of the soil profiles along the right-of-way in question. The important advantages of this method of mapping soils are the speed with which soil surveys can be made, the wide range of information which it yields, and the extensive insight into the character of the site which is obtained by the engineer making the soil survey. This insight is very important since the soil engineer who makes the soil survey also assists in checking the plans during the design period, and finally he inspects the subgrade during the construction period.

In the design of flexible type roads two sets of criteria are used, one for selecting the type of wearing course and a second for determining foundation design. The volume and type of traffic largely control wearing course design, and while there is no fixed procedure governing the use of this traffic factor our engineers keep the outline in Table 1 in mind when deciding upon pavement type.

Sub-base and subgrade designs are controlled by the soil, drainage, and climatic characteristics of the site rather than by the type of flexible surfacing to be placed. The questions are often asked, "After the soil profile has been identified, how is the foundation treatment arrived at? What criteria is used and how was it developed?"

The procedure has been one of observing and recording highway behavior over the various soils found in this State. To illustrate, some years ago it became necessary to provide unemployment relief throughout the State by instituting a program of public works. This program involved a wide range of highway improvements including one of bituminous surface treatment over existing gravel roads. The selection of projects to be surface treated was partly based on employment needs in their respective areas with the results that many known uncorrected foundation conditions were included in the program. Soil maps were prepared for each of these projects in order to have an accurate record of the natural soil and drainage environment. Then at intervals during the next critical fall, winter and spring seasons, inspections were made and all failures were plotted on the soil maps. The road behavior was definitely correlated with soil and drainage by this means. This part of the program consequently served as a statewide study for the development of design criteria adapted to the design of bituminous surface treated roads. Similarly the continuous follow-up on other highway types has served to define and extend design criteria to include all combinations of foundations and surfaces. Table 2 shows the type of information obtained. It lists soil aggregate and bituminous surface treatment projects which were constructed on soils subject to loss of stability during the spring break-up period. The purpose of the study was to determine the influence of a conventional 12-in. sand sub-base on the extent of break-up. Note that the sub-base reduced the percentage of failure from 52 to less than two.

These special studies are continuously in progress. The results may or may not be formally published, but they are always written up and circulated among interested department employees. Subsequently, they find their way into instructions and specifications. In addition, they serve as a basis for the design of new construction and for the planning of betterment projects.

The annual condition surveys made during the spring break-up season are the most important of all field checks insofar as flexible surfaces are concerned. The purpose of these surveys is to study and record the behavior of existing roads with special emphasis on projects where traffic indicates the need for a higher type of flexible surfacing.

The value of these condition surveys is utilized to the maximum by recording the observed behavior directly on the soil survey maps. Thus a fund of soil engineering knowledge is accumulated so that on new projects the foundation problems can be determined and most of the resulting design requirements satisfied by simply identifying the soil profile and indicating its limits. This statement is illustrated by the subgrade design charts (Soil Engineering Data and Recommendations) contained in the Michigan Field Manual of Soil Engineering.

It has been 20 years since Charles Kellogg, now head of the Soil Survey Division, U. S. Department of Agriculture, made the first soil survey for highway design purposes in Michigan. This survey uncovered special conditions of soil and ground water which in this instance determined the grade elevation, drainage system, and typical cross section used. At that time there was no tabulation of soil engineering data for the various soil profiles recognized. The soil surveyor therefore included a comprehensive report with each soil survey discussing in detail the engineering significance of the soils mapped and the drainage conditions observed. The modern soil survey report is shorter and includes only variations from or additions to design recommendations published in the soil engineering manual.

For the average road project the soil survey procedure consists of mapping a strip 200 ft wide using the standard scale of 1 in. equals 100 ft. On this map are shown the soil names and the boundaries separating the various soil profiles identified. In addition, it is conventional to show soundings for rock, water table, clay depths and peat depths whenever the soil survey indicates that these will be controlling factors in the final designs. Ordinarily, peat swamps require a special set of sounding notes obtained by the engineering survey party, in which case it is the duty of the soil engineer to check the classification of swamp materials (Fig. 1). Occasionally, definite quantitative information may be needed if certain soil materials are to be used in the manufacture of stabilized gravel or if embankments are to be constructed using definite density control. Samples of the materials involved are then sent to the central laboratory for testing in order that binder contents, optimum moistures and densities can be calculated.

After the soil survey has been received in the design section the soil map is transferred to the plans. The soil engineering data are reviewed and evaluated along with other factors governing design and finally incor-

TABLE 2

COMPARISON OF ROAD BEHAVIOR ON OIL AGGREGATE AND SURFACE TREATED GRAVEL IN CLAY AREAS WHERE CONSTRUCTED WITH AND WITHOUT 12-IN. OF SAND SUB-BASE

County	Project No.	T.L. Route and Description	Length	Year Built	Type of Surface		Total and Partial Failure as of Summer 1943		Subgrade Soil
					Oil Agg.	Surf. Treat.	Without Sub-base	With Sub-base	
			mi.				%	%	
Eaton	23-34	M-50 Charlotte-Eaton Rapids	9.85	1941	X			0.0	Loams and Clay
	23-28	M-50 Eaton Rapids S.	5.90	1939	X			0.1	Loams and Clay
	23-35	M-100 Potterville-Grand Ledge	8.30	1940		X	73.3		Clay
	23-10	M-50 from M-43 SE toward Charlotte	6.70	1940		X	56.9		Clay
Genesee	25-42	M-57 M-13 E. to Montrose	1.40	1941	X			1.0	Clay
Gladwin	26-19	M-61 W. of Gladwin	1.70	1940	X			0.0	Clay
Huron	32-45	M-142 Verona E.	7.20	1940	X			2.20	Clay
Ingham	33-51	M-47 Williamston N.	3.18	1940		X	40.1		Sandy Clay
	33-17	M-92 Stockbridge N.	1.45	1940		X	64.0		Sand and Clay
Jackson	38-36	M-106 Jackson NE	7.05	1940	X			3 5	Sandy Clay and Clay[a]
	38-36	M-106 Munith W	3.35	1940	X			7.5	Sandy Clay and Clay[a]
	38-26	M-50 Tompkins to County Line	6.10	1941	X			0.6	Sandy Clay
	38-25	M-50 Tompkins S.	7.40	1937	X		30.0		Sandy Clay
	38-44	M-50 Jackson NW	2.6	1936	X		35.2		Sandy Clay
	38-37	M-99 US-12 N.	4.35	1937	X		18.8		Sandy Clay
	28-37	M-99 Springport S.	3.10	1940	X			3.4	Sandy Clay
	38-37	M-99 Co. Line to Springport	3.60	1940	X			8.9	Sandy Clay
Lapeer	44-27	M-90 N.	3.75	1941	X			0.35	Sandy Clay
	44-28	M-90 Lapeer N.	11.77	1940	X			0.50	Sandy Clay
Lenawee	46-32	M-34 Adrian to Hudson	9.52	1936	X		80.7		Clay (heavy)[b]
		M-34 Hudson E.	2.48	1940		X	76.2		Clay
	46-30	M-156 Morenci N.	9.74	1940		X	45 0		Clay
Oakland	63-55	M-150 Rochester N.	7.40	1941		X	61.6		Clay
	63-43	M-87 from US-10 W.	3.00	1935	X		53.5		Clay
	63-43	M-87 Holly E.	3.00	1936	X		31.0		Sandy Clay
	63-15	M-87 Holly to Fenton	3.00	1938	X		42.2		Clay
Saginaw	73-60	M-81 Saginaw E.	3.76	1940		X	50.6		Clay
	73-44	M-57 Chesaning E. to M-13	8.30	1941	X			0.0	Clay
Sanilac	74-5	M-19 Peck S. to County Line	7.00	1940		X	52.0		Clay
	74-45	M-90 Croswell E.	4.30	1940		X	56.5		Clay
	74-19	M-46 Carsonville to Pt. Sanilac	5.60	1940		X	60 4		Clay
Shiawassee	76-30	M-47 Perry S. to County Line	3.30	1940		X	43.2		Clay
St. Clair	77-41	M-19 Yale N. to County Line	1.70	1941		X	36.0		Clay
Tuscola	79-46	M-46 Richville to Vassar Rd.	4.62	1939	X		31.0		Clay
	79-40	M-38 Mayville W.	1.00	1940	X			0.0	Clay
		Total	176.47		21	14			
		Average					51.96	1.77	

[a] Failures over peat swamps
[b] Built as an oil agg. in 1936—Resealed in 1940

porated in the new plans. These plans are then checked in the field by representatives from the design and construction sections in company with the soil engineer who made the tions should some soil, drainage or erosion problem seem inadequately provided for.

During construction operations the soil engineer determines the actual limits for

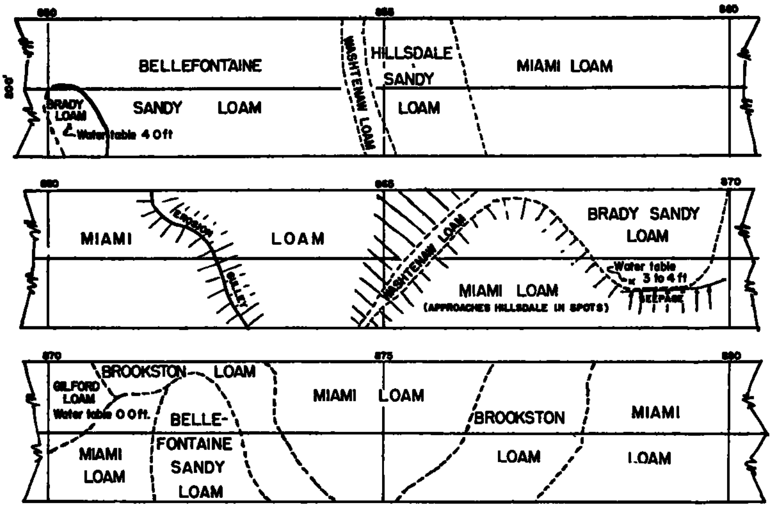

Figure 1

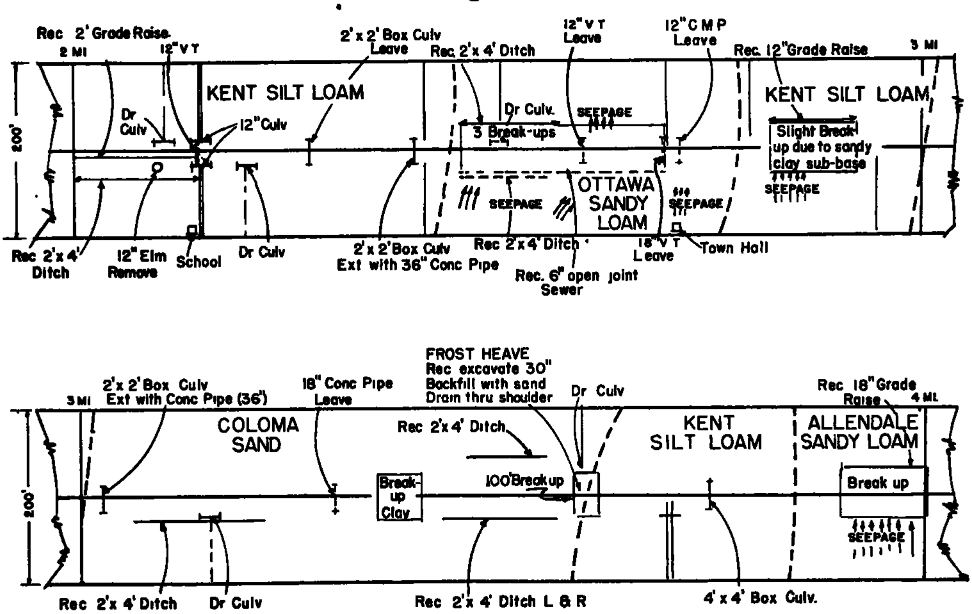

Figure 2

soil survey. Thus the soil engineer has an opportunity to interpret soil information for the benefit of other members of the checking party and also to make further recommenda- estimated quantities of frost heave excavation and tile drainage installations provided for on the plans. These limits can be determined faster and more accurately after cut sections have been opened than at the time the soil survey is made. The identification of the soil profile indicates roughly the amount of these items to be provided for on plans, but in Michigan's variable glacial deposits final dimensions can best be fixed when the cut is made and the grade exposed for study in detail. During this period the soil engineer serves as consultant on such problems as foundations for structures, peat marsh treatment, slope treatment, erosion control, borrow materials, and density control in embankment construction.

This standard soil survey procedure may be varied to meet special conditions. In connection with flexible pavements one of these special conditions is presented by the so-called betterment program of sealing or surface treating existing gravel roads. Projects of this type are low cost and do not involve the conventional surveys and plans. In this case the soil map with subgrade corrections and other recommendations may serve as plans for the project (Fig. 2).

Michigan soil survey methods lend themselves to application in a wide range of design, construction, and maintenance activities. They are fast, simple, and economical of personnel. The field identification of soil profiles is completed first. Sampling and testing operations follow. The most important function of the field identification survey is to supply soil engineering design information, but in addition to this function it also contributes in a number of ways to the value of laboratory test results. First, it provides area significance to test results. Second, it yields information concerning the extent to which the environment of the sample may be normal at the time of sampling. Third, it indicates changes which may be expected in this environment. Finally, it suggests the influence which these changes will exert on the significance of test results. In this varied manner the soil survey supplies the background for the design of flexible surfaced roads in Michigan where subgrade conditions so quickly express themselves in surface behavior.

DEVELOPMENT OF A PROCEDURE FOR THE DESIGN OF FLEXIBLE BASES

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SYNOPSIS

The design procedure described in this paper is the result of an investigation, still in progress, set up to establish a relationship between field performance of granular bases and bearing values obtained in the laboratory by means of the California bearing test, or modifications thereof.

The field investigation involved condition surveys of bituminous surfaces placed on granular bases, the determination of thickness, density and moisture content, and North Dakota cone bearing value of the subgrades. Samples of the base materials and subgrades were sent to the laboratory for analysis and bearing values. Field moisture and density determinations were also made to determine seasonal and annual fluctuations in bases and subgrades.

The field studies revealed that failures had occurred within practically the entire range of moistures and densities found in the road, which would indicate generally inadequate thickness of base on plastic soil subgrades. There was some relation between moisture content and the plastic limit of the subgrade soils. At more than 95 percent of the test points the subgrade densities were between 90 and 105 percent of AASHO-T99 maximum density and averaged 97.2 percent. It was apparent that under these density conditions the subgrade moisture content was the most important factor in determining whether or not failures occurred at any given thickness. The field data also indicated that during the