Use of Agricultural Soil Maps for Highway Engineering in Nebraska

O. L. LUND, Assistant Engineer of Materials and Tests, and O. B. GRIESS, Senior Geologist; Division of Materials and Tests, Nebraska Department of Roads

● THE Nebraska Department of Roads makes rather extensive use of the agricultural soil maps which are published by the Conservation and Survey Division of the University of Nebraska and the U.S. Department of Agriculture. It has often been said that this group of maps is one of the most valuable aids for soil survey and materials prospecting work. A tremendous saving in time and money has been effected in the past 20 years through the daily use of these maps.

The agricultural soil maps are used for the purposes shown in the following table:

PURPOSES FOR WHICH AGRICULTURAL SOIL MAPS ARE USED IN NEBRASKA

Stage of Project Development		Use
Programing		Estimating costs of flexible pavements for programing purposes.
Design	Before soil and materials survey	Locating slope stability problems. Estimating the required thickness of flexible pavements. Estimating the granular foundation course requirements for rigid pavements. Estimating the need for a clay blanket on gravel surfaced roads.
	During soil and materials survey	Planning and conducting the soil survey. Locating deposits of materials for highway construction.
	During period of plan preparation	Estimating drainage and runoff characteristics for drainage structure design.

The existing soil maps are considered to be quite adequate in 47 of the 93 counties of Nebraska. High priority has been assigned by state and Federal agencies to the resurvey of the soils in about 15 additional counties. The existing soil maps are considered to be of some assistance in about 15 other counties. The soils in 4 counties are chiefly dune sand and are so well known that no survey is needed. It will be seen that the coverage is fairly complete with these maps, and that the situation will be even better in the near future.

The Nebraska Department of Roads has indicated its great interest in the continuing improvement and availability of the agricultural soil maps by joining with the Bureau of Public Roads of the U.S. Department of Commerce, the Conservation and Survey Division of the University, and the Soil Conservation Service of the U.S. Department of Agriculture in the preparation of an engineering chapter for each of the reports for counties presently being surveyed or to be surveyed in the future. The department of roads performs the tests on the samples taken by the surveying organizations and assists in the review of the tables and text materials for each county. The department also reviews its records for test data which may be added to those obtained on the samples submitted for each county. This procedure provides a more complete set of test data in each case.

A word of caution perhaps should be inserted at this point. The information obtained from the soil maps must not be expected to be precise. Even though careful work is performed by those who conduct the soil surveys in the field and every effort is made to make the maps as accurate as possible, it is obvious that soil changes in the horizontal, as well as in the vertical direction cannot be delineated exactly without an unreasonable amount of work. In the use of these maps one becomes accustomed to a certain amount of variation and allows for it when it is found. He is not surprised, when he drills a hole in a spot indicated by the soil map to be a possible source of sand, to learn that the sand which was noted by the original surveyor did not extend as far or as deep as indicated. One learns to use the map as a guide in his work in soils, but does not expect it to be infallible.

PROGRAM ESTIMATES

Agricultural soils maps are of great value in preparing program estimates for flexible pavements in Nebraska. They are used in conjunction with the cost summary map (Fig. 4) which is maintained up-to-date by the division of materials and tests. By the use of the two maps together a quick cost estimate can be obtained for any proposed flexible pavement in any area of the state.

The Nebraska Department of Roads usually programs construction work for a 2-yr period. At this time, the materials and tests division provides cost estimates for flexible paving for a large number of proposed projects within a short period of time. Also, quite often during the biennium the materials and tests division is asked to furnish cost estimates for programing purposes within such short periods that time is not allowed to investigate the soils in the field. The procedure used is as follows:

1. The alignment of the proposed project is superimposed on the soil map showing the approximate locations of the soil changes.
2. The soil profile for each of the soils encountered along the alignment is determined by reference to tabulated information available in the office. In many cases the trained individual is already familiar with the soil from previous experience.
3. The type of flexible pavement to be constructed in each section is determined on the basis of the soil profile.
4. The estimate for the selected type of flexible pavement is made by averaging the cost of similar roads in the immediate area, as shown on the cost summary map.

A typical example where this procedure was used is the Bellwood West project. In Figure 1 the alignment for the project has been indicated on the soil map. It will be noted that four soils are encountered within the project. These are soils of the Sparta, O'Neill, Waukesha and Judson series. From the typical soil profile sketches (Figs. 2 and 3) the general type of soil material is determined. It will be seen that the soils between Station 100± and Station 240± are of the Sparta and O'Neill series. The parent materials for both of these soils are sands. There are two standard procedures in Nebraska for flexible pavement construction in sand, the choice depending on the traffic density:

1. Bituminous sand surface course. Filler and cutback asphaltic oil are added directly to a 5-in. depth of subgrade sand. After thorough mixing, aeration of the excess diluent, laydown and compaction, a seal coat is constructed thereon. This type is for light traffic.
2. Bituminous sand base course. This is similar to the bituminous sand surface course, but instead of the seal coat, a 2- or 3-in. asphaltic concrete surface course is applied for roads carrying heavier traffic.

Between Station 240± and Station 310± of the project the soils are predominantly of the Waukesha and Judson series. A study of the typical profiles shown for these soils indicates that they are silt-clay in nature, containing little sand. The typical construction on this type of soil consists of granular subbase course, soil aggregate base course, and asphaltic concrete surface course.

Thus, on this project there are two sections requiring entirely different designs for flexible pavement. In the preparation of an accurate cost estimate this information is essential. Figure 4 shows a small section of the cost summary map previously men-

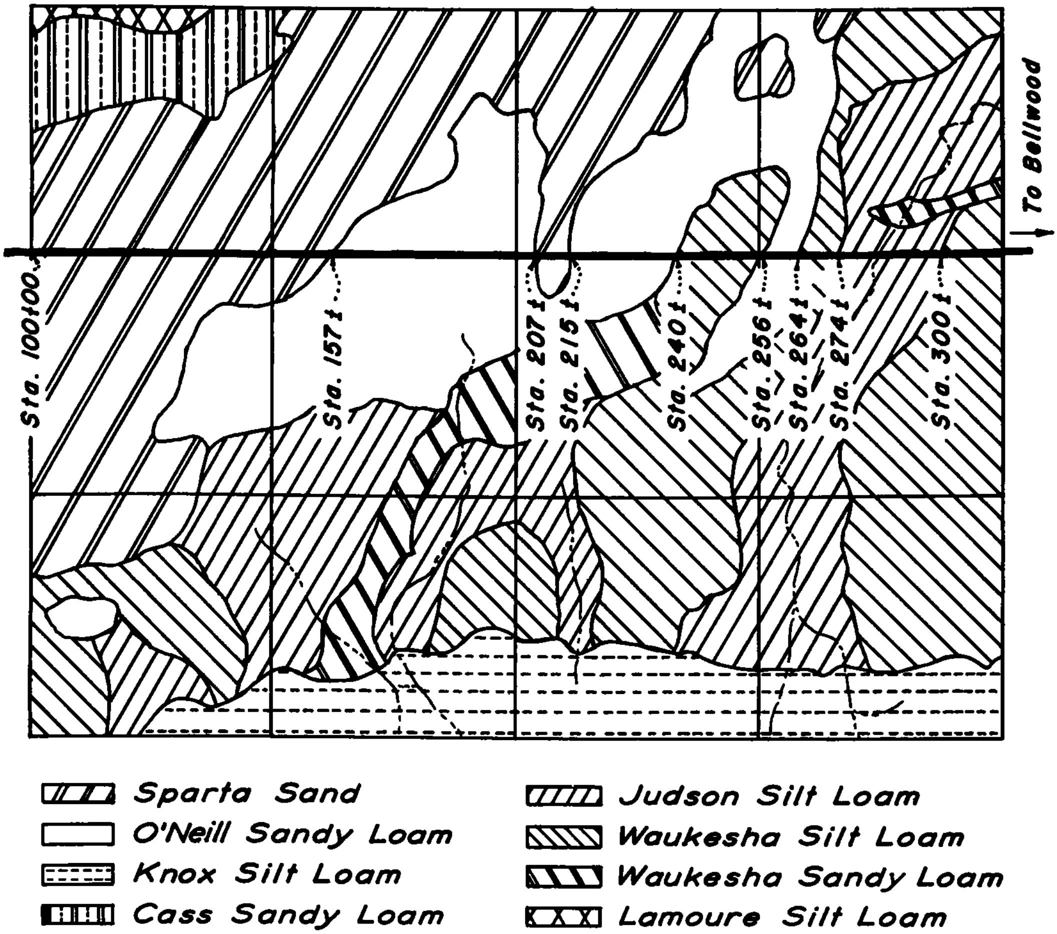


Figure 1. Agricultural soil map, section near Bellwood West project, Butler County.

tioned. It may be observed that the actual costs of recently constructed flexible pavements are shown for the region near Bellwood. Costs are available for both of the types of construction which will be required on the Bellwood West project. The project immediately south of Genoa is representative of the western end (Station 100± to Station 240±) of the Bellwood West project, where the soil is largely sand and an estimate of approximately $18,000 per mile for this type of construction is obtained.

Several of the other recently constructed projects in the vicinity are of the type required for the silty-clay soils on the eastern end (Station 240± to Station 310±) of the project. An average of the actual costs of these projects is about $27,500 per mile and this figure may be used as a program estimate for this section of the Bellwood West project.

This procedure is based on similar drainage characteristics and traffic density. If an estimate is to be made for a road having markedly different traffic or drainage conditions, appropriate adjustments are incorporated for these factors.

The estimate would not have been as accurate had it been based on the cost summary map alone without the information from the soil map.

SLOPE STABILITY PROBLEMS

Nebraska has three general types of slope stability problems which can be identified on the soil map:

1. Wind erosion on slopes consisting of fine or dune sand.
2. Water erosion on slopes consisting of extremely silty loess.
3. Sloughing of cut slopes consisting of clayey shales such as in the Pierre formation.

Approximately ⅓ of the State of Nebraska is covered with a dune sand material which is extremely susceptible to wind erosion when exposed by the removal of the vegetative cover which normally protects it. The dune sands occur principally in one large area;

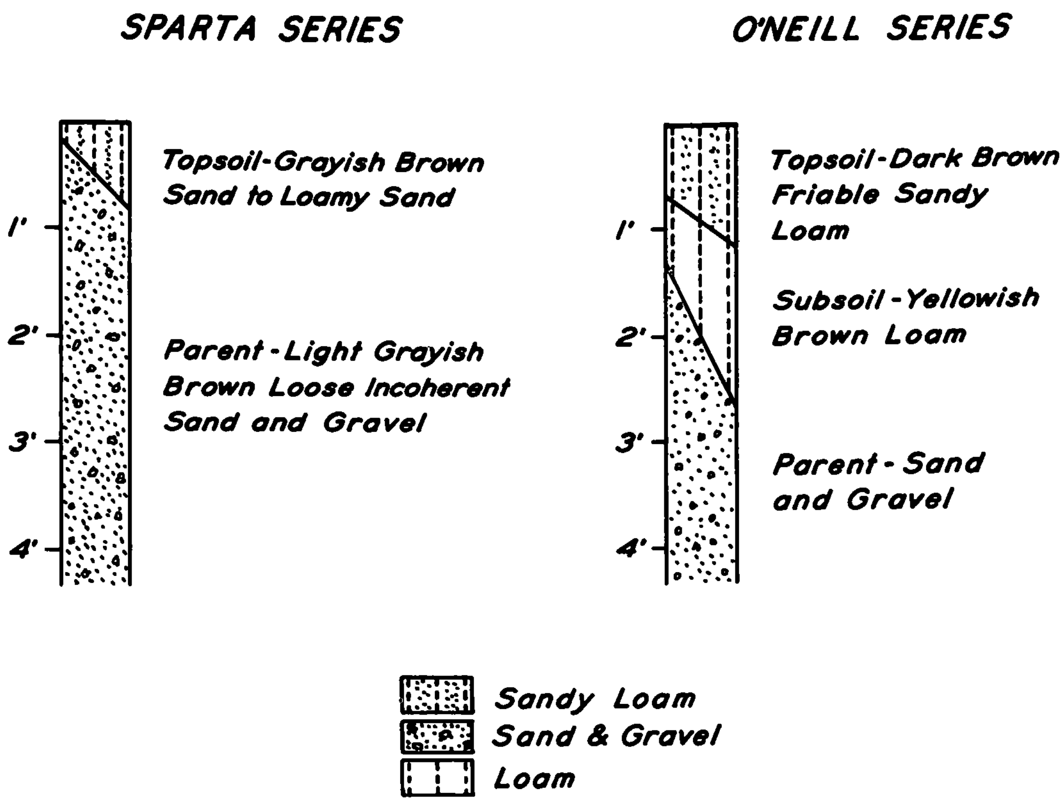


Figure 2. Typical soil profile.

however, there are also innumerable smaller areas of sand scattered throughout the western ¾ of the state. In the early programing and planning stages of project development, the department is able to forecast the necessity of slope protection for any section of road to be constructed to a sufficiently accurate degree for estimating purposes, by examination of the agricultural soil map. Then later, after the soil survey is completed, the exact locations of the protection to be planned is determined on the basis of the soil survey.

Approximately ½ of Nebraska is mantled with Peorian or recent loess. The loess is usually high in silt content and contains little sand. This material is quite susceptible to water erosion on exposed slopes, and in many cases special measures are required, such as construction of ditch checks and the placement of selected topsoil. Inasmuch as the soil series name always reveals the parent material, it is possible by reading the soil map to locate these problem areas for preliminary estimating prior to making the soil survey.

Certain limited areas have outcrops of Cretaceous shales, principally the Pierre.

These shales are subject to sloughing and the development of slides of serious nature for highways. If precautionary measures are not taken during the construction of any project having such conditions, the maintenance problems become enormous. In many cases, alignment changes can be made to avoid locations of exposed shales. A study of the soil map is made early to identify the areas where these problems may be encountered.

FLEXIBLE PAVEMENT THICKNESSES

In the normal course of events the materials and tests division is required to provide the estimated total required thickness of flexible pavements prior to the soil survey.

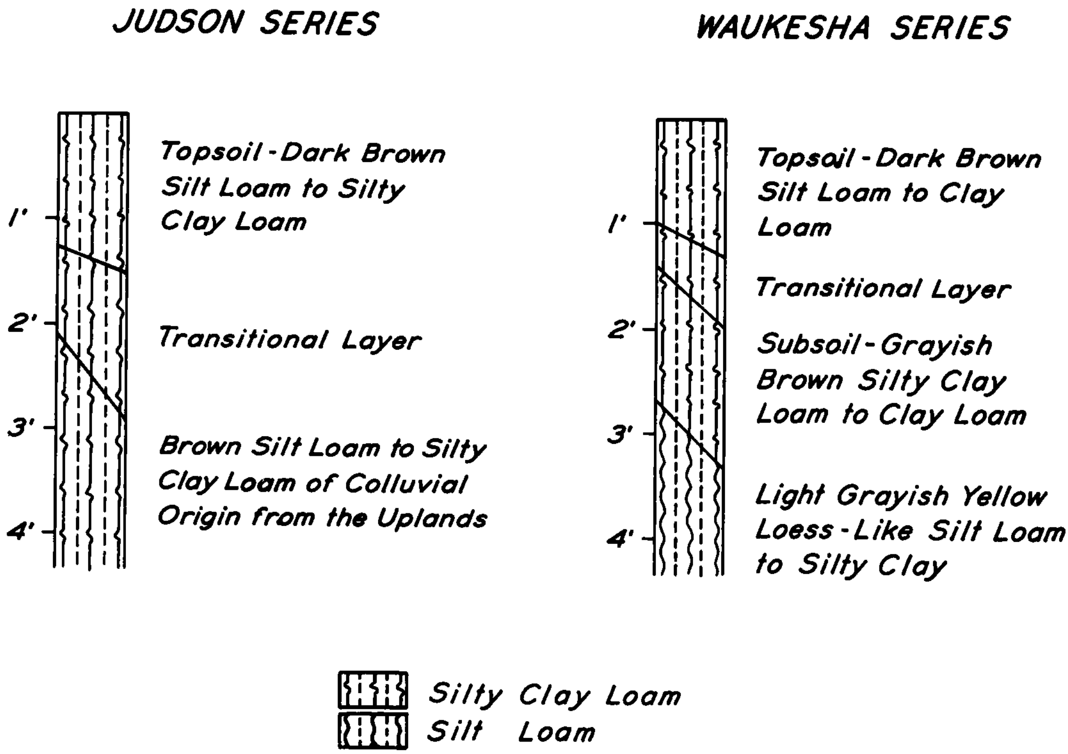


Figure 3. Typical soil profile.

The design division uses this information in the early stages of plan preparation. The excavation and embankment quantities are balanced on a tentative basis until the data from the soil survey are available. Occasionally rebalancing of cut and fill is necessary, based on recommendations furnished by the materials and tests division after the soil survey is completed.

The Bellwood West project in Butler County will be used to illustrate the use of soil maps in estimating required thicknesses of flexible pavements prior to the highway soil survey.

The procedure for determining the locations and extents of the different soil areas along the project is exactly the same as that under "Program Estimates."

Tabulated information for each soil series (see example in Fig. 5) common in Nebraska includes test data developed from samples taken on highway soils and materials surveys over a period of many years. From the tabulated data, the summary (Table 1) and following table can be prepared for the Bellwood project:

Sta. to Sta.		Soil Series	Terrain Conditions	Soil Test Data	
				% Ret. No. 200	G.I.
100±	240±	Sparta and O'Neill	Level to gently rolling terrace	50-93	0-3
240±	310±	Waukesha and Judson	Level to gently rolling terrace	3-8	8-11

The Bellwood project is in eastern Nebraska where the average annual rainfall is about 27 in. The axle loading factor (defined in Table 2) is about 50. Applying the four factors (axle loading, group index, situation, and rainfall) in Table 2, the approximate

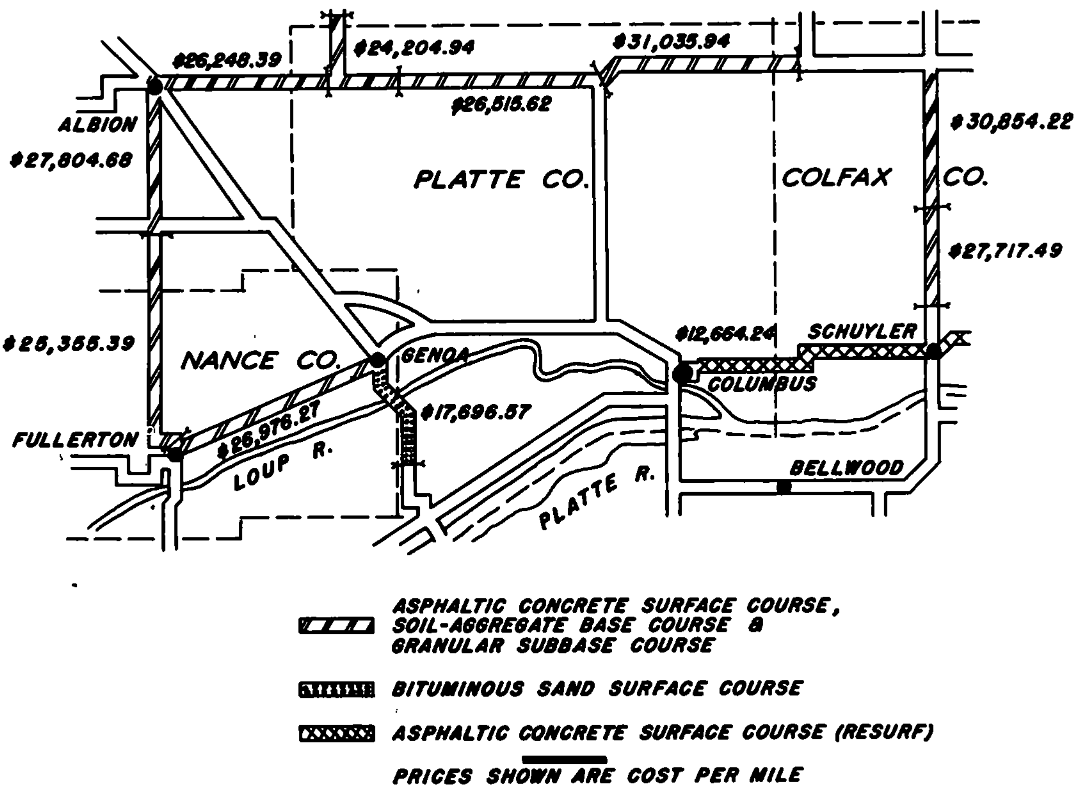


Figure 4. Cost summary map.

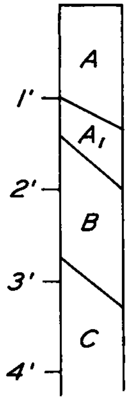
required thicknesses of flexible pavement are as follows: Station 100± to Station 240±, 6 in.; Station 240± to Station 310±, 10 in.

RIGID PAVEMENTS

The need for granular foundation course for rigid pavement is tentatively determined by inspection of the soil map, prior to the soil survey. Soil survey data are later used to confirm or adjust the tentative requirements established by the soil maps.

Nebraska's criteria for construction of granular foundation course for rigid pavements are based on the sieve analysis and the plasticity index. Sandy soils with a min-

WAUKESHA SERIES *



THIS SERIES INCLUDES FRIABLE PRAIRIE SOILS DEVELOPED FROM WATER LAID MATERIAL OR OUTWASH PLAINS AND STREAM TERRACES THE SOILS ARE USUALLY WELL DRAINED AND ARE LEACHED OF THEIR CARBONATES TO A DEPTH OF MANY FEET. THE TOPOGRAPHY IS FLAT TO GENTLY ROLLING.

- SOIL PROFILE -

A - TOPSOIL - DARK BROWN SILT LOAM TO CLAY LOAM

A_1 - TRANSITIONAL LAYER

B - SUBSOIL - GRAYISH BROWN SILTY CLAY LOAM TO CLAY LOAM

C - LIGHT GRAYISH YELLOW LOESS-LIKE SILT LOAM TO SILTY CLAY

* PEDOLOGICAL DATA FROM THE UNIVERSITY OF NEBRASKA DIVISION OF CONSERVATION AND SURVEY AND U.S. BUREAU OF CHEMISTRY AND SOILS

HORIZON	HYDROMETER ANALYSIS		LL	PI	SIEVE ANALYSIS, % RETAINED						AASHO CLASS
	% SILT	% CLAY			4	10	40	50	100	200	
			BUTLER COUNTY								
TOPSOIL	67	25	35	12				1		8	A-6(9)
SUBSOIL	70	27	41	16				0		3	A-7-6(11)
PARENT	78	17	32	9				0		5	A-4(8)
			THAYER COUNTY								
TOPSOIL	68	24	31	7				0		8	A-4(8)
SUBSOIL	62	37	41	17				0		1	A-7-6(11)
PARENT	71	28	39	14				0		1	A-6(10)
			YORK COUNTY								
TOPSOIL	74	22	34	8				0		4	A-4(8)
SUBSOIL	68	30	37	11				0		2	A-6(8)
PARENT	68	31	36	12				0		1	A-6(9)

Figure 5. Nebraska Department of Roads—soil test data.

imum of 60 percent retained on the No. 200 sieve and having a PI of 6 or less on primary roads are considered to be suitable for pavement subgrades without granular foundation course.

TABLE 1

SUMMARY OF TYPICAL TEST DATA FOR FOUR SOILS IN BUTLER COUNTY

Soil Series	Horizon	Hydrometer Analysis % Silt	Hydrometer Analysis % Clay	LL	PI	Sieve Analysis % Retained No. 10	No. 50	No. 200	AASHO Class.
Sparta	Topsoil	19	3	NP	NP	0	31	73	A-2-4(0)
	Parent	6	1	NP	NP	3	61	93	A-3(0)
O'Neill	Topsoil	20	9	NP	NP	0	37	71	A-2-4(0)
	Subsoil	34	16	24	8	0	25	50	A-4(3)
	Parent	5	2	NP	NP	2	49	93	A-3(0)
Waukesha	Topsoil	67	25	35	12	0	1	8	A-6(9)
	Subsoil	70	27	41	16	-	0	3	A-7-6(11)
	Parent	78	17	32	9	-	0	5	A-4(8)
Judson	Topsoil	67	25	35	12	0	1	8	A-6(9)
	Colluvium	68	25	24	12	-	0	7	A-6(9)

TABLE 2

REQUIRED THICKNESS FOR FLEXIBLE PAVEMENT[a]

Group Index	Required Thickness (in.) ALF[b] 50	ALF[b] 100	ALF[b] 200	ALF[b] 300	ALF[b] 400	ALF[b] 500	Adjust.[c] (in.)
-4	3	3½	4	4½	5	5½	±½
0	5	5½	6½	7	8	9	±1
4	6½	7½	8½	10	11	12	±1½
8	8½	9½	11	12½	14	15½	±2
12	10	11½	13½	15	17	19	±2½
16	12	13½	16	18	20	22	±3
20	14	15½	18	20½	23	25½	±3½
24	15½	17½	20½	23½	26	29	±4
28	17½	19½	23	26	29½	32½	±4½
32	19½	21½	25½	29	32½	36	±4½

DEFINITIONS

Rainfall:
- Light—less than 19 in. per year
- Medium—19 in. to 26 in. per year
- Heavy—more than 26 in. per year

Situation:
- "A" upland and terrace—ridges and good drainage
- "B" upland and terrace—level
- "C" bottom land and basin—water table deep
- "D" bottom land and basin—water table high

Axle loading factor:
- Axle loading factor is equal to the sum of the number of axles per day exceeding five tons and the number of axles per day exceeding seven tons

[a]From Nebraska flexible pavement design curves.
[b]Axle loading factor.
[c]Adjustment for situation and rainfall.

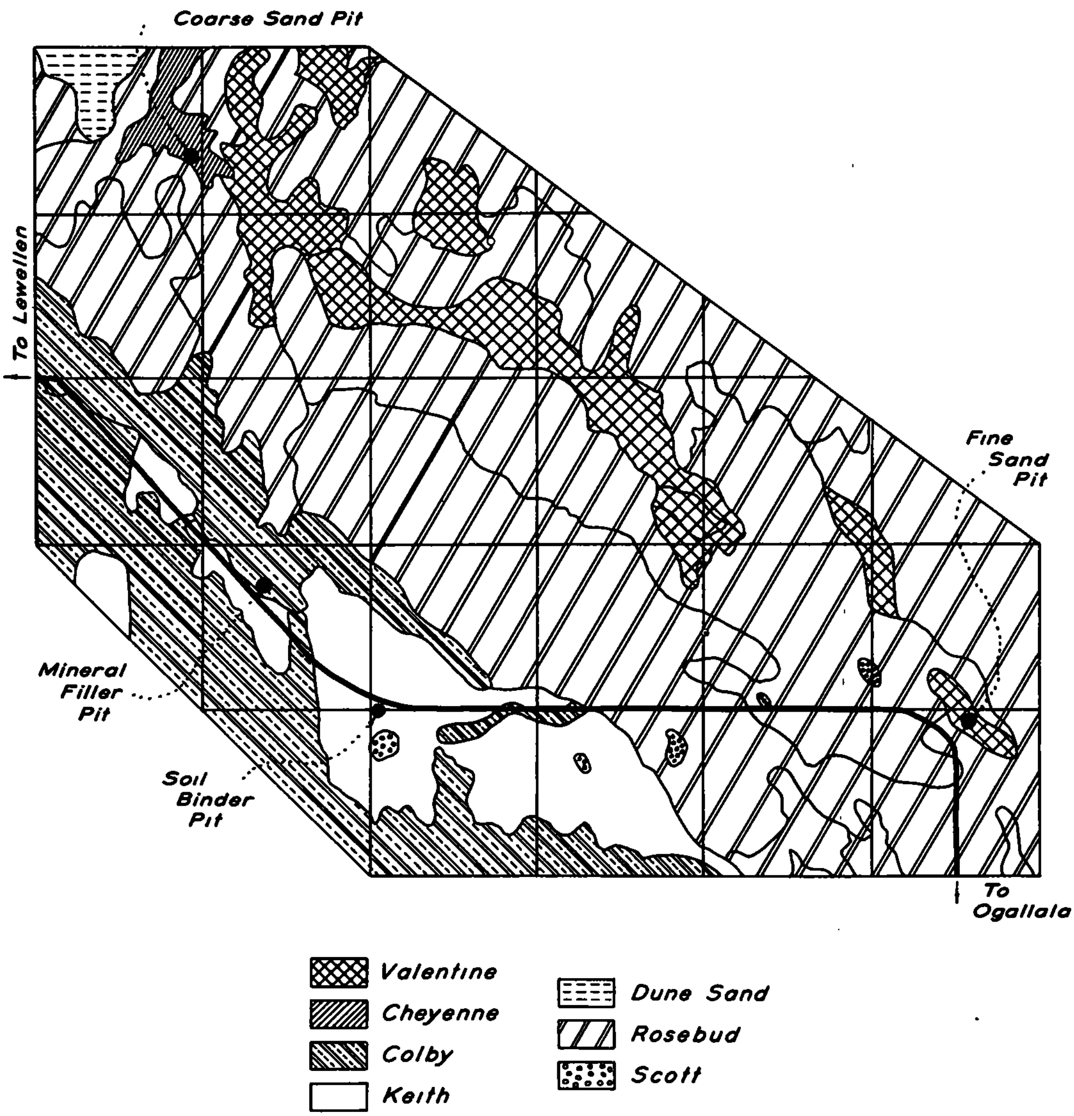


Figure 6. Agricultural soil map: section near Ogallala-Lewellen project, Keith County.

In the case of the Bellwood West project, the sandy section between Station 100± and Station 240± would be considered to be satisfactory without granular foundation course. Although the soil map and the tabulated information indicate that some of the topsoil and subsoil may have slightly less sand than required under the established criteria, these probably could be avoided in the subgrade by selective placement of soils.

The section between Station 240± and Station 310± obviously would require granular foundation course throughout most of its length.

GRAVEL SURFACED ROADS

Occasionally it is desirable to have a project lie over for a year or two after grading and prior to construction of pavement. This is possible in silt clay areas, by constructing a gravel surface course for temporary use. However, in the sandy soils of Nebraska, this procedure is not feasible unless a silt-clay blanket is placed on the subgrade sand before applying the gravel.

A glance at the soil map in the early stages of project development will reveal to the designer if the soils are adaptable to temporary use as a graveled road.

SOIL AND MATERIALS SURVEYS

The party chief preparing to conduct a soil and materials survey for a proposed project in Nebraska always makes a thorough study of the agricultural soil map covering the area within 5 or 10 miles of the project. It has been found through years of experience that much time, effort and expense can be saved by making such a study before leaving the office.

In planning for the soil survey, the party chief superimposes the alignment of the project on a soil map and observes which soils series will be encountered, thus establishing the terrain and soil conditions. If the soil map indicates a wide variety of soils along the project, he will know beforehand that many borings and much sampling will be required to accurately delineate the different materials to be excavated. On the other hand, if the soil map indicates a great degree of uniformity in the soils from one end of the project to the other, he will be able to reduce the number of borings and samples, and, in some cases, the survey can be abbreviated to the extent that only a few borings are made per mile.

The assistance provided by the agricultural soil map in locating construction materials is probably the basis for the greatest saving of all. In connection with the materials surveys, it should first be pointed out that the Nebraska Department of Roads locates a large portion of the materials used in the construction of base and surface courses. Among the items which are almost always located by state prospecting crews are soil binder for use in construction of base courses and subbase courses; soil type mineral filler used in the construction of road-mixed bituminous surfacing; and fine sands, coarse sands and gravels used in the construction of base courses, subbase courses and bituminous surfacing. The right-of-way division takes options on these local materials, and the pit locations and test data are shown in the plans. Inasmuch as it is not necessary for the several contractors interested in bidding on a project to conduct individual materials surveys, a considerable saving is effected. Also this plan makes it more difficult for a contractor to obtain an exclusive option on a source of scarce material.

In the use of the soil map as an aid in prospecting for local materials, the party chief should become so well acquainted with the materials indicated by any soil series that he can see the locations of different deposits on the soil map without reference to the descriptive text.

Figure 6 is an example where materials suitable for construction of the entire subbase, base and surface courses were located by inspection of the agricultural soil map. Figure 6 shows a portion of the area along the road between Ogallala and Lewellen. The materials needed for the construction of the flexible pavement on this road included soil binder, mineral filler, fine sand and coarse sand or gravel. Through previous experience and by the examination of the soil map and tabulated data in the office, the party chief was able to locate the following materials:

1. Soil binder. Keith soils are formed on level uplands and have parent materials consisting of Peorian loess. Their topsoils and parent materials are, for the most part, silt loams. However, due to the slow surface drainage and vegetative cover, there has developed a subsoil having somewhat greater cohesive characteristics than the parent material or the topsoil. The party chief knew before he left the office that he would make borings into Keith areas in attempting to find sufficiently cohesive material to serve as soil binder. Table 3 and Figure 7 indicate the characteristics of the material which was found in a Keith area and which served satisfactorily as a soil binder.

2. Mineral filler. The Peorian loess in this area is a silt loam, which has served as a mineral filler in many miles of Nebraska's roads. Finding suitable mineral filler was no problem, because this material was so widespread in this area. However, if the mineral filler was taken from a Keith area, an unsightly hole would be left which could not be drained, because Keith areas are level. In addition to this, the topsoil

TABLE 3

SUMMARY OF TYPICAL TEST DATA FOR FOUR SOIL MATERIALS USED IN CONSTRUCTION OF FLEXIBLE PAVEMENTS, KEITH COUNTY

Soil Series	Horizon	Hydrometer Analysis % Silt	Hydrometer Analysis % Clay	LL	PI	Sieve Analysis % Retained No. 4	No. 10	No. 50	No. 100	No. 200
Colby	Parent	84	7	24	3	-	-	-	0	9
Keith	Subsoil	61	26	34	14	-	-	-	0	13
Valentine	Parent	-	-	NP	NP	-	-	3	50	92
Cheyenne	Parent	-	-	NP	NP	12	31	84	90	94

and subsoil would have to be removed as overburden. The party chief knew that Colby soils are formed on Peorian loess in areas having steep slopes. Due to the fast run-off, little or no soil development has taken place on Colby areas. A satisfactory source of mineral filler with no overburden in a drainable pit was found in the Colby area (Table 3 and Figs. 6 and 7).

3. Fine sand is found as a parent material for many different soil series in Nebraska. In the particular area under discussion, the most likely prospect seemed to be the Valentine series. Inasmuch as these soils are formed on gently rolling terrain with loose, incoherent sand as the parent formation, the party chief prospected these areas and easily found the fine sand pit indicated in Table 3 and Figures 6 and 8.

4. Coarse sand and gravel. Nebraska has very little coarse gravel within its borders. In this particular area, the coarsest materials available are the coarse sands

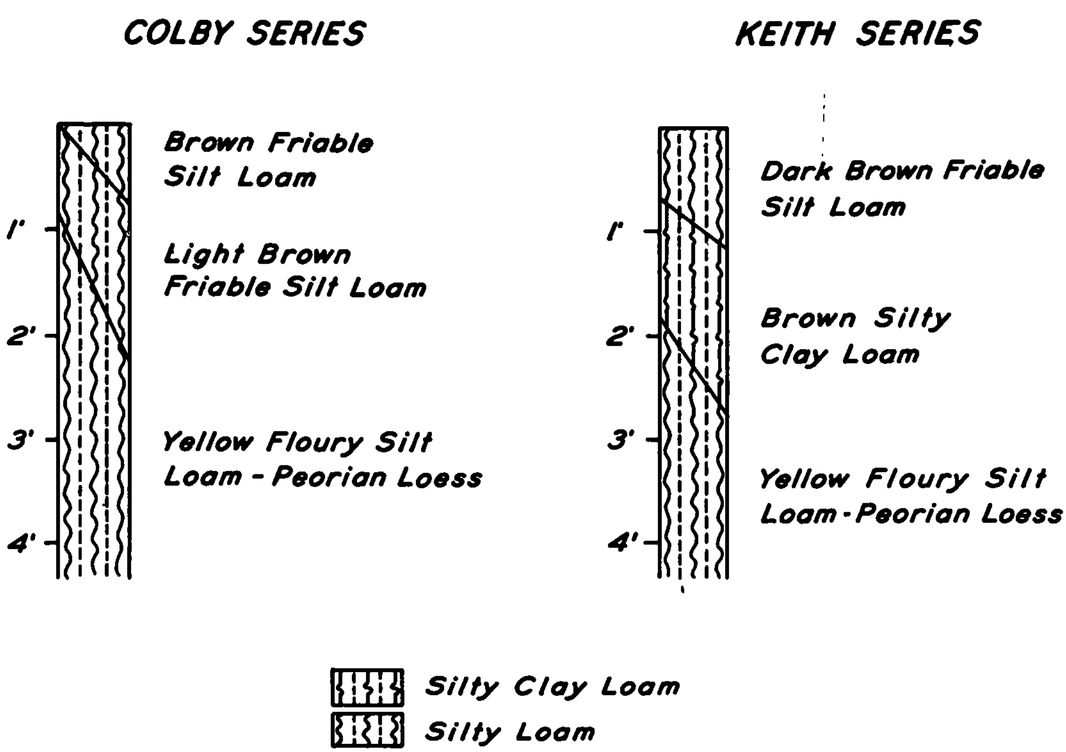


Figure 7. Typical soil profile.

which are the parent materials for the Cheyenne series. These were transported from the Rocky Mountains in stream channels during Tertiary and Pleistocene periods, and have therefore become worn and rounded. Sometimes they are used as found, but more often the finer materials are screened out and the coarser fractions are then used as gravel. The soil map showed the party chief the nearest source of these materials which are indicated as Cheyenne soils in Table 3 and Figures 6 and 8.

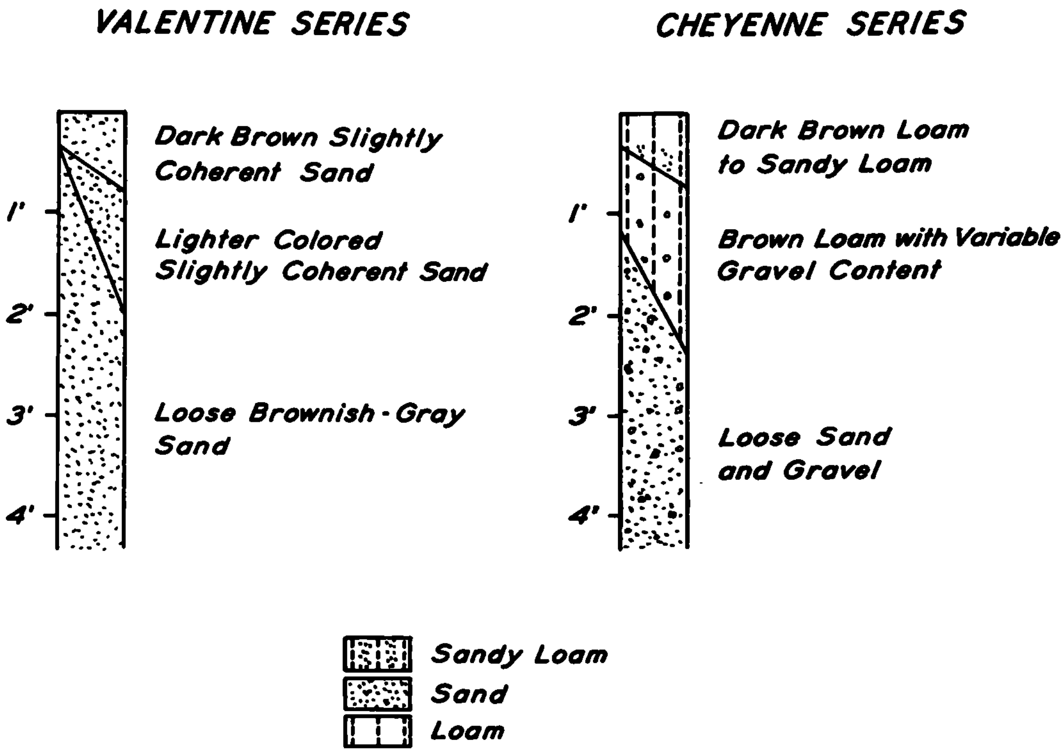


Figure 8. Typical soil profile.

The materials shown in Table 3 were located solely by review of the soil map, before leaving the office. It is obvious that a tremendous saving in time, effort and money can be effected by use of the soil maps in this manner.

It perhaps should be mentioned here that every suitable pit which is located during the materials survey is shown on a county map in the office and typical test results are tabulated. The party chief also examines this storehouse of information prior to departing for his soil and materials survey.

DRAINAGE AND RUNOFF CHARACTERISTICS

The design division uses the agricultural soil maps to determine drainage and runoff characteristics for large areas. A sheet of transparent acetate is placed on the section of the soils map for which the drainage area is to be determined. The drainage areas and streams, as shown on the soil maps, are traced on the acetate. The area outlined on the transparency includes a part of the upland ridges determined to be the divides between two drainage areas. The locations of the divides are estimated by halving the distances between two dendritic drainage patterns. A knowledge of the soils series descriptions is of some help in locating the divides.

The area traced on the transparent acetate then is determined in square miles by use of the planimeter. Large upland sink-like depressions or basin areas are usually excluded from the area outlined by the main drainage streams. The principal soil texture included within the drainage area is determined by the soil series shown on the soil map. A runoff factor is selected according to the texture of the principal parent soil. This runoff factor is applied to the entire drainage area with no consideration given for minor occurrences of soils developed on widely different parent materials.

This method applied to soil maps for upland or rolling terrain. Ordinarily, drainage areas for terraces bordering major streams are considered to be less accurate than those for the upland areas.

CONCLUSIONS

By using the information available on the soil maps for tentative design purposes, prior to the soil survey, significant savings in time are regularly effected. By using the soil map information great savings in prospecting and soil survey costs are accomplished. The soil map information backs up and supplements the soil survey information, thus improving its quality.