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Type of Milk Tank Mounted on Semi-Trailer Similar to That Used in Chicago Dairy District

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FIELD METHODS USED IN SUBGRADE SURVEYS

BY THE U. S. BUREAU OF PUBLIC ROADS ON THE PACIFIC HIGHWAY, WASHINGTON

Reported by A. C. Rose, Associate Highway Engineer

THERE is scarcely a road of any considerable length anywhere but has for its subgrade at various points a variety of soils differing more or less widely in the physical properties which affect the condition and supporting value of the subgrade. Minor differences may be found from foot to foot of the length of any highway; but generally it will be found that a soil of the same general type prevails for a considerable distance within which the general characteristics of the subgrade are fairly uniform.

The characteristics which it is most important to determine in considering the suitability of any soil to serve as a highway subgrade seem to be the degree to which it will absorb and hold water and the amount of swelling or shrinking which occurs when water is added to or taken from it. These characteristics are ascertained in the laboratory by tests applied to samples of the soil to determine its moisture equivalent percentage and volumetric shrinkage.[1] They may be approximately determined in the field by means of simplified tests developed by the writer in connection with a study of subgrade soils in the Pacific Northwest and described in a previous issue of this magazine.[2] Attention is called to the fact, however, that the shrinkage factor as determined by the laboratory and the field tests are not comparable, since in the former case the moisture content of the soil is the capillary saturation, while in the latter case it is the moisture equivalent percentage.

These tests have been found to be very helpful in establishing the characteristics of doubtful soils; but they are not the only means employed, nor are they even the most important of the methods by which the characteristics of a highway subgrade are determined. The first step in a subgrade survey is to establish the location of the various soil types. Until this is done the selection of representative test samples is impossible, and the results of tests made can be applied only to the particular location from which the samples are taken. But when the soil types are identified and the points at which the soil changes from one type to another determined, it then is possible to select samples representative of each type, and the test results may be considered as applying to all parts of the road in which the sampled types of soil are found.

UNITED STATES BUREAU OF SOILS SURVEYS VALUABLE TO THE HIGHWAY ENGINEER

The greatest aids the highway engineer has for making these subgrade surveys are the publications and maps of special areas which are prepared by the United States Bureau of Soils. These are printed in the form of bulletins and give descriptions of the origin, color, physical characteristics, drainage conditions, etc., of the soils and also show a typical mechanical analysis for each class. The series names used in designating the soils, such as Aiken, Olympic, etc., indicate the origin of the parent material from which the soils are derived, while the type names, such as sand, silt-loam, silty clay loam, clay, etc., are based principally upon the relative percentages of the various constituents of the soil as shown by the mechanical analysis.

For certain areas detailed soil bulletins have been prepared; in others only reconnaissance surveys have been made; and in still other sections no surveys have been carried on. The more definite the information, the easier it is to carry on a subgrade survey. When a detailed and recent bulletin of an area is available it is a comparatively easy matter to walk over a road project and establish the location of the soil types from the colored areas on the soil map, the location of the road and other physical features such as streams and lakes on the map, and the accompanying description in the bulletin.

When reconnaissance surveys only may be had the difficulty is considerably increased. The object of these surveys was to cover a large territory at a small expense. Therefore the detailed soil types on heavily timbered sections may not be shown, and it may also be found that small areas of some types which are large enough to affect highway subgrade may be omitted. In other cases the accurate parts of the maps may be confined largely to the sections productive from an agricultural standpoint. Areas covered by such reconnaissance surveys require detailed investigation in order to identify small areas of soil types which are not shown separately on the map.

The worst condition, however, is presented by the unmapped areas. In these it is necessary to study adjacent areas which have been mapped and extend the nomenclature to the unmapped area under consideration or better yet to secure from one of the agricultural colleges the assistance of an expert in soil mapping who will establish the soil series and type names found in the unmapped section.

If only a short road project is to be investigated the soil maps are useful for determining the several types but the series names need not be established unless it is expected to extend the survey over a large area or over an entire State highway system.

INFORMATION GIVEN BY BUREAU OF SOILS BULLETINS

The Bureau of Soils survey bulletins show the topography and drainage, the general climatic conditions, the geological history of the area and give a classification of soils as to series and types. The description of the soil series shows the color of the soil and subsoil, the nature and origin of the parent material, the topography and drainage where found, and the general characteristics as well as the natural vegetation usually found on the soil. The mechanical analyses determine the classification of the series into types based upon the percentages of the sand, silt, and clay constituents. All of this information presented in the bulletins is useful in identifying the soils in the field.

[1] For a description of the moisture equivalent and volumetric shrinkage tests as made in the laboratory see PUBLIC ROADS, vol. 6, No. 2, April, 1925.

[2] Practical Field Tests for Subgrade Soils. PUBLIC ROADS, vol. 5, No. 6, August, 1924.

THE SENSE OF FEELING A VALUABLE AID IN DETECTING SOIL TYPES

In making subgrade surveys it is a decided advantage to the investigator to be able to check his estimates by rubbing samples of the soil between the fingers. It is remarkable how accurately a specimen may be classified after the operator has had some experience in this work; and, because of the importance of this method for reducing the cost and time of the work, it may be well to discuss it here at some length.

As a rule sands feel gritty; silts, velvety, smooth, and floury; and clays, which are smooth and plastic, offer considerable resistance to pressure, roll into balls when moist and adhere to the fingers. By the degrees in which they combine these salient characteristics of the primary constituents, soils other than pure sands, silts, and clays may be distinguished as sandy loams, loams, silt-loams, sandy clays, clay-loams, silty clay-loams, and silty clays. The writer has never become sufficiently expert in this work to be confident of the estimates made of some of these gradations where the degree of variation is slight. Proficiency is acquired only by instruction from those who have learned the art, but the following notes by Prof. Charles F. Shaw [3] will be helpful.

Sand.—Sand is loose and granular. The individual grains can readily be seen or felt. Squeezed in the hand when dry, it falls apart when the pressure is released. Squeezed when moist, it will form a cast, but will crumble when touched. Sands are classified as coarse, medium, fine, or very fine sands, depending on the size of the grains that compose them.

Sandy loam.—A sandy loam is a soil containing much sand but which has enough silt and clay to make it somewhat coherent. It has a gritty feel, and the sand grains can readily be seen. Squeezed when dry, it forms a cast which can easily be broken, but if squeezed when moist a cast can be formed that will bear careful handling without breaking. Sandy loams are classed as coarse, medium, fine, or very fine sandy loam, depending on the size of the grains of which they are formed.

Loam.—A loam is a soil having an even mixture of the different grades of sand and of silt and clay. It is mellow with a somewhat gritty feel, yet fairly smooth and rather plastic. Squeezed when dry, it forms a cast that will bear careful handling, while the moist cast can be handled quite freely without breaking.

Silt-loam.—A silt-loam is a soil having little sand and only a small amount of clay, over half of the grains being of the size called "silt." It may appear quite cloddy but the lumps can be readily broken, and when pulverized it feels soft and floury. Either dry or moist it will form casts that can be handled freely without breaking. If squeezed between thumb and finger it will not "ribbon" but will give a broken appearance.

Clay loam.—A clay-loam soil in the field is dense and compact and breaks into clods or lumps. These are hard to break when dry. When the soil is moistened it can be pinched between the thumb and finger to form a thin "ribbon" which will break readily, barely sustaining its own weight. The moist soil is plastic and will form a cast that will bear much handling. It does not crumble readily but tends to work into a heavy puddled mass.

Clay.—A clay soil is dense and compact, forming very hard lumps or clods. It is composed of very fine particles, which stick together to make a very plastic or putty-like mass when wet. The soil can be pinched out to form a long, flexible "ribbon."

Adobe.—The term "adobe" indicates a structural condition. Any soil that will shrink on drying and break into blocks with wide cracks is called an adobe. Most adobes are clay adobes, but there are clay-loam adobes, and some sandy-loam adobes have been found.

All of the above classes of soil, if mixed with a considerable amount of gravel or stone, may be classed as gravelly sandy loams, gravelly clays, etc., or as stony sandy loams, etc. Sandy clay and sandy clay loams may also occur.

[3] Professor of Soil Technology, University of California.

CLAY CONTENT A VITAL FACTOR

The importance of the Bureau of Soils bulletins lies to a large extent in the fact that they present accurate information concerning the clay content of the soil. From an agricultural standpoint this is a vital factor, because the amount and character of the clay present determine whether the soil is light and porous and of high productivity, or heavy, hard to drain, and difficult to work. To the highway engineer and road builder a knowledge of the quantity and character of the clay content is important because it seems to be a well established fact that these factors determine the degree to which the soil will heave when frozen or shrink and swell with variations in moisture content. The amount and kind of clay in the soil are, therefore, critical elements both to the agronomist and the highway engineer; and it is chiefly because they supply reliable information with regard to these elements that the maps made by the Bureau of Soils for agricultural purposes are an invaluable aid in making a road subgrade study.

It is true that these soil maps will not give information relative to all the soils which make up the subgrade. In rugged country the roadbed both in cuts and fills will be composed of soil which has been excavated from beneath the 6-foot layer included in the soil survey.[4] On the other hand, a large percentage of our highways are built through level or gently rolling topography and the excavations do not reach deeper than 6 feet. For these areas the soil maps are entirely adequate but even in the rugged country the soil surveys are of great assistance because the series names, such as Aiken, Melbourne, etc., are determined principally from the geological formation and the nature of the parent rock from which the soil was formed. As a rule the soils of any series, found at any depth (even greater than 6 feet) below the surface, bear a marked similarity. It follows therefore that for all conditions, the Bureau of Soils surveys, wherever they have been completed, present fundamental data from which the highway engineer may proceed to determine more specific and pertinent information concerning the subgrade.

Unfortunately soil surveys have not been completed and published for a considerable portion of the country and it becomes necessary, therefore, in many cases to identify the soils in the unmapped areas by comparison with similar samples taken from nearby areas which have been mapped or from mapped areas which bear the greatest resemblance to the unmapped area under consideration. Of course it is not necessary to attempt to determine the Bureau of Soils series and type name for a restricted subgrade study of, say, a 10-mile project, the results of which will not be used in further work. On the other hand, if it is expected to extend the subgrade studies over a large area or over an entire State highway system it is desirable to determine the Bureau of Soils nomenclature in order that the soil tests made upon one road project may be used for evaluating the quality of the same soil series and type when found on another project. It is not to be inferred from this that

[4] The Bureau of Soils surveys formerly included mechanical analyses of the upper 6 feet of the soil in the western States and the upper 3 feet in the eastern States with often a brief description of the probable character of the subsoil at greater depths. The present practice is to describe all the soil and subsoil regardless of the depth down to the parent material with mechanical analyses. The depth now covered may reach to 10 or 15 feet. This makes the later surveys particularly valuable for evaluating highway subgrades since these data include all the soil encountered in making the cuts and fills.

a single test of a soil type is considered sufficient to identify it as a good or bad subgrade wherever it is found. On the contrary there are found to be variations in the test values for the same soil series and type which make it necessary that a sufficient number of tests be made in any region so as to determine the upper and lower limits of the variations in the test values. In many cases these upper and lower limits will fall above the critical value which has been established for a good subgrade soil and therefore these will be classed thereafter as bad subgrade soils wherever they are found and without further tests. In the event that the upper and lower limits are found to be less than the critical value for a good subgrade soil they will be called good soils. In a number of cases, however, there will be found soils whose upper and lower test limits will fall above and below the critical value established for a region. These are doubtful soils and must be tested in all cases.

DIGEST OF AVAILABLE DATA FIRST STEP IN SURVEY

In conducting a subgrade survey it is advisable as a first step to digest all available information concerning the soils of the area. If a Bureau of Soils survey bulletin is available the description of the soils contained in the bulletin may be reduced to a convenient tabular form as shown in Table 1.[5] From the same bulletin it will generally be possible to obtain a description of the topographic position of the various soils, i. e., whether they are found generally in mountainous, upland, or valley sections. With this information available it is convenient to prepare a diagram such as Figure 1, which, when used in the field, will aid the investigator by narrowing the range of soils to be considered in identifying the particular soils found on the project.

METHODS OF SURVEY VARIED TO MEET CONDITIONS

The methods used in making the subgrade survey will vary according to whether the road project is included in an area for which a recent and detailed Bureau of Soils bulletin is available, whether only a reconnaisance survey bulletin has been completed, or whether the area is unmapped. In the first case very little preliminary work is necessary before the field work begins. In the unmapped areas it is safer where possible to secure the assistance of a soil expert from a local agricultural college, because this is the most difficult problem that is likely to be encountered. The average case, however, may be said to be represented by an area covered by a reconnaissance survey because some of the old surveys were made before the modern methods and more detailed classifications were adopted and many of these old records are in existence. To illustrate a method which may be applied under average conditions the writer has selected as a basis for discussion the survey made on a 53-mile portion of the Pacific Highway in a section of the State of Washington covered by a Bureau of Soils reconnaissance survey.

FIELD INVESTIGATIONS

After a thorough study of the United States Bureau of Soils survey bulletin, the field work of the subgrade study was begun. A Dodge sedan automobile, a remnant of the World War, was used for the transportation of the investigators and the soil-testing apparatus. A closed car is particularly adapted to this type of work because it provides shelter for taking notes during rainy and stormy weather, which is the best time to observe drainage conditions. First the investigators rode or walked over the entire project and established the survey stations of the changes in soil types. An approximate idea of the location of the soil series was obtained from the course of the project on the Bureau of Soils map (Fig. 2); but the condensed and tabulated descriptions of the soils of the region, similar to those given in Table 1, and the diagram of their location with respect to the topography shown in Figure 1 furnished the most reliable means of checking the identification of the soil series. For instance, it was evident from Figure 1 that a residual soil found in the rough, mountainous districts must be either Olympic, Aiken, Melbourne, or Underwood. By a comparison of the field

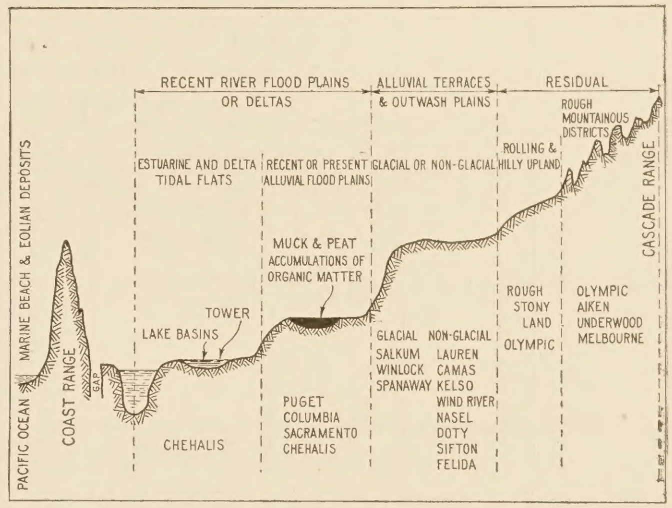

FIG. 1.—A general topographical cross section of southwestern Washington showing the location of the several soil series. Such diagrams greatly simplify the identification of soils by reducing the number of possibilities

observations with the characteristics shown in Table 1 it was then possible to arrive at the series name by a process of elimination, checking the types by feeling between the fingers. The importance of this latter check can not be unduly stressed. It was possible by this means in the Pacific Highway study to locate in the vicinity of streams narrow belts of the Chehalis series which were not considered of sufficient importance by the Bureau of Soils to include in the reconnaissance survey map.

The boundaries between the soil types were often well defined and frequently could be determined within 1 or 2 feet. At other places the transition from one soil type to another was gradual and it was necessary to approximate the point of change within a belt perhaps 40 or 50 feet wide. Having determined the points of change, the various series and types of soils encountered and the survey stations of the points of change were tabulated as shown by the example given in Table 2.

[5] The data in Table 1 were digested from the Reconnaissance Survey of Southwestern Washington, U. S. Department of Agriculture, Bureau of Soils, issued May 15, 1913.

Table 1.—*Description and history of some of the soils encountered on the Pacific Highway*

Series	Colors: Soil	Colors: Subsoil	Derivation	Origin and material	Topography	Characteristics	Drainage	Types
RESIDUAL SOILS								
Olympic	Light brown to reddish brown.	Brown lighter than soils.	From basaltic rocks which underlie surface at from 3 to 25 feet and occur in weathered fragments on surface and in soil and subsoil.	Frequently of silty texture. In small areas some andesitic material and locally some colluvial material from the same rocks has been included.	Rough, hilly, or mountainous. Some areas comparatively level.	Outcrops of basalt and presence in soil of fragments of same rock.	Thorough to excessive.	Stony loam (Ost). Loam (Ol). Silt-loam (Osl). Stony clay-loam (Os). Silty clay-loam (Osc). Clay (Oc). Dark colored land-slide phase.
Aiken	Dark brick red or purplish red to dark.	Bright red or reddish brown.	From basalt with admixture in some places of materials from andesitic or other eruptive rocks.	Residual bowlders and small fragments of rock found through soil mass. Bed rock lies shallow.	Areas lie on slopes or plateau-like uplands. Gently sloping to steep, rough, and broken.	Brick-red color of soil.	Efficiently to excessively drained.	Stony clay (As). Silty clay-loam (Ac).
Underwood	Yellow brown to gray brown.	Same as soil	Residual origin, but include some areas of colluvial formation.	Fragments of basalt size of small gravel to large bowlders, many of spherical form frequently found in soil and subsoil.	Rolling to steep and hilly foothill districts and foot slopes of mountains.	Numerous soft iron pellets occur in soil. Most numerous near surface and range from coarse sand to pellets ½ inch in diameter.	Well drained.	Loam (Ul).
SOILS OF THE GLACIAL PLAINS AND RIVER TERRACES								
Lauren	Reddish or light brown to dark brown.	Light brown or brown, sometimes mottled.	Probably formed from ancient alluvial or marine sediments derived from basaltic rocks, porous.	Soil underlain by porous substratum of stratified sand and fine gravel with occasional pockets or strata of coarse gravel.	Occupies elevated terraces lying adjacent to and above present stream valleys.	Presence of soft iron-cemented pellets on surface.	Well drained.	Gravelly coarse sandy loam (Lg). Sandy loam (Lsl). Fine sandy loam. (Lf). Silt-loam (Ls).
Camas	Light to dark brown.	Light to reddish brown.	Recent alluvial terraces from basaltic rocks.	Type occupies low terraces and alluvial fans at mouths of small creeks emptying into Columbia. Soil and subsoils contain rounded or subangular gravel and bowlders.	Surface level to gently sloping or undulating.	Soils contain numerous iron pellets. Outcrops of basalt and angular fragments of basalt occur on steeper slopes.	do	Stony gravelly loam (Cst). Gravelly sandy loam (Gg). Silt-loam (Cl).
Kelso	Grayish to reddish brown.	do	Material forming terraces which lie about 40 feet above bed of present flood plains is derived from glacial deposits and in part from areas occupied by residual Olympic and Melbourne soils.	Subsoil underlain by substratum of gray silt-clay and sand containing pockets of fine water-worn gravel. Basaltic bed rock.	Surface gently sloping or undulating.		do	Silty clay-loam (Ks).
SOILS OF THE RECENT FLOOD PLAINS AND DELTAS								
Sacramento	Dark gray to drab or black.	Drab or brown may be mottled.	Recent alluvial flood plain material deposited from shifting stream currents or slack flood waters. Has been transported long distances.	Comes from quartz-bearing and quartz-free igneous rock and metamorphic rock and some from sedimentary rock and glacial material. Contains a large amount of organic matter. Deeper subsoil at 3 to 5 feet is fine sand.	Occupies stream bottoms and flood plains. Often marked by sloughs subject to overflow. Surface varies from irregular to smooth.	Large amount of organic matter.	Subject to overflow.	Silty clay-loam (Sc).
Chehalis	Gray or drab to reddish brown, dark brown to black.	Yellow-gray, sometimes mottled, light brown, dark brown, or black.	Material has been eroded mainly from fine-textured soils occupying the uplands and deposited in river valleys in times of flood.	Recent alluvial, occupying valleys of streams that traverse humid regions of residual soils from basalt and sedimentary rocks.	Almost level. Sloughs or abandoned stream channels are frequent.	Heavier types contain much organic matter.	Good natural drainage.	Loam (Ch). Silty clay-loam (Ccl). Clay-loam (Cc). Silty clay (Cs). Clay (C).

Table 1.—*Description and history of some of the soils encountered on the Pacific Highway*—Continued

SOILS OF THE MARINE BEACH AND ÆOLIAN DEPOSITS

Series	Colors		Derivation	Origin and material	Topography	Characteristics	Drainage	Types
	Soil	Subsoil						
Westport fine sand.	Gray to white sand.		Shore drift	Material which has been built up above sea level by the combined action of waves and wind.	Occupy spits on each side of entrance to Willapa Bay and narrow strips on the seaward side of a part of the areas occupied by Westport fine sand.	No agricultural value. Lie above high tide. Inundated during heavy storms.	Good	Fine sand (We).
Coastal beach and dune sand.	Gray to light yellow gray fine sand.	Mottled yellow, gray and brown fine sand.	Material derived from beach deposits. Type confined to western part of Pacific County, Wash.	Aeolian origin. Top, incoherent, fine sand, 12 to 14 inches. Subsoil the same to depth of 3 feet or more. Surface has small percentage of organic matter.	Marked by a series of low, rounded ridges 5 to 25 feet high with corresponding depressions between. Lies very little above sea level. A few small level areas occur.	Typical mottled subsoil. Vegetation on long sandy areas a stunted growth of fir. Dense under-growth of salal.	do	Costal beach and dune sand (Cd).

SOILS DERIVED MAINLY FROM ORGANIC DEPOSITS

Series	Soil	Subsoil	Derivation	Origin and material	Topography	Characteristics	Drainage	Types
Muck and peat	Brown	Grayish black to black.	Occupy poorly drained areas.	Occur in basins where conditions are favorable for growth and preservation of rank vegetation. Organic matter in various stages of decomposition. Consist of few inches of coarse vegetable fiber underlain by 18 to 20 inches of grayish black to black muck which in turn rests on a bed of peat. Underlain by fine sand at 3 to 5 feet.	Areas are flat and lie low. Covered with water during a part of the year. Some areas occur on terraces or uplands and are underlain by impervious clay.	Underlying sand at 3 to 5 feet.	Poorly drained.	Muck and peat (Mp).

Table 2.—*Identification of soil types*

Town	Mile number	Station to station	Soil series	Soil type	Abbreviation
La Center	0	850			
		879+23- 902+80	Felida	Silt-loam	Fs.
	1	902+80- 933+00	do	do	Fs.
		933+00- 937+00	Aiken	Silty clay-loam	Ac.
		937+00- 949+00	Felida	Silt-loam	Fs.
		949+00- 955+60	Aiken	Stony clay	As.
	2	955+60-1, 008+40	do	do	As.
	3	1, 008+40-1, 012+00	do	do	As.
		1, 012+00-1, 045+50	Felida	Silt-loam	Fs.
		1, 045+50-1, 058+50	Aiken	Stony clay	As.
		1, 058+50-1, 061+20	Felida	Silt-loam	Fs.
	4	1, 061+20-1, 089+00	do	do	Fs.
		1, 089+00-1, 114+00	Aiken	Stony clay	As.
	5	1, 114+00-1, 120+00	do	do	As.
		1, 120+00-1, 124+00	Puget	Fine sandy loam.	Pl.
		1, 124+00-1, 125+50	Felida	Silt-loam	Fs.
		1, 125+50-1, 133+50	Puget	Fine sandy loam.	Pl.
		1, 133+50-1, 135+00	Felida	Silt-loam	Fs.
		1, 135+00-1, 138+00	Puget	Fine sandy loam.	Pl.
		1, 138+00-1, 143+00	Felida	Silt-loam	Fs.
Bridge over North Fork Lewis River		1, 143+00-1, 155+30	Bridge	None	
		1, 155+30-1, 166+80	Puget	Fine sandy loam.	Pl.
Woodland	6	1, 166+80-1, 179+40	do	do	Pl.
		1, 179+40- =84+32			
		84+32- 99+00	do	do	Pl.
		99+00- 100+35	do	Silt-loam	Ps.
		100+35- =0+35			
		0+35- 23+00	do	do	Ps.
		23+00- 24+17	Kelso	Silty clay-loam	Ks.
	7	24+17- 51+00	do	do	Ks.
		51+00- 76+97	Olympic	do	Osc.
	[1] 8	76+97- 129+77	do	do	Osc.
	41	152+89- 164+00	Toutle	Very fine sand	Ts.
		164+00- 168+50	Olympic	Silty clay-loam	Osc.
		168+50- 172+00	Toutle	Very fine sand	Ts.

Table 2.—*Identification of soil types*—Continued

Town	Mile number	Station to station	Soil series	Soil type	Abbreviation
		172+00- 189+00	Toutle over.	Very fine sand over	Ts.
			Olympic	Silty clay-loam	Osc.
		189+00- 198+50	Puget	Fine sandy loam.	Pl.
Toutle River bridge		198+50- 200+00	Bridge	None	
		200+00- 201+50	Kelso	Silty clay-loam	Ks.
		201+50- 205+69	Toutle	Very fine sand	Ts.
	42	205+69- 223+00	do	do	Ts.
		223+00- 243+00	Puget	Silt-loam	Ps.
		243+00- 252+00	Kelso	Silty clay-loam	Ks.
		252+00- 258+49	Olympic	do	Osc.
	43	258+49- 270+00	do	do	Osc.
		270+00- 281+00	Puget	Silt-loam	Ps.
		281+00- 304+00	Kelso	Silty clay-loam	Ks.
		304+00- 311+29	Olympic	do	Osc.
	44	311+29- 348+00	do	do	Osc.
		348+00- 364+09	Kelso	do	Ks.
	45	364+09- 389+00	do	do	Ks.
		389+00- =0+00			
		0+00- 27+89	do	do	Ks.
	46	27+89- 62+00	do	do	Ks.
		62+00- 80+69	Winlock	Silty clay	Wsc.
	47	80+69- 92+50	do	do	Wsc.
		92+50- 318+17			
		318+17- 277+18	do	do	Wsc.
	48	277+18- 224+38	do	do	Wsc.
	49	224+38- 171+58	do	do	Wsc.
	50	171+58- 118+78	do	do	Wsc.
	51	118+78- 79+00	do	do	Wsc.
		79+00- 72+00	Chehalis	Silty clay-loam	Ccl.
		72+00- 65+98	Salkum	do	Ss.
	52	65+98- 13+18	do	do	Ss.
	53	13+18- 11+15	do	do	Ss.
North end Toledo bridge		11+15-			

[1] Data for miles 9-40, inclusive, omitted for sake of brevity.

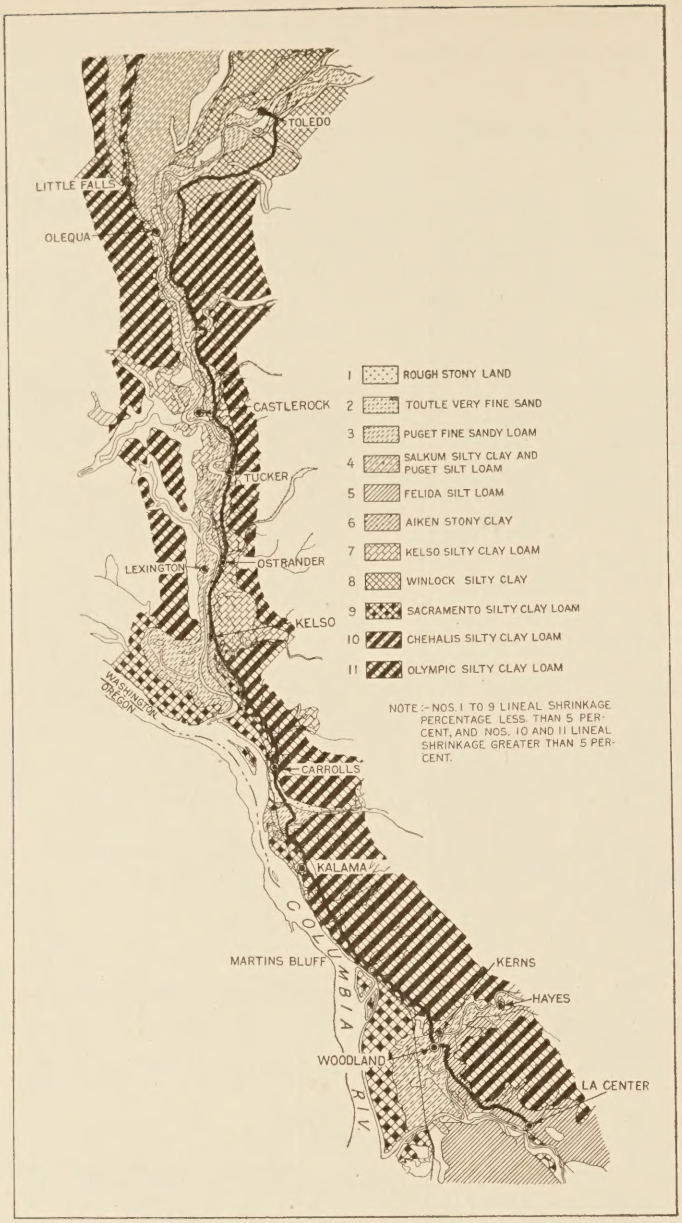

FIG. 2.—The variations in soil types on the Pacific Highway between La Center and Toledo, Wash., are shown by the legends which shade from white to black with the increase in the clay content of the soil

TABLE 3.—*Results of field tests*

Sample No.	Location of sample: Layer	Location of sample: Station	Mile No.	Soil series and type	Moisture equivalent (average of 2 runs)	Lineal shrinkage (average of 2 runs)	Volumetric shrinkage (computed)
					Per cent	*Per cent*	*Per cent*
63	Topsoil	996+25	2. 8	Aiken stony clay	31. 2	2. 49	7. 3
64	Subsoil	996+25	2. 8	do	35. 9	9. 19	25. 0
65	Topsoil	1, 080+50	4. 4	Felida silt-loam	28. 3	2. 4	7. 3
66	Subsoil	1, 080+50	4. 4	do	30. 7	4. 0	11. 7
67	do	1, 141+00	5. 5	Locally known as blue clay.	22. 8	2. 9	8. 7
68	do	174+00	9. 8	Olympic clay	57. 2	14. 1	36. 1
69	do	492+00	27. 0	do	40. 3	9. 4	25. 8
70	Topsoil	505+00	27. 3	Puget fine sandy loam.	26. 3	0. 1	0. 5
71	Subsoil	505+00	27. 3	do	34. 0	1. 3	4. 0
72	Topsoil	513+00	27. 4	Sacramento silty clay-loam.	43. 6	3. 6	10. 6
73	Subsoil	513+00	27. 4	do	42. 6	4. 3	12. 5
74	Topsoil	16+50	28. 7	Kelso silty clay-loam	21. 9	1. 1	3. 1
75	Subsoil	16+50	28. 7	do	23. 6	0. 6	2. 0
76	Topsoil	19+83	28. 8	Puget silt-loam	37. 3	2. 1	6. 1
77	Subsoil	19+83	28. 8	do	27. 8	1. 6	4. 8
78	Topsoil	12+00	29. 3	do	36. 8	1. 0	3. 0
79	Subsoil	12+00	29. 3	do	26. 5	0. 5	1. 5
80	Subsoil, 20 feet down.	141+00	31. 8	Kelso silt-loam	26. 8	0. 5	1. 5
81	Topsoil	236+00	33. 6	Kelso silty clay-loam	34. 4	3. 2	9. 8
82	Subsoil	236+00	33. 6	do	26. 9	1. 6	5. 0
83	do	105+00	40. 1	Toutle gravelly coarse sand.	8. 2	. 0	. 0
84	Topsoil	119+00	40. 4	Toutle very fine sand.	26. 4	. 0	. 0
85	Subsoil	119+00	40. 4	do	32. 6	0. 6	2. 0
86	Topsoil	139+22	40. 7	Olympic silty clay-loam.	36. 4	7. 8	21. 8
87	Subsoil	139+22	40. 7	do	33. 5	3. 6	10. 6
88	Topsoil	168+00	41. 3	Winlock silty clay	36. 4	3. 5	10. 5
89	Subsoil	168+00	41. 3	do	30. 1	4. 4	12. 6
90	Topsoil	73+50	46. 9	Chehalis silty clay-loam.	41. 3	8. 1	22. 0
91	Subsoil	73+50	46. 9	do	35. 3	7. 1	19. 8
92	do	25+00	52. 8	Salkum silty clay	40. 2	1. 9	6. 0
93	do	25+00	52. 8	do	41. 3	1. 0	3. 0

TABLE 4.—*Maximum and minimum values of the lineal shrinkage of soils on the Pacific Highway*

	Soil series and type	Abbreviation	Extent		Lineal shrinkage	
					Topsoil	Subsoil
			Miles	*Per cent*	*Per cent*	*Per cent*
Residual soils.	Olympic silty clay-loam.	Osc	16. 84	31. 80	7. 8	3. 6
	Olympic clay	Oc	. 90	1. 70		9. 4–14. 1
	Aiken stony clay	As	2. 03	3. 83	2. 5	9. 2
	Aiken silty clay-loam	Ac	. 08	. 15		
	Rough, stony land	Rsl	2. 65	5. 00		
Soils of glacial plains and terraces.	Toutle gravelly coarse sand.	Tg	. 05	. 09		
	Toutle very fine sand	Ts	2. 05	3. 87		. 6
	Salkum silty clay	Ss	1. 15	2. 17	1. 9	1. 0
	Winlock silty clay	Wsc	5. 11	9. 63	3. 5	4. 4
	Kelso silty clay-loam	Ks	10. 84	20. 44	1. 1–3. 2	. 6–1. 6
	Felida silt-loam	Fs	2. 61	4. 91	2. 4	4. 0
Soils of the recent plains and deltas.	Puget fine sandy loam	Pl	3. 97	7. 50	. 1	1. 3
	Puget silt-loam	Ps	2. 11	3. 97	1. 0–2. 1	. 5–1. 6
	Columbia fine sand	Cfs	. 42	. 79		
	Sacramento silty clay-loam.	Sc	. 63	1. 19	3. 6	4. 3
	Chehalis silty clay-loam.	Ccl	. 13	. 24	8. 1	7. 1
	Bridges, etc		1. 44	2. 72		
	Total		53. 01	100. 00		

The project was then retraced and representative samples were selected from the types previously identified. These samples consisted of two full seamless galvanized salve cans of each type. The cans were 3 inches in diameter and 2½ inches deep. Some of the excavations being of such a depth that the subgrade was composed of material beneath the top layer described in the Bureau of Soils survey, special samples of these subsoils were taken and these were treated as special types.

By utilizing in this way the Bureau of Soils data in combination with the test by feeling with the fingers, it was possible to identify on the Pacific Highway project some 76 changes in the soil types, but these included only 16 different series and types and it was necessary to make field tests on only 31 samples in order to secure the limiting values for all the soils encountered. This gives some idea of the saving in time and labor made possible by the use of the Bureau of Soils bulletin. If this bulletin or similar data had not been available for the area it might have been necessary to make hundreds of tests in order to secure accurate information with regard to the soils of the entire project.

TABLE 5.—*Mechanical analysis of soil types found along the Pacific Highway by the United States Bureau of Soils survey*

Soil: Series	Soil: Type	Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
			P.ct.	*P.ct.*	*P.ct*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*
Olympic	Silty clay-loam.	Soil	0.5	3.0	1.4	5.6	10.0	53.6	25.7
		Subsoil	.3	2.0	1.5	4.2	6.5	44.6	40.7
Do	Clay [1]								
Aiken	Stony clay	Soil	.5	2.1	2.1	4.9	5.5	38.4	46.5
		Subsoil	.2	1.5	1.1	3.9	6.0	49.1	38.1
Do	Silty clay-loam.	Soil	.2	1.4	2.0	5.9	12.3	51.5	26.7
		Subsoil	.4	1.3	1.4	4.7	9.0	62.5	20.7
Rough, stony land.[2]									
Toutle	Gravelly coarse sand.	Soil	11.2	22.8	13.3	22.1	11.4	14.6	4.7
		Subsoil	12.1	22.4	12.7	22.3	12.5	14.4	3.5
Do.[3]	Very fine sand.								
Salkum	Silty clay	Soil	.5	1.2	1.1	3.3	3.1	59.4	31.5
		Subsoil	.2	1.1	1.2	3.2	3.6	55.6	34.6
Winlock	do	Soil	.0	1.4	.8	1.9	3.0	60.3	32.2
		Subsoil	.0	2.1	1.3	3.3	4.7	57.6	30.6
Kelso	Silty clay-loam.	Soil	.5	2.6	1.7	2.9	3.6	60.1	28.5
		Subsoil	.2	1.5	1.1	2.1	2.0	71.1	21.8
Felida	Silt loam	Soil	.4	3.2	1.7	3.3	11.9	63.6	15.8
		Subsoil	.0	1.0	.6	2.2	10.7	69.7	15.7
Puget	Fine sandy loam.	Soil	.4	.3	1.8	24.0	20.3	43.1	10.0
		Subsoil	.1	.3	3.1	66.7	21.0	6.7	1.7
Do	Silt-loam	Soil	.0	.2	.1	2.0	4.4	82.7	10.5
		Subsoil	.1	.4	3.5	37.4	22.9	32.5	3.7
Columbia [4]	Fine sand								
Sacramento	Silty clay-loam.	Soil	.0	.3	.6	1.7	.8	72.2	24.1
		Subsoil	.1	.5	.6	1.1	1.3	70.3	25.9
Chehalis	do	Soil	.0	.1	.1	2.6	5.8	64.8	26.4
		Subsoil	.0	.0	.2	1.9	1.0	64.7	32.1

[1] Large proportion of clay present.
[2] No analysis is given but considerable quantities of reddish brown clay are intermingled with the rock.
[3] No analysis given but a large proportion of very fine sand and a small percentage of organic matter is present in the soil. Large proportion of very fine sand in the subsoil.
[4] Practically all sand.

IDENTIFICATION OF BUREAU OF SOILS TYPE NAMES MAKES POSSIBLE A GREATER SAVING OF TIME ON FUTURE WORK

More important, however, than the saving of time on a single project is the fact that the correlation of the results of the tests with the series to which the soils belong will be useful in still further reducing the amount of testing required when the same soils are encountered on other projects. When the tests have been made on a sufficient number of roads to establish the limiting values for all the soils of a region, then it should be possible to make future subgrade surveys with a Bureau of Soils bulletin and map without making any tests except those which will always be required on the soils which vary in characteristics so as to be always doubtful.

The degree of certainty with which the characteristics of particular soils may ultimately be established by means of repeated tests may be appreciated by reference to Table 3. Two of the soils listed in the table—the Kelso silty clay-loam and the Olympic clay subsoil—will be used as an example. The lineal shrinkage percentages of the Kelso soil as determined by the tests varied from 1.1 to 3.2. The corresponding percentages for the Olympic soil varied from 9.4 to 14.1. Although the range in the latter case may seem rather great, there is in both cases a sufficient similarity in the values to establish the first soil as a good subgrade material and the latter as a bad subgrade material.

SOIL SAMPLES SUBJECTED TO SIMPLE FIELD TESTS

The soil samples selected in the manner described above were subjected to simplified field tests to determine their moisture equivalent and lineal shrinkage percentages. The methods employed in making these tests have been described in detail in a previous issue of PUBLIC ROADS,[6] and these descriptions are repeated here briefly for convenient reference.

Moisture equivalent percentage test.—The test is made by taking a 500-gram sample of air-dried soil, breaking up the lumps, placing the sample in a bowl, adding water slowly from a burette, and mixing the water and soil until it reaches the consistency of putty and may be compacted with a spoon or spatula without any free water remaining on the surface. Water is then allowed to drop upon the smoothed surface as long as it is absorbed. Before the moisture equivalent percentage is reached the sample will absorb water readily but when the critical value is passed the surface will assume a wet, shiny appearance. The sample is then weighed and dried out at 105° C. and the percentage of water is calculated on the basis of the dry weight of the soil.

Lineal shrinkage percentage test.—A 300-gram sample of soil wetted to moisture equivalent percentage is packed in ½-inch layers in a galvanized iron mold (1 inch by 1 inch by 10 inches) with a wooden tamper (½ inch by 1½ inches by 14 inches). The bars thus formed, after being weighed, are pushed from the mold upon a porcelain plate and calipered and then oven-dried at 105° C. and calipered again. The difference in length computed as a percentage of the wet length of the bar is considered the lineal shrinkage percentage.

The lineal shrinkage rather than the volumetric shrinkage is considered the preferable test because the vertical distortion of the subgrade due to the volume changes in the soil is believed to have the greatest effect upon the stability of the pavement.

The results of the tests made on the samples taken on the Pacific Highway are shown in Table 3, and the maximum and minimum values of the lineal shrinkage percentage for each soil together with the extent of the occurrence in the road bed are given in Table 4. This particular test is thus summarized because it is the critical test for subgrade soils. The moisture equivalent test is valuable principally as an indication of what the lineal shrinkage may be, and a similar value attaches to the mechanical analyses of the Bureau of Soils, shown in Table 5, because of the more or less close relation of the moisture equivalent percentage and the clay content of the soil.

SHORT CUTS POSSIBLE ON RECONNAISSANCE SUBGRADE SURVEYS

In advance of the definite classification of the subgrade soils of a region by the methods suggested above, it is possible to avoid a considerable amount of testing on rough, reconnaissance surveys by accepting the clay content of the soils as shown by the mechanical analyses of the Bureau of Soils as a rough criterion of their value. Such rapid surveys may be necessary when only a limited amount of time is available for the subgrade study. From the examination of a large number of soils in the Pacific Northwest it has been found to be the general rule that when the Bureau of Soils mechanical analysis shows a percentage of clay of 20 or less the lineal shrinkage percentage will be less than 5 per cent, which is below the limiting safe percentage for a subgrade soil in the Pacific Northwest. For instance, consider the Felida silt-loam. According to the mechanical analyses made by the Bureau of Soils (Table 5) this soil has a clay content of 15.8 per cent. The lineal shrinkage was found

[6] Practical Field Tests for Subgrade Soils, PUBLIC ROADS, vol. 5, No. 6, August, 1924.

by tests to be 2.4 per cent, which confirms the soil as a good subgrade material. (See Table 3.) Similarly it will be observed that all the soils listed in Table 5 as having a clay content of 20 per cent or less are shown in Table 3 to have safe lineal shrinkage values.

On the other hand, there are a number of soils the clay content of which exceeds 20 per cent which also are shown by the shrinkage tests to fall within the safe limit, but such soils should always be considered of doubtful value until their suitability is definitely proved by shrinkage tests. For example, Table 5 shows the Winlock silty clay to have a clay content of 32.2 per cent. This was therefore a doubtful subgrade material until the lineal shrinkage percentage was determined to be 3.5 per cent, which established it as a good subgrade soil. Sometimes, however, the clay content by mechanical analysis is very deceptive. An example of this may be seen in the Chehalis silty clay-loam with a clay content according to Table 5 of 26.4 per cent. While this percentage exceeds the limiting value of 20,

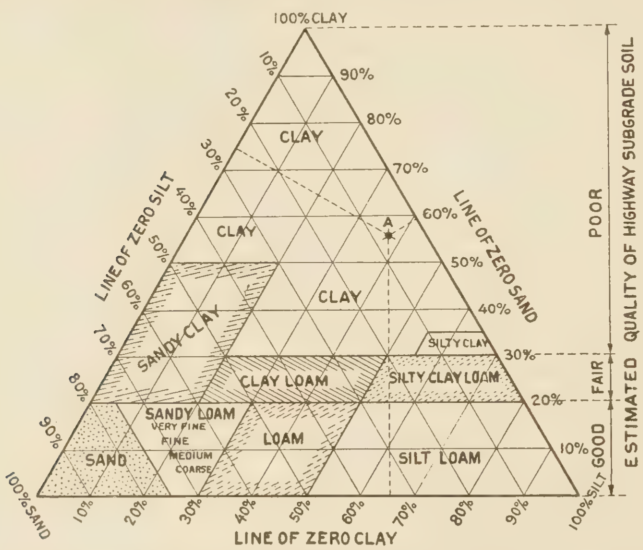

FIG. 3.—Trilinear soil classification chart for identification of good and bad subgrade soils in reconnaissance surveys. The nomenclature of the type areas is designed to agree with that of the United States Bureau of Soils

adopted as the rough criterion for the Pacific Northwest, it does not greatly exceed it, yet the shrinkage tests showed this material to have a lineal shrinkage percentage of 8.1, which far exceeds the 5 per cent believed to be the limit for a good subgrade soil.

The writer does not advocate that the limits of clay content suggested for the Pacific Northwest be accepted for any region without verification. They are simply a guide to what seems to be a logical method. On the contrary, it is recommended that the various soil series and types as classified by the Bureau of Soils be tested a number of times over different areas of the same general region until it is believed that the upper and lower limits of the variations in the test values have been established. It is very likely that an investigator will then be able to walk over a road project through an area which has been mapped by the Bureau of Soils and, after identifying the soil types and determining their location, pick out at once the good and bad subgrades on the basis of tests made on similar soils found elsewhere in the region. But even under the most favorable circumstances doubtful soils may be found which will require testing before judgment may be passed upon them.

For rough reconnaissance survey purposes the soil classification triangle, Figure 3, may be used in connection with the Bureau of Soils survey bulletins for evaluating the subgrades. The triangle is plotted according to Professor Ferêt's method (Annales Des Ponts et Chaussées, 1892); and the nomenclature of the type areas is designed to agree with that adopted by the Bureau of Soils to describe the various soil types. The percentage of clay of 20 by mechanical analysis is shown as the upper limit for a good subgrade soil. Where the clay content by mechanical analysis is greater than or near 20 per cent the soil may make a doubtful or bad subgrade and these soils should be tested in all cases. Tests for lineal shrinkage show many soils within the zone of 20 to 30 per cent of clay to have a lineal shrinkage percentage of less than 5 per cent. These have therefore been roughly classified as fair subgrades. But, generally speaking, soils with a clay content by mechanical analysis of 30 per cent or more have a lineal shrinkage of more than 5 per cent and are, therefore, believed to be bad subgrade material.

In a former article [7] the writer stated that for road soil reconnaissance survey purposes the clay content by mechanical analysis may be considered as equal to the moisture equivalent percentage. This statement was based upon the following formula developed by Briggs and Shantz: [8] Moisture equivalent $= 0.02$ sand $+ 0.22$ silt $+ 1.05$ clay. Field tests have indicated that for rough reconnaissance survey purposes this formula could be modified so that the clay content could be considered as equivalent numerically to the moisture equivalent percentage. This is not always true, especially when the silt content is high and the clay content low. But because of the variable character of soils it is not believed that any formula of this kind can be developed which will hold true in all cases, nor even in a majority of cases. The moisture retentivity varies not only with the size of the soil particles but also with the character of the surface and structure of the grains, whether they be glazed or rough, solid or porous. In general, however, the moisture equivalent percentage does increase with the percentage of clay, and on the basis of tests made by the writer the clay content alone seems to be as good an indicator of the moisture equivalent as the formula of Briggs and Shantz.

INTERPRETATION OF THE SOIL TESTS

As previously pointed out the most important of the test results are the lineal shrinkage percentages. These afford the best indication of the probable behavior of the soil in the subgrade. But it must be borne in mind that the shrinkage percentage is materially affected by the presence of coarse material. The shrinkage test is made on samples of the soil from which all particles larger than 1 millimeter ($\frac{1}{25}$ inch) have been excluded by screening. If, therefore, a considerable amount of coarse material is present in the soil as it occurs in the field the actual field shrinkage may be considerably less than the test values indicate. Consequently it is necessary to estimate the amount of coarse material present in the field and to use this information in conjunction with the test values for shrinkage to identify finally the unsuitable subgrade soils.

[7] Practical Field Tests for Subgrade Soils. Public Roads, Vol. 5, No. 6, August 1924.

[8] The wilting coefficient for different plants and its indirect determination. U. S. Dept. of Agriculture Bulletin No. 230.

TABLE 6.—*The reduction in the lineal shrinkage percentage of a Cove clay soil caused by the addition of varying amounts of sand of various gradings*

Kind of mixture	Moisture equivalent—average of two runs	Lineal shrinkage—average of two runs	Volumetric shrinkage (computed)
	Per cent	*Per cent*	*Per cent*
1 part medium sand to 1 part of soil	20.1	1.64	5.0
1 part medium sand to 2 parts of soil	25.7	2.75	8.0
1 part medium sand to 5 parts of soil	35.4	5.30	15.0
1 part medium sand to 10 parts of soil	38.1	9.08	24.9
1 part medium sand to 20 parts of soil	39.4	11.10	29.9
1 part coarse sand to 2 parts of soil	25.9	5.20	15.0
1 part fine sand to 2 parts of soil	27.5	7.32	20.5
All soil	40.5	13.46	35.2

	Per cent
Coarse sand:	
Passing ¼-inch and retained on 10-mesh sieve	33
Passing 20-mesh and retained on 40-mesh sieve	67
Medium sand:	
Passing 10-mesh and retained on 20-mesh sieve	33
Passing 20-mesh and retained on 40-mesh sieve	67
Fine sand:	
Passing 40-mesh and retained on 200-mesh sieve	100

TABLE 7.—*Locations on project where lineal shrinkage percentage of soil exceeds 5 per cent*

Locality	Station to station	Soil series
La Center to Woodland	933 – 937	Aiken.
	949 –1,012	Do.
	1,045+50–1,058+50	Do.
	1,089 –1,120	Do.
Woodland to Martins Bluff	51 – 219	Olympic.
Martins Bluff to Kalama	219 – 452	Do.
Kalama to Carrolls	474+50– 589+07	Do.
	589+07– 0+00	
	0 – 67+50	Do.
	78+50– 80+50	Do.
	230 – 250	Do.
Carrolls to Kelso	250 – 319+50	Do,
	322+50– 509	Do.
Kelso to Ostrander	None	
Ostrander to Castlerock	None	
Castlerock to Toledo	127 – 148	Do.
	164 – 168+50	Do.
	172 – 189	Do.
	252 – 270	Do.
	304 – 348	Do.
	72 – 79	Chehalis.

TABLE 8.—*Locations on project where lineal shrinkage of soil together with intermingled rock is estimated to exceed 5 per cent*

Locality	Station to station	Soil series
La Center to Woodland	933 – 937	Aiken.
	1,045+50–1,058+50	Do.
	1,089 –1,120	Do.
Woodland to Martins Bluff	162+50– 185	Olympic.
	202 – 207+50	Do.
Martins Bluff to Kalama	281 – 313	Do.
	314+50– 452	Do.
Kalama to Carrolls	12 – 33	Do.
	230 – 250	Do.
Carrolls to Kelso	250 – 255	Do.
	346 – 381	Do.
	390 – 421	Do.
	449 – 498+50	Do.
Castlerock to Toledo	127 – 148	Do.
	164 – 168+50	Do.
	304 – 348	Do.
	72 – 79	Chehalis.

The sample of Olympic clay taken at Station 174 in the sliding ground 4 miles north of Woodland on the Pacific Highway may be cited as an example to show the difference between the actual field shrinkage and the test shrinkage value. The sample passed through the 1-millimeter screen showed a lineal shrinkage of 14.1 per cent (a singularly high value). A sample of unscreened soil from exactly the same location, with some sand and small pebbles present, showed a lineal shrinkage of only 8.2 per cent, thus showing how materially the shrinkage is reduced by relatively small quantities of coarse material.

The effect of various quantities of coarse material on the lineal shrinkage is further shown by field tests made on a sample of Cove clay in Oregon. The results of adding to this soil various percentages of coarse, medium, and fine sand are shown in Table 6 and Figure 4. It will be observed that this soil when tested with the coarse material excluded showed a lineal shrinkage of 13.46 per cent, which would class it as a very undesirable subgrade soil. Yet the addition of 1 part of medium sand to 5 parts of the screened soil is sufficient to reduce the shrinkage to practically 5 per cent and thus convert it into a fairly satisfactory material.

On the Pacific Highway the tests showed the soil to have a lineal shrinkage percentage greater than 5 per cent at the locations listed in Table 7. But within these sections an examination of the soil in the field showed that there were considerable areas in which the

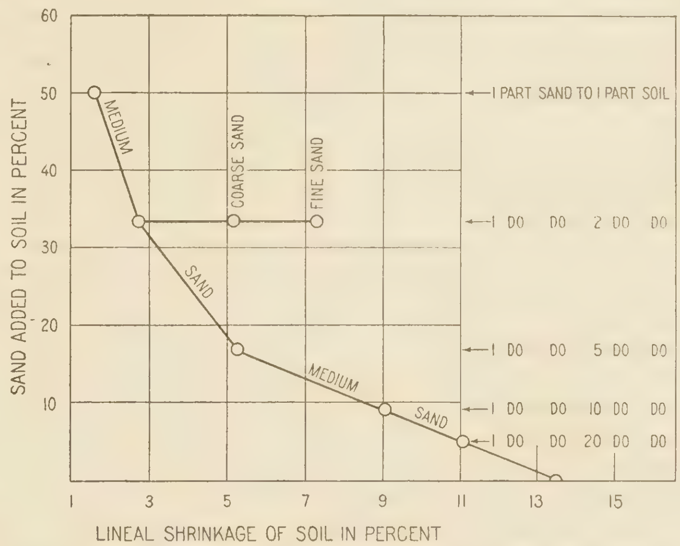

FIG. 4.—Results of tests made on a sample of Cove clay soil to show the decrease in lineal shrinkage resulting from the addition of sand

soil was only a fraction of the mantle rock. In these cases the actual shrinkage of the soil in the field was estimated from the test values and the observed field conditions, and it was finally concluded that the lineal shrinkage would probably exceed 5 per cent only in the sections listed in Table 8, the aggregate length of which was 48,350 feet or 9.2 miles, and only about 17 per cent of the 53-mile section. The soils in these sections, it will be noted, were mainly of the Aiken and Olympic series, in which the clay content, according to Table 5, is higher than in any other soils found on the project.

In making the above correction for the presence of coarse material in the soil the relative percentages of soil and rock were estimated and the resulting shrinkage was computed with the voids in the rock assumed at 50 per cent. For example, if the soil were found to have a lineal shrinkage of 8 per cent, and the mantle rock were composed of 70 per cent soil and 30 per cent rock with the soil filling the voids in the rock, it was computed that 55 per cent of the entire mass would shrink and the composite lineal shrinkage of the mass would be 4.4 per cent.

(Continued on page 115)

EARTH PRESSURE AGAINST ABUTMENT WALLS MEASURED WITH SOIL PRESSURE CELLS

BY THE DIVISION OF TESTS, U. S. BUREAU OF PUBLIC ROADS

Reported by J. V. McNARY, Highway Bridge Engineer, U. S. Bureau of Public Roads

THE different theories for determining the pressure of filling material against retaining walls now in general use give, for the same assumptions, comparable results. Variation in results is caused mainly by variation in the values assigned to the constants of the formulae. Different authorities give constants for the same conditions of filling which show a wide range. A digest of the standard specifications of the several States, which are presumed to cover what might be termed average conditions, shows that formulae are employed which give results that range from the pressure that would be caused by a fluid weighing 15 pounds per cubic foot to that which would be caused by a fluid weighing 36 pounds per cubic foot.

These variations emphasized by the not infrequent incipient failure and the occasional complete failure of abutment and wing walls have given rise to the feeling that in many instances the constants are not properly chosen or that other factors which receive insufficient attention are of major importance.

The soil pressure cell,[1] developed by the Bureau of Public Roads, has made possible the measurement of the force exerted by a fill against an abutment or retaining wall under actual working conditions. Tests have been made with this instrument at the Bennings Road and Sixteenth Street bridges in Washington, D. C., on hydraulic fills of clay at the Arlington Experimental Farm, Arlington, Va., and at the Skellit Fork bridge, near Wayne City, Ill. Only the Sixteenth Street and Skellit Fork bridge tests are described here, but a single reading from each of the tests mentioned above with formulae from several handbooks, all reduced to equivalent fluid pressures, are shown in Figure 1 for purposes of comparison.

The conclusion drawn from these actual tests is that the pressure of earth against a retaining wall should not under ordinary conditions be assumed to be less than that which would be developed by a fluid weighing 30 pounds per cubic foot. By definitely showing that a direct relation exists between the high pressures measured and a condition of high moisture content prevailing at the time, the tests also indicate the importance of suitable provisions for draining the fill. Such provisions should be regarded as major features of the work of equal importance with the design and construction of the wall itself.

THE SIXTEENTH STREET BRIDGE TEST

The Sixteenth Street Bridge carries the street over Military Road. Military Road leaves the floor of the main valley and ascends to high ground to the east through a branch ravine and Sixteenth Street, descending at a uniform grade of about 5 per cent, from the high ground 1,500 feet to the south crosses this ravine and reaches the main valley floor about 1,000 feet north of the bridge site. Thus the bridge is located on a hillside and the topography is such that the south or uphill abutment and wing walls intercept the ground water flow and the surface drainage from the long hill above. The abutments are founded on good shale and

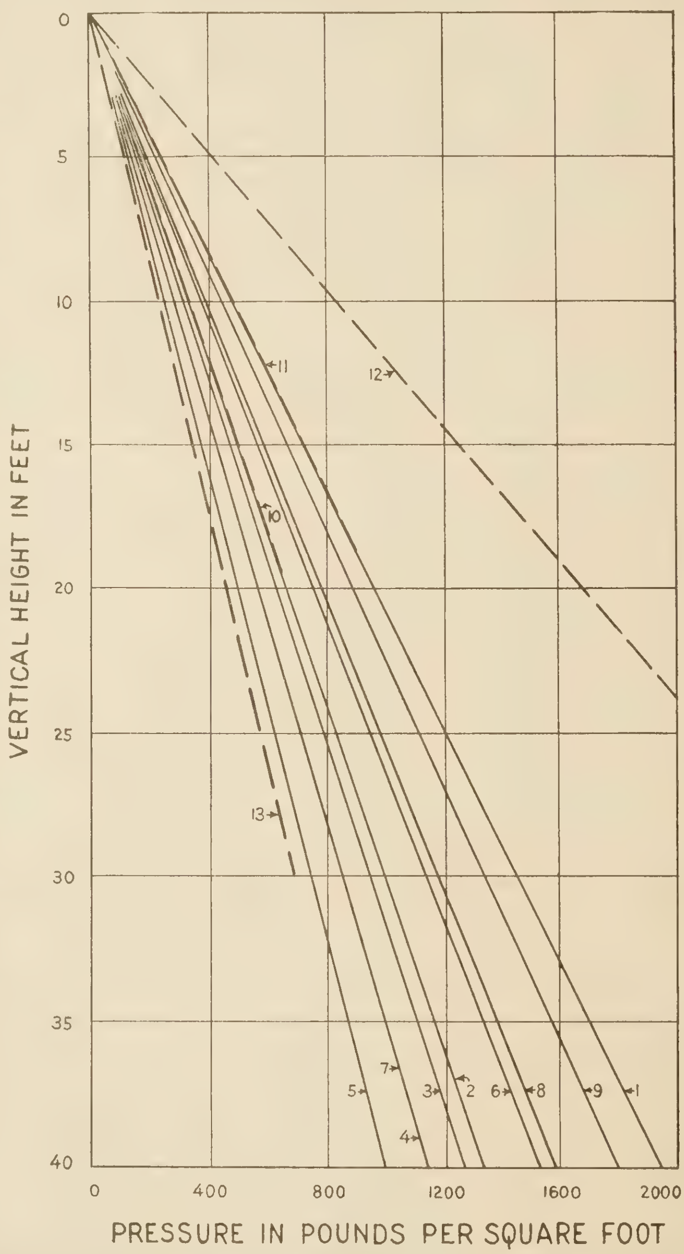

FIG. 1.—Pressures determined by Rankines formula for different kinds and conditions of filling compared with pressures determined by Bureau of Public Roads Soil Pressure cells. Results from Rankines formula shown by solid lines and dash lines show experimental results.

KEY

(1) Worst case of "ordinary earth, wet; weight per cubic foot, 120 pounds; angle of repose, 25°." Equivalent to fluid weighing 48.7 pounds per cubic foot. Hool and Johnson Concrete Engineers Hand Book.

(2) Most favorable case of "ordinary earth, wet; weight per cubic foot, 100 pounds; angle of repose, 30°." Equivalent to fluid weighing 33⅓ pounds per cubic foot. Hool and Johnson Concrete Engineers Hand Book.

(3) Retaining wall fill, weighing 100 pounds per cubic foot; angle of repose, 30°. Equivalent to fluid weighing 33⅓ pounds per cubic foot. Author gives C=16. Equivalent to fluid weighing 32 pounds per cubic foot. Paaswell.

[1] For description of the soil pressure cell, see PUBLIC ROADS, vol. 3, No. 28, August, 1920.

(4) Customary assumptions; fill weighing 100 pounds per cubic foot; angle of repose, 1½ to 1=33° 40′. Equivalent to fluid weighing 28.7 pounds per cubic foot.
(5) "Dry earth; weight per cubic foot, 100 pounds; angle of repose, 36° 53′." Equivalent to fluid weighing 25 pounds per cubic foot. American Civil Engineers Pocket Book.
(6) "Mud; weight per cubic foot, 100 pounds; angle of repose, 26° 34′." Equivalent to fluid weighing 38.2 pounds per cubic foot. American Civil Engineers Pocket Book.
(7) "Sand, gravel, and clay; wet; weight per cubic foot, 115 pounds; angle of repose, 36° 53′." Equivalent to fluid weighing 28.7 pounds per cubic foot. American Civil Engineers Pocket Book.
(8) "Soil dumped into water; weight per cubic foot, 70 pounds; angle of repose, 15° 57′." Equivalent to fluid weighing 39.5 pounds per cubic foot. American Civil Engineers Pocket Book.
(9) "Clay dumped into water; weight per cubic foot, 80 pounds; angle of repose, 15° 57′." Equivalent to fluid weighing 45 pounds per cubic foot. American Civil Engineers Pocket Book.
(10) Bureau of Public Roads tests, Benning Road Bridge, D. C. Equivalent to fluid weighing 33.4 pounds per cubic foot.
(11) Bureau of Public Roads tests, Sixteenth Street Bridge, D. C. Equivalent to fluid weighing 48.4 pounds per cubic foot.
(12) Bureau of Public Roads tests on hydraulic fill of clay. Equivalent to fluid weighing 84.5 pounds per cubic foot.
(13) Bureau of Public Roads tests, Skellit Fork Bridge, Wayne City, Ill.; low moisture content in filling material; no rain between time of filling and date of readings. Equivalent to fluid weighing 23.2 pounds per cubic foot.

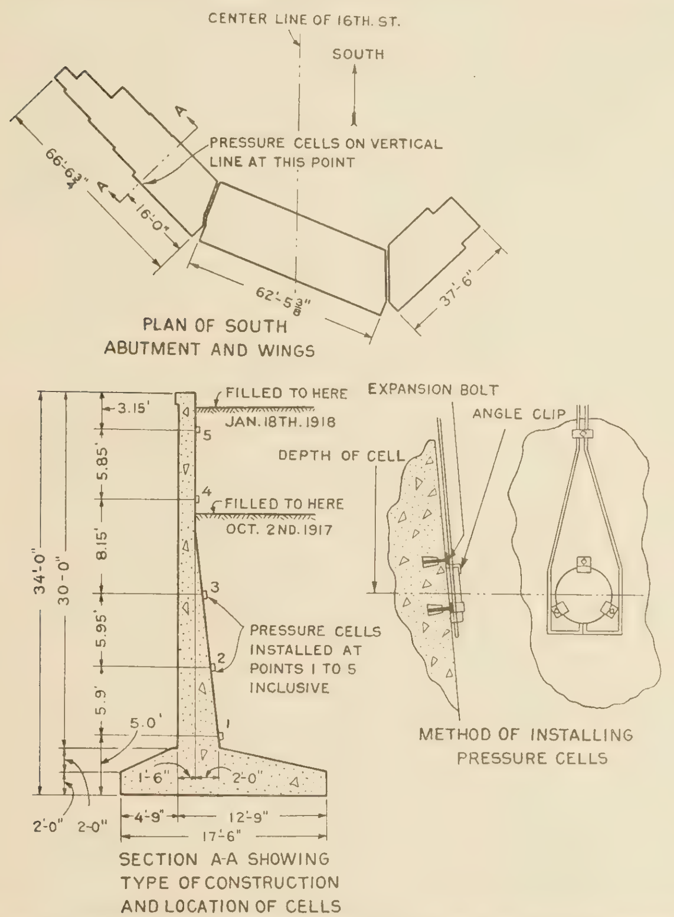

FIG. 2.—The plan of an abutment and a section of the wing wall of the Sixteenth Street Bridge

are constructed in three separate units. The breast walls or abutments proper are of mass concrete of the gravity type while the wings are of the reinforced-concrete, cantilever type. No provision for draining the fill was made in either the abutment or wings. The filling material which was placed with hand shovels, was very thoroughly compacted by a force of men with hand rammers. The shovelers and rammers were so proportioned that the material was well tamped in horizontal layers of from 1 to 3 inches in thickness. Filling was started August 29, 1917, and by October 2, 1917, had been carried up to a point 6.85 feet above cell No. 3 where work was discontinued. It was resumed the first of the year and filling was completed by January 18, 1918. Figure 2 shows the plan of this abutment and a section of the wing wall.

Five standard soil-pressure cells were placed back of the southeast wing wall. As the installation was made after the wall was completed it was not possible to set the faces of the cells in the plane of the back of the wall; instead the cells and their connections had to be attached to the back of the wall with expansion bolts. The location of the cells and the method of installing them are also shown in Figure 2.

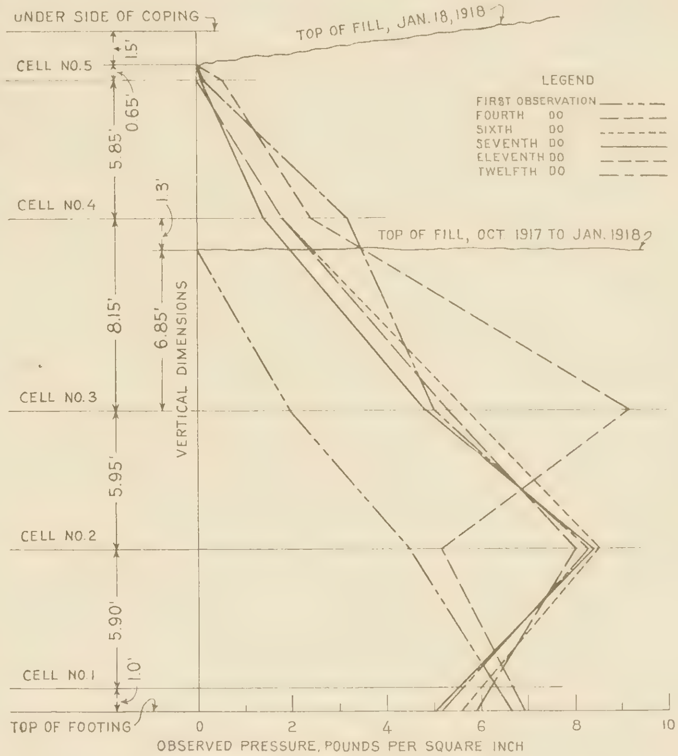

FIG. 3.—The observed pressures on the soil pressure cells used in the Sixteenth Street Bridge test

From October 2, 1917, to January 27, 1919, 12 observations were made at this bridge, the first 3 during the interval while work was suspended. The pressures read on the soil pressure cells are given in the following table and are shown graphically in Figure 3.

Observation	Date	Pressures as determined by pressure cells				
		No. 1	No. 2	No. 3	No. 4	No. 5
	1917	*Pounds per square inch*	*Pounds per square inch*	*Pounds per square inch*	*Pounds per square inch*	*Pounds per square inch*
1	Oct. 2	6.3	4.5	1.95	----------	----------
2	Nov. 12	6.3	4.5	2.2	----------	----------
3	Dec. 4	6.3	[1] 4.2	2.1	----------	----------
	1918					
4	May 4	6.2	8.0	5.3	[2] 1.8	(3)
5	May 9	6.6	8.4	5.7	1.6	0.2
6	May 14	(4)	8.5	5.7	1.8	0.2
7	June 17	5.4	8.4	5.0	1.4	0.1
8	June 28	5.5	8.4	4.8	1.4	0.7
9	Aug. 8	5.9	8.9	4.9	(5)	0.1
10	Oct. 11	5.8	8.5	4.8	[6] 1.7	0.5
11	Dec. 20	6.65	5.15	9.15	(5) (6)	0.55
	1919					
12	Jan. 27	5.6	8.28	5.00	[7] 3.2	0.15

[1] Air pressure ran to about 5 pounds per square inch before a short circuit was discovered.
[2] Cell No. 4 slightly clogged.
[3] Two feet broken off of wire pipe.
[4] Air pressure exceeded the earth pressure before a short circuit was discovered. Readings a few minutes later showed only 1.5 pounds per square inch. Cell should return to normal after fill readjusts itself.
[5] Wire pipe broken, pipe system partially clogged.
[6] Air pipe closed.
[7] Reading taken on wire pipe, pipe almost closed.

The absence of any definite increase of pressure on cell No. 1 from the increased depth of fill is probably due to the internal friction of the filling material, since this cell is only one foot above the top of the concrete footing which slopes away from the back of the wall.

In the eleventh observation an unusually low pressure on cell No. 2 is accompanied by an unusually high pressure on cell No. 3. This is believed to be due to readjustment within the fill. It is probable that the fill in the region of cell No. 2 subsided as the result of natural consolidation while the upper material was partially supported by arch action against the abutment in the region of cell No. 3, thus relieving cell No. 2 of pressure while cell No. 3 was subjected to the increased pressure created by the arch action. The next observation gave a normal reading on cell No. 2 with a low reading on No. 3 and a high reading on cell No. 4, showing that in the process of consolidation the arching action was working toward the top of the fill and gradually disappearing.

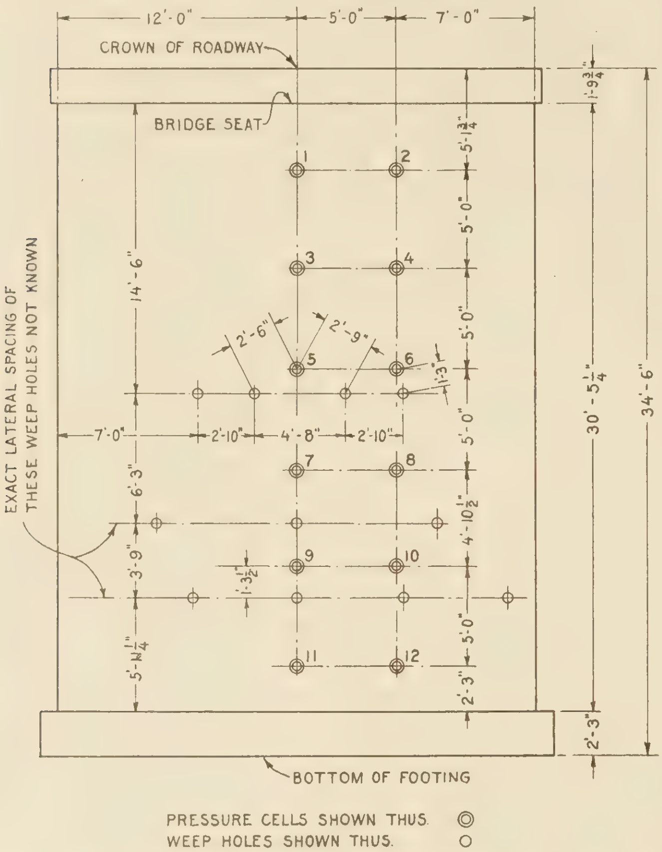

FIG. 4.—The location and spacing of the soil pressure cells used in the Skellit Fork Bridge test

The weight per cubic foot of a fluid that would give a total pressure equal to the total observed pressure for each observation is given in the table following:

Observation	Weight of equivalent fluid	Observation	Weight of equivalent fluid
	Pounds per cubic foot		*Pounds per cubic foot*
1	47.6	7	44.2
2	48.8	8	44.6
3	47.0	9	46.3
4	46.4	10	45.8
5	48.8	11	54.4
6	48.3	12	48.9

Although on good foundation material and of a cross-section that should satisfactorily support the ordinarily assumed loads, the wall has moved outward at the top about two inches, thus confirming the presence of the unusually high pressures shown by the pressure cells.

The filling material was of a clayey nature and the initial observation was undoubtedly affected by the thoroughness of the mechanical compacting while it was being placed. Continued high pressure, however, is most probably due to a high moisture content. As previously stated the wall is so situated that it intercepts both ground water flow and surface drainage and is not provided with any means of drainage. The joint between the wing wall and the abutment wall discharges seepage throughout its entire height showing that the fill becomes saturated to the top. Comparison with the Weather Bureau records shows that the higher pressures were observed after a period of several days precipitation and the lowest pressure at the end of a period of no precipitation. The highest pressure, shown by observation No. 11, was noted six days after a precipitation of 2.87 inches in the form of snow on unfrozen ground with the temperature above freezing each day.

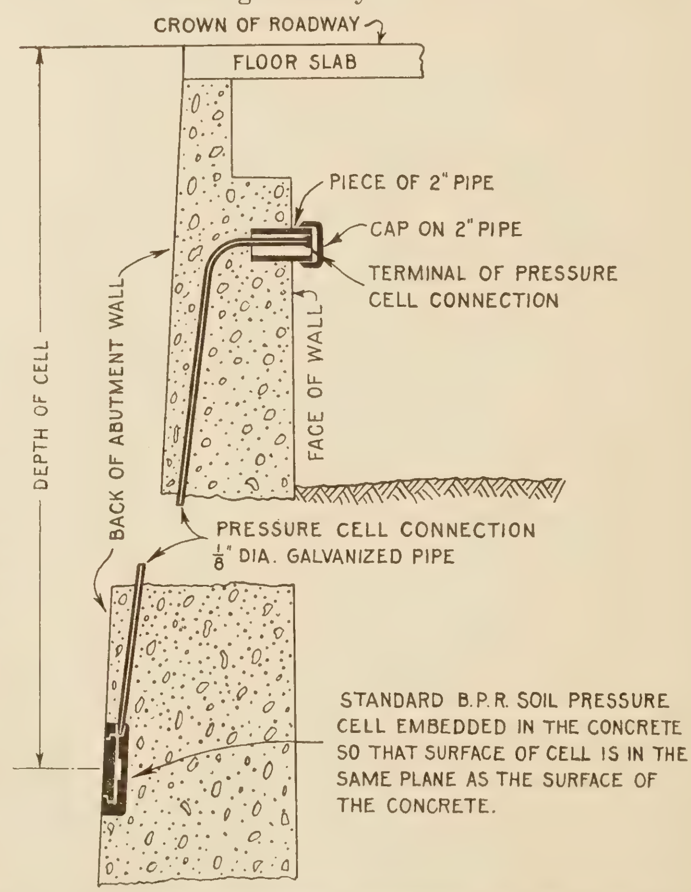

FIG. 5.—The manner of installing the soil pressure cells in the Skellit Fork Bridge test

SKELLIT FORK BRIDGE TEST

The test on the bridge over Skellit Fork was made by the Bureau of Public Roads in cooperation with the division of highways of the Illinois Department of Public Works and Buildings. The entire crossing consists of the bridge over the stream channel, and fills, on a level grade, raised a few feet above high water across the rest of the flood plain. The flood plain is subject to inundation practically every spring.

The abutment is of the Illinois standard reinforced U type, 32 feet, 3¼ inches from the top of the footing to the grade line, and 24 feet wide on the face wall.

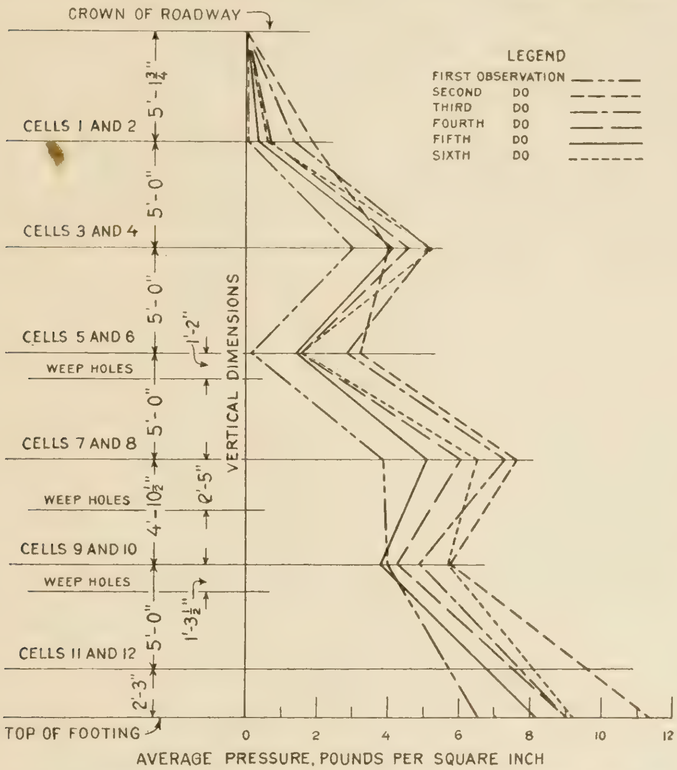

FIG. 6.—Average pressures on cells at the same elevation in the Skellit Fork Bridge test

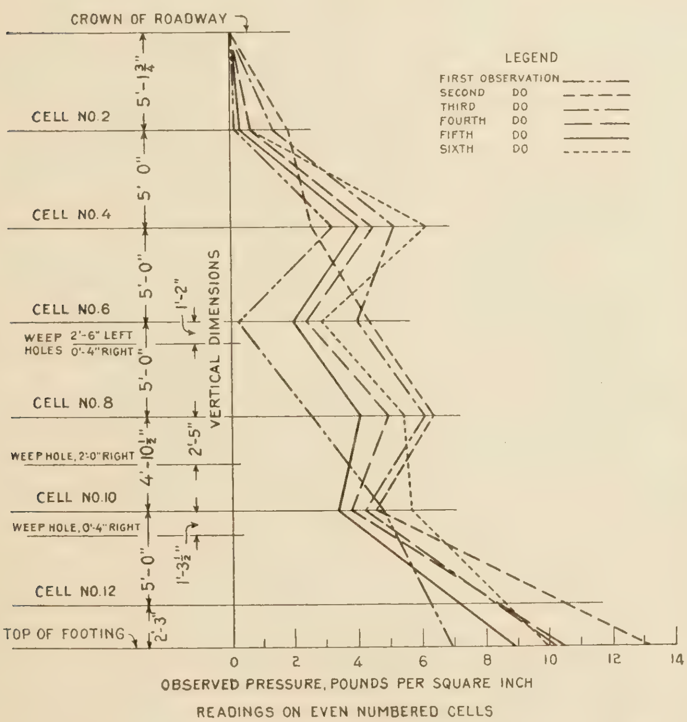

FIG. 7.—Observed pressures on the even-numbered cells in the Skellet Fork Bridge test

The Illinois standard practice in regard to methods of construction, drainage, and manner of placing the filling material were followed.

The installation was planned and the first cells placed by a representative of the Bureau of Public Roads after which the installation was completed by the Illinois division of highways. Two cells were used at each elevation in order to reduce the effects of local areas of high or low pressure. The location of the cells is shown in Figure 4 and the manner of installing them is shown in Figure 5. Observations were made jointly by representatives of the Bureau of Public Roads and the State division of highways. A total of six observations have been made up to the present time, the data from which are given in the following table:

Observation	Date	Pressures as determined by pressure cells (pounds per square inch)					
		No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
1	1921 Nov. 8	0.0	0.1	2.86	3.2	0.2	0.2
2	1922 Apr. 28	1.77	1.87	5.6	2.53	2.10	4.37
3	May 27	1.30	1.40	5.37	5.13	1.70	3.97
4	July 21	0.73	0.70	4.76	4.52	0.83	2.33
5	Aug. 28	0.50	0.27	4.28	4.05	0.90	1.93
6	1923 June —	0.57	0.70	4.50	6.15	0.50	2.35

Observation	Date	Pressures as determined by pressure cells (pounds per square inch)					
		No. 7	No. 8	No. 9	No. 10	No. 11	No. 12
1	1921 Nov. 8	5.23	2.56	3.2	4.8	5.3	6.25
2	1922 Apr. 28	8.86	6.4	7.0	4.53	8.92	10.45
3	May 27	8.47	6.15	5.77	4.17	7.30	8.30
4	July 21	7.20	4.97	4.83	3.77	6.82	8.30
5	Aug. 28	6.15	4.08	4.33	3.33	6.50	7.15
6	1923 June —	7.50	5.55	5.75	5.70	7.70	8.63

The first observation was made November 8, 1921. The filling had been completed but a short time and there had been no rain between the time of completion and the making of the observations, so that the data represent the pressure due to an artificially compacted filling having a low moisture content. As the filling was done at the close of the dry season and considerable moisture would evaporate during the process of handling and placing of the material it is probable that the moisture content of the fill was lower than it might be expected to be at any subsequent time.

The second observation was made April 28, 1922, within 24 hours after high water had receded from the abutment. The spring of 1922 was marked by heavy snows, long continued heavy rains, and excessively high water, and the stream was over its banks a number of times during the month before the observation was made. The water content of the fill therefore was probably as near to the point of saturation as would ordinarily be obtained in a roadway embankment and abutment fill.

No unusual conditions existed at the time of the third, fourth, and fifth observations which were made in May, July, and August of 1922. The sixth observation was made during the first week of June, 1923, shortly after the subsidence of the spring floods and the moisture content of the fill was probably considerably above the average. The observed pressures are shown graphically in Figures 6, 7, and 8.

The readings on cells Nos. 5 and 6 are exceptionally low. An explanation of this phenomena might be found in the character and method of placing the fill in the vicinity of these cells, the possible interruption of the work for a considerable length of time near this elevation, and the weather conditions. However, data concerning these features are not available.

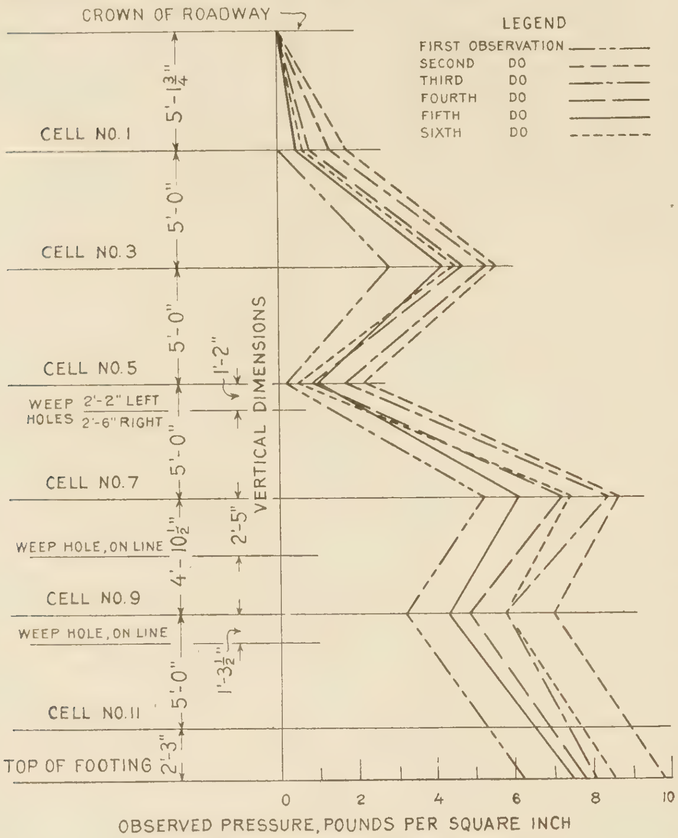

Fig. 8.—Observed pressures on the odd-numbered cells in the Skellit Fork Bridge test

In the second observation cells Nos. 2 and 4 exhibit the same phenomena as cells Nos. 2 and 3 at the Sixteenth Street bridge in the eleventh observation. On the subsequent observations these cells showed normal readings.

It is believed that the pronounced irregularities of the pressure curves may be accounted for in part by the method of drainage. The weep holes consist of openings through the wall without any provisions for conducting the seepage to them. It would be expected therefore, that the portion of the fill drained would be immediately above the opening and its size would depend on the character of the filling material and lapse of time. Examination of the curves shows the peaks of pressure to occur at those cells most distant from the weep holes. The cells more distant from the weep holes show a greater increase in pressure when the moisture content of the fill is raised, and a greater reduction in pressure as the interval of time between the period of high moisture content and the time of observation increases.

The weight per cubic foot of a fluid that would give a total pressure equal to the total observed pressure for each observation is given in the following table:

Observation	Weight of equivalent fluid	Observation	Weight of equivalent fluid
	Pounds per cubic foot		*Pounds per cubic foot*
1	23.2	4	34.7
2	44.1	5	29.8
3	40.5	6	38.0

It will be noted that the lowest pressure was observed immediately after the fill was placed and was equal to that caused by a fluid weighing 23.2 pounds per cubic foot. The highest pressure occurred at the time of highest moisture content of the fill and was equal to that caused by a fluid weighing 44.1 pounds per cubic foot.

As the fill lost a part of its water content the pressures gradually decreased but did not go as low as the initial observation, although the fifth observation, which showed the next lowest pressure, was taken at the same time of year and when the fill, except for the solidification which had taken place during the year, was in practically the same condition. This pressure was equal to that caused by a fluid weighing 29.8 pounds per cubic foot.

Even after the fill had settled for a year and a half the pressure again became quite high when the moisture content increased, reaching a value equal to that which would be produced by a fluid weighing 38 pounds per cubic foot.

It is believed that the differences in pressure shown by the various readings are algebraic quantities made up of a gradual increase in pressure caused by the natural settling and compacting of the fill and an increase or decrease in pressure as the water content increases or decreases. The former factor will gradually decrease with the lapse of time so that after the fill has reached its final settlement the total variation in pressure may be attributed to the fluctuations in the water content of the filling material.

TRANSPORTATION OF MILK BY MOTOR TRUCK IN THE CHICAGO DAIRY DISTRICT

A STUDY OF HIGHWAY UTILIZATION BY THE U. S. BUREAU OF PUBLIC ROADS

Reported by E. L. BROWNE, Agricultural Economist

APPROXIMATELY 44,000 8-gallon cans of milk were delivered daily to the city of Chicago during 1924 by 26 railroads, which carried 68 per cent of the supply, and 141 motor trucks, which transported 32 per cent. If any milk consumed in the city was delivered in any other way the amount was negligible.

Thirty years ago the bulk of the supply was brought into the city in wagons and distributed by the individual producers. The city had then less than half its present population. In the course of the next year or two the growth of the population and the extension of urban development into the surrounding country crowded the dairy farms back beyond a wagon's haul distance of the city, and by 1898, according to an early report of the department of health, a large part of the city's supply was being delivered by railroad, the report showing a daily rail delivery by 17 roads of 16,100 8-gallon cans.

Another change in the method of transportation began about 1904, when the electric railroads began to take over a portion of the business from the steam roads. The amount hauled by the electric roads increased from year to year until the competition of the motor truck began to make itself felt, and finally the truck compelled the discontinuance of electric-road shipments in 1924. The movement reached its height between 1915 and 1920, and the largest electric carrier in the Chicago tributary area held on until January, 1924, although its shipments had decreased from 179,022 8-gallon cans in 1920 to 80,322 in 1923.

As shown by Table 1, the total daily delivery of milk to the city in 1910 was 31,245 8-gallon cans, of which 29,400, or 94 per cent, were transported by steam railroads; 600 cans, or 2 per cent, by electric railroads; and 1,245, or 4 per cent, by wagon. By 1924 the electric railroad and wagon shipments had ceased and only the steam railroads and the motor truck shared in the delivery of the 43,994 8-gallon cans, which were transported daily, the former with 68 and the latter with 32 per cent of the business. The motor truck had taken over all the business formerly handled by the electric roads and the wagons and a part of the business of the railroads, although the shipments of the latter remained practically the same in volume as they were in 1910.

TABLE 1.—*Milk delivered daily to Chicago consumers, 1910 and 1924*

Method of transportation	1910 Number of 8-gallon cans	1910 Per cent of total	1924 Number of 8-gallon cans	1924 Per cent of total
Steam railroads	29,400	94	29,904	68
Electric railroads	600	2		
Wagons	1,245	4		
Motor trucks			14,090	32
Total	31,245	100	43,994	100

REASONS FOR INCREASE IN MOTOR-TRUCK DELIVERY

It is not difficult to account for the change from wagon to motor truck delivery. The building up of a circle of suburban towns, golf courses, and subdivisions about the city has simply crowded the dairy farms back until it is no longer possible to make deliveries by wagon on account of the excessive time required for the haul.

As to the other business that has been developed by the motor truck—a part of it comes from areas within a 50-mile radius of the city which formerly were too far

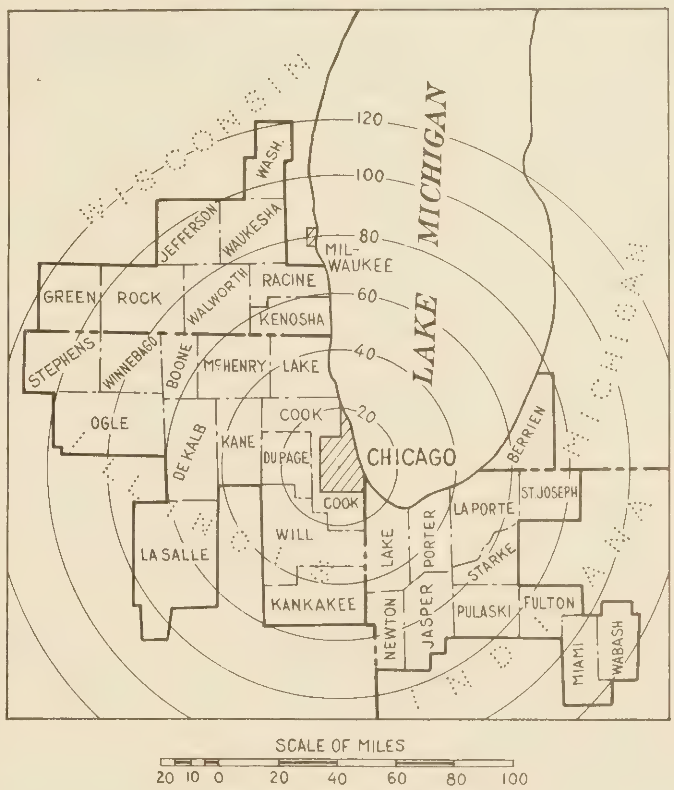

FIG. 1.—The Chicago milk shed

distant both from the city and from the railroad shipping points to be reached by wagon haul. The balance has been taken from the steam and electric railroads, mainly within the 50-mile zone, as a result of certain advantages possessed by the truck, among which the following are the most important:

1. The truck passes the producer's gate, thereby furnishing a service which can not be duplicated by the railroads.
2. The driver of the truck acts as the producer's agent from the farm to the city dealer and performs a marketing as well as a transportation service.
3. Shipment by truck instead of by railroad reduces the number of handlings from half a dozen or more to only two.
4. The trucks lose fewer cans than the rail carriers.

5. An estimated saving of 5 cents a hundredweight is effected on all milk trucked in by the elimination of the haul from the railroad milk platform to the city milk dealer.

As practically all of the business formerly handled by the electric roads originated within the short-haul zone, the advantages possessed by the motor truck have enabled it to make such inroads as finally to force the discontinuance of the electric service. The steam roads also have lost a considerable part of their short-haul business, but by developing new territory beyond the normal trucking radius have kept the volume of their shipments up to the 1910 level. The evidence of this change in the character of the railroad business is the considerable increase of milk mileage reported by railroads operating in territories where motor vehicle competition is especially keen.

PRESENT SOURCES OF SUPPLY AND METHODS OF TRANSPORTATION

Chicago's milk supply is produced by 350,000 cows owned on 25,000 dairy farms located in northeastern Illinois, southern Wisconsin, and northwestern Indiana. (See fig. 1.) During periods of extreme shortage some

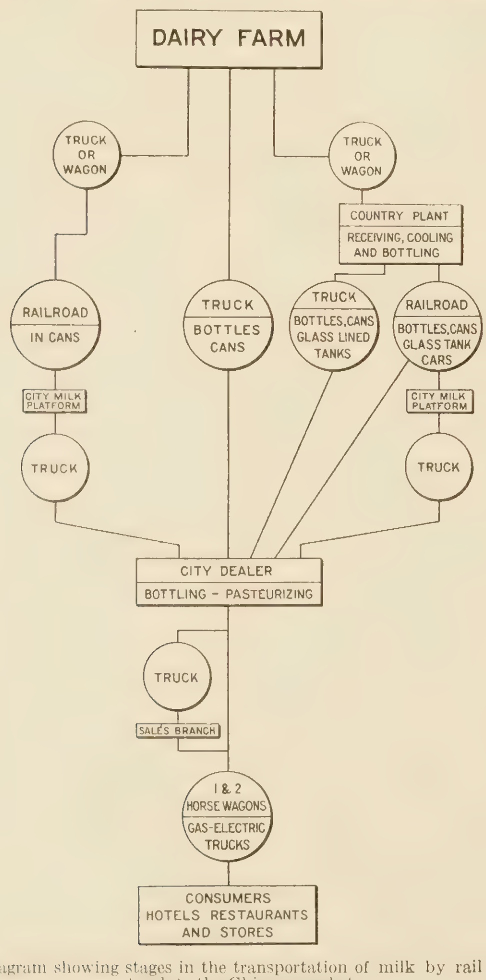

FIG. 2.—Diagram showing stages in the transportation of milk by rail and motor truck to the Chicago market

milk is shipped from eastern Iowa and southwestern Michigan.

Approximately 25 per cent of the milk produced is shipped directly either by road or railroad from the producer to the city milk dealer. The larger balance is received from the producers at country milk plants, most of which are operated and owned by the dealers, and which are classified according to their character and purpose as—

1. Country bottling plants, where milk is received, pasteurized, cooled, and bottled for shipment to the city.
2. Receiving stations, where milk is weighed in, cooled, and prepared for shipment in cans or glass-lined tank cars or trucks.
3. Cream stations, which are smaller and less expensive stations, where cream is purchased and pasteurized.

The milk that is collected at these country plants and that which is shipped by railroad must first be hauled to the plant or railroad shipping point. This is called country hauling and is often accomplished individually or by groups of farmers who agree to carry the milk in turn or employ a driver to haul it. Then there is the man who makes a business of country hauling. He usually operates in territories of heaviest production and covers a regularly laid out route, employing for the purpose trucks during most of the year, but substituting horses in times of heavy snowfall. Practically all milk that is shipped by railroad is handled first on a country haul whether it passes through a country plant on its way to the city or not; that which is shipped by truck moves directly to the city except when it is received at a country plant. The 8 or 10 gallon can is the capacity in general use in this area.

The milk which is shipped directly to the city and that which is handled through country plants subsequently finds its way to the Chicago market by one of the following methods:

I. By truck.
   1. Direct from the farm in 8-gallon cans.
   2. From receiving stations in glass-lined tank trucks.
   3. In bottles from certified milk farms.
   4. In 8 or 10 gallon cans from receiving stations.

II. By railroad.
   1. Direct in 8 or 10 gallon cans.
   2. From receiving stations in glass-lined tank cars.
   3. In bottles from country bottling stations.
   4. In 8 or 10 gallon cans from receiving stations.

The several methods of transportation, the number of handlings, and the character of the containers used for each method are shown diagrammatically in Figure 2.

DELIVERY TIME AND REGULARITY OF TRUCK AND RAIL SERVICE

Country bottling plants.—The delivery time under this system from producer to consumer for the oldest portion of each day's supply—namely, the evening milking—is approximately 36 to 44 hours. The general practice is to take the evening's and morning's milk to the country plant between the hours of 6 and 9 a. m. At the plant it is weighed, clarified, pasteurized, cooled, and bottled in the forenoon. In the afternoon of the same day it is loaded into cars, iced, and shipped to the city. The cars are switched at once to the industrial sidings controlled by the dealers, unloaded directly onto their platforms, and transferred to the waiting wagons for morning delivery. The milk is in transit from four to six hours, depending on the length of the haul and the time consumed in making the railroad transfer.

Can shipments.—When the milk is pasteurized and bottled in the city the practice of the producer is to deliver both night's and morning's milk to the railroad shipping point between the hours of 6 and 8 a. m., where it is picked up by a local milk train and transported to the various city milk platforms. The average haul for can milk approximates 48 miles. The greatest distance from which regular milk trains carry milk in cans is 90 miles. Milk on such trains is seldom refrigerated. It is usually in transit from two to four hours, and an additional hour is required for city hauling.

Trucked-in milk.—Trucked-in milk is usually picked up from small milk platforms placed at intervals along the roadside. During the summer months many trucks cover lanes and side roads, taking milk directly from the farm milk houses. In the winter months

Fig. 3.—Truck with trailer designed to comply with the sanitary regulations of Chicago

and when the frost is coming out of the ground the bulk of the milk is hauled by the farmer to the hard-surfaced road where it is picked up by the truck. On a large milk route a 3½-ton truck can pick up a full load (80 to 120 cans) in one hour. After loading, the truck increases its speed for the remainder of the

Table 2.—*Average trip time in hours for trucks of various capacities hauling in the various mileage zones*

Capacity of truck	Mileage zones						
	5–9	10–14	15–19	20–24	25–29	30–34	35–39
	Trip time						
	Hours	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*
Less than 1 ton	1						
1 ton			1¼		1½		
1¼ tons				1½		2	
1½ tons				1½		3	
2 tons			2		2½	3	
2½ tons			1¾	2	2¼	2½	3
3 tons			2		3	3	
3½ tons			2	2¼	2¾	3	3
5 tons		1½	2	2¼	2½	2¾	3½
Over 5 tons			2½		3		

Capacity of truck	Mileage zones					
	40–44	45–49	50–54	55–59	60–64	70–74
	Trip time					
	Hours	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*
Less than 1 ton						
1 ton	3¼			3½		4½
1¼ tons	3					4½
1½ tons		3½				
2 tons	3½	4	4			
2½ tons	3¼		4	4	4¼	
3 tons				5		
3½	3½	3¾	4	5		
5 tons	4	4	4½	5½		
Over 5 tons	3½				5	

trip to the city plant. Milk is usually picked up between the hours of 6.30 and 8.30 a. m. during the summer months and one-half to an hour later in winter. An inclosed truck of the type required by the Department of Health is shown in Figure 3; and the points from which milk is shipped by truck are shown in Figure 4.

Table 2 shows the average trip time of trucks of various capacities engaged in hauling milk in the various mileage zones. The averages which are based on records of 141 trucks show that there is a marked correlation between capacity and speed. Thus it will be noted that the trucks operating from points 20 to 74 miles distant make a higher average speed. The relatively slower speed of trucks operating within the 20-mile zone is undoubtedly due to congestion and the frequency with which grade crossings are met. The latter handicap is especially noticeable on roads entering the city from the south.

BULK SHIPMENT

Bulk transportation, new as it is, is attracting more attention in Chicago than any other new feature of milk transportation. This method has developed along two lines—the tank truck and the tank car. Each is adapted to certain methods of marketing and each has a distinct sphere of operation.

Fig. 4.—Origin and method of transporting all milk originating within motor trucking radius of Chicago

Tank cars.—Tank-car delivery is especially suitable for dairies which are located on industrial sidings and which receive milk from country plants located directly on the railroad. In this case it is possible to load the milk directly from the country station, often by gravity, and to pump it from the car at the city storage plant. If either the dairy or the country station is not provided with rail facilities it is necessary to employ the tank truck as a connecting link, and in such a case it is preferable to use the trucks for direct delivery, unless the distance is beyond the economic range of truck haulage.

Not all dealers, however, can make use of tank-car service, even when they have direct rail facilities, because the quoted rail rate is based on a minimum load of 40,000 pounds, and relatively few country

FIG. 5.—Map showing country plants served by railroad in the Chicago dairy district

plants can supply this amount daily throughout the year. It is not impossible, of course, to load a tank car at more than one bulk station, but if this is attempted the additional stations may not be handled profitably during the surplus season.

TABLE 3.—*Railroad tank car installations in the Chicago dairy district*

Stations	Distance	Time en route	Rate per hundredweight	Railroad	Number of cars
	Miles	*Hours*	*Cents*		
Spring Grove, Ill	53.8	3½–4	21	C., M. & St. P.	3
Avalon, Wis	88.9	4 –6	24	do	3
Plato Center, Ill	45.4	2½–3	------	I. C	2
Slinger, Wis	117.5	6 –7	27	C., M. & St. P.	3
Freeport, Ill	130.0	6 –7	27	do	3
Bassetts, Wis	64.0	4	24	do	4
Big Foot Prairie, Ill	70.0	5 –6	------	Via electric and C. & N. W.	4
Algonquin, Ill	52.8	3½	21	C. & N. W	4
Capron, Ill	69.5	5 –6	24	do	4
Round Lake, Ill	46.1	3½–4	21	C., M. & St. P.	2
Marengo, Ill.[1]	60.0	4	------	C. & N. W	3
McHenry, Ill.[1]	50.5	3½–4	------	do	3
Woodstock, Ill.[1]	51.3	3½–4	------	do	3
Pearl City, Ill.[1]	123.0	6 –7	27	C. G. W	3

[1] Cars not yet in operation.

The tank car tends to extend the limits of the milk shed by providing relatively cheap transportation from distant points. Several are now being operated, for instance, into Wisconsin districts which have never heretofore shipped market milk to Chicago. The railroads are willing to quote reduced rates on the bulk shipments because the capacity of a tank car, which is approximately 51,000 pounds, is more than twice the capacity of a car loaded with 8 or 10 gallon cans. For example, the rate charged per hundredweight for milk shipped from Slinger, Wis., in tank cars is only 27 cents. (See Fig. 5.) Slinger is 117.5 miles from Chicago, and the rates for milk shipped in cans or bottles are 45 cents per hundredweight for milk in 10-gallon cans, 49 cents for milk in 8-gallon cans, and 72 cents per hundredweight for bottled milk.

There are 14 tank-car installations in the Chicago district all of which are now in operation or shortly will be. The shipping distance for these installations varies from 45 to 130 miles, the shipping time from two and one-half to seven hours and the number of cars employed from two to four, as shown in Table 3.

Tank trucks.—The glass-lined tank truck is admirably suited for the hauling of milk from country stations to city plants, especially when neither is located directly on a railroad and when the distance is not beyond the economic range of truck haulage. Its service is limited to the picking up of a load of milk at a receiving station, although it is possible, as in the case of the tank car, to secure the load from more than one station. It can not be successfully used to collect small quantities of milk along the road, principally because the pooling of the milk of various producers in one tank prevents the proper sampling and checking of sour milk should there be any. Another reason is that the frequent opening of the tank would lead to contamination.

The capacities of the tanks range from 800 to 2,000 gallons, the most practical size being 1,250 gallons. Some of the larger tanks when loaded to capacity exceed the maximum highway weight limits in some States, and it has been found expedient for this reason to mount them on semitrailers. This distributes the load over six wheels and meets all regulatory restrictions. (See Fig. 6.)

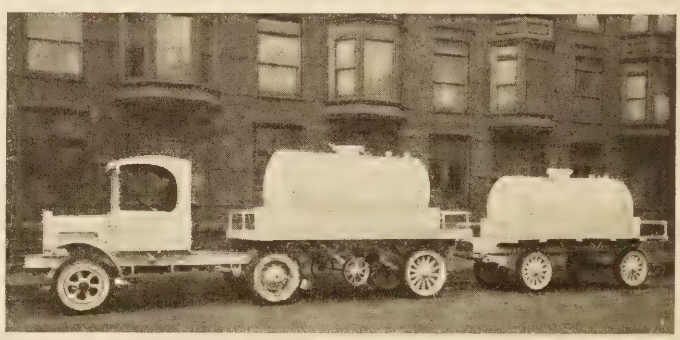

FIG. 6.—The use of tank trucks and trailers has attracted considerable attention in the Chicago area

In the majority of cases tank trucks are owned by the city distributors, although a few motor trucking companies use them on a contract basis. It is not practicable to ascertain the cost of operating the trucks which are owned by the dairies. The rates charged by the hauling contractors are slightly higher than comparable rail rates for tank-car service. From Lowell, Ind., for example, the present tank-truck rate is 23 cents a hundredweight for the distance of 42 miles, as compared with a tank-car rate of 21 cents per hundredweight for distances of 40 to 45 miles. It is apparent, therefore, that a dairy operating its own trucks could easily equal the rail rate.

There are 20 glass-lined units operating over the highways in the Chicago area. A number were put into service during 1924 and there seems to be a growing tendency to convert country bottling plants within 40 or 50 miles of the city into receiving stations and transport the milk in bulk to city dairies and bottling plants. The principal reasons for this change are the high rail rates on bottled milk and the completion of many new highways within trucking radius of the city. Within the past two years no less than a dozen country bottling stations have been converted into bulk receiving stations for these reasons. Those well located within trucking range on good highways are using tank trucks, while the more distant stations are operating tank cars.

A list of the tank truck installations now in operation in the Chicago area is given in Table 4. All of these trucks operate within a radius of from 20 to 60 miles, the average length of route being 34.2 miles. In Tables 5 and 6 are shown the sizes of the tanks used on the trucks of the several capacities and the mileage zones in which the trucks of the various sizes are operated.

TABLE 4.—*Tank truck installations in the Chicago dairy district*

Receiving station	Route	Distance	Operating time to Chicago	Tank capacity	Number	Capacity of truck
		Miles	*Hours*	*Gallons*		
Wauconda, Ill.	Rand Road via Milwaukee Avenue.	46	3¾	1,500 1,250 1,250 1,250	2	5-ton trucks and 2 trailers.
Palatine, Ill.	Northwest Highway and Milwaukee Avenue.	33	2½	1,250 1,250	1	5-ton truck and trailer.
Sollitt, Ill.	Dixie Highway and Halsted Street.	32	2½	1,000	1	3½-ton truck.
Monee, Ill.	Via Chicago Heights and Halsted Street.	32	3	1,500	1	7½-ton tractor and semi-trailer.
Mount Prospect, Ill.	Northwest Highway.	20	2	1,500	1	10-ton tractor and semi-trailer.
Crown Point, Ind.	Jackson Highway via Hammond.	32	2¾	1,500	1	5-ton tractor and semi-trailer.
Lowell, Ind.	do.	42	3¾	1,250	1	5-ton truck.
Bartlett, Ill.	Via Lake Street.	25	2	1,250	1	Do.
Ontarioville, Ill.	do.	22	2	1,250	1	Do.
Virgil, Ill.	St. Charles Road via Roosevelt Road.	50	4	1,250 1,000	1 1	3½-ton truck. 2½-ton truck.
Orland, Ill.	Via Ninety-sixth and One hundred and eleventh Streets and Vincennes Avenue.	29	3	1,500 1,000	1 1	5-ton truck. 3½-ton truck.
St. Charles, Ill.	Geneva and Roosevelt Road.	45	3½	2,000 1,630	1 1	10-ton tractor and semi-trailer. Do.
Cloverdale, Ill.	Lake Street.	27	2	1,250	1	5-ton truck.

TABLE 5.—*Number and capacity of trucks and tractors upon which are mounted the various sizes of glass-lined tanks*

Size of tanks (gallons)	Number of trucks and tractors of various capacities				
	2½ tons	3½ tons	5 tons	Over 5 tons	Total
1,000	1	2			3
1,250		1	6		7
1,500			2	3	5
1,630				1	1
2,000				1	1
Total	1	3	8	5	17

TABLE 6.—*Number and capacity of tank trucks operating in the various mileage zones*

Mileage zones	Number of trucks of various capacities				
	2½ tons	3½ tons	5 tons	Over 5 tons	Total
20–29		1	4	1	6
30–39		1	2	1	4
40–49			2	3	5
50–59	1	1			2
Total	1	3	8	5	17

COMPARISON BETWEEN TANK CAR AND TANK TRUCK SERVICE

As previously stated the tank truck and the tank car have each their distinct field of service, the car serving best in the long haul areas especially from plants lying immediately upon the railroad, and the truck in the short-haul zones from plants located on good highways. Where facilities are available and circumstances are such that either form of equipment could be used the truck has an advantage over the tank car because of the smaller investment required for tank-truck service. For a given quantity of milk delivered, less tank capacity is required for truck service than for rail service. This is due to the fact that the trucks can complete the round trip between the country receiving station and the city dairy in a day while the cars normally require more than one day.

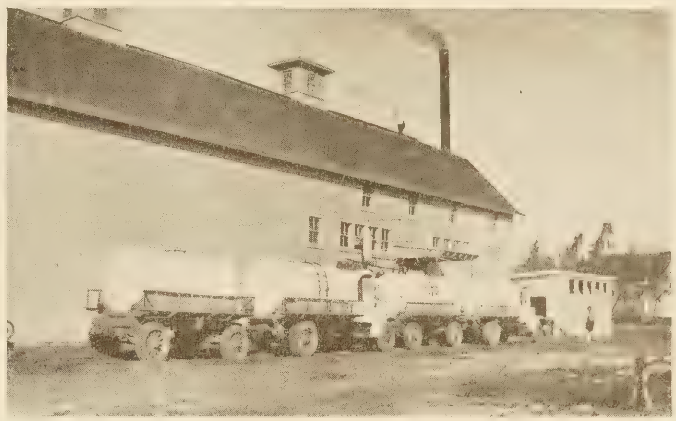

FIG. 7.—The tank trucks are often filled by gravity at the country stations

The tank trucks move out into the country during the early morning hours and are filled at the collecting station, often by gravity, and usually in from 12 to 15 minutes. They leave the station for the city between 10.30 and 11 in the morning, after all milk from the surrounding country has been brought in and cooled, deliver their loads in the early afternoon and are then made ready for the return to the country the following morning.

The use of tank cars, on the other hand, requires that there shall be at least one extra car, generally two and sometimes three, for each car unloaded daily at the city plant. Within a radius of 40 miles two cars often suffice for a single installation. For greater distances, however, there is generally a car loading at the country station and another in transit for each car unloaded at the city end of the haul.

To illustrate the comparative investment required for the two types of equipment, assume that a city dealer receives 6,000 gallons of milk daily which can be shipped either by rail or by truck over hard-surfaced roads. If the milk is hauled in tank trucks, three trucks and two trailers will be required to carry the five 1,250-gallon tanks, and the cost of the outfit will be $24,250. To transport the same quantity by rail will probably require three tank cars of 6,000 gallons each, and the cost will be $45,000. If two tank cars can be made to serve the cost will still exceed that of the tank-truck outfit by 25 per cent.

The tank truck is more flexible for handling the variable output of country stations than the tank car. During the late summer and fall when milk production decreases the dealer operating tank trucks and trailers can suspend the operation of a truck or trailer, during slack periods. In the case of tank-car delivery the rates which apply to these shipments are for a minimum carload of 40,000 pounds. It is a serious matter in times of shortage to operate partly filled cars at the full rate, and it is, therefore, imperative to operate tank cars in connection with stations having a 40,000-pound minimum volume.

MOTOR TRUCK AND RAIL MILEAGE AND RATES

Country hauling.—The rates charged for country hauling are directly proportional to the distance and condition of the roads on the various routes. From Table 7 it will be seen that those dairymen living along unimproved highways pay from 25 to 50 per cent more than those in sections where improved roads have been completed. The value of an improved road to a community can easily be measured in the light of these facts.

TABLE 7.—*Rates paid for country hauling at various stations of a large Chicago dairy*

Station	Types of roads	Distance	Hauling charge per hundredweight
		Miles	*Cents*
Dundee, Ill	Concrete and gravel	3–15	12, 15, 18
Herbert, Ill	Gravel, mostly dirt	3–12	15, 20, 25
Batavia, Ill	Concrete and gravel	3– 9	15, 18, 20
Byron, Ill	Gravel and dirt	3– 9	15, 20, 25
Wauconda, Ill	Concrete and gravel	3– 8	10, 12, 14
Mokena, Ill	Gravel and dirt	5–10	20, 25
Gurnee, Ill	Concrete and gravel	5–11	18, 20
Poplar Grove, Ill	Mostly dirt, some gravel	3– 9	15, 20, 25
Ringwood, Ill	Gravel	5–12	15, 20
Maple Park, Ill	Gravel and dirt	5–10	15, 20, 25
Clinton, Wis	Concrete, gravel, dirt	3–10	12, 15, 20, 25
Brooklyn, Wis	Gravel and dirt	3– 9	15, 18, 25
Janesville, Wis	Concrete, gravel, dirt	3–12	15, 20, 25
Bristol, Wis	Concrete and gravel	3–10	15, 20
Capron, Ill	Mostly gravel	3– 7	8, 10, 12, 15, 17
Big Foot Prairie, Ill	High type of gravel	3– 6	10, 12, 14, 15
Harvard, Ill	do	3– 9	10, 12, 15, 18
Crystal Lake, Ill	Mostly gravel	3–10	15

The rates range from 8 cents per 100 pounds for relatively short distances over improved roads to 25 cents for a 12-mile haul. There are, however, glaring inconsistencies in some of the rates charged for specific distances. Where the rates seemed high and out of line it was found that the trucks operated over roads which had not been improved. For example, the milk delivered to the station at Dundee is transported over gravel and concrete roads for distances of 3 to 15 miles at a rate of from 12 to 18 cents per hundred pounds, while twenty-five miles west of Dundee at Herbert the haulage rate over dirt roads for distances of from 3 to 12 miles is 20 to 25 cents.

THE EFFECT OF TRANSPORTATION RATES ON THE EXTENSION OF THE MILK SHED

Transportation rates and the extension of the milk shed supplying Chicago are rather closely related. The phenomenal development of production to the northwest is largely due to the energetic work of certain railroads running through that section in securing and developing fluid milk shipments. While the railroads have tended to push the dairy district out beyond its present limits the motor truck has intensified production within fifty miles of Chicago and this has had a counter effect.

The cost of shipping 100 pounds of milk in 10-gallon cans to Chicago by railroad is shown in Figure 8. By plotting the railroad rate at different shipping stations on the various railroads and connecting by means of a line the stations having the same rate, the rate zones for rail shipments to Chicago are outlined. The production of milk by counties in thousands of gallons is also shown. As shown by the map there is no uniformity in the system of rates.

The largest portion of Chicago's milk supply is produced within 75 miles of the city, in the territory bounded by the rate zone of 40 cents per hundred pounds. There is sufficient milk produced in the zone

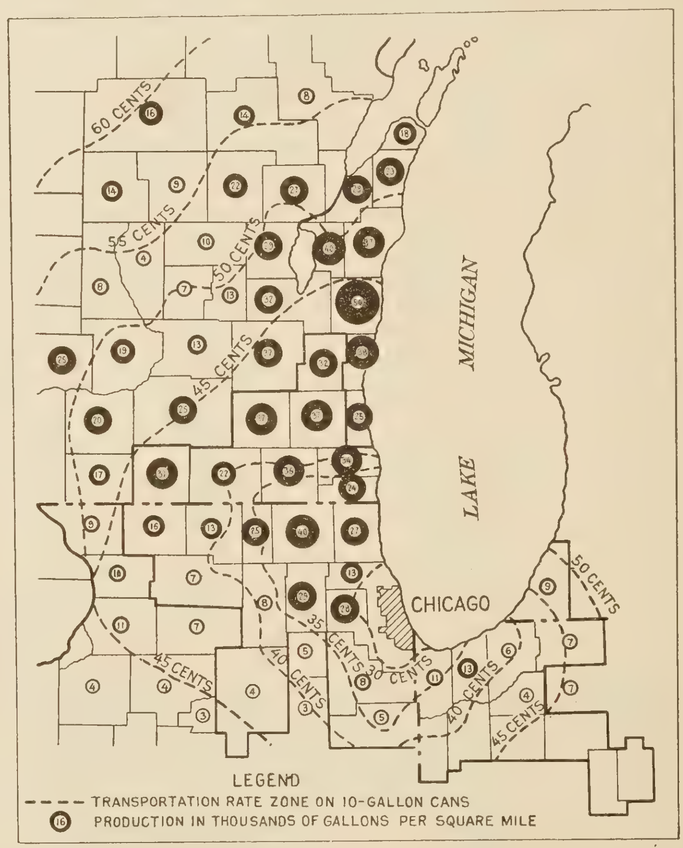

FIG. 8.—Map of the Chicago dairy district and tributary area showing the production of milk by counties in thousands of gallons per square mile. The cost per 100 pounds of shipping milk by rail in 10-gallon cans is indicated by the dotted lines forming the outer limits of the rate zones. Note the heavy production between the 40 and 45 cent rate lines. Most of this milk is now condensed or made into butter or cheese

bounded by the transportation rates of 40 and 45 cents to meet all needs in the immediate future, and some of this milk is already finding its way to Chicago in glass-lined tank cars.

Truck and rail rates on direct shipments.—Milk transportation rates by truck conform quite closely to the rates charged by the rail carriers operating in the adjoining territory. It must be remembered, however, that on railroad shipments the dealer must pay the cartage from the railroad milk platform to his plant, in addition to the rail tariff. With the truck this cost is absorbed in the rate charged.

Truck rates are more nearly proportional to distance than rail rates for the first 30 miles. The general tendency among the rail carriers is to charge a blanket rate for the first 25 or 30 miles and, for greater distances, a proportional increase according to distance. These characteristics of the truck and rail rates are illustrated by Figure 9 and the comparative rate schedule in Table 8.

TABLE 8.—*Truck and rail rates on direct shipments*

Railroad			Truck		
Distance	Rate on cans of not exceeding 10 gallons capacity	Rate on cans of not exceeding 8 gallons capacity	Distance	Range of rate per 8-gallon can [1]	Average rate per 8-gallon can
Miles	*Cents*	*Cents*	*Miles*	*Cents*	*Cents*
1–25	30	27	1–10	15	15
26–30	32	29	11–15	16–18	17
31–35	33	30	16–20	18–20	19
36–40	35	32	21–25	20–24	22
41–45	36	33	26–30	22–28	25
			31–35	24–30	27
			36–40	26–34	30
			41–45	28–36	32
			46–50	30–40	35

[1] Practically all cans on trucks in Chicago dairy district are of 8-gallon capacity.

While there seem to be inconsistencies in some of the truck rates for the same mileage zone, a tabulation of the rail rates would show even less uniformity. A close investigation of the truck rates reveals a marked increase in the rate where the truck route follows poor roads.

In the various sections of the dairy district there are as many different systems of computing rates for hauling milk as there are motor trucks. Certain operators charge by the gallon, others by the hundredweight, while the most common method is a stated rate per 8-gallon can. Still another method used by hauling contractors handling bulk shipments in tank trucks is to charge a stipulated amount for all milk up to 2,000 gallons. One dealer has a contract with a trucking company operating two tank trucks to haul his milk at the rate of 30 cents per hundredweight for a 50-mile haul. The railroad rate for this country plant is 33 cents per hundredweight, or 3 cents more than the truck rate, and, in addition, the city dealer saves the cost of cans and the cost of carting the milk from the railroad milk platform to the city plant. The trucking company owns the trucks and glass-lined tanks and assumes all road responsibility.

Basis for truck rates.—In determining the rate, the length of the haul naturally is one of the prime considerations; road conditions constitute another. The fact that milk in cans is very perishable and bulky must also be taken into consideration, and also the fact that where a complete delivery is made from the dairy farm or roadside platform to the city dealer a service is rendered which is not duplicated by the railroad. This additional service should be considered in fixing the rate. Practically no rates have been established on the basis of cost, plus a reasonable profit. A satisfactory rate must be one which is low enough to attract business and high enough to offer a reasonable profit. Where conditions do not permit the establishment of such a rate, a route should not be established.

THE VALUE OF HARD SURFACED ROADS

Good roads are a prerequisite to successful motor truck operation. The unfortunate operator who tries to maintain his service over highways which are virtually impassable for a part of the year finds that his daily operating costs far exceed the average normal expenses, and eventually he realizes that his profits are seriously affected. Very few operators appreciate the increased expense which results in this way from bad roads; but that there are some that do consider the condition of the highway in proportioning haulage charges is illustrated by the rates given in Table 9, which also prove the value of hard-surfaced roads in keeping down transportation rates.

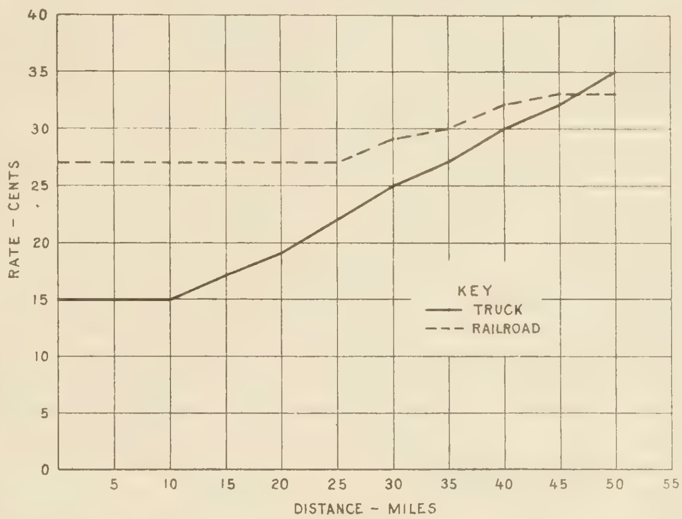

FIG. 9.—Diagram showing the average rates for the hauling of milk various distances into Chicago by motor truck and railroad

TABLE 9.—*Road types and their effect on haulage rates*

Station	Type of hauling	Type of road	Distance	Hauling charge per hundredweight
			Miles	*Cents*
Garden Prairie, Ill.	From station to Chicago in cans.	Concrete	66	35
Herbert, Ill	Country hauling	Dirt and gravel	3–12	15–20–25
Sollitt, Ill	From station to Chicago in tank truck.	Concrete	32	[1] 17.15
Lake Geneva, Wis.	Country hauling	Concrete and gravel.	5–15	15–20
Lemont, Ill	"Pick-up" route	Dirt and concrete.	19	36.4

[1] 1½ cents a gallon.

As an instance of the value of hard roads, a large Chicago dairy, which had a receiving station on a rail line which was no longer operated, believed for a time it would have to abandon its plant. As the section in which the plant was located is a highly productive dairy district, the company made every effort to find another means of transportation. About this time the Rand road was completed, furnishing 46 miles of hard-surfaced road to the city. An installation of two tank trucks and two trailers is now operated daily between this station and the Chicago plant with the result that the highway has saved the closing down of the plant and the community retains a profitable place to market its milk.

As another instance, a large Chicago dairy operated glass-lined tank trucks between Chicago and their country plant at Bassetts, Wis., a distance of 77 miles. Of this distance approximately 68 miles are hard surfaced and the remainder unimproved and extremely difficult to traverse during prolonged wet spells. The operation was very successful in good weather, but the installation finally had to be abandoned because of the miring of trucks in mud holes along the unsurfaced portion of the route in wet weather, and the milk is now hauled from this plant in railroad tank cars. The officials of the company state that the operation of tank trucks was successful in every detail except over the 8 or 9 miles of unimproved road. The regularity of service so essential in milk transportation could not be maintained under these adverse conditions.

Many highly productive dairy districts have been developed in communities which have inadequate rail service, by the building of hard roads which enable the motor truck to collect daily milk and other farm produce for the near-by city.

ZONES OF OPERATION AND KINDS OF TRUCKS USED

At the close of 1924 there were 141 motor trucks engaged in the transportation of milk into the city of Chicago. While these trucks are handling considerable milk from bulk receiving stations the largest volume comes direct from the producer. Much of this milk formerly moved by rail, uniced, in regular baggage cars from a zone the maximum radius of which was 75 miles. It is estimated that there are about 1,800 railway can shippers left and it is highly probable that the number will continue to decrease as the use of the motor truck increases.

Table 10 gives the amount of milk transported in cans, tank trucks, and in bottles and also the number of trucks engaged in each operation. It is highly significant to note that 17 tank units haul approximately 23 per cent of the trucked-in milk.

TABLE 10.—*Methods of trucking milk and the daily amounts transported*

Means of transportation	Units	Number of units	Number of gallons	Number of trucks	Percentage of total trucked-in milk	Average number of gallons per truck
"Pick-up" can truck.	8-gallon cans	10,682	85,456	122	76	700.4
Tank trucks and trailers.	Various capacities 1,000–2,000 gallons.	20	26,630	17	23	1,566.4
Certified bottled milk.	Cases of 12 quarts each.	209	627	2	1	313.5
Total			112,713	141	100.0	860

TABLE 11.—*Number of milk trucks operating in the various mileage zones*

Zone	Number of trucks	Percentage of total number
Miles		*Per cent*
0–9	1	0.7
10–19	7	4.9
20–29	47	33.3
30–39	39	27.6
40–49	26	18.4
50–59	17	12
60–69	2	1.4
70–79	2	1.4
Total	141	100

The distances over which these trucks operated ranged from 8 to 75 miles. As shown in Table 11, only eight trucks or approximately 5 per cent come from points less than 20 miles away. So much land has been subdivided and taken over by golf links that very little milk is produced within the 20-mile zone. The land given over to agriculture within this zone is devoted to truck gardening which is more intensive and profitable than dairying on such high-priced land. The largest number of trucks operate in the 20-29 mile zone while only four trucks or less than 3 per cent operate over 60 miles.

The motor units engaged in milk hauling are of varying capacities, ranging from ¾-ton trucks to 10-ton tractors. The 2½-ton and 3½-ton sizes are by far the most popular capacities as shown by Table 12. They are well adapted to the average route and can make excellent speed over hard roads after their load has been picked up.

TABLE 12.—*Number of milk trucks, by capacities—Chicago dairy district*

Capacity	Number of trucks	Percentage of total number
Tons		*Per cent*
Less than 1	1	0.7
1	6	4.2
1¼	4	2.8
1½	4	2.8
2	9	6.4
2½	43	30.5
3	5	3.6
3½	42	29.8
5	22	15.6
Over 5	5	3.6
Total	141	100.0

The following table gives the carrying capacity in cans of the various sizes of trucks:

TABLE 13.—*Average number of 8-gallon cans loaded on trucks of various capacities*

Capacity	Number of 8-gallon cans	Capacity	Number of 8-gallon cans
Tons		*Tons*	
Less than 1	20–25	3	70–90
1	30	3½	80–120
1¼	35	5	100–140
1½	40	Over 5	150–200
2	50	Tractor and semi-trailer	150–200
2½	60–70		

RETURN LOAD BUSINESS NOT DEVELOPED

Very few milk truck operators carry any return load. Occasionally a load of feed or farm implements is carried, but this type of business has never grown to the proportions it has in a number of other cities, especially Baltimore. One reason is that the city is so large that it takes too much time to gather up a load. Another is that the success of a well-organized return-load movement depends largely on the establishment of a central freight depot, and as yet there has been no attempt to establish such a depot.

MILK TRUCK REGULATION

The Department of Health of the City of Chicago has recently made a thorough investigation with reference to transportation of milk into the city by motor truck.

The methods and equipment used in picking up milk by truck, in some instances, were quite unsatisfactory to the Health Department and in view of this fact it has been found necessary to enforce the following regulations:

1. All milk trucks used in the transportation of milk or cream must be completely inclosed, having permanent tops and sides constructed either of wood or metal.

2. A list giving the names and post office addresses of all dairymen whose milk is hauled regularly and names of dealers supplied must be submitted to the department at least every 60 days.

3. A time schedule is to be arranged similar to that used by rail transportation companies, so that each farm will be reached at approximately the same time each day, thus obviating the necessity of milk standing out unprotected for any considerable length of time before the arrival of the truck.

4. Arrangements must be made to load all milk from raised covered platforms, whether it be on the farm or at certain other points where more than one dairyman loads his milk.

5. Trucks must be maintained in a clean and sanitary condition and be cleaned thoroughly after each day's use.

While it is doubtful if milk shipped by truck is received in any better condition than rail shipments, yet marked improvement in quality has taken place since the establishment of loading platforms along the highways. The truck has reduced the number of handlings to a minimum which lessens the chance of contamination greatly.

There is no common carrier regulation of motor trucks of any kind at present in force in the State of Illinois, and the only license fees paid are the ordinary State motor truck license and the wheel tax. The latter is only paid where the truck is owned in some incorporated city or village which levies such a tax.

OVERLOADING

There is a very small percentage of overloading in the milk hauling business. Most of the trucks are purchased with the view of taking care of the surplus milk produced in May and June, and they are, therefore, of sufficient capacity to carry their normal loads and come within all regulations. Some of the larger tank trucks were found to be overloaded but in all cases this has been remedied by mounting the tanks of large capacity (1,500 gallons or more) on semitrailers thereby distributing the load over six wheels.

Milk truck operators from northwestern Indiana are demanding truck legislation which will give them an idea of what lawful weights can be carried in the spring of the year when moderately loaded trucks are ordered from the highways. In order to operate at such times most Indiana operators find that they must own or hire surplus trucks of 1-ton capacity, which from the operator's point of view is a very unsatisfactory condition. The real solution to the problem is more hard-surfaced roads which will allow trucks of the larger capacities to operate freely at all seasons of the year.

FIELD METHODS USED IN SUBGRADE SURVEYS

(Continued from p. 101)

RECOMMENDATIONS BASED ON THE SURVEY

In general the shrinkage of the soil even in sections included in the 9 miles referred to above was found to be of no serious consequence. It was decided, therefore, that the greatest attention should be devoted to securing adequate drainage.

Before making recommendations as to the design of the pavement, the adjacent sections of paving in good condition were studied. Assuming soil conditions, traffic and climate to be the same on a pavement project in the same region, it is probable that the same general type would be adequate where similar conditions existed in the proposed project.

The immediate subsoils of the Olympic, Aiken, Salkum, Winlock, Kelso, and Felida series were compact. This impervious layer restricted drainage and made it necessary to recommend the laying of a grade line which would place the excavation beneath it. Otherwise deep side ditches should be provided. This was apparent especially in the Kelso formation in the vicinity of Ostrander. The impervious subsoil was from 2 to 8 feet below the surface, and beneath it was found a friable silt and fine sand stratified with some clay. This lower subsoil drains well and makes a hard, compact, nonshrinking subgrade.

From Woodland to Carrolls the road was built through sand, solid rock, loose rock, etc. With the exception of some sliding ground, these materials, it was decided, should afford an excellent foundation for a pavement.

The Puget series vibrates under train traffic. This was especially noticeable at Ostrander where fills of this series have settled considerably and caused serious cracking and deformation of the reinforced concrete overhead crossing over a logging railroad. The quaking, however, was not considered sufficient to reduce materially the life of the proposed pavement provided the subgrade was permitted to reach ultimate settlement.

The liberal use of culverts and tile drains and the construction of deep side ditches was considered to be the best means of preventing failures from inadequate drainage. Additional subbase seemed necessary only where the existing crushed stone surfacing had been removed or was too thin. This surfacing was placed by the State, in line with its stage-construction policy, when the grade was built, and in most places it was preserved intact to serve as a subbase for the new pavement.

Where the lineal shrinkage of the soil exceeded 5 per cent it was recommended that protective measures be adopted; and the three methods recommended were the use of the thickened-edge type of pavement, the building of a 4-inch subbase or the use of steel reinforcement.

The State adopted a combination of all three methods. The pavement which was completed in the fall of 1923 is 20 feet wide with a center thickness of 6½ inches and an edge thickness of 9 inches on the entire project with the exception of the 15-mile section between La Center and Kalama where the thin edge, thick center (6″–7½″–6″) design was used. Wherever the soil was found to have a lineal shrinkage factor in excess of 5 per cent the pavement was reinforced, except where the existing crushed stone surface was thought to be adequate to serve as a subbase.

A casual inspection of the pavement a year later, in the fall of 1924, showed it to be in excellent condition.

REPORT FORM

The report form used on the Pacific Highway subgrade survey follows:

1. Brief description of highway.
2. Information in regard to adjacent roads.
   (*a*) Location.
   (*b*) Type.
   (*c*) Subbase and character of soil.
   (*d*) Year built.
   (*e*) Present condition.
   (*f*) Summary.
3. Description of this project: Type, etc.
4. Topography.
5. Geological structure.
6. Soil types encountered.
   (*a*) Data on borings.
   (*b*) Results of soil analysis.
7. Drainage conditions.
8. Climatological data.
9. Traffic census.
10. Recommendations.
   (*a*) Drainage—surface and subsurface.
   (*b*) Pavement design—reinforcement or subbase.
11. Remarks.
12. Photographs.

CHANGE IN SOIL TESTING METHODS CONTEMPLATED

In making a subgrade survey it is essential that the various soil types occurring along the proposed locations be determined, as well as the physical properties of the respective types. The determination of these two factors requires that a large number of soil samples be taken and analyzed in the laboratory.

It would seem advisable to adopt any means by which the time and labor involved in sampling and analyzing could be re uced to a minimum, and, as pointed out elsewhere in this issue, the surveys of the United States Bureau of Soils which cover a large part of the United States would seem to be of inestimable value to the highway engineer for this purpose.

Unfortunately the test methods used by the Bureau of Soils, especially in the mechanical analysis test, differ from those which have been standardized in highway engineering laboratories. The former involve the use of millimeter sieves for separating the fractions of the soil, while the latter are based on sieves the meshes of which are measured in English units. On account of this difference in practice materials which are classified as clay, silt, loam, and sand by the Bureau of Soils are not identical with the materials to which the same names are applied by highway investigators, and this difference stands in the way of a convenient use of the large amount of useful information acquired by the agriculturists.

The article published in this issue makes out a convincing case for the use of the Bureau of Soils bulletins. It does not seem that a difference in method so slight and so easy to eliminate should be permitted indefinitely to embarass the utilization of such valuable and voluminous data; and the Bureau of Public Roads is contemplating a change in its methods of making the mechanical analysis which will bring them into conformity with the methods of the other Federal bureau. There are a number of considerations both for and against the change which will make it necessary to give the matter very careful consideration, and final action will not be taken until the advisability of the change has been fully demonstrated. In the meantime the bureau will welcome the advice and suggestions of highway and testing engineers either for or against the proposal.

A TEST FOR DETERMINING THE AMOUNT OF SHALE IN SAND USING A LEAD ACETATE SOLUTION

By P. M. Hegdal, Engineer of Tests, North Dakota State Highway Commission

During the summer of 1924 the writer developed a test for determining the amount of shale in sand by the use of a lead acetate solution. The advantage of the method, which is described below, lies in the fact that a very heavy solution is obtained which is not sluggish or sirupy. This is a very desirable quality as the thick liquid, if sluggish, prevents all fine particles of the sand from subsiding regardless of their specific gravity.

The description of the lead acetate method follows:

To about 2 kilograms of ordinary commercial acetate (sugar of lead) add about 600 or 700 grams of distilled water. Boil in a glazed pan into the top of which a standard testing sieve will fit, until it is all dissolved. This solution must be kept over a flame or hot plate while the testing is being done as at ordinary temperatures it is a solid. It should be kept near the boiling point and its specific gravity should be kept about 2.40 (approximately) by boiling off water to increase, and by adding distilled water to decrease its weight.

Use that portion of a 500-gram sample of washed dried sand which is retained on a No. 50 sieve.

Sprinkle the sand to be tested into the hot solution, stirring in the floating sand. All the shale will float and can best be skimmed off with a spoon fashioned from a strip of 20-mesh brass screen 2 by 6 inches in size, which may be emptied by dipping it into a pan of hot water. The shale should then be washed in warm water till clearly dried and weighed, and the weight in grams divided by five gives the percentage of shale.

To recover the lead acetate, set a No. 50 sieve in the top of a second pan of the size mentioned above and dump the hot solution into the sieve. The sand will be retained on the sieve and can be removed from it by washing with warm water.

If crystalline C. P. lead acetate is used, heat it without the addition of water to prepare the solution.

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

ANNUAL REPORT

Report of the Chief of the Bureau of Public Roads, 1924.

DEPARTMENT BULLETINS

No. 105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913.
*136. Highway Bonds. 20c.
220. Road Models.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
*314. Methods for the Examination of Bituminous Road Materials. 10c.
*347. Methods for the Determination of the Physical Properties of Road-Building Rock. 10c.
*370. The Results of Physical Tests of Road-Building Rock. 15c.
386. Public Road Mileage and Revenues in the Middle Atlantic States, 1914.
387. Public Road Mileage and Revenues in the Southern States, 1914.
388. Public Road Mileage and Revenues in the New England States, 1914.
390. Public Road Mileage and Revenues in the United States, 1914. A Summary.
407. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
*463. Earth, Sand-Clay, and Gravel Roads. 15c.
*532. The Expansion and Contraction of Concrete and Concrete Roads. 10c.
*537. The Results of Physical Tests of Road-Building Rock in 1916, Including all Compression Tests. 5c.
*583. Report on Experimental Convict Road Camp, Fulton County, Ga. 25c.
*586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916. 10c.
*660. Highway Cost Keeping. 10c.
*670. The Results of Physical Tests of Road-Building Rock in 1916 and 1917. 5c.
*691. Typical Specifications for Bituminous Road Materials. 10c.
*704. Typical Specifications for Nonbituminous Road Materials. 5c.
*724. Drainage Methods and Foundations for County Roads. 20c.
*1077. Portland Cement Concrete Roads. 15c.
*1132. The Results of Physical Tests of Road-Building Rock from 1916 to 1921, Inclusive. 10c.
No. 1216. Tentative Standard Methods of Sampling and Testing Highway Materials, adopted by the American Association of State Highway Officials and approved by the Secretary of Agriculture for use in connection with Federal-aid road construction.
1259. Standard Specifications for Steel Highway Bridges, adopted by the American Association of State Highway Officials and approved by the Secretary of Agriculture for use in connection with Federal-aid road work.
1279. Rural Highway Mileage, Income and Expenditures, 1921 and 1922.

DEPARTMENT CIRCULAR

No. 94. TNT as a Blasting Explosive.

FARMERS' BULLETINS

No. *338. Macadam Roads. 5c.
*505. Benefits of Improved Roads. 5c.

SEPARATE REPRINTS FROM THE YEARBOOK

No. *727. Design of Public Roads. 5c.
*739. Federal Aid to Highways, 1917. 5c.
*849. Roads. 5c.

OFFICE OF PUBLIC ROADS BULLETIN

No. *45. Data for Use in Designing Culverts and Short-span Bridges. (1913.) 15c.

OFFICE OF THE SECRETARY CIRCULARS

No. 49. Motor Vehicle Registrations and Revenues, 1914.
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.
63. State Highway Mileage and Expenditures to January 1, 1916.
*72. Width of Wagon Tires Recommended for Loads of Varying Magnitude on Earth and Gravel Roads. 5c.
73. Automobile Registrations, Licenses, and Revenues in the United States, 1916.
161. Rules and Regulations of the Secretary of Agriculture for Carrying out the Federal Highway Act and Amendments Thereto.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH

Vol. 5, No. 17, D-2. Effect of Controllable Variables Upon the Penetration Test for Asphalts and Asphalt Cements.
Vol. 5, No. 20, D-4. Apparatus for Measuring the Wear of Concrete Roads.
Vol. 5, No. 24, D-6. A New Penetration Needle for Use in Testing Bituminous Materials.
Vol. 10, No. 7, D-13. Toughness of Bituminous Aggregates.
Vol. 11, No. 10, D-15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.

* Department supply exhausted.

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

STATUS OF FEDERAL AID HIGHWAY CONSTRUCTION

AS OF

JUNE 30, 1925

STATES	FISCAL YEARS 1917-1924			FISCAL YEAR 1925									BALANCE OF FEDERAL AID FUND AVAILABLE FOR NEW PROJECTS	STATES
	PROJECTS COMPLETED PRIOR TO JULY 1, 1924			PROJECTS COMPLETED SINCE JUNE 30, 1924			*PROJECTS UNDER CONSTRUCTION			PROJECTS APPROVED FOR CONSTRUCTION				
	TOTAL COST	FEDERAL AID	MILES	TOTAL COST	FEDERAL AID	MILES	ESTIMATED COST	FEDERAL AID ALLOTTED	MILES	ESTIMATED COST	FEDERAL AID ALLOTTED	MILES		
Alabama	$ 4,598,721.63	$ 2,186,247.54	464.1	$ 1,371,376.08	$ 676,950.32	147.7	$ 15,450,912.60	$ 7,494,856.47	804.8	$ 300,107.34	$ 146,749.34	24.8	$ 2,290,029.33	Alabama
Arizona	8,338,365.41	4,287,683.88	527.8	1,241,768.02	728,436.06	86.0	2,186,015.75	1,346,463.82	158.1	279,009.17	170,502.49	32.9	2,018,785.75	Arizona
Arkansas	11,094,751.31	4,424,345.63	944.4	2,215,438.77	955,836.10	104.5	7,175,728.71	3,252,163.54	387.4	625,385.62	279,793.16	43.4	1,414,425.57	Arkansas
California	12,999,075.03	5,647,148.17	533.7	9,347,100.96	5,072,101.44	361.1	9,322,361.01	4,412,288.58	230.4	1,113,234.62	633,572.38	36.3	3,800,831.43	California
Colorado	8,108,070.31	4,029,898.97	502.6	3,768,633.63	2,037,915.37	148.6	3,555,355.79	1,844,058.78	158.9	1,227,702.32	543,845.34	53.4	2,477,399.54	Colorado
Connecticut	3,062,872.02	1,269,558.60	73.6	1,495,767.27	549,810.06	28.0	1,993,218.91	606,847.75	30.9	309,513.05	98,151.61	6.2	1,331,627.98	Connecticut
Delaware	3,056,832.22	1,007,714.83	72.5	1,224,727.59	488,475.82	34.6	489,503.74	213,581.10	12.3	882,478.16	332,834.75	18.9	62,548.50	Delaware
Florida	961,134.07	461,470.92	48.8	1,998,139.65	944,017.05	47.5	8,787,223.95	4,279,162.51	251.8	116,547.09	91,547.09	0.1	1,403,567.43	Florida
Georgia	17,167,373.32	7,955,805.20	1214.2	2,988,629.05	1,450,561.26	264.1	11,245,752.26	5,544,980.07	740.9	523,497.72	228,475.30	34.6	1,253,164.17	Georgia
Idaho	8,181,697.92	4,092,395.52	506.8	1,212,978.88	722,936.74	93.3	2,454,035.02	1,535,661.67	154.9	414,504.97	259,857.84	37.1	1,003,887.23	Idaho
Illinois	26,964,706.06	12,279,546.33	804.7	13,045,775.04	6,360,529.95	431.5	7,979,727.96	3,863,458.50	270.4	487,835.78	243,917.89	17.4	3,880,518.33	Illinois
Indiana	7,577,444.16	3,655,540.97	225.7	6,061,728.49	2,906,914.71	196.4	14,852,730.92	7,195,558.57	432.9	848,584.16	418,630.58	23.2	2,074,440.17	Indiana
Iowa	23,195,778.19	9,237,031.86	1682.9	4,076,507.02	1,870,461.13	314.0	7,505,888.60	3,315,441.22	434.6	939,082.01	457,695.00	89.5	2,525,903.79	Iowa
Kansas	17,084,136.48	6,043,176.80	502.7	9,315,559.29	3,712,096.52	328.7	12,808,547.40	5,388,167.91	600.3	416,777.30	125,551.21	12.8	2,104,656.56	Kansas
Kentucky	10,822,980.31	4,613,947.28	429.4	4,009,343.97	1,592,047.31	155.5	8,298,279.66	3,724,887.09	299.0	590,422.33	295,211.15	40.0	1,557,253.17	Kentucky
Louisiana	8,488,463.18	3,636,143.36	661.2	3,450,961.79	1,643,727.50	266.4	3,571,757.27	1,724,822.29	170.0	370,484.38	185,242.18	2.8	1,072,768.67	Louisiana
Maine	6,911,058.78	3,299,935.38	230.7	1,263,222.53	607,934.95	50.7	1,151,207.40	544,027.42	42.1				1,323,214.25	Maine
Maryland	6,760,044.42	3,213,321.78	243.2	1,372,462.48	636,061.37	51.2	1,932,936.76	815,245.52	57.1	1,323,161.77	589,541.15	85.0	30,563.18	Maryland
Massachusetts	10,191,202.02	4,105,727.22	232.8	3,856,454.20	1,361,934.06	67.8	5,501,324.46	1,424,297.34	84.2	599,497.74	188,790.00	10.9	1,929,149.38	Massachusetts
Michigan	13,434,135.07	6,060,612.23	494.5	2,799,865.73	1,267,704.68	118.1	14,787,520.89	6,990,273.05	475.2	182,013.44	85,902.19	0.3	3,700,506.85	Michigan
Minnesota	24,037,561.24	9,885,843.07	2292.0	6,378,124.65	2,852,798.97	429.2	6,706,509.32	3,182,300.00	683.9	2,799,814.74	882,900.00	146.4	638,727.96	Minnesota
Mississippi	7,888,193.89	3,828,941.39	655.0	2,404,091.90	1,159,761.34	148.4	8,854,700.33	4,421,094.52	491.3	794,462.49	396,184.64	41.6	1,017,251.11	Mississippi
Missouri	11,352,027.70	5,245,899.18	803.5	6,016,128.87	2,973,512.25	315.4	27,236,575.44	11,406,669.15	869.2	651,118.18	247,931.89	18.4	483,902.53	Missouri
Montana	8,867,279.16	4,384,335.12	791.4	1,289,321.25	933,188.03	130.2	2,112,322.39	1,550,333.81	182.8	988,759.09	551,613.73	117.1	5,095,419.31	Montana
Nebraska	7,876,337.16	3,714,691.59	1440.4	1,430,037.20	674,831.91	130.2	8,523,160.75	4,126,635.19	929.3	1,233,565.07	616,782.52	43.0	3,899,973.79	Nebraska
Nevada	3,460,245.52	1,853,624.98	225.6	1,457,220.17	1,234,674.80	131.7	5,116,444.07	4,329,875.30	449.9	80,728.23	70,814.79	16.9	349,407.13	Nevada
New Hampshire	3,076,750.19	1,487,867.58	171.3	1,088,937.67	498,359.29	36.8	882,156.80	426,087.09	28.9	237,118.87	99,631.96	6.2	288,643.08	New Hampshire
New Jersey	7,623,795.12	2,661,531.49	148.7	4,337,562.33	1,159,148.50	70.4	9,090,363.22	3,246,713.23	63.8	1,453,881.96	338,176.67	19.0	118,759.11	New Jersey
New Mexico	5,306,286.45	2,758,849.68	714.3	3,411,712.73	2,155,220.93	367.0	4,353,981.22	2,887,782.68	394.6	205,006.08	126,078.73	12.1	1,846,565.98	New Mexico
New York	18,862,742.49	8,257,844.44	572.7	9,735,027.18	3,971,232.09	258.8	30,005,625.87	10,225,242.60	621.0	6,715,000.00	1,888,481.45	125.0	6,022,443.42	New York
North Carolina	12,567,732.97	5,676,767.66	884.7	8,446,717.44	3,069,696.93	235.1	8,280,397.44	3,553,613.80	217.1	1,392,882.10	638,502.26	43.6	1,054,848.35	North Carolina
North Dakota	9,088,973.11	4,418,505.42	1587.9	1,740,290.71	850,425.05	329.6	3,314,335.51	1,672,819.67	467.1	777,838.74	395,708.64	95.3	2,206,896.22	North Dakota
Ohio	33,122,751.43	11,879,917.99	962.5	8,449,501.38	3,365,075.94	228.6	9,494,395.75	3,397,125.05	285.1	3,306,077.79	1,321,667.35	100.0	2,965,965.67	Ohio
Oklahoma	12,986,865.26	5,888,852.03	497.3	7,800,159.68	3,784,038.31	354.9	7,030,055.22	3,324,602.25	311.9	863,610.54	429,928.50	46.7	864,386.91	Oklahoma
Oregon	12,082,873.17	5,819,093.79	655.6	2,305,315.53	1,323,270.84	139.0	3,016,966.63	1,745,532.24	136.9	610,268.96	366,846.04	38.9	431,084.09	Oregon
Pennsylvania	36,825,248.98	14,114,694.79	729.7	6,229,586.21	2,107,329.18	120.6	30,880,520.14	8,168,048.18	529.2	7,073,904.07	2,045,175.88	155.2	1,526,490.97	Pennsylvania
Rhode Island	1,774,397.25	779,227.96	46.0	854,098.95	340,460.13	18.8	1,798,608.99	518,589.59	26.3	661,890.35	135,450.00	9.0	524,938.32	Rhode Island
South Carolina	9,016,476.73	4,124,045.22	924.4	2,146,871.11	997,222.32	311.5	6,546,967.82	2,938,981.67	373.3	870,524.91	354,687.35	35.1	325,158.44	South Carolina
South Dakota	8,674,597.86	4,244,636.27	989.8	3,416,836.81	1,745,242.73	458.1	7,593,468.47	3,742,326.64	1011.4	354,871.00	180,198.22	54.6	21,296.14	South Dakota
Tennessee	6,805,683.35	3,313,936.07	259.6	6,983,457.63	3,418,143.70	238.3	12,364,278.08	5,587,754.44	422.7				1,327,787.79	Tennessee
Texas	42,341,998.56	16,190,624.91	3122.8	11,778,972.27	4,867,315.21	784.3	25,177,136.37	10,515,352.63	1509.1	2,640,405.17	955,298.80	185.3	3,611,336.45	Texas
Utah	3,304,423.75	1,895,805.92	219.0	2,954,735.66	1,923,030.99	204.1	2,953,903.45	2,014,706.49	226.1	252,461.79	186,821.71	25.3	942,574.89	Utah
Vermont	1,922,114.16	942,769.12	74.4	1,093,060.35	510,125.33	33.4	1,207,289.94	578,117.66	26.6	439,151.67	151,623.81	8.9	716,968.08	Vermont
Virginia	10,035,301.48	4,801,782.43	562.5	3,064,418.53	1,470,215.77	113.7	10,127,047.08	4,560,134.02	348.7	1,705,250.71	760,025.29	65.4	450,508.49	Virginia
Washington	11,364,615.67	5,290,895.45	457.0	1,967,888.51	826,316.42	69.7	3,015,386.61	1,426,900.00	127.3	833,280.25	361,000.00	22.3	1,100,553.13	Washington
West Virginia	5,489,747.96	2,365,041.53	255.6	1,853,452.91	865,251.80	71.1	5,194,890.10	2,178,214.28	149.2	2,066,068.51	754,510.03	49.9	388,409.36	West Virginia
Wisconsin	16,753,903.15	7,441,033.57	1325.3	3,053,237.76	1,478,607.05	126.4	3,570,401.52	1,746,214.36	180.4	1,772,286.08	877,878.00	90.3	4,008,026.02	Wisconsin
Wyoming	6,127,625.61	3,078,098.70	687.6	2,682,193.72	1,660,997.97	294.4	3,766,266.56	2,363,221.79	257.2	594,953.17	382,502.00	54.2	137,477.54	Wyoming
Hawaii							342,277.22	97,440.00	6.5				633,810.00	Hawaii
TOTALS	549,655,391.27	237,852,399.82	32452.9	190,485,399.55	87,801,946.18	9445.4	389,606,481.37	171,448,571.53	17123.0	52,925,019.39	20,892,230.91	2195.3	80,254,851.56	TOTALS

* Includes projects reported completed (final vouchers not yet paid) totaling: Estimated cost $ 105,123,086.96 Federal aid $ 47,606,101.14 Miles 4,587.2