PROGRESS REPORT ON STUDY OF TURF GROWTH ON SOIL MIXTURES AVAILABLE FOR HIGHWAY SHOULDER CONSTRUCTION IN MICHIGAN

by

J. Tyson
Soils Science Department
Michigan State College

and

E. A. Finney
Research Laboratory
Michigan State Highway Department

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Tyson
Finney

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In 1944 a study of the growth of grass on various soil mixtures available for the construction of highway shoulders in Michigan was undertaken as a joint research project between the Soil Science Department of Michigan State College and the Research Laboratory of the Michigan State Highway Department.

The main objective of the study was to determine the effect of mixing various amounts and kinds of soils into the top six inches of the commonly used sand and gravel subbase (base course) or shoulder materials on the growth of grass and upon the stability of the shoulders produced with them. The soils selected for mixing with the sand and gravelly subbase or shoulder materials were those commonly available for this purpose in southern Michigan.

The investigation consists of two parts. The first part pertains to the establishment of an experimental test area in which turf growth and stability of different soil mixtures could be studied under controlled conditions. The second phase involves a comprehensive field study and evaluation of turf growth and stability of existing highway shoulders throughout Michigan. This paper is essentially a progress report summarizing the results obtained so far in connection with the experimental test area.

The work indicates that Chewing's fescue is an excellent grass to plant on sandy and gravelly stabilized shoulder materials. Topsoils consisting of Miami loam, Brookston loam and Bellefontaine sandy loam can be satisfactorily mixed with sands and gravels to produce turf. In certain cases mixtures of clay and peat are successful. Chewing's fescue should be planted alone or with a small amount of the so-called nurse-grasses. An excess of nurse-grasses which germinate quickly is detrimental to the establishment of the Chewing's fescue especially in the second year when the nurse-grasses disappear.

Rutting tests indicate that all of the soil mixtures under study do not possess satisfactory stability characteristics when wet. All factors considered, the data indicate that 22-A processed gravel is the best of the soil mixtures in relation to stability and turf growth.

The report includes a description of the test area, and a discussion of the turf development on the various soil mixtures. In addition, methods employed in conducting stability tests on the individual grass plots are presented together with test results.

DESCRIPTION OF EXPERIMENTAL TEST AREA

The surface soil was removed from an area forty feet wide and ninety-six feet long with a bulldozer. Granular materials consisting of; (1) incoherent sand, (2) graded sand, (3) pit run gravel and (4) processed gravel (Michigan State Highway Specification 22-A) was laid down in parallel strips eighteen inches deep and ten feet wide in a north-south direction.

Additive soil materials were spread in strips eight feet wide, crossing the four granular materials in an east-west direction. These additive soil materials consisted of Miami loam surface soil, Brookston loam surface soil, mixtures of subsoil clay and peat and Bellefontaine sandy loam overlay on gravel pit including surface material and B horizon down to gravel. Figure 1 presents a layout of the test area showing the position of the granular base materials and the kind and percentages of additive soil materials used. Figure 2 shows a view of test area while under construction. These soil materials were incorporated into the top six inches of the granular base materials by mixing over and over with shovels until as homogenoous a mixture as possible was obtained. The soil in the test area was compacted by rolling repeatedly with a cultipacker drawn by a 4 wheel Case tractor until no further consolidation was apparent. An attempt was made to simulate as nearly as possible shoulder construction conditions on regular highway projects.

Fertilizer of a 10-6-4 grade was broadcast over the area at the rate of 500 pounds per acre. A grass seed mixture composed of equal parts of Kentucky blue grass, Chewing's fescue, and domestic ryegrass was sown at the rate of forty pounds per acre. The fertilizer application was repeated about April 1st of each year. The grass was allowed to grow without mowing in the fall of 1944 and since that time it has been mowed four to six times each year with the ordinary sickle-bar type mower.

The experimental test area was constructed, fertilized and sown in August 1944.

PLAN OF GRASS PLOTS

Each Plot 10 Foot by 8 Foot

	Incoherent Sand-Dune	Graded Sand	Pit Run Gravel Parent Material Fox-Bellefontaine C-Horizon	Processed Gravel M.S.H.D. Spec. 22-A
Miami	(1) 10%	(13) 10%	(25) 10%	(37) 7%
Miami	(2) 20%	(14) 20%	(26) 20%	(38) 15%
Miami	(3) 30%	(15) 30%	(27) 30%	(39) 25%
Brookston	(4) 10%	(16) 10%	(28) 10%	(40) 7%
Brookston	(5) 20%	(17) 20%	(29) 20%	(41) 15%
Brookston	(6) 30%	(18) 30%	(30) 30%	(42) 25%
Peat and Clay	(7) Clay 10% Peat 5%	(19) Clay 10% Peat 5%	(31) Clay 10% Peat 5%	(43) Clay 10% Peat 5%
Peat and Clay	(8) 15% 10%	(20) 15% 10%	(32) 15% 10%	(44) 15% 10%
Peat and Clay	(9) 25% 15%	(21) 25% 15%	(33) 25% 15%	(45) 25% 15%
Bellefontaine Top Soil	(10) 50%	(22) 50%	(34) 50%	(46) 50%
Bellefontaine Top Soil	(11) 75%	(23) 75%	(35) 75%	(47) 75%
Bellefontaine Top Soil	(12) 100%	(24) 100%	(36) 100%	(48) 100%

Figure 1

Description of Soil Materials

The soil materials considered in the investigation are described in the following manner.

Miami Series: Miami is a well-drained clay soil ranging in texture from a loam to a silt loam occurring on undulating to rolling moraines and till plains. The soil is slightly plastic and easily compacted when moist, hard and dusty when dry, and soft and slick when wet. The soil is in the A-6 group of Public Roads Administration Soil Classification.

Brookston Series: Brookston soil is characterized as a poorly drained clay and ranges in texture from a loam to a clay loam. Under normal conditions, the soil is soft to plastic but will become tough to hard when dry. This soil falls in Group A-6 of Public Roads Administration Soil Classification.

Bellefontaine Series: The surface soil of Bellefontaine ranges in texture from sandy loam to a loam. The "B" horizon is a reddish brown color and consists of a mixture of sand, gravel and clay. The quantity of clay is sufficient to render the mass sticky when moist; moderately hard when dry. The soil falls in A-1 group of Public Roads Administration Soil Classification.

Fox Series: The surface soil of Fox ranges in texture from a sandy loam to a loam. The Fox soil is similar to Bellefontaine but is distinguished from it by more nearly level surface features, by a greater uniformity of the "B" horizon, and a uniform substratum of stratified gray sand and gravel which contains a high percentage of calcareous material. The soil falls in group A-3 of Public Roads Administration Soil Classification.

Incoherent Sand: Obtained from the Coloma soil series which ranges in texture from a sand to a loamy sand. It is loose, relatively low in water holding capacity and subject to wind erosion. Falls in Group A-3 of Public Roads Administration Soil Classification.

Graded Sand: A residue washed sand from a local gravel pit, woll graded from coarse to fine.

Pit-Run Gravel: C Horizon of Bellefontaine Series.

Processed Gravel 22-A: Road surfacing aggregates without clay binder soil. Consists of crushed gravel, and conforms to the grading and physical requirements for Michigan State Highway Department's specification for 22-A.

Clay: This soil was obtained from Miami Series, C Horizon.

Peat: Woody peat from local deposit.

The physical characteristics of the different soil materials have been summarized in Table 1.

GROWTH OF TURF

Although there are no adequate standard methods of measuring the quality of turfs for highway shoulders such as are used in agricultural research for measuring the productive capacities of pasture and meadow turfs, an attempt has been made during the past three growing seasons to evaluate the quality of the turf by estimating the percentage of grass coverage or, in other words, the density of the turf. A turf for highway shoulders is considered to be satisfactory if it is distributed fairly evenly over the ground and covers 65 to 70 percent of the surface area. Turf which covers 90 to 100 percent of the area may present a more pleasing appearance, but it is not necessarily more suitable for shoulders. The effect of the various soil mixtures on the growth of the grass are shown in Table II.

TABLE II - PERCENTAGE OF DIFFERENT GRASSES IN TURF FOR 1945, 1946 AND 1947

INCOHERENT SAND

			'45	'46	'47
MIAMI	1	F	50	60	25
		Q	50	30	75
	2	F	50	65	45
		Q	50	35	55
	3	F	65	75	50
		Q	35	25	50
BROOKSTON	4	F	95	98	100
		R	5		
	5	F	80	98	100
		R	20		
	6	F	70	98	100
		R	30		
CLAY-PEAT	7	F	80	98	100
		R	20		
	8	F	70	100	95
		R	30		
	9	F	70	100	98
		R	30		
BELLEFONTAINE	10	F	50	98	85
		Q	0	0	10
		R	50		
	11	F	50	75	85
		Q	10	15	15
		R	40		
	12	F	20	75	60
		Q	20	15	35
		R	60		

GRADED SAND

			'45	'46	'47
MIAMI	13	F	50	50	25
		Q	50	50	75
	14	F	60	65	35
		Q	40	30	65
	15	F	70	65	35
		Q	30	35	65
BROOKSTON	16	F	95	98	100
		R	5		
	17	F	95	98	100
		R	5		
	18	F	60	98	100
		R	40		
CLAY-PEAT	19	F	95	100	100
		R	5		
	20	F	95	100	100
		R	5		
	21	F	100	100	100
BELLEFONTAINE	22	F	60	50	95
		R	40		
	23	F	50	30	50
		Q	10	50	45
		R	40		
	24	F	20	45	50
		Q	20	45	45
		R	60		

PIT RUN GRAVEL

			'45	'46	'47
MIAMI	25	F	80	70	40
		Q	20	25	60
	26	F	60	60	45
		Q	40	35	55
	27	F	60	60	35
		Q	25	35	65
		R	15		
BROOKSTON	28	F	70	98	90
		Q	0	0	10
		R	30		
	29	F	70	90	97
		Q	0	10	3
		R	30		
	30	F	40	100	90
		Q	0	0	5
		R	60		
CLAY-PEAT	31	F	65	100	100
		R	35		
	32	F	60	100	100
		R	40		
	33	F	55	100	98
		R	45		
BELLEFONTAINE	34	F	50	75	90
		R	50		
	35	F	50	40	50
		Q	10	40	40
		R	40		
	36	F	20	35	50
		Q	20	50	45
		R	60		

22-A PROCESSED GRAVEL

			'45	'46	'47
MIAMI	37	F	80	80	70
		Q	20	20	30
	38	F	60	75	45
		Q	20	25	55
		R	20		
	39	F	60	50	35
		Q	20	45	65
		R	20		
BROOKSTON	40	F	50	95	95
		R	50		
	41	F	20	95	95
		R	80		
	42	F	20	95	95
		R	80		
CLAY-PEAT	43	F	60	100	100
		R	40		
	44	F	50	100	98
		R	50		
	45	F	50	98	100
		R	50		
BELLEFONTAINE	46	F	70	75	95
		R	30		
	47	F	50	80	95
		Q	10	10	5
		R	40		
	48	F	20	50	50
		Q	20	35	50
		R	60		

F = Chewing's fescue Q = Quackgrass R = Ryegrass

The Kentucky bluegrass did not survive in competition with the domestic ryegrass and Chewing's fescue even in the first year on these soil mixtures.

Domestic ryegrass germinated quickly and grew rapidly in the fall of 1944 and 1945. The growth of the ryegrass was proportional to the amount of fine material in the mixtures, an excellent cover being produced on the plots which contained the highest percentages of fines. The largest growth of grass in the fall of 1944 and in 1945 was produced on plot 42 consisting of 25% Brookston loam surface soil mixed into the 22-A gravel material. The growth of the grass on plots 41,12, 24, 36, and 48 was almost as large as on plot 42. Plot 41 consisted of 20% Brookston loam surface soil mixed with the 22-A gravel material and plots 12, 24, 36, and 48 had 6 inches of Bellefontaine sandy loam placed over incoherent sand, graded sand, pit-run gravel, and 22-A gravel respectively.

Chewing's fescue was the only grass that survived to any extent in 1945 on plots 16 to 21 inclusive. These plots are the ones in which Brookston loam surface soil and mixtures of clay and peat are added to the graded sand base material. It was the dominant grass on all plots on dune sand, pit-run gravel, and 22-A gravel base in 1945 with the following exceptions: (1) Ryegrass predominated on all plots on which 6 inches of Bellefontaine sandy loam was placed over the base material; (2) Ryegrass predominated on the 22-A gravel base material to which 20 and 30 percent Brookston loam surface soil was added and on the pit-run gravel material in which 30 percent Brookston loam surface soil was added.

The turf on the plots in which 75 and 100 percent Bellefontaine sandy loam and those in which Miami loam surface soil was added contained from 10 to 50 percent of quackgrass. Roots and rhizomes of quackgrass were introduced into these plots with the Miami and Bellefontaine surface soils. Some weed seeds, plantain, sorrel, dock, dandelions, and thistles were likewise introduced with the surface soils. These weeds have reproduced and grown vigorously in the turf, especially on the plots in which Bellefontaine sandy loam was added to the granular base materials.

During the growing season of 1945 and the following winter, all of the domestic ryegrass disappeared from the turf. The net result was that the turf, on plots on which the luxuriant growth of the domestic ryegrass retarded the growth of Chewing's fescue, became very thin with incomplete coverage of the surface in 1946. This was especially true of the plots with 22-A graded gravel, pit-run gravel, and graded sand materials in which 20 and 30 percent of Brookston loam surface soil were mixed.

The turf on almost all of the plots except those with the incoherent sand base material deteriorated during the 1946 growing season because of the extremely low rainfall. The total rainfall from June 20 to September 1 was approximately .05 inch. Chewing's fescue and quackgrass, two grasses that are extremely drought tolerant, i.e., they become dormant during drought periods and recover quickly when moisture is again available recovered remarkably during the fall of 1946 and the growing season of 1947. The moisture conditions in 1947 were extremely favorable for the growth of grasses.

The quackgrass introduced with the Miami loam and Bellefontaine sandy loam soils grew vigorously in 1947, a season of relatively high rainfall, especially in the spring. The quackgrass grew so vigorously on the plots in which Miami loam surface soil was added that the turf contained at least 50 percent quackgrass except that on the plot consisting of 10 percent Miami loam mixed with 22-A gravel. On the plots in which Bellefontaine was added to the granular base materials the proportion of quackgrass in the turf was influenced by the soil mixtures. There was only a very small amount of quackgrass in one of the plots containing 50 percent Bellefontaine sandy loam, 5 to 45 percent quackgrass in the plots containing 75 percent Bellefontaine sandy loam, and 35 to 50 percent in the plots containing 100 percent Bellefontaine sandy loam.

PERCENT TURF COVERAGE

The quality of turf for shoulder purposes is reflected in the density of coverage of the soil surface rather than in the total growth of the grass. The estimated densities of the turf coverage on the plots for the years 1945, 1946, and 1947 are shown in Table III. These data indicate the effect of the soil, of the seasonal climatic conditions, and of the grass varieties used in the seed mixtures and introduced as vegetative material with the surface soil on the turf.

TABLE III - PERCENT COVERAGE OF TURF 1945-1946-1947

	INCOHERENT SAND				GRADED SAND				PIT RUN GRAVEL				22-A PROCESSED GRAVEL			
	Plot	'45	'46	'47	Plot	'45	'46	'47	Plot	'45	'46	'47	Plot	'45	'46	'47
MIAMI	1	30	60	95	13	20	50	95	25	40	65	95	37	60	60	95
	2	45	70	100	14	50	65	100	26	55	70	100	38	65	70	100
	3	65	70	100	15	65	65	100	27	65	70	95	39	70	70	100
BROOKSTON	4	40	65	85	16	30	35	55	28	60	30	60	40	70	70	95
	5	55	75	95	17	40	60	65	29	75	40	65	41	85	75	95
	6	65	75	95	18	60	40	75	30	80	25	50	42	95	75	95
CLAY-PEAT	7	40	70	85	19	30	20	25	31	55	40	60	43	60	60	90
	8	45	75	95	20	30	20	35	32	50	40	70	44	60	70	90
	9	55	75	95	21	25	30	55	33	55	45	70	45	60	60	95
BELLEFONTAINE	10	50	70	100	22	50	40	70	34	55	40	75	46	70	60	95
	11	75	85	100	23	75	40	90	35	75	50	90	47	75	60	95
	12	90	90	100	24	90	80	100	36	90	75	100	48	90	75	100

From the data given in Table III, it is noted that satisfactory highway shoulder turf was produced in 1945 on all of the plots containing 22-A gravel material, and on all plots in which 30 percent Miami loam, 30 percent Brookston loam, or 75 and 100 percent Bellefontaine sandy loam were used as additive materials with the incoherent sand, graded sand, or pit-run gravel base materials. Likewise the turf was satisfactory on the two plots in which 10 and 20 percent Brookston loam was mixed with the pit-run gravel base material.

The turf on the 22-A gravel and the incoherent sand base materials was satisfactory for highway shoulder purposes in 1946, with grass coverages ranging from 60 to 90% of the surface. Likewise the turf, on all plots in which 20 or 30% Miami loam surface soil was the additive material, was within the satisfactory range, with 60 to 90 percent grass coverage. The same was true of all plots in which the granular base materials were covered with a layer of 6 inches of Bellefontaine sandy loam.

The turf on the plots in which graded sand or pit-run gravel were the base materials was not as good, in general, as that produced on the 22-A graded gravel and on the incoherent sand base materials. Likewise the turf produced on plots in which clay-peat mixtures were used as the additive soils were not as satisfactory, generally, as that on the plots in which the loam and sandy loam surface soils were used. However, the turf on the plots consisting of pit-run gravel and graded sand base materials, in which Brookston loam was added, was very poor in 1946. This was because of the domination of the ryegrass in the early stages of establishment on these soil mixtures and of its subsequent disappearance from the turf.

The growth of the grass was much improved generally during 1947, a season of relatively high rainfall, especially during the spring and early summer. Turf was so thin and scattered as to be termed unsatisfactory on only seven plots, 16, 19, 20, 21, 28, 30, and 31. The soil mixtures and turf coverages on these plots were as follows:

(16) 10% Brookston loam with graded sand, 55% coverage;

(19) 10% clay plus 5% peat with graded sand, 25% coverage;

(20) 15% clay plus 10% peat, with graded sand, 35% coverage;

(21) 25% clay plus 15% peat with graded sand, 55% coverage;

(28) 10% Brookston loam with pit-run gravel, 60% coverage;

(30) 30% Brookston loam with pit-run gravel, 50% coverage;

(31) 10% clay plus 5% peat with pit-run gravel, 60% coverage;

Satisfactory turf was produced on all plots with incoherent sand or with 22-A graded gravel base materials regardless of type of additive soil.

STABILITY OF GRASS PLOTS

One year after the grass plots were constructed and seeded, two types of stability tests were conducted on the grass plots to determine their ability to support loads under dry and saturated conditions. The first series of tests consisted of applying a static load through a 100 square inch bearing plate and measuring the amount of penetration at different load increments. The second series of tests were made to check the resistance of the grass plots to rutting. This was accomplished by driving a heavy truck across the plots and measuring the depth of the rut caused by the moving wheels.

The plate bearing tests were made when the soil was in a normal dry condition, whereas the truck tests were conducted when the soil was both in a dry and in a saturated condition.

Plate Bearing Tests

A five ton truck was loaded with gravel and other ballast. It was backed into such a position that the rear of the box was above the area to be tested. The 100 square inch plate was placed on the ground and worked slightly until it rested in a level position. An angle iron frame supporting a Federal one-thousandth dial was moved into place so that the dial stem was at the center of the plate. A slotted cylinder was placed over the dial and adjusted until the dial face could be read through an opening. The cylinder was capped by a special plate to which a hydraulic jack was attached. A calibrated dynamometer ring was fastened to this assembly, and the upper fitting on this ring reacted against blocks under the truck box. A general view of the apparatus is shown in Figure 3 and details may be seen in Figure 4.

After a small preliminary load had been applied to seat the plate, the bearing plate was loaded. Five hundred pound increments were applied in fairly rapid sequence. As soon as the dial showed no further settlement the next increment of load was applied. This was repeated until the limit of the dial travel was reached. Graphs were constructed for each test, but for comparative purposes the subgrade modulus "k" for a 2500 pound load has been tabulated in Table IV for each grass plot. The soil moisture condition was noted at the time of test. The bearing plate tests were made only under normally dry soil conditions. Only one series of penetration tests was conducted.

TABLE IV - RESISTANCE OF TURF TO BEARING PLATES (100 SQ. IN.)

Load - 2500 lbs.

Plot No.	Penetration (inches)	"k"	% Moisture	Plot No.	Penetration (inches)	"k"	% Moisture
1	0.540	46	D	25	0.200	125	A
2	0.490	51	D	26	0.152	164	A
3	0.800	31	D	27	0.106	236	A
4	0.640	39	D	28	0.158	158	A
5	0.335	75	D	29	0.185	135	A
6	0.435	57	D	30	0.167	150	A=2.67
7	0.520	48	D	31	0.205	122	A
8	0.440	57	D	32	0.500	50	B
9	0.230	109	D	33	0.575	43	B
10	0.480	52	C	34	0.582	43	B
11	0.610	41	C	35	0.390	64	B
12	0.900	28	C	36	0.670	37	B
13	0.240	104	D	37	0.087	287	A
14	0.250	100	D	38	0.110	227	A
15	0.235	106	D	39	0.140	179	A
16	0.440	57	D	40	0.193	130	A
17	0.325	77	D	41	0.162	154	A
18	0.350	71	D	42	0.250	100	A=4.11
19	0.375	66	D	43	0.160	156	A
20	0.570	44	D	44	0.590	42	B
21	0.480	52	D	45	0.520	48	B
22	0.350	71	C	46	0.360	69	B
23	0.430	58	C	47	0.220	114	B
24	Failure	---	C	48	0.545	46	B

Moisture Code (% Moisture)

	Plot 6	Plot 18	Plot 30	Plot 42
A	3.83	5.53	2.67	4.11
B	10.25	8.41	4.68	6.26
C	10.22	11.16	5.23	5.85
D	10.01	7.39	4.85	4.59

$$k = \frac{P}{A\ z}$$

P = Load in pounds
A = Bearing area in square inches
z = Penetration in inches
k = Modulus of subgrade stiffness in pounds per cubic inch.

Rutting Tests

The second test for stability of the grass plots was conducted by driving a loaded truck over each plot and noting the depth of the wheel rut. The load used was 10,000 pounds on a rear axle supported by two 10.00-20 tires at 70 p.s.i. pressure. The truck was driven in creeper gear just rapidly enough to prevent stalling in the poor sections. Figure 5 is a picture of a section of low stability. Figure 6 shows a more typical rut. Because of difficulties encountered in getting the truck over the plots only one run was attempted.

The effect of the passage of the truck was measured by using profiles. Reference stakes were driven each side of each plot. A straight edge was placed across these stakes and at six inch intervals vertical measurements were made with a scale to the ground. Profiles were made before rutting, after rutting in the dry state, and again after rutting in the saturated state. The data for the rutting test is given in Table V.

Discussion of Test Results

At the time of conducting tests, the turf growth had not developed sufficiently to contribute materially to the stability of the soil base material. However, the tests do show the relative stability of each grass plot in relation to its soil content.

The results will be discussed in light of the two major features of the study: (1) the effect of adding certain top soils to incoherent or granular base materials to produce stability and plant growth and (2) a comparative study of granular materials for shoulder work.

TABLE V - RESISTANCE OF TURF TO RUTTING

Load 5,000 lbs. per wheel (10,000 lbs. on rear axle - 2 wheels)

Plot No.	Rut Depth in. (dry)	"k"	% Moisture (dry)	Rut Depth in. (wet)	"k"	% Moisture (wet)
1	3.5	20		1.9	37	8.7
2	2.6	27		2.8	25	
3	1.3	54		3.1	23	
4	1.9	37		4.0	17	
5	1.4	50		3.2	22	
6	1.1	64	3.83	2.2	32	20.6
7	2.4	29		3.3	21	
8	2.7	26		3.4	21	
9	1.6	44		2.5	28	
10	1.6	44		3.2	22	
11	0.4	175		2.4	29	
12	0.8	87		5.0	14	18.1
13	5.3	13		2.4	29	7.8
14	3.4	21		2.8	25	
15	2.0	35		2.7	26	
16	3.4	21		3.6	19+	
17	3.9	18		4.2	17	
18	2.0	35	5.53	2.3	30	11.1
19	3.5	20		2.9	24	
20	2.2	32		2.9	24	
21	1.9	37		2.5	28	
22	0.5	140		3.3	21	
23	0.6	117		1.2	58	
24	0.3	233		4.2	17-	17.7
25	2.8	25		2.8	25	5.8
26	2.0	35		2.8	25	
27	1.4	50		2.2	32	
28	2.3	30		2.4	29	
29	1.4	50		2.0	35	
30	0.3	233	2.67	2.0	35	8.1
31	1.2	58		2.0	35	
32	1.8	39		2.9	24	
33	0.3	233		3.0	23	
34	0.3	233		2.2	32	
35	0.4	175		2.0	35	
36	0.4	175		2.8	26	19.1
37	0.5	140		3.6	19+	7.2
38	0.1	700		3.4	21-	
39	0.0	00		2.8	25	
40	1.0	70		2.9	24	
41	0.4	175		2.9	24	
42	0.7	100	4.11	3.0	23	
43	0.4	175		2.9	24	
44	1.1	64		3.2	22	
45	0.2	350		2.1	33	
46	0.3	233		2.0	35	
47	0.4	175		2.2	32	
48	0.2	350		3.8	18+	17.7

Figure 7 contains a graphic summary of the load test data showing the subgrade modulus "k" factor for each plot area including both types of tests and for depth of penetration for each test condition. As a means of evaluating the four different base materials on basis of stability, the average "k" factor was determined for each soil base group by averaging the "k" values of the respective plots for all three sets of tests. The average of these average "k" values was used as a basis for selecting the best base material. The average "k" factor for the four base granular materials was found to be as follows: Incoherent sand 44, graded sand 50, pit-run gravel 79 and 22-A gravel 100. The plots having a "k" factor above average are now classified in Table VI in order of their performance.

The data in Table VI indicate that the overlay from gravel pits in Bellefontaine sandy loam produces very stable shoulders when mixed with incoherent sand, graded sand and pit-run gravel materials. The highest stability in the incoherent sand group was found in plot 11, in which 75% Bellefontaine sandy loam was mixed; the highest and next to highest on graded sand on plots 22 and 23 with 50% and 75% Bellefontaine sandy loam respectively; and the second and third highest on pit-run gravel on plots 34 and 35 with 50% and 75% Bellefontaine sandy loam respectively.

High stability was produced, likewise, on incoherent sand with the mixture of 25% clay and 15% peat in plot 9 and with 20% and 30% Brookston loam surface soil in plots 5 and 6; likewise with 20% and 30% Miami loam surface soil in plots 14 and 15 on graded sand base; with 25% clay plus 15% peat in plot 33 and with 30% Brookston loam surface soil in plot 30, both on pit-run gravel.

Table VI

SUMMARY OF TURF PLOTS WITH HIGHEST STABILITY

Rating	Incoherent Sand			Graded Sand			Pit Run Gravel			22-A Gravel		
	Plot No.	Added Soil	Turf Coverage (1)	Plot No.	Added Soil	Turf Coverage	Plot No.	Added Soil	Turf Coverage	Plot No.	Added Soil	Turf Coverage
1	11	75% Bellefontaine	75 100	22	50% Bellefontaine	50 70	30	30% Brookston	80 50		15% Miami	65 100
2	9	Clay 25% Peat 15%	45 100	23	75% Bellefontaine	75 90	34	50% Bellefontaine	55 75		25% Miami	70 100
3	6	30% Brookston	65 100	15	30% Miami	65 100	35	75% Bellefontaine	75 90		15% Brooks- ton	85 95
4	5	20% Brookston	40 85	14	20% Miami	50 100	33	25% Clay 15% Peat			10% Clay 5% Peat	60 90

(1) Minimum coverage for satisfactory service considered 60 to 65 percent.
Top figure percent coverage for 1945, bottom figure 1946.

Good stability was given by the addition of 15% and 25% Miami loam, 15% Brookston loam, and the mixture of 10% clay and 5% peat on 22-A gravel.

An interesting stability relationship among the four granular base materials is shown in Figure 8. The data in Figure 8 indicate that shoulders in which 22-A gravel is used will be more stable than those with incoherent sand, graded sand, or pit-run gravel materials.

CONCLUSIONS

Chewing's fescue which is tolerant of droughty soil conditions proved to be an excellent grass to plant on sandy and gravelly shoulder materials when suitable stabilizing soil was added.

Miami loam, Brookston loam, mixtures of clay and peat, and Bellefontaine sandy loam have all been found to be satisfactory for mixing with sandy and gravelly base materials for the production of turf. The Miami loam surface soil and the Bellefontaine sandy loam overlay from the gravel pit in this case had the added advantage that they contained a large amount of quackgrass roots and rhizomes. The establishment of the quackgrass in these plats, especially where miami loam was added, aided in the development of a uniform, thick turf.

Subsoil clay to furnish binder, and peat to furnish organic matter mixed with the coarse sandy and gravelly base materials will produce turf successfully except on washed graded sand. However fescue should be planted alone to eliminate competition from nurse-grasses and larger applications of fertilizer made to make up for the lack of organisms and plant food in the raw subsoil materials.

Brookston loam surface soil was found to be satisfactory material to mix with the various granular materials for the growth of grass. However the seed mixtures should be adjusted so that the so-called nurse-grass (in this case domestic rye-grass) does not grow so vigorously that it retards the establishment of the permanent grass (Chewing's fescue).

Generally, Chewing's fescue should be planted alone on highway shoulders containing coarse sandy and gravelly materials. When domestic rye-grass or other socalled nurse grasses are seeded in the mixtures they germinate quickly and produce a rapid early growth.

This tends to retard the establishment of the Chewing's fescue to the detriment of the turf in the second year when the rye-grass disappears. This was especially true on the plots where the larger percentages of fines were added and on the graded sand and pit-run gravel where clay-peat mixtures were added. However, when smaller percentages of fines were added, the rye-grass blended well with the fescue to produce a good cover in the first year without having a detrimental effect on the turf in the second year. This grass should likewise be sown alone on 22-A gravel material where 20% and 30% Brookston loam has been added. A mixture of three parts Chewing's fescue and one part domestic rye-grass could be used effectively on all other soil mixtures added to the 22-A gravel material.

Kentucky blue grass did not survive in the turf under the conditions of this experiment.

There was good correlation between the bearing plate tests and the rutting studies. In general the plate tests were less severe than the rutting tests.

The 22-A gravel material in addition to producing satisfactory turf with all added soils, was found to exhibit greater stability than the other granular materials.

Bellefontaine sandy loam, 50% and 75% mixtures produced high stability with incoherent sand, graded sand, and pit-run gravel. Likewise the turf was considered satisfactory on these plots.

Good stability was produced on incoherent sand with 20% and 30% Brookston loam; on graded sand with 20% and 30% Miami loam; on pit-run gravel with 30% Brookston and with a mixture of 25% clay and 15% peat; and on 22-A gravel with 15% and 25% Miami loam, with 15% Brookston loam, and with a mixture of 10% clay and 5% peat.

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Discussion of Report by Tyson and Finney

(Questions were addressed to the co-author, Mr. Finney)

Isn't compaction by cultipacker insufficient to provide a stabilized shoulder material? Was a heavy roller used at any time?

No roller was used. A cultipacker was used, which was pulled by a four-wheel Case tractor. This was done to give compaction comparable to normal compaction on highway shoulders under present practices.

Were density determinations made? There should be a uniform method of determining densities. What is the simplest method of obtaining densities?

No density tests have been made, but are planned on this or subsequent work. The methods of determining density as specified by the ASTM and AASHO are accepted by soils engineers generally. Determinations are made in increments rather than full depths.

Is there need for both plate and rutting tests? (The plate test seems to have been less severe.)

It may be that both are not necessary. Perhaps the rutting test by use of the truck is more indicative of shoulder value. However, the plate test will tie in better on a comparative basis with other data accepted by engineers. It is also of value to correlate with rutting tests.

Change in seed formulas might be valuable as the percentage of rye grass used was evidently too high.

Tentative plan is to try other seed mixtures.

Were mulches used? Use of mulches might improve quality of turf and extend seeding season.

No mulches were used, but might be included in future tests.