Turf Investigations for Airports and Highways

E. J. Yoder
Joint Highway Research Project
and
W. H. Daniel
Department of Agronomy
Purdue University.

During the past war a great need arose for building new airports for defense and training purposes. The smaller airports that carried light traffic were for the most part not paved, but rather consisted of turf cover. The need for adequate turf on these airports is at once apparent when the hazard of dust is considered. The need for dust control is critical from the standpoint of damage done to aircraft engines as well as decreased visibility and the discomfort to personnel. Another problem of concern, particularly in the case of civil airports is that of beautification of the area adjacent to the waiting rooms.

A good growth of turf will cut down on the erosion of side slopes. The increase in load carrying capacity of a sod cover over that of a saturated soil is well known. Further, mechanically stabilized soil has long been recognized as being adequate for landing areas for light planes and berms for highways. Mechanical stabilization alone, however, does not give the complete answers to these problems. It was with these factors in mind that in 1946 the Corps of engineers U. S. Army financed a research project at Purdue University to investigate the effect of turf on several granular materials (1, 2). This work was a cooperative project between the Joint Highway Research Project and the Department of Agronomy at Purdue. The investigation was divided into two parts, one a laboratory and greenhouse study and the other a field investigation.

Later, in 1948, the Indiana State Highway Commission constructed an experimental granular shoulder for purposes of investigating further the use of turf on granular materials. These studies were all reported by Willis Skrdla in his thesis submitted to the faculty of Purdue University in partial fulfillment of the requirements for the degree of Doctor of Philosophy (2).

In 1950, the Joint Highway Research Project entered into a contract with the U. S. Corps of Engineers to construct several experimental turf plots to investigate further the problems associated with growing turf on various types of materials (3).

This paper presents a summary of the turf experiments carried out to date as well as several general statements regarding growing turf. For purpose of clarity the paper is divided into two parts: (1) laboratory investigations and (2) field investigations

PART I—LABORATORY INVESTIGATION

The purpose of the laboratory portion of the investigation was two-fold. First, it was the purpose to study the effect of soil content on turf growing characteristics of several granular materials and in turn to study the effect of turf on the strength characteristics of soil-aggregate mixtures. The second phase was set up to investigate the plant nutrient supplying power of the various materials.

Five granular materials were studied. They were: gravel, sand, crushed limestone, crushed traprock, and a natural sandclay. Two soil binder materials were added in varying quantities to each of the granular materials with the exception of the sandclay. The quantity of soil was varied so that the percentage passing the No. 200 mesh sieve was varied from 4.5 per cent to 15.5 per cent by weight. The two soil binders, designated pedologically as Crosby, were of late Wisconsin drift age occurring on the level to gently undulating areas of the till plains. One soil represented the "A" horizon and the other the "B" horizon. Table I shows the results of classification tests made on the raw materials.

TABLE I
Physical Properties of the Materials Used in Laboratory Study

Material	Apparent Specific Gravity	% Finer #200 Sieve	% Finer 0.005 mm.	Liquid Limit (%)	Plastic Limit (%)
Gravel	2.74	0.1	----	----	N.P.*
Sand	2.74	0.3	----	----	N.P.
Limestone	2.73	0.8	----	----	N.P.
Traprock	3.08	1.6	----	----	N.P.
Sandclay	----	10.8	----	----	N.P.
Crosby "A"	2.67	90.5	22	27	N.P.
Crosby "B"	2.68	89.0	30	36	17

* Non-Plastic.

The maximum size aggregate in the gravel crushed limestone and crushed traprock was ¾ inches. The graduation of each of the aggregates was adjusted so that each had approximately the same grain size distribution curves. It will be noted that each of the granular materials contained some dust. The gradation of each was adjusted so that the actual amount passing the No. 200 mesh sieve, after the soil was added, was as shown in Table II.

TABLE II
Quantity of Soil in Soil-Aggregate Mixtures

Material	Quantity of Soil (% pass #200)	Type of Soil
Sand	10.5, 15.0	Crosby "A"
Sand	10.5, 15.0	Crosby "B"
Gravel	7.0, 10.5	Crosby "A"
Gravel	7.0, 10.5	Crosby "B"
Limestone	4.5, 7.0, 10.5, 13.0, 15.5	Crosby "A"
Limestone	7.0, 10.5	Crosby "B"
Traprock	4.5, 7.0, 10.5, 13.0, 15.5	Crosby "A"
Traprock	7.0, 10.5	Crosby "B"
Sandclay	Natural Material	Natural Material

PROCEDURES

For the laboratory experiments the materials were compacted into clay-tile cylinders seven inches high by six inches in diameter. Four specimens of each soil aggregate mixture were compacted to a height of six inches by means of a 10-pound impact hammer. They were compacted in six layers using 55 blows of a 10-pound hammer.

After compaction, the specimens were taken to the greenhouse where they were supplied with all the fertilize elements considered essential for good plant growth including nitrogen, potassium, phosphorous, and calcium. All the specimens were placed on a layer of vermiculite to keep them moist. One-half the specimens were seeded with Alta fescue at the rate of 120 pounds per acre. The remainder were kept in their original condition.

During the growing period the tops of the grass were clipped, on those specimens with turf, 2½ inches from the surface of the aggregate, dried and weighed. A total of four cuttings were made at different intervals. After the fourth clipping the grass stems were cut off at the surface of the aggregate and C. B. R. tests performed on all specimens both those with and without turf.

Briefly stated the C.B.R. test is a penetration test in which the specimens are penetrated with a piston having an end area of three square inches at a constant rate of .05 inches per minute. Figure 1 shows the equipment set-up for a C.B.R. test. A surcharge weighing 12 pounds was used on the specimens. The C.B.R. was calculated as the ratio of the unit load on the piston at 0.1 inches penetration to that of the standard load of 1000 p.s.i.

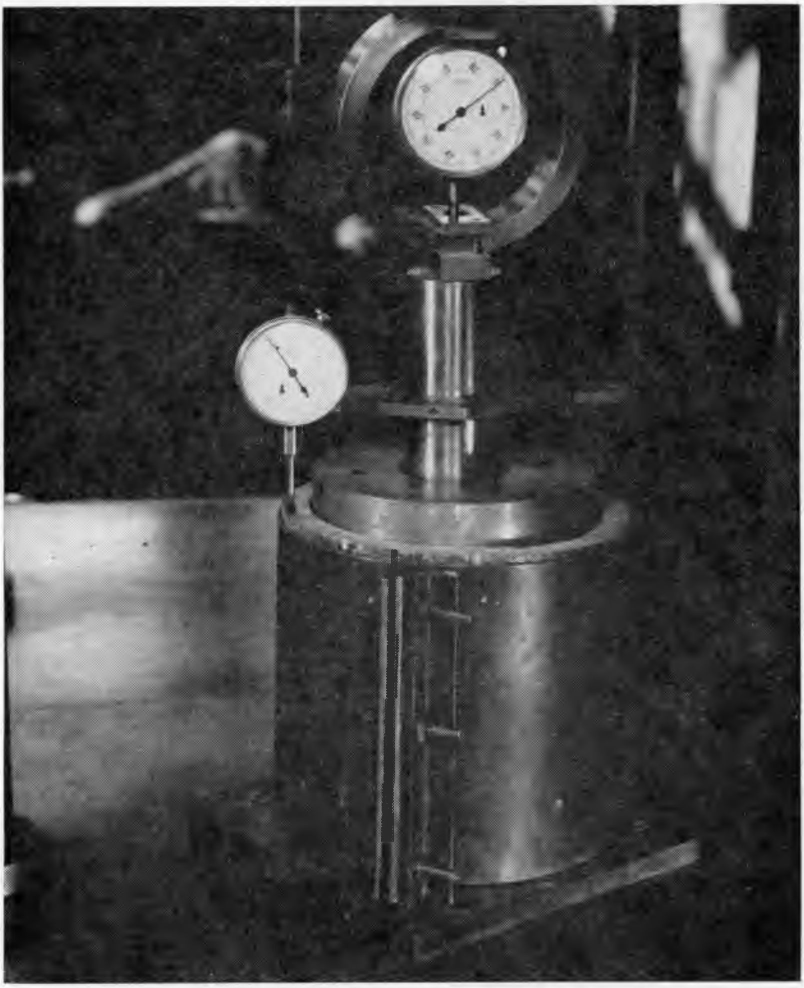


Fig. 1, Equipment set-up for laboratory C. B. R. test. The clay cylinders were reinforced with a metal casing.

RESULTS OF C.B.R. TESTS

Figure 2 shows a group of typical C.B.R. penetration curves. These show the results of the tests made on the gravel specimens. It will be noted that all the curves were slightly concave for low penetrations. However, those specimens with turf were definitely concave due to the mat of roots that were on top the specimens. These curves were all corrected by drawing a straight line parallel to the steepest portion of the curve but through the origin. The

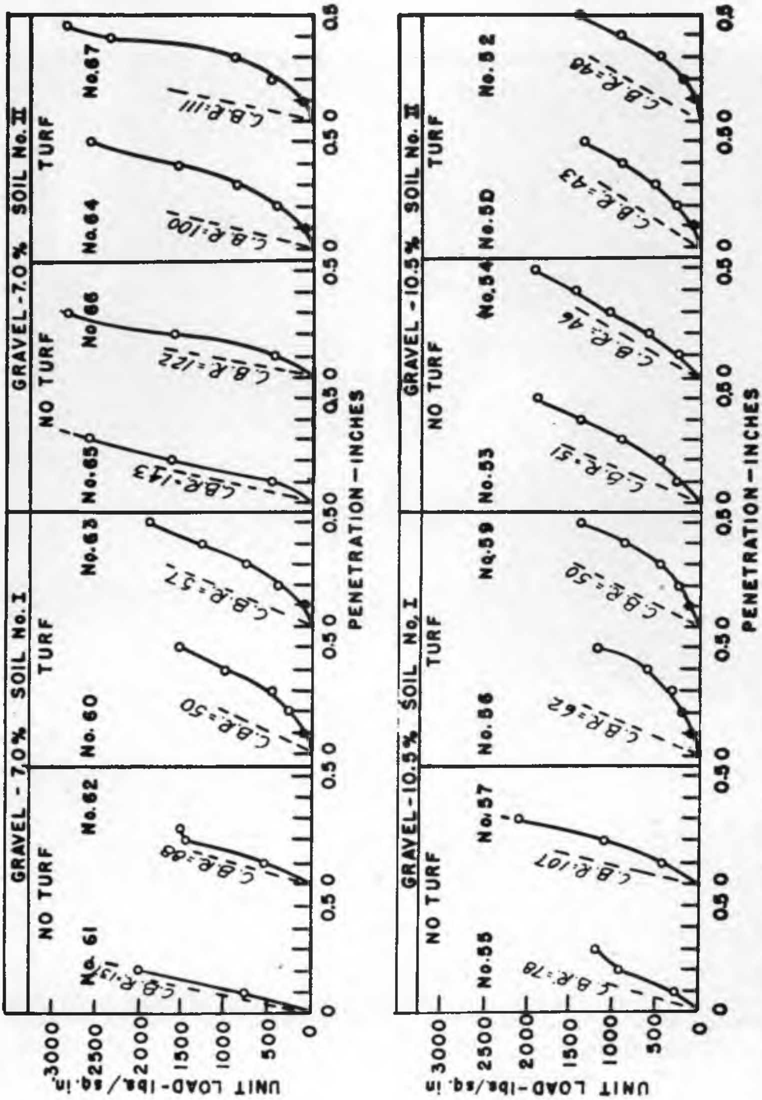


Fig. 2. Typical C. B. R. penetration curves showing effect of turf growth on bearing ratios.

bearing ratio was then calculated on the basis of the new unit load at 0.1 inch penetration.

Figures 3 through 6 show the effect of turf on the bearing ratios of the samples. For the most part the turf had the affect of decreasing the bearing ratios. On just one material, sand, the C.B.R. of the speimens with turf were higher than those with no turf. The sandclay material showed a large decrease in bearing ratio with turf.

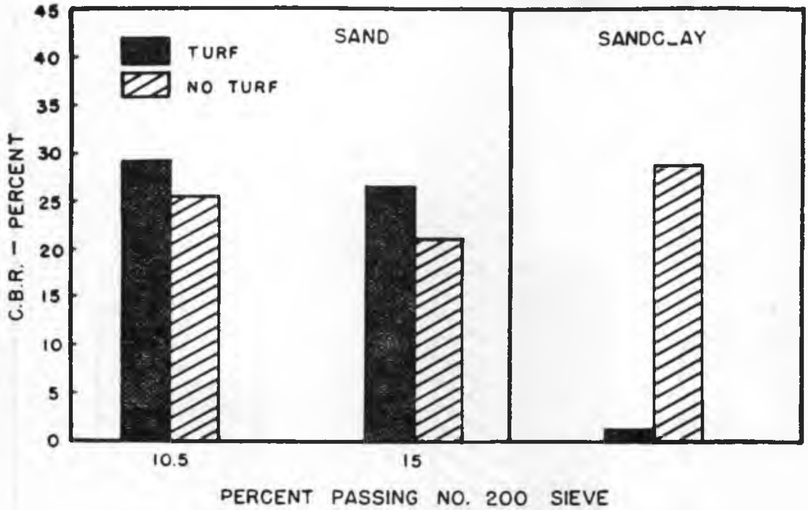


Fig. 3. Effect of turf on laboratory C. B. R. of sand.

Considering figure 5, limestone, it can be seen that the specimens with no turf resulted in increased bearing ratios up to approximately 13 per cent soil, but that those specimens with turf had approximately the same bearing ratio irrespective of soil content.

TURF DEVELOPMENT

The affect of each of the aggregates on turf development is shown in Table III. This table shows the average dry weight of roots and tops for the specimens irrespective of the quantity and type of soil mixed in the aggregate. Inspection of this table reveals that the fine grained materials, sand and sandclay, produced the greatest amount of tops and roots. This table partially explains the results of the C.B.R. tests inasmuch as the sandclay showed the greatest reduction in bearing ratio and the greatest turf growth. The sand, however, showed the reverse—that is, increased bearing ratios of the turf specimens over those with no turf.

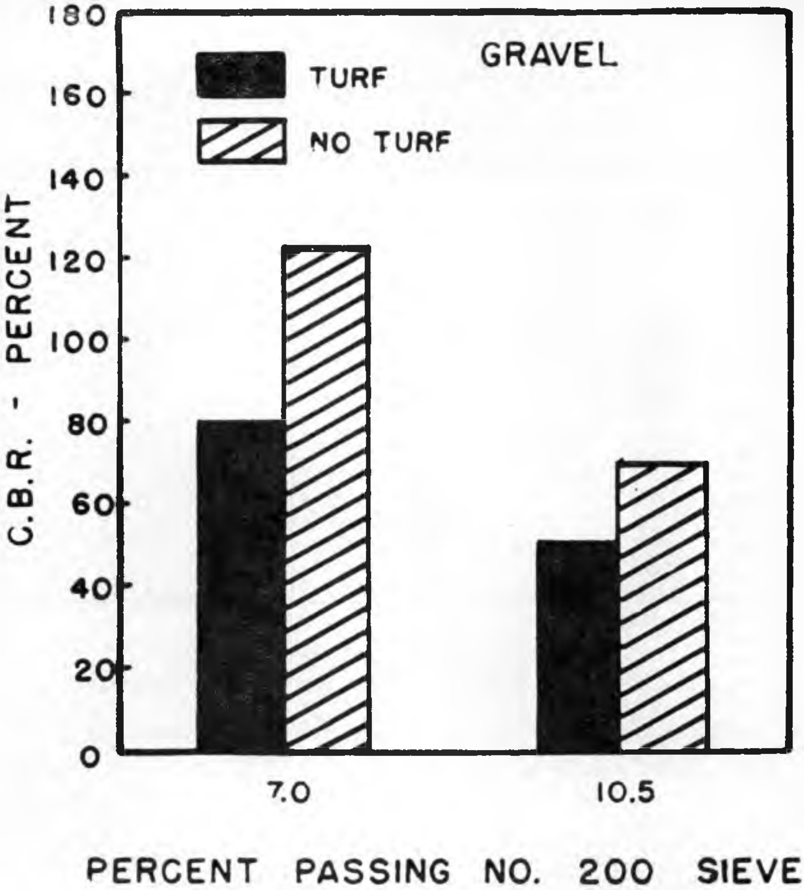


Fig. 4. Effect of turf on laboratory C. B. R. of gravel

TABLE III
Average Dry Weight (Grams) of Tops and Roots
of
Alta Fescue Produced on Each Type of Aggregate

Aggregate	Roots				Tops
	Section No.			Total	Average of four Harvests
	1	2	3		
Sand	3.3	0.7	0.02	4.02	4.1
Gravel	2.6	0.7	0.02	3.32	3.3
Limestone	2.1	0.2	T	2.30	2.8
Traprock	2.2	0.2	0.03	2.43	2.8
Sandclay	6.5	3.1	T	9.60	4.2

In the case of the limestone and traprock mixtures the total amount of roots and tops were approximately the same but the turf affected the bearing ratios of the two materials differently (see Figures 5 and 6). This can be explained in part, at least, by the depth to which the roots penetrated the specimens. The roots penetrated deeper into the traprock than into the limestone.

It was observed throughout the experiment that water was absorbed more readily by the specimens with turf than those with no turf. The most impermeable specimens were those containing the optimum amounts of soil (7.0% to 15.0%).

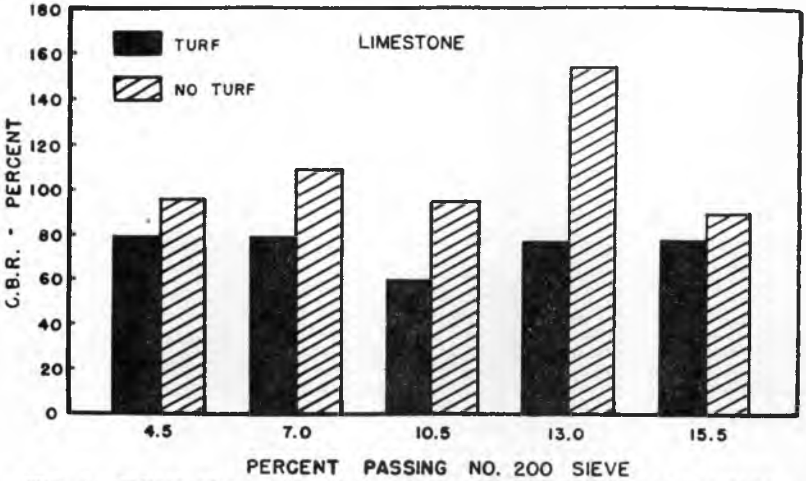


Fig. 5. Effect of turf on laboratory C. B. R. of crushed limestone.

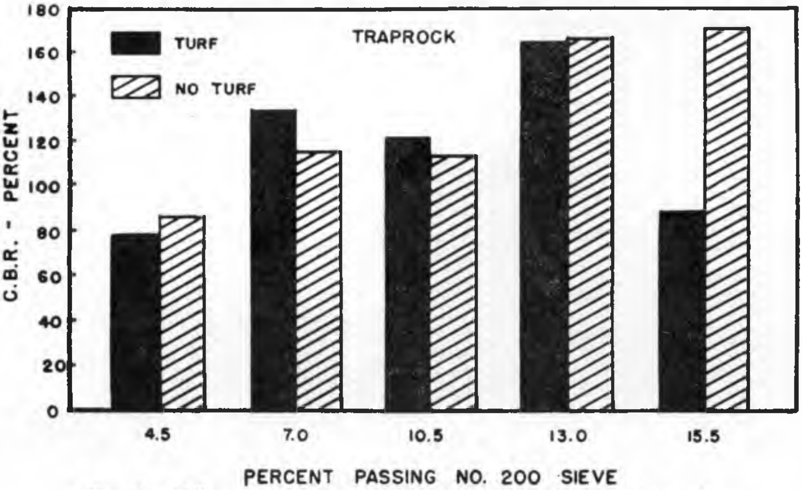


Fig. 6. Effect of turf on laboratory C. B. R. of traprock.

This investigation brought out that turf could be established on all of the aggregates tested. Apparently the optimum of amounts of soil, on the basis of density and strength, was sufficient to insure good growth of turf so long as the essential elements were present. More dry matter was produced on mixtures containing the Crosby "A" as binder, however, the difference was not great. The traprock showed considerable promise inasmuch as a good growth of turf resulted with little or no decrease in C.B.R.

The result of tests in which several of the elements were not added to the aggregate indicated that Alta fescue was affected most by nitrogen and phosphorous deficiencies.

PART II—FIELD INVESTIGATIONS

This investigation was a continuation of the laboratory studies. It was patterned after the greenhouse investigation in so far as the same aggregates were tested with the exception of the traprock. The materials were placed in a test plot 60 feet by 210 feet to a compacted depth of 12 inches. Prior to placing the base materials the subgrade was scarified and compacted to the depth

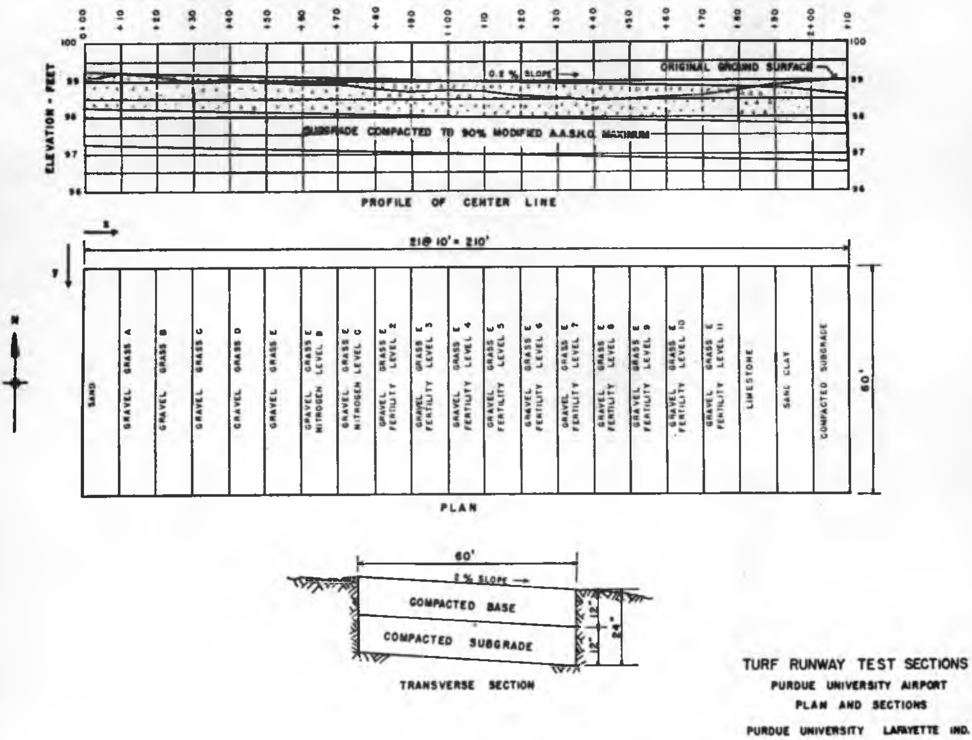


Fig. 7. Plan and section of test plot Purdue airport.

of 12 inches. Figure 7 shows a general layout of the turf test sections. It will be noted that a total of 21 sections were built, one sand, one crushed limestone, one sandclay, one of the natural subgrade and 17 of gravel.

CONSTRUCTION OF TEST PLOT

Prior to placing the aggregates the subgrade was scarified and compacted to approximately 90 per cent Modified A.A.S.H.O. density. This was done by compacting the soil with a sheepsfoot roller in three, 4-inch lifts. The subgrade soil was a sandy loam characteristic of the overburden of the glacial terrace on which the plot was built. California Bearing Ratio tests were made on the compacted subgrade (see Figure 8).

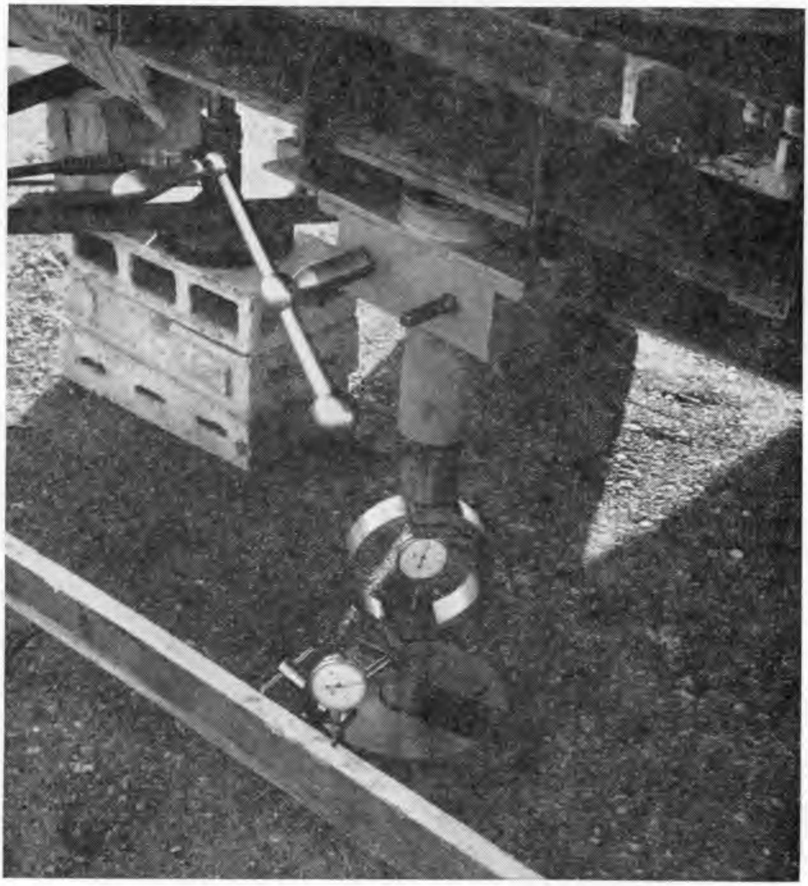


Fig. 8. Field C. B. R. test set-up.

The results of the tests made on the subgrade are listed below. The compaction data represents the average of 5 tests, the density data the average of 21 tests, and the field C.B.R. the average of 9 tests.

Passing #200 sieve	38%
Average maximum dry density	115.8#/cu. ft.
Average compacted dry density	110.5#/cu. ft.
Average C.B.R. @ 0.1 inch penetration	13%

The base materials were constructed in much the same manner as the subgrade. The filler material used in the aggregates was a glacial drift parent material of Wisconsin Age. The aggregates were placed by hand to a depth of about 6 inches. The required amount of filler and fertilizer was spread and mixed in by means of a Roto Tiller. The aggregates were compacted by use of a sheepsfoot and 10-ton three wheel roller. The above procedure was then repeated for the second 6-inch lift.

The results of tests made on the base materials are listed below:

Sand	
Passing #200 sieve	28%
Maximum dry density	136.8#/cu. ft
Compacted dry density	129.1#/cu. ft.
Field C.B.R. @ 0.1″ penetration	15%
Gravel	
Average passing #200 sieve	13%
Average maximum dry density	141.9#/cu. ft.
Average compacted dry density	139.5#/cu. ft.
Average field C.B.R. @ 0.1″ penetration	64%
Crushed Limestone	
Passing #200 sieve	15%
Maximum dry density	136.8#/cu. ft.
Compacted dry density	129.5#/cu. ft.
Field C.B.R. @ 0.1″ penetration	40%
Sandclay	
Passing #200 sieve	30%
Maximum dry density	127.0#/cu. ft.
Compacted dry density	123.8#/cu. ft.
Field C.B.R. @ 0.1″ penetration	76%
Subgrade	
Passing #200 sieve	40%
Maximum dry density	121.7#/cu. ft.

Compacted dry density	119.5#/cu. ft.
Field C.B.R. @ 0.1″ penetration	32%

The sections were fertilized during construction and the fertilizer was thus mixed throughout the depth of the aggregates. A basic rate of 160 pounds of nitrogen, phosphorous pentoxide, and potash was used on the plots. Nitrogen was applied as ammonium nitrate; phosphorous as 20 per cent superphosphate and potash as 60 per cent muriats. The fertilizer was varied between the rates listed below:

	N	P_2O_5	K_2O
Highest Rate	320#/acre	160#/acre	160#/acre
Lowest Rate	0#/acre	160#/acre	160#/acre

A list of the grass mixtures is as follows:

1. Kentucky bluegrass
2. Woodruff special airport flight strip mixture.
   - 21.60% Kentucky Blue grass
   - 24.75% Red fescue
   - 6.85% Mixed bent
   - 14.50% Perennial Rye grass
   - 24.40% Red Top
3. Oregon Chewings Fescue
4. Alta fescue in combination with Ladino clover and birdsfoot trefoil.
   - 90.7 % Alta fescue
   - 6.96% Birdsfoot
   - 2.34% Ladino
5. Alta fescue

All grasses and mixtures were spread at a rate of 86 pounds per acre. Straw mulch was spread on the section at the rate of 2 tons per acre.

U. S. 52, SOUTH OF LAFAYETTE, INDIANA

The work done in this portion of the experiments was a cooperative program between the Indiana State Highway Commission and the Agronomy Department. The engineering phase was carried out by the Joint Highway Research Project and the agronomy department supervised the agronomic phases. The purpose of this phase was to study the response of several grass species to different fertilizers on stabilized gravel. The endpoint was to study the use of granular shoulders to support emergency traffic.

This project was constructed on a 2,500 foot section of the outside shoulder of north-bound dual lane of Highway 52 at Monroe, Indiana (See Figure 9). The original shoulder material was bladed

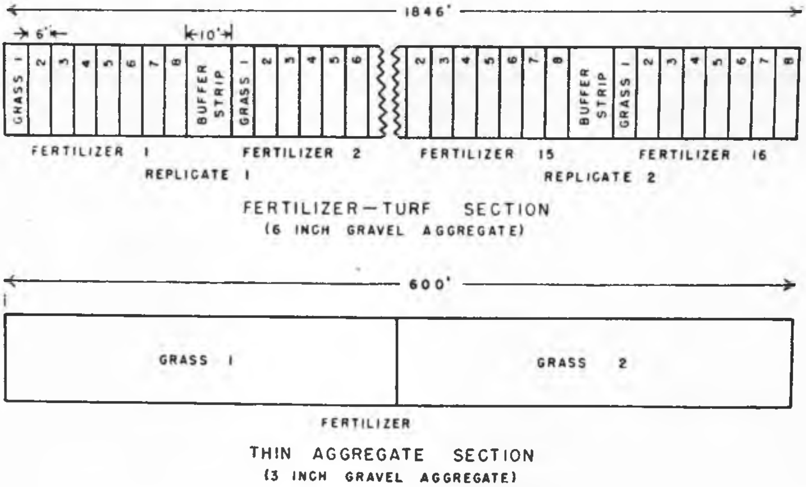


Fig. 9. Plan of test plot U. S. 52.

off to a depth of 6 inches, then the subbase compacted to 95 per cent of maximum density with a three-wheel, 10-ton roller. The 6 inch stabilized shoulder was constructed in two lifts of 3 inches each with fertilizer being rototilled into each lift. After the second layer was rototilled, straw was spread at 2 tons per acre, then cut into the aggregate with a disk. After rolling to anchor the straw, the plots were seeded and rolling continued until 98 per cent maximum density was obtained. Several sections were placed to a depth of just 3 inches.

On the main test area 16 different fertility treatments were replicated twice. The various fertilizer components in the 16 treatments varied between these rates per acre.

	N	P_2O_5	K_2O
Highest rate used	640#/acre	3600#/acre	320#/acre
Lowest rate used	160#/acre	320#/acre	160#/acre

Results of physical tests made on the plots are as follows:

Passing #200 sieve	10%
Maximum Dry Density	128.5#/cu. ft.
Compacted Dry Density	126.0#/cu. ft.

JOINT HIGHWAY RESEARCH PROJECT TEST ROAD

This test section was built in the summer of 1950 under contract with Corps of Engineers, Vicksburg, Mississippi. The purpose was to obtain data on growth of turf on several granular materials and was an extension of a series of tests made in Mississippi. The materials, sand, sand-gravel, and clay gravel; and a clay soil were placed to two depths. Several different fertilizers and seeding rates were applied on each of these depths.

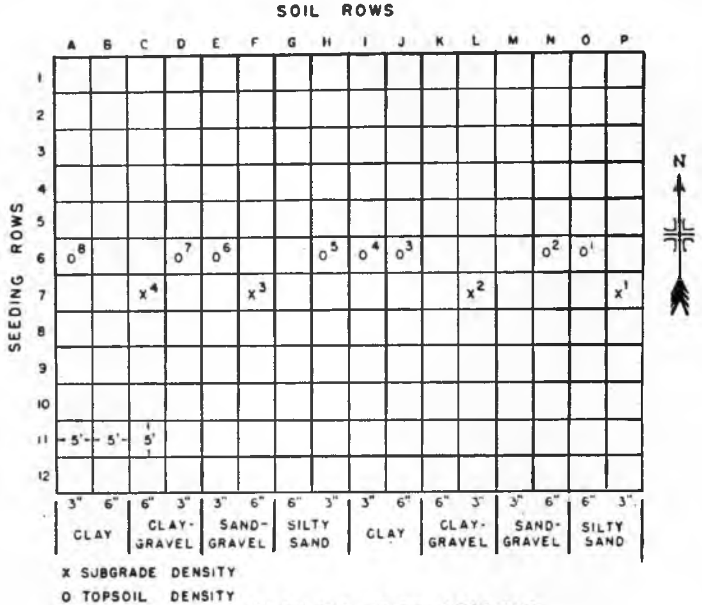
CONSTRUCTION OF TEST PLOT

Figure 10 shows a plan and section of the test plot. These sections were constructed on the undulating uplands of Wisconsin Drift. Prior to placing the aggregates the subgrade was excavated to the required depths and compacted by means of a small smooth wheel roller. No attempt was made to compact the soil to a specific density. After compaction, density and classification tests were made on the subgrade, the results of these tests are as follows:

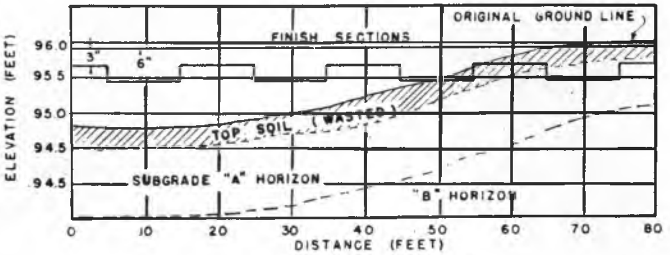
Liquid Limit	23%
Plasticity Index	4%
Passing #200 Sieve	70%
Average Compacted Density	95.4#/cu. ft.

The base materials were placed by hand and thoroughly mixed by means of a small Roto Tiller. The seed and fertilizer were then spread on the plot at the required rate. As was the case with the subgrade, no attempt was made to compact the base materials to a specific density. The results of the tests made on the base materials are as follows:

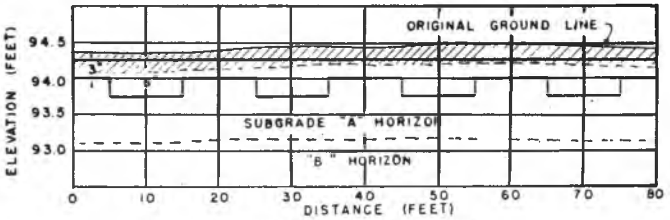
Clay	
Liquid Limit	41%
Plasticity Index	20%
Passing #200 Sieve	86%
Average Compacted Dry Density	88.5#/cu. ft.
Clay Gravel	
Liquid Limit	30%
Plasticity Index	14%
Passing #200 Sieve	10%
Average Compacted Dry Density	116.0#/cu. ft.



PLAN OF TURF SECTIONS



SECTION - NORTH EDGE



SECTION - SOUTH EDGE

Fig. 10. Plan and section of test plot, JHRP test road.

Sand Gravel	
Liquid Limit	N.P.
Plasticity Index	N.P.
Passing #200 Sieve	15%
Average Compacted Dry Density	115.5#/cu. ft.
Sand	
Liquid Limit	N.P.
Plasticity Index	N.P.
Passing #200 Sieve	25%
Average Compacted Dry Density	103.0#/cu. ft.

The seed formula used was made up of four parts by weight of Alta fescue and one part by weight of Kentucky Bluegrass. Fertilizers used were commercial 0-15-15 and nitrate of soda. The complete fertilizer and seed rates are shown in Table IV.

BEARING STRENGTH OF TURF PLOTS

Originally it was planned to test the sections at the airport soon after turf had become well established so that some measure of relative strengths could be obtained. However, it was not feasible to do so until five and a half years later. At this time field C.B.R. tests were made on each of the materials. An attempt was made during this testing program to test several bare spots as well as places where turf had become firmly established.

Figures 11 and 12 show the results of these tests. The bar graph shows the results of 24 C.B.R. tests. Test results were

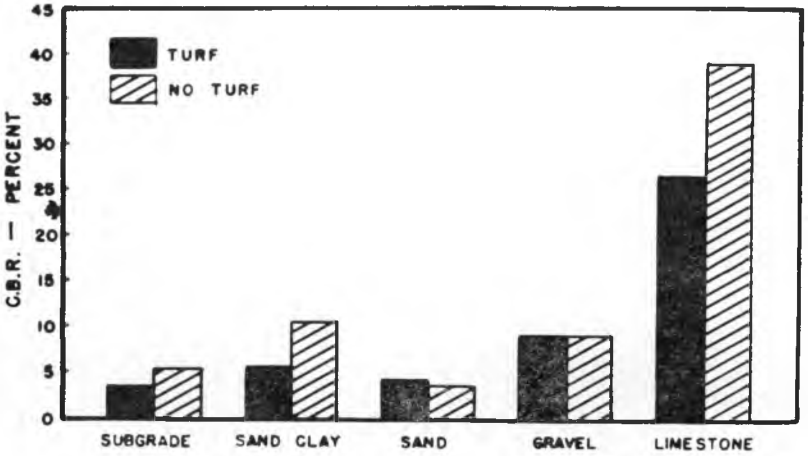


Fig. 11. Effect of turf on field C. B. R.

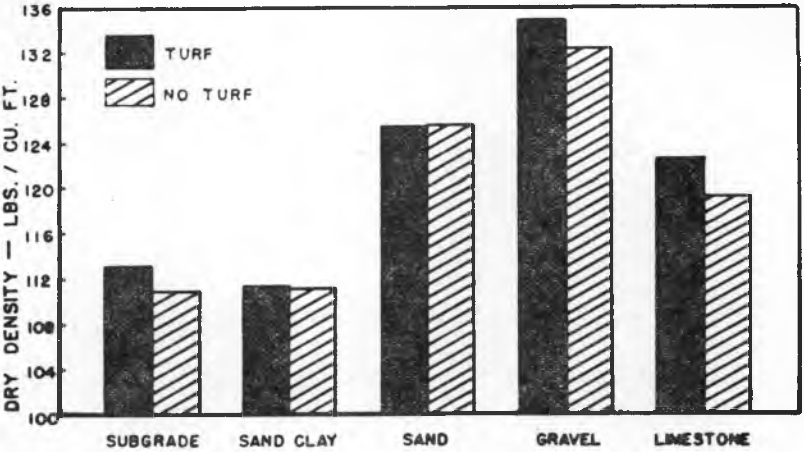


Fig. 12. Density of base materials, Purdue airport.

TABLE IV
Fertilizer and Seed Rates

Row No.	Rate (pounds per 1,000 sq. ft.)			
	Nitrogen	Phosphorous	Potash	Seed
1*	2.5	2.6	2.6	2.7
2	2.5	2.6	2.6	5.4
3	2.5	2.6	2.6	10.8
4	None	2.6	2.6	2.7
5	5.0	2.6	2.6	2.7
6	5.0	2.6	2.6	5.4
7	5.0	2.6	2.6	10.8
8	None	2.6	2.6	5.4
9	10.0	2.6	2.6	2.7
10	10.0	2.6	2.6	5.4
11	10.0	2.6	2.6	10.8
12	None	2.6	2.6	10.8

* See Figure 10 for explanation of row numbers.

averaged to minimize discrepancies that normally creep into this type of test. It will be noted that the same general trend is shown as was indicated by the laboratory C.B.R. tests. With the exception of the sand section, the turf showed the noticeable effect of reducing the C.B.R. value. The limestone showed the greatest decrease in strength with turf.

The densities of the various materials are of particular interest also. With the exception of the sand, and sand clay sections, the turfed areas had higher dry densities than did the bare spots. A general decrease in density was noted from the original placement density.

It must be kept in mind that surface roots greatly affect the penetration type of test. Surface roots have the effect of acting as a very weak paving surface. Consolidation of this type of material is great, which in turn causes the low C.B.R. values.

Unfortunately no bearing tests were made on the plot along U. S. 52. However, visual inspection has shown that the stabilized shoulders are much stronger than the natural soil. This is well illustrated in Figure 13. This figure shows a composite of three photographs taken along U. S. 52. The upper photographs were taken at the end of the 3-inch section. The one on the left shows ruts formed by a truck in the natural subgrade. It is significant that no appreciable ruts were made in the stabilized portion. The photo in the upper right-hand corner was taken just across the highway. It can be seen that deep duts were cut here. The lower photo shows a berm on U. S. 52 By-Pass. Again no ruts were cut into the stabilized portion next to the pavement.

TURF GROWTH

On all test projects where granular materials or moved soil materials have been used the nitrogen supplied by added fertilizer has not lasted more than a few months during growing weather. Repeated semiannual applications are indicated as the granular material does not store large amounts of nitrogen in the root zone if applied. For example, 250 pounds of pelleted ammonium nitrate per mile of roadway applied with a 10-foot spreader on each berm of the road should be sufficient for one application. Ideally one application in spring and one in early fall should be adequate for most granular stabilized soils. Of course, turf once established can be neglected, even on granular materials, with only a gradual deterioration in quality.

Most granular materials that were used for stabilizing have been alkaline, that is, above pH 7. The gravel used on U. S. 52 had a pH of 8.3 in 1948, a pH of 7.9 in 1951. Initial weathering probably removed part of the calcium.

On high pH materials, phosphorous is quite deficient and easily fixed. And since young plants, particularly, are favored by plenty of available phosphorous, many fertilizers are relatively high in this nutrient. Three tests of available P_2O_5 have been made to date on these soil materials. These are shown in Table V.

Fig. 13. View of granular stabilized shoulders. Note the deep ruts cut into the natural subgrade and lack of driver control on the soil.

It is surprising that the available P_2O_5 has remained rather constant.

Highway engineers and landscape architects have constantly wondered what grasses and mixtures to use for the severe wear and compaction conditions of berms. Of the grasses that were tested, the grasses listed in Table VI have been rated from 1-best to 5-poorest during a three-year period.

It has been brought out that Alta and Kentucky 31 fescues are well adapted to roadside and airport use. The seed is large, it germinates quickly and the plant has a very deep root system. Also, it grows well in late fall and early spring, thus giving protection and growth when most needed over winter and early spring. Crown vetch has been very successful in Pennsylvania tests and a combination of Alta fescue and crown vetch may be very desirable. Kentucky bluegrass has been a standby in Indiana and can be mixed

TABLE V
Nutritional Tests

Test Location & Soil	P_2O_5 Added 6"/A	Time of Test			pH	
		Oct. 1948	July 1949	Nov. 1951	1948	1951
Highway—Gravel	1800	591	582	544	8.5	7.9
Gravel	320	176	175	226	8.3	7.9
Gravel	320	121	124	132	8.4	7.8
Airport — Limestone	160	80	10	19	8.1	7.9
Gravel	160	80	30	41	8.1	7.9
Sand Clay	160	80	50	57	5.0	6.8
Subgrade	160	80	59	63	5.8	7.0

TABLE VI
Rating of Grasses that Were Tested

Planted in Fall, 1948	Time of Rating		
	July, 1949	June, 1950	Oct., 1951
Alta fescue	1.0	1.0	1.0
Kentucky bluegrass	2.4	3.0	2.5
Chewings fescue	3.0	2.5	2.5
Flight mix, Woodruff's	3.0	3.6	3.8
Ryegrass, Domestic	5.0	5.0	5.0

with Alta in a mixture, for example, 60 pounds Alta fescue and 20 pounds Kentucky bluegrass per acre.

Perhaps the biggest job in developing a turf shoulder is getting the individual bluegrass, Alta fescue or other seed to become an established plant, that is to develop a crown and buds which can go dormant in drought or winter and then develop new growth. The problem of high seeding rates, planting at all time of the year, extent of mulching, varying heavy rates of fertilizer, concern over the per cent of fines (200 mesh) in the soil—all these phases of work are attempting to more or less guarantee a sufficient number of seedlings surviving until turf plants are established. It has been firmly established that it actually takes comparatively few plants per square foot to produce at least an 85 per cent cover under favorable growing conditions.

Adequate turf can be established on granular materials. This was brought out forcibly in all the tests. From the results of these studies, it appears that a shallow stabilized layer is quite satisfactory. In fact, the results of the experiments made at the Joint Highway Research Project test road have indicated that grass does better on 3 inches of gravel than on 6 inches, when the subgrade is a fine grained soil. Figure 14 illustrates this. Figure 14-A shows a closeup of 3 and 6-inch gravel. The 3-inch depth has shown up consistently better. The remaining pictures in Figure 14 show the effect of 1 unit, 2 units, and 4 units of nitrogen used per 1,000 sq. ft.

The key to establishing and maintaining stabilized shoulders is threefold: first, choosing the best adapted grasses; second, securing a satisfactory plant establishment; and third, repeated light nitrogen fertilization. If a clean road shoulder is exposed to traffic in bad rutting conditions, it should have prompt timely follow-up in redragging and repair (at the proper soil moisture, before holes get too deep). However, turf may be injured or neglected for a much longer period of time with much less prompt attention.

BIBLIOGRAPHY

1. Skrdla, W. H. and Yoder, E. J., "Final Report on Phase 1 of Turf Runway Investigations," Unpublished report submitted to U. S. Corps of Engineers, Mariemont, Ohio.
2. Skrdla, W. H., "The Establishment and Maintenance of Turf on Stabilized Granular Materials," Thesis submitted to Purdue University in partial fulfillment of the requirements for the degree of Doctor of Philosophy, 1949.

3. Yoder, E. J., "First Progress Report on Construction and Observation of Turf Test Sections," Unpublished report submitted to Waterways Experiment Station, Vicksburg, Mississippi, 1951.

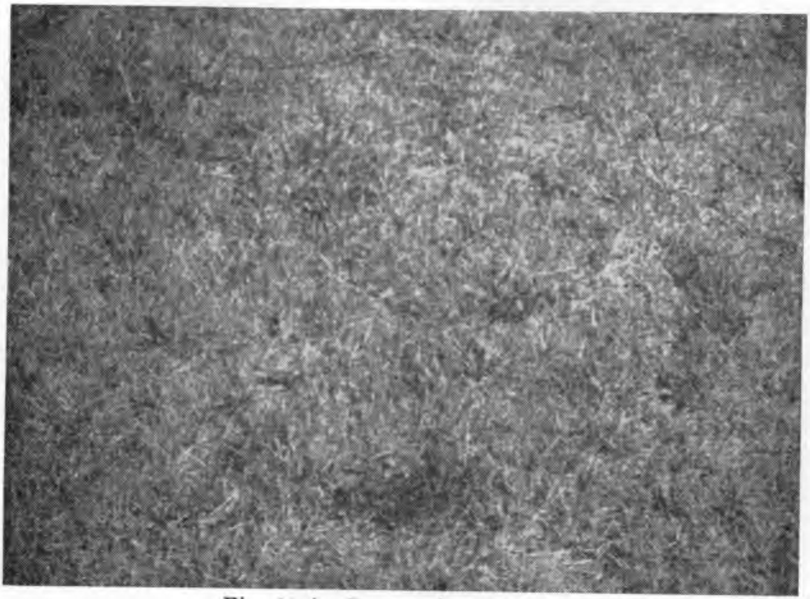


Fig. 14-A. Two Units Nitrogen.

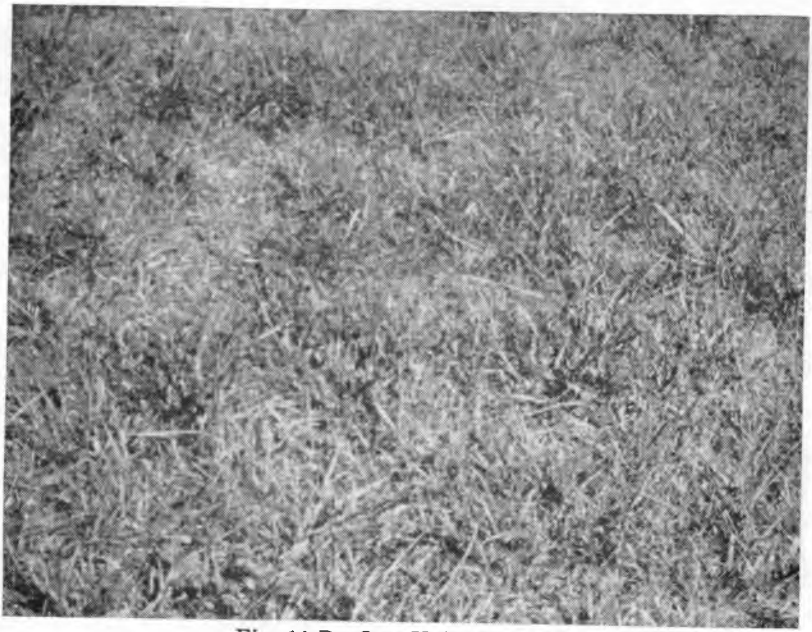


Fig. 14-B. One Unit Nitrogen.

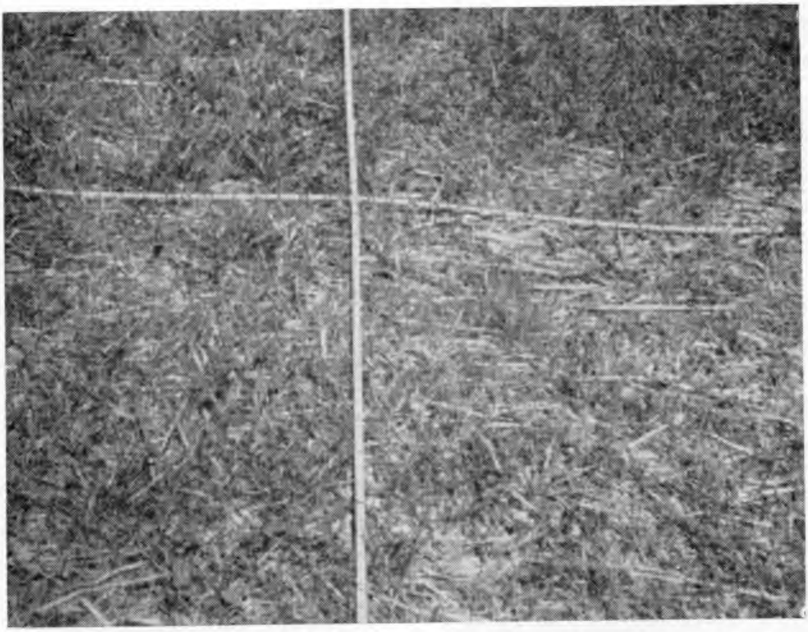


Fig. 14-C. Upper 3″ gravel, Lower 6″ gravel.

Fig. 14-D. Four Units Nitrogen.