REPORT OF SUBCOMMITTEE
ON
PLANT ECOLOGY

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GRASS GROUND COVERS FOR HIGHWAY AREAS

Methods of establishment of grass ground covers to protect bare soil are now standard highway construction operations in States where grasses are a natural part of the open country landscape. Accumulated information regarding seeding and sodding practice derived from the experimental work done in the past seven years of the roadside development program has been useful. But, as this report will try to outline, highway, soil and landscape engineers have only begun to solve many of these grassing problems.

For example, a recent survey shows that some two million pounds of grass seed were used by the State highway departments during 1940. Only about thirty kinds of grasses were used in this work, whereas we have some eleven hundred species of native and naturalized grasses in North America.

We know that many native drought resistant grasses in all regions succeed in establishing themselves under soil and moisture conditions where no artificial grassing method can apparently succeed.

We know that seed of many of these best native grasses is not available in the open market, particularly in the warm humid and dry climatic regions.

It will be the purpose of this report to briefly summarize the high points of an analysis which has covered about two thousand State Highway Projects in all regions of the country. From records of this highway field work and from available publications, we have derived certain basic principles which appear to apply to seeding, sodding and grass mulching operations wherever grasses can be grown.

We will also try to indicate by this analysis a few of the main problems on which we must have more field investigation, if we are to have better grass ground covers on our highway areas.

Definition of Terms

The term grass as here used will refer to the true grasses only. These include the cereals or grains (rye, wheat, etc.), bunch grasses such as broomsedge, bluestems or Indian grass, and low dwarf turf grass types, such as Kentucky bluegrass, the bent grasses, Buffalo grass, Bermuda grass, and the like. The legumes (clovers, vetches and lespedezas) have many special uses in highway seeding practice but will not be discussed except where incidental to the establishment and growth of the true grasses.

Under methods of establishment of grasses are included the following:

Seeding - (broadcast seeding, drill seeding, row seeding) is the establishment of grass by seed.

Hay Mulch Seeding - Seed for certain common native grasses cannot be secured from commercial sources. Such grasses have been established by cutting grass containing the seed and spreading the cut hay over slopes to be seeded.

Sprigging - (check sprigging, row sprigging, broadcast sprigging) is the establishment of a grass by planting individual grass plants, sprigs, stolons or rhizomes, usually in rows and at

a measured spacing. This is a variation of the method of broadcast planting of stolons or root cuttings of the turf forming grasses commonly used for grasses such as the Bents, which have been used in northeastern and northwestern coastal regions.

Broadcast sodding - (topsoil planting) (mulch sodding) (grass mulching) (broadcast sprigging). A sodding method based on the excavation of grass sod or turf with several inches of the soil below the sod. This mixture of sod and earth is spread over a prepared 'seed bed' or area to be sodded.

Block Sodding - (check sodding) (tuft sodding) (spot sodding). A method of sodding based on the use of small squares or blocks of sod placed at definite intervals on the ground surface. To be successful, block sodding implies the use of grasses which spread by stolons or root stocks (rhizomes), and the occurrence of good soil between blocks or tufts of sod.

Strip Sodding - (trench sodding). A method of sodding used on slopes usually considered too steep for successful seeding. Sod strips are usually placed at right angles to the direction of highway slopes. Bare spaces between strips are usually seeded.

Solid Sodding - (block sodding), as the name implies, is the use of continuous cover of sod placed in rectangular sections or rolled strips. Solid sodding is usually confined to drainage channels and other special areas where immediate soil protection is required.

Nurse Crop - A quick germinating annual or perennial grass or grain crop which serves to shade the slower growing, tender turf forming grasses until these are well established.

Legume - For the purposes of the report, a legume is a plant of the clover, vetch, or lespedeza or related group, which has the ability to fix nitrogen in the soil by means of bacteria in the nodules on its roots.

The Climatic Regions

Grass types and species on a given area are a direct result of certain combinations of temperature, rainfall and other climatic factors.

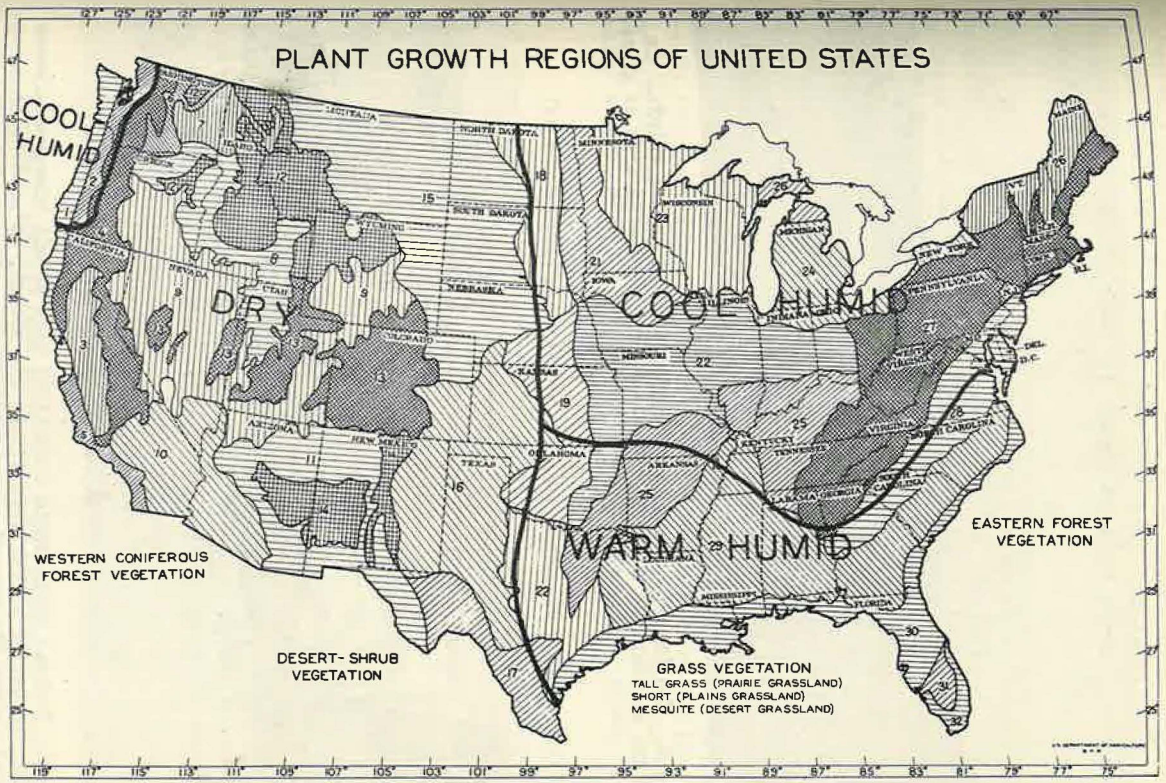


FIGURE 1. THIS MAP IS ADAPTED FROM THAT FOUND IN FIGURE 2, PAGE 4, U. S. DEPARTMENT OF AGRICULTURE FARMERS' BULLETIN 1482 - "TREES FOR ROADSIDE PLANTING" BY F. L. MULFORD. THE NUMBERED REGIONS ARE AREAS HAVING ABOUT THE SAME GROWING CONDITIONS FOR EQUAL ELEVATION. DARKER AREAS ARE HILL AND MOUNTAIN REGIONS WHERE ALTITUDE AND TOPOGRAPHY HAVE A MOST IMPORTANT LOCAL INFLUENCE ON PLANT GROWTH.

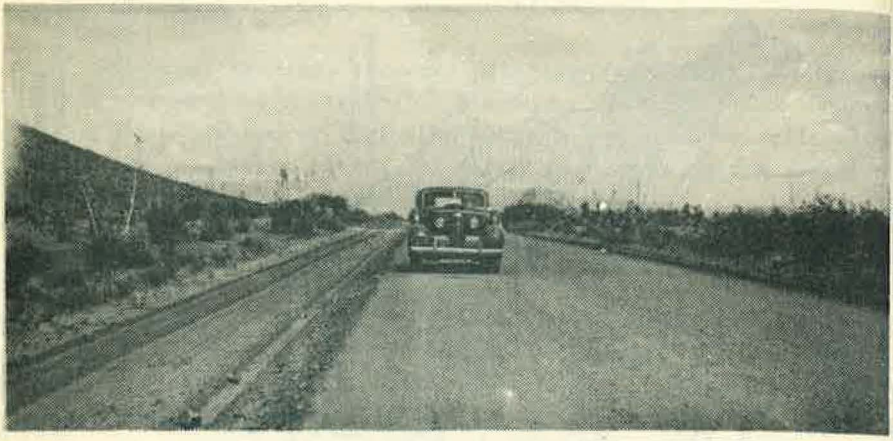


Figure 2. The Desert. An Arizona roadside where annual rainfall is less than the approximate 12 inches necessary for semi-arid type of grass.

Figure 3. Typical cool, humid conditions here permit bluegrass-fescue types of sod, to become established within one season, by seeding on mulched lightly topsoiled slopes. Because of difficulty of machine mowing these steep slopes, this sod will be permitted to gradually become converted to a ground cover of native aster, goldenrod and blueberry, Sumac or sweet fern types of shrubs.

Examination of the map in Figure 1 will show a very general and somewhat arbitrary division of the United States into three climatic regions. Except for local islands in these regions caused by high altitude and special location with regard to prevailing rain bearing storm winds, each of these regions shows certain climatic characteristics.

The Cool Humid Region receives 20 or more inches of annual rainfall, and includes the great part of the Northern and Central hardwood and Northern evergreen forests, the tall grass prairie types of vegetation and the Northwest Coastal forests. Some of the best turf grasses are readily grown in this region. Since the best turf grasses here produce abundant seed, seeding is a common practice.

The Warm Humid Region includes the Gulf and South Atlantic Coast areas and the lower Mississippi bottom lands. Rainfall here is equal to or better than the average in Cool Humid areas. Warm season temperatures and rates of evaporation during the growing season are higher, however, and the typical grasses of the Cool Humid region cannot as a rule be readily established or grown here.

The turf forming grasses, such as Bermuda grass, carpet grass and others, do not produce abundant viable seed over the great parts of this region. As a rule, therefore, seeding is not practicable, and sprigging or sodding methods are used on highway areas.

The Dry Region. In the plains area lying between the tall grass prairies and Southern Pine forests to the East and the Rocky Mountain, Sierra Nevada and Coast Mountain ranges on the West rainfall is generally lower than the average 18 to 20 inches required for all but the most drought resistant grasses. Local native grasses can be established in all but arid or desert areas, (See Figure 2) but seed in large quantities for many of the best of these is not as yet available from commercial sources.

Grasses of the Cool Humid Region

Because of contact with the 'Old Countries' and partly because of a climate resembling that of Western Europe, the grasses used in seeding highway and park areas in the Cool Humid region up to the present are largely of imported types and strains. Kentucky bluegrass, red fescue, redtop and several common types of Bent

grasses have been largely developed from European or New Zealand types of dwarf turf forming grasses.

There are also in the Cool Humid region many native bunch grasses which can and will in the future be developed for highway slope protection. Where these native grasses are dominant on abandoned fields in a locality, every possible effort should be made to develop methods of establishing such grasses on cut and fill slopes. These many bunch grass types are drought resistant, grow well in poor sand and clay soils, have fine winter color and furnish quick and effective soil protection particularly on steep rough slopes where a smooth dwarf turf cannot be maintained. Such bunch grass types cannot, however, replace the dwarf turf grasses for use on shoulders, gutters and other special areas where a smooth turf is required. (See Table 1)

Grasses of the Warm Humid Region. Here Bermuda grass is the lawn or turf grass species supplemented by carpet, St. Augustine and other dwarf turf grasses to the South. For protection of cut and fill slopes many native bunch grass types are found which withstand drought and heat and poor soil better than do some of the dwarf species. Unfortunately, seed for these native grasses is not commercially available, though the Department of Agriculture and State Experiment Stations are carrying on research in seed collection methods. (See Table 2)

Grasses of the Dry Region. Only a very small percentage of available native grasses have been used in grassing or seeding roadsides in the dry region. In the North, the Fairway strain of crested wheatgrass (Agropyron cristatum) has been seeded; and successful experiments have been conducted with Western wheatgrass, smooth bromegrass, dropseed (Sporobolus species) and a few others.

In the southern half of the prairie regions curly mesquite (Hilaria), buffalo grass (Buchloe), slender wheatgrass, and western wheatgrass (Agropyron species), sand reedgrass (Calamovila), and various other native types have been tried on an experimental scale. The U. S. Department of Agriculture and the Agricultural Experiment Stations of the various States are conducting experiments in the collection of seed and in seeding methods for these native grasses and their use in the future will be undoubtedly expanded. (See Table 3).

TABLE 1

SOME TYPICAL GRASSES USED OR SUGGESTED FOR TRIAL BY STATE HIGHWAY DEPARTMENTS

COOL-HUMID REGION

(Names of turf grasses from article "Common Names of Turf Grasses," by Pieters and Davis - *Turf Culture*, April 1939)

Type of grass[1]	Part of Region where best used[2]	Common name	Scientific name	Methods usually established by:	Special soil requirements, if any	Best adapted for use on highway
1 Turf	N - SE - NW	Kentucky blue grass	Poa pratensis	Seeding - sod	Good loam or clay loam	Shoulders, gutters, slopes
2 Turf	N - SE - NW	Canada blue	Poa compressa	Seeding	Less fertile clays than above	" " "
3 Nurse grass	N - SE - NW	Red top[4]	Agrostis alba	Seeding	Various moist to wet	" " "
4 Turf	NE - NW Coast	Bent grasses	Agrostis palustris Agrostis tenuis	Seeding stolons " "	Acid soils	Shoulder, gutter
5 Turf	NE - NW Coast	Red (chewing's) fescue	Festuca rubra	Seeding	Best on acid-sandy soils Stands shade	Shoulder, gutter
6 Bunchy turf	N - E	Sheep's fescue	Festuca ovina	Seeding	As above	Cut-fill slopes
7 Coarse-Nurse temporary bunchy	N to SE	Domestic rye grass	Lolium multiflorum	Seeding	Various soils	Cut-fill slopes
8 Finer nurse Turf	N to SE	Perennial rye grass	Lolium perenne	Seeding	Various	Slopes, gutters, shoulders
9 Turf	N to SE	Trivialis blue grass	Poa trivialis	Seeding	As for K. blue - in shade	Shoulder, gutter
10 Turf	SE	Korean lawn grass	Zoysia japonica	Stolons	Various	Shoulder, gutter
11 Loose bunch	N to Middle	Timothy	Phleum pratense	Seed	As for K. blue	Slopes
12 Bunch	NE to SE	Orchard grass	Dactylis glomerata	Seed	Various shade	Slopes
13 Turf	Central - West	Smooth brome	Bromus inermis	Seed	Various	Slopes to shoulder
14 Bunch	NE to Central	Indian grass	Sarghastrum nutans	Planting, mulching[6]	Poor sand to clay	Slopes only
15 Bunch	SE to Central	Broom sedge	Andropogon virginicus	Planting, mulching[6]	Poor clay	Slopes only
16 Dune	NE to Virginia NW Coast	Eu. beach grass[5]	Ammophila arenaria	Planting	Dune sands beach	Slopes, gutters
17 Dune	N and E[3]	Am. beach grass[5]	Ammophila brevigulata	Planting	Beach sands	Slopes, gutters

NOTES: [1]Grasses designated as turf types are suitable for airfield use.

[2]See Figure 1, page 67.

[3]Great Lakes and New Jersey to Virginia along the Atlantic Coast.

[4]Red Top under some conditions is considered as a turf grass.

[5]Experiments with seeding not yet conclusive.

[6]Further experiments needed.

TABLE 2

SOME TYPICAL GRASSES USED OR SUGGESTED FOR TRIAL BY STATE HIGHWAY DEPARTMENTS

WARM-HUMID REGION

Type of grass[1]	Part of Region where best used[2]	Common name	Scientific name	Methods usually established by:	Special soil requirements, if any	Best adapted for use on highway
1 Turf	SE Virginia to Gulf	Bermuda grass	Cynodon dactylon	Sprigging, sodding	Various soils Loamy silt to clay	Slopes, shoulders, gutters
2 Turf	Deep South to Gulf	Centipede grass	Eremochloa ophiuroides	Sprigging, sodding	Moist sandy soils	* * *
3 Turf	Deep South to Gulf	Narrow leaved carpet grass	Axonopus affinus	Sprigging, sodding	Moist sandy - coastal	* * *
4 Turf	South to Gulf	Broad leaved carpet grass	Axonopus compressus	Sprigging, seeding	Moist sandy - sandy loam	* * *
5 Turf	Florida - Gulf area	St. Augustine grass	Stenotaphrum accundatum	Sprigging	Mucky - sand - stands shade	* * *
6 Bunch or coarse - turf	Florida - Gulf	Long leaved reed grass	Calamovilfa longifolia	Planting	Dune - sand	Slopes only
7 Temporary turf	South to Gulf	Italian rye grass	Lolium multiflorum	Seed	Various	Slopes, gutters, shoulders
8 Coarse turf	South to Gulf	Crab grass	Digitaria sanguinalis	Seed	Various clays	Slopes, gutters, shoulders
9 Turf	South to Gulf	Korean lawn grass	Zoysia japonica	Sprigging	Sandy soils - to clays	* * *
10 Bunchy - coarse	Georgia to Gulf		Panicum amarum	Planting	Beach, sand dune	Slopes only
11 Coarse mat-like	Gulf		Panicum repens	Planting	Beach sand	Gutters, slopes

NOTES: [1]Grasses designated as turf types are suitable for airfield use.

[2]See Figure 1, page 67.

Figure 4. A highway in typical warm, humid region. Here on a sandy soil, sprigged bermuda grass has become well established on both slopes and gutters. On shoulders and slopes where guardrail has been eliminated, and all sharp angles rounded, mowing can be done with efficient motorized equipment.

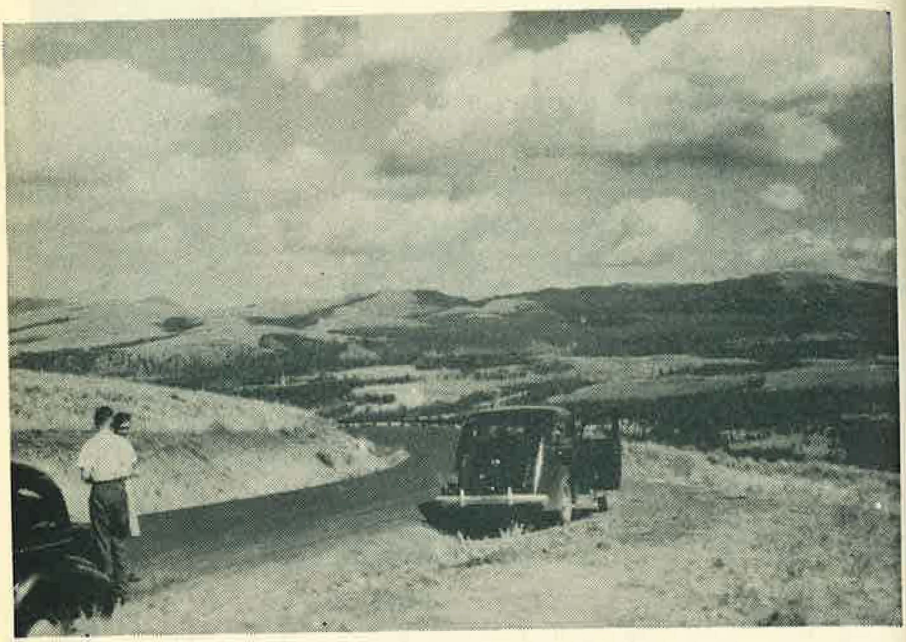


Figure 5. Typical Dry Region Country in the foothills of the Rocky Mountains. Annual rainfall of approximately 12 to 15 inches permits good grass ground cover on highway areas--provided slopes are well flattened and rounded and such drought resistant grasses as Crested Wheat Grass seeded on a well prepared seed bed. The slope to the left might well have been flattened to 3:1 to open vision on the curve and to encourage grass growth.

TABLE 3

SOME TYPICAL GRASSES USED OR SUGGESTED FOR TRIAL BY STATE HIGHWAY DEPARTMENTS

DRY REGION

Type of grass[1]	Part of region where best used[2]	Common name	Scientific name	Methods usually established by:	Special soil requirements, if any	Best adapted for use on highway
1 Turf	Northern plains	Crested wheat grass (Fairway strain)	Agropyron cristatum	Seeding	Various soils on alkaline side	Shoulder, slopes, gutters
2 Bunchy - coarse turf	Middle southern plains	Western wheat grass	Agropyron smithii	Seeding	Soils on alkaline side	Slopes
3 Bunch	Middle plains	Prairie beard grass	Andropogan scoparius	Seeding, mulching[3]	Various dry soils	Slopes
4 Coarse turf to bunch	Middle northern plains	Blue grama	Bouteloua gracilis	Seeding[3]	Various	Slopes, shoulder, gutter
5 Bunch	Northern and middle plains	Side oats grama	Bouteloua curtipendula	Seeding[3]	Various	Slopes
6 Bunch	Northern plains	Canada wild rye	Elymus canadensis	Seeding[3]	Various	Slopes
7 Turf	Middle southern plains	Buffalo grass	Buchloe dactyloides	Block sodding	Various usually loams and clays	Shoulders, gutter, slopes
8 Turf	Southern plains	Tobosa grass	Hilaria mutica	Seeding[4]	Heavy clay	Shoulders, gutters, slopes
9 Turf	Southern plains	Curly mesquite	Hilaria belangeri	Vegetative seeding[4]	Various	Shoulders, gutters, slopes
10 Turf	Southern plains	Vine mesquite	Panicum obtusum	Vegetative seeding[4]	Various	Particularly gutters
11 Bunchy turf	Middle plains	Sand drop seed	Sporobolus cryptandrus	Seeding[3]	Sandy soil	Slopes
12 Coarse turf	Middle plains	Smooth brome grass	Bromus inermis	Seeding	Various	Slopes, shoulders, gutters

NOTES: [1]Grasses designated as turf types are suitable for airfield use.

[2]See Figure 1, page 67.

[3]These grasses not yet used on highways on large scale because of lack of seed supply from commercial sources. Research needed on methods of gathering seed. Cutting of hay and mulching with cured hay containing seed may be possible solution.

[4]Seed for southwest plains grasses not available on open market. Vegetative methods as for Buffalo grass recommended for trial. Experimental work by Soil Conservation Service and others indicates that early spring vegetative methods will probably succeed under highway conditions.

General Conditions Which Favor Grasses

As experience has now shown, well selected grasses can be established in any climatic region, by one of several methods, on highways where rainfall permits grass growth and where limiting conditions such as drainage, bad soil texture, or low soil fertility can be improved or modified to favor grass growth.

Site conditions which favor the growth of grass ground covers in all regions include for example:

1. **Open sunlight.** Few grasses can survive unless some degree of sunlight can reach them. Under conditions of complete shade, various types of vine or herbaceous ground covers are usually indicated.

2. **Surface moisture.** An average annual precipitation of more than 12 inches with occasional rain during the growing season or heavy snow previous to it, are essential for rapid turf grass establishment. Under highway conditions artificial watering is seldom practicable. Deep rooted bunch grasses can sometimes be grown on highway slopes under climatic and soil conditions too dry for dense turf or sod formation. Certain shrub ground covers will grow under conditions which permit no grass growth.

3. **Adequate drainage.** Most grasses prefer well drained sites. Few grasses will long survive standing water about their roots. Sub-surface drainage measures may be necessary for satisfactory turf production on impervious clays or clay loam soils, particularly on traffic islands, waysides, airfields and the like, where runoff occurs at a slow rate because of flat grades.

4. **Moderate slopes.** All grasses grow more readily under conditions which permit surface water to penetrate the ground. Rate of surface runoff increases as slopes become steeper and penetration of surface water diminishes accordingly. On very steep slopes (1½:1 or steeper), grasses will usually tend in the humid regions to be replaced by deeper rooted perennial or woody ground cover plants which do not depend on surface water alone for survival. The choice of a ground cover type should be governed accordingly where ground cover other than grasses can be grown. Grasses will also require occasional mowing. Such mowing can be readily done on

easy to moderate slopes (2½ or 3:1 or flatter) without recourse to hand labor.

5. Permeable soil. Friable sandy or loamy soils are of great advantage in encouraging rapid grass growth. Dense healthy grass sod can rarely be maintained on hard clays which bake or glaze during summer weather unless fine cinders, gravel or sand and similar porous materials can be added to such clay soils. Nature loosens up hard soils and adds organic matter to them in humid regions by means of coarse annual weed growth which tends to develop a modified soil on which perennial weeds can grow. Growth and decay of the perennial weeds in turn tends to provide a still more friable and porous soil with added organic matter which encourages establishment of permanent grasses.

6. Reasonable fertility. Rapid establishment and growth of grasses depends to a large extent upon available plant nutrients. Thus commercial fertilizers with 10:6:4 or other high nitrogen content may be of great value when added to poor soil on the average highway slope or shoulder area. In dry western regions the value of farm manures has been emphasized by roadside seeding and sodding experiences because the organic matter contained helps to conserve moisture in the soil. Once grasses are established, natural growth and decay of root and top systems tends to add organic matter to the soil and improve both texture and fertility.

7. Maximum and minimum temperatures. In general each type and species of grass appears to have certain daily maximum and minimum temperatures which favor or discourage rapid germination of seed and rapid growth of grass after germination. The fact that a grass such as red fescue does not compete successfully with other grasses south of the approximate Mason and Dixon line is probably due largley to high daily summer temperature averages in southern regions. Bermuda grass, by contrast,[1] seems to be largely controlled by high summer temperatures which are as favorable to it as they are unfavorable to the red fescue. In other words, northern grasses appear to be unaffected by cold winter temperatures but adversely

1. It was determined by laboratory and field experiments that Bermuda grass seed, for example, does not germinate until average daily temperature reaches a point between 60 and 65 degrees, F. (This would mean that viable Bermuda grass seed in Northern Maine, for example, might fail to germinate altogether.) See University of Arkansas Bulletion No. 409 by E. L. Nielson.

effected by hot weather during the growing season. Bermuda grass is not only unable to withstand heavy long continued frost, but is also adversely effected by cool summer temperatures in the north or cool spring temperatures in the northern part of the warm humid region.

8. Soil reaction. Certain groups of grasses require acid soils, among these being the common bent grasses and red or Chewing's fescue. Others tend to survive only on slightly acid or neutral soils, Kentucky bluegrass being a case in point. A third group of grasses, as for example salt grass (Distichlis), requires definitely alkaline soils. Where pH content (acidity or alkalinity) is a controlling factor it may be a 'waste of time' to try to alter such soils by liming or other methods except on relatively small areas. Rather should a grass type be selected which fits the prevailing pH content of common existing soils on highways or airports.

The 'plant indicator method' of soil and site analysis may be both quick and sure in case of doubt. For example, on highways where existing and living ericaceous plants are common, soils are certain to be definitely acid.

From the standpoint of highway design, the meaning of these factors is clear. Slopes, gutters and road shoulders must be even more carefully designed (See Figure 6) with corresponding care in soil preparation in localities and regions where climate and soil are unfavorable to grass growth than elsewhere, if such highway areas are to be quickly and completely protected against erosion.

Analysis of the Site

We have thus seen that there are limiting factors on every site which control the rapid and permanent establishment of grasses. Good technical analysis of these factors, as well as of those concerned with traffic use of grassed areas, is the key to success. Factors such as temperature, rainfall and others which cannot be modified must be accepted, and methods and grass seeds or sod selected and adjusted to them.

Factors such as soil texture, soil fertility and drainage can sometimes be improved and modified by the use of common local or easily procured materials. Where such improvement of the site

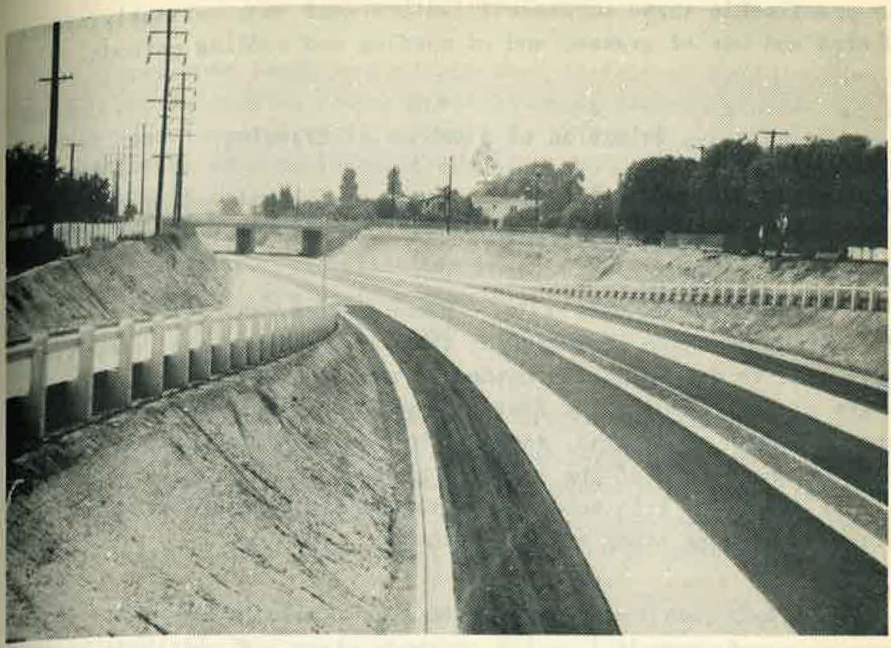


Figure 6. A new highway in Dry Region country. Here slopes are too steep for ready establishment of any type of ground cover. Special mulching, fertilizing and watering must now be done if these slopes are to be protected. Without slope protection gutters and culverts may well become clogged with earth during the first heavy rainfall after construction. Successful ground cover establishment must be built into original design.

is practicable these adjustable factors need not seriously affect choice and use of grasses and of seeding and sodding methods.

Selection of a Method of Grassing

The following factors tend to influence or determine the choice of a method of grassing:

Character of the site. Slope ratios, character of soil, direction in which slope faces; these and other local conditions will tend to determine the method of grassing. As a rule, on moderate slopes (about 2:1 or flatter) under reasonably favorable soil, and climatic conditions, seeding is the preferred method in all regions where seed of the required grasses can be secured. On steep slopes (1½:1 or 1:1) seeding is rarely effective unless combined with mulching or other special methods.

Growth habit of grass species. Certain low dwarf grass species, such as buffalo grass, Bermuda grass and centipede grass, do not usually produce large yields of viable seed. Many native grass seeds are not handled in quantity by commercial dealers. Such grasses must, of course, be established by sodding, sprigging or other vegetative methods for the time being.

Cost of work. On open country highways, where woodland, prairie or farm lands are found, costly solid or block sodding methods will usually be avoided in favor of simple economical mulching and seeding or broadcast sodding at 1/5 to 1/10 the cost of solid sod. Only in special areas such as drainage channels can the cost of solid sodding be justified as a rule.

Season when work must be done. Seeding is usually most successful during early spring or early fall seasons during which soil is easily worked and rainfall can normally be depended upon in a particular locality. Sodding or sprigging in humid regions may be done during late spring and early summer seasons when seeding will normally fail to produce results, and may be fairly successful during any season of the year when the ground can be worked, in regions of good summer rainfall and reasonably favorable soil texture.

Soil Preparation and Fertilizing

Experience tends to indicate that texture of soil is perhaps the most usual limiting factor in establishing healthy grasses under average roadside conditions. Fertility is also a major factor influencing rate of establishment particularly on poor clay or sandy soils. A well tilled, reasonably fertile and friable seed bed or base for sodding is thus usually the 'sine qua non' for successful seeding or sodding. Fertility can be obtained by use of complete commercial fertilizers or farm manures. Good tilth, however, is a product of correct mechanical and chemical soil analysis plus man and machine labor.

Plows, harrows and similar agricultural equipment are commonly used in soil preparation for any large scale seeding or sodding operation. Well flattened and smoothly rounded cut and fill slopes, and broad well rounded gutters are usually necessary, therefore, for successful grassing operations on any large roadside mileage; first, because tractor or horse-drawn equipment cannot be readily used on slopes much steeper than about 3:1; and secondly, because hand methods of tillage required on 2:1 or steeper slopes cannot be as thorough or as economical as practicable machine methods on a well graded cross section. It will be understood that under extremely favorable porous soils with rainfall evenly distributed through the growing season, such as in Northern New England, or the Northwest Pacific Coast, grass can almost be grown on a 'barn roof' or on slopes as steep as 1½:1. In the dry southwest, for example, a broad well rounded cross section with all slopes 4:1 or flatter such as the State of Texas has developed is an absolute necessity for satisfactory grass ground cover in that region.

Where soils are impervious and summer temperatures high, it would appear that failure of grassing operations may often be expected unless soils are amended by adding sand, cinders or equivalent fine granular materials to heavy clays. Also a well flattened and rounded cross section with moderate slopes should be installed before seeding or sodding, preferably during original construction. Water must penetrate slope and shoulder surfaces if a drought resistant deep rooted sod is to be obtained. Both steep slopes and impervious soils limit or check this penetration.

Time and space do not permit discussion of uses of lime and fertilizers here, but the outstanding results secured by use of

10:6:4 and other complete high nitrogen content fertilizers together with ground limestone where indicated by soil analysis speak for themselves in a number of cooperative projects by the U. S. Golf Association (Greens Section) and the Bureau of Plant Industry throughout the country. Fertility in the form of nitrogen permits young grasses to become well established before the hot dry summer or freezing and thawing of winter begins, to put the new grasses to the final test of survival. Ground limestone improves almost any soil texutre and renders plant nutrients more quickly available for the use of grasses. Fertilizers to be most effective will probably best be well incorporated into the top two to three inches of soil. Topdressing as practiced in parks and on golf courses and lawns must be reduced to a minimum under the long mileage of the usual open country highway system. This implies fairly heavy application of fertilizers in original seeding operations. (See Turf Culture, March 1941, pages 142 to 155 'Principles Underlying Fertilization of Turf,' and pages 155 to 169 'Buying Fertilizer for Turf.')

Observations Regarding Seeding Practice

Climatic and soil conditions vary widely in localities of all regions, and seeding methods on roadsides must be adaptable to limiting factors which may be present on any site. There are, however, certain principles which appear to apply wherever grasses can be established by seed.

1. A friable porous soil seed bed above a firm reasonably porous or tile drained subbase is usually necessary for successful seeding. Some addition of nitrogen in the form of a complete fertilizer can always be recommended so that young grasses become quickly established and are ready for the hot summer or cold winter weather.

2. Grass seed mixtures should be of known adaptability to climatic and existing site, soil and drainage conditions. For example, common bluegrasses should not be seeded on dry region roadsides nor will western wheat grass 'do much' in the Northeast.

3. Seeding should be done at a favorable season in spring or fall or during late fall or winter when no germination of seed before the next growing season is likely. In other words, if germination occurs just before or during a dry hot or very cold season

grass plants will usually fail to survive. For example, fall seeding in Maryland should be done before about September 15, or after December 15 when no germination will be expected before spring.

4. Seed should be of known species, known purity and viability and sown at a measured rate per unit of area. (See Table 4) Without such control of seeding it is impossible to check operations for causes of failure.

5. Mechanics of seeding operations must not induce checks in grass growth. Common operations which reduce rate of grass growth, or prohibit growth, are: covering seed deeper than about 1/2 inch, seed bed too loose in sandy soils or seed bed compacted with heavy rollers where clay and clay loam soils occur.

6. Roadside seeded areas particularly on slopes should be mulched with hay, straw, manure or other materials when available, especially on slopes facing to the south and west. Mulch used on seeded areas should be shallow and loose enough so that 'ground surfaces may be visible through the mulch.'

7. Seeding operations should be performed under supervision of experienced personnel. Establishment of a permanent grass turf may often be more difficult from a technical point of view under average roadside conditions than establishment of any other type of ground cover. The appearance of fine young grass, or of well established sod may indicate success at first. A season or two later, however, unless seeding or sodding was well planned to fit the site the grassed area may be completely bare of cover.

8. Seeding is the preferred method over all others where viable seed is available and where site conditions and purposes of grassing permit it. Even in the warm humid region future seed sources may be developed for Bermuda and other grasses and present sprigging or sodding methods replaced by seeding.

Observations Regarding Vegetative Grassing Methods

Various methods of sodding, strip sodding, block sodding, broadcast sodding or sprigging are used.

After a study of specifications for these operations we have tried to segregate a few principles which appear to apply in all regions to any vegetative method of grassing.

TABLE 4

Minimum Percentages of Purity, Germination, and Pure Live Seed and Maximum Percentages of Weed Seed to be expected in High Quality Seed of the More Important Turf Grasses, Together With the Approximate Number of Seeds in a Pound of Each

	Minimum purity	Minimum germination	Minimum pure live seed (*)	Maximum weed seed	Approximate number of pure seed in a pound
Kentucky bluegrass	98	88	86	0.3	2,250,000
Trivialis bluegrass	98	88	86	0.3	2,500,000
Redtop	99	91	90	0.5	5,000,000
Colonial bent	99	91	90	0.2	8,000,000
Creeping bent	98	92	90	0.2	6,000,000
Velvet bent	94	85	80	0.4	10,000,000
Chewings fescue	99	86	85	0.2	600,000
Red fescue	95	85	81	0.2	600,000
Bermuda grass	99	91	90	0.2	1,750,000
Italian ryegrass	99	95	94	0.2	225,000
Perennial ryegrass	99	93	92	0.4	300,000
Crested wheatgrass	98	92	90	0.3	330,000

(* Purity times germination)

From *Turf Culture* - March 1941

1. Soil preparation. A well loosened reasonably fertile 'seed bed' with sufficient fertilizer in the form of a complete commercial fertilizer to give sod or sprigs a quicker start, is usually desirable in vegetative operations as it is with seeding.

2. Grass sod or grass plants or cuttings should be selected from common available sources where soil and moisture conditions are roughly equivalent to those on sites to be grassed. Sandy or clay soils, shortage or surplus of moisture, and well defined acid or alkaline soil reactions represent factors, among others, which control correct choice of kind of grass plants or sod.

3. All grass sods, roots or plants must be kept moist during grassing operations. Wherever possible, cutting of sod or sprigs should be done at about the same rate as installation to reduce time of storage of plants or sod. This is another way of saying that, as far as possible, living grass sod should be cut as near as possible to the site of final installation.

4. Methods of sodding or sprig planting are usually adjusted to the special soil protection problems of the site. Thus solid sodding is indicated in drainage channels or on steep slopes where surface water flows in heavy volume and at high velocity. Sprigging or strip, block or broadcast sodding are used on slopes or shoulders where there is no such concentration of surface water. These methods in time will produce results equal to or better than solid sodding.

5. Methods of vegetative grassing are adjusted to meet special growth habit of grasses used. Thus Bermuda grass is adapted to shallow broadcast sodding because of its mat-like stolon growth; Beach grass, with its heavy coarse rhizomes, is 'deep planted' in tufts or sprigs.

6. Mulching has not been practiced with sprigging or sodding methods of grassing to the same extent as with seeding methods. A loose shallow hay mulch well shaken at the time of application should aid sprigged or sodded grass as it does new seeding.

7. Broadcast sodding or sprigging is preferred over solid or strip sodding wherever practicable. Cost of broadcast (mulch) sodding averages about that of seeding under equivalent conditions. Cost of solid sodding per area unit may be 10 to even 20 times that of seeding or broadcast sodding.

Some Common Mistakes in Grassing Operations

Analysis of past seeding and other grassing operations brings out a number of errors which are being, or should be corrected.

1. Selection of seed formulas, or grass plants, without reference to evident limiting factors of the site. For example, cool humid grass species such as Kentucky bluegrass have been used in dry region roadside seeding; sod from good moist pasture soils has been placed on dry infertile cuts and fills. Grasses which prefer very sandy soils have been planted and seeded on clayey or loamy soils and vice versa.

2. Seeding at too high a rate on relatively sterile roadside soils. Observation indicates that rates of seeding as low as 35 to 50 pounds per acre may produce satisfactory results. In the Plains area rates of seeding lower than this are often recommended. Roadside seeding at a rate of more than 150 pounds per acre has generally failed to produce grass turf equal in stamina and drought resistance to that from lower rates of seeding in the two humid regions. Rates of 35 to 50 pounds per acre have frequently produced excellent results particularly on dry sites.

3. Seeding of lawn types of grasses on infertile clays or dry sandy soils. Lawn dwarf turf types of grasses have been specially developed for good moist 'controlled' types of soils. Broomsedge, Indian grass and similar types of existing native grasses usually tend to take over infertile roadside sites, regardless of original seeding or sodding. Seed sources should logically, therefore, be developed for these native grasses particularly for cut and fill areas outside the gutter line where a low turf is not needed, and where topsoiling or intensive soil amendment is impracticable.

4. Covering seeds too deeply, either with soil or mulches or both. Young grass plants are delicate and cannot penetrate more than shallow mulch or soil coverings. One half inch of clay soil may kill 90 percent of young grass plants. One half inch of sand in a dry region may be about the right cover. As a rule the finer the seed the lighter should be the earth cover. (See Table 5)

5. Seeding or sodding too late in Spring or Fall in regions of very hot summer or very cold winter. Young grass plants suddenly

TABLE 5

Relation between seed weight and total percentage of emergence of typical grasses, averaged for five types of covering soil ranging from clay loam to light sandy loam.

Kind of Grass	No. of Seeds per pound	Percentage of emergence in green house at different depths of earth cover in inches				
		0	½	1	2	3
Sudan grass	50,000	79	63	57	51	47
Meadow fescue	225,000	94	89	81	52	13
Perennial rye grass	300,000	99	96	96	87	69
Crested wheat grass	330,000	83	74	64	15	1
Orchard grass	600,000	76	57	45	11	0
Timothy	1,200,000	85	75	61	3	0
Kentucky blue grass	2,250,000	83	61	23	0	0
Redtop	5,000,000	80	60	38	0	0

NOTES:

(1) Above table adopted from 'The Emergence of Grass and Legume Seedlings Planted at Different Depths in Five Soil Types' by R. P. Murphy and A. C. Arny - Journal of the American Society of Agronomy - January 1939.

(2) Note that the finer grass seeds should be covered very lightly for maximum grass production. Coarse heavy seeds may survive a 2 or 3 inch cover.

(3) Above tests under field conditions show relative emergence percentages with germination reduced 25 percent to 30 percent for some seeds as compared to above.

(4) According to Murphy and Arny - 'If the depth of planting which gives the maximum total emergence is used for a given species it should be possible to obtain a desirable stand by planting less seed per acre than has been practiced by farmers and often recommended by agronomists.' 'The depth of planting was found to be the most important factor which determined the total emergence of seedlings-----.'

forced to withstand extreme hot and dry or cold freezing weather usually die. Young grass plants, like young wild animals are, in nature, born at a season which favors survival.

6. Seeding or sodding on soils too poor to produce satisfactory grass growth. Formation of a good grass turf usually requires addition of fertility particularly with respect to nitrogen. 10:6:4 or equivalent fertilizers and inclusion of inoculated legume with grass seed are advisable where practicable and desirable.

7. Lack of proper soil preparation before seeding or sodding, particularly on shoulder and gutter areas where dwarf turf types of grasses should be used. Soil amendments to improve texture are often called for, particularly on shoulders, and usually in gutters also.

8. Use of heavy undecomposed hay or straw mulches on seeded areas or lack of a light loose mulch on hot dry sites where mulching would be beneficial. Use of fresh sawdust, pine straw or other mulch materials are actually poisonous to grass.

9. Cutting of sod of turf grasses too thick. Present information appears to indicate the desirability of cutting sod of bluegrass and similar turf grasses to a thickness which will permit easy handling without surplus soil. (An average of 1½ to 2½ inches)

10. Using a heavy admixture of two or more kinds of fast growing temporary nurse grasses in seed formulas. A single nurse grass such as redtop may aid permanent grasses to become established. Adding other coarse fast growing, temporary grasses such as domestic rye grass, timothy, or orchard grass, and the like to redtop, for example, may choke out the fescue or bluegrasses which complete a desirable seed formula for the northeastern region. One 'nurse' grass in a seed formula is usually enough.

11. Using 'low grade' commercial fertilizers in too small amounts. Economies of using one ton of 10:6:4 fertilizer (or equivalent) to replace two and one half tons of 4:8:6, for example, required for equal nitrogen content are apparent. Under average soil conditions application of 10 to 40 pounds of 10:6:4 fertilizer per 1,000 square feet may be required for adequate seeding results on shoulder and gutter areas. Fertilizing which gives young grass a

real start toward maturity before the heat and drought of summer is worth while. Anything less than this may be a waste of time and money.

12. Use of solid sodding on areas where seeding and mulching, sprigging, or broadcast sodding will establish a satisfactory grass turf of equal quality at an average of one-tenth of the cost of the solid sodding method. On open country roads, solid sodding should be confined to drainage channels, or gutters or elsewhere where other grassing methods will not furnish necessary immediate protection. Cost is the final deciding factor in any type of highway development. Maintenance in future years may be more important than 'first cost.'

SUMMARY

The following conclusions are drawn based upon experience of the State highway departments, the U. S. Department of Agriculture and other agencies in establishing grass ground covers on highway areas.[1]

1. Some of our most drought resistant native turf and bunch grasses are not being used in the establishment of ground cover on highways. Of several hundred species of grasses only about 30 are now in common use on highways. Most of these grasses are of lawn types and most are adapted to cool humid or northern warm humid regions only.

2. Most of our common lawn or park turf grasses are not adapted to dry infertile soils. This type of grasses should as far as practicable be replaced by grasses which have more stamina under roadside conditions, particularly on rough cut and fill slopes.

3. Grasses which are well adapted to any one of the three broad climatic regions are not dependable under average roadside conditions in any other region. Border zones between main climatic regions represent conditions of special difficulty, where careful site analysis is essential.

4. Certain basic site conditions are favorable to grass establishment and growth. Where one or more of these limiting

1. See Appendix III, Page 105a, for typical grassing specifications.

conditions is not favorable, experience would indicate that compensation in the form of liberally flattened and rounded slopes and added fertilizers and soil amending materials is indicated.

5. Successful grassing operations to a large extent depend upon analysis of limiting factors of sites for seeding or sodding by well trained landscape personnel, followed by methods designed to counteract these limiting factors.

6. In all climatic regions the selection of grasses and methods of grassing should be based upon analysis of such factors as traffic use, character of site, soil, growth habit and seed production of available grasses and seasons when work must be done.

7. In all regions, both seeding and sodding must be preceded by proper soil preparation to meet soil conditions. Mechanical and chemical soil analysis are the foundations of proper soil preparation which may include soil fertilizing and amendment with ground limestone, sand or other soil materials plus adequate tillage.

8. The fundamental principles of seeding and sodding apply wherever grasses can he grown without irrigation. Observation of existing soil and of existing natural vegetation including grasses, and tree and shrub types, will provide means of rapid and accurate analysis of the site. Correct analysis of site conditions followed by correct selection and methods of establishment are the keys to success in all grassing operations.

Avoidance of mistakes in past practice is essential if progress is to be made in the future.

RECOMMENDATIONS

Under the present War Emergency, we believe the development of improved and economical methods of establishing grass ground covers on exposed highway soils to be the most important single objective of the Committee on Roadside Development.

Many access roads to cantonment and defense industrial areas have only recently been completed, but already the problem of soil and slope protection on these roads is an urgent one. The War Department has frequently asked and received the cooperation of

members of this committee in selecting grasses for airfields, and on matters of slope and soil protection and on highway cross section improvement.

The proposed development of highway flight strips will also call for improved grass turfing methods.

With these points in mind, your Committee makes the following suggestions:

1. That roadside development projects during 1942 aim to develop effective combinations of mulching and seeding to replace intensive solid and strip sodding and shrub planting methods often emphasized in the past.

2. That aid of the commercial seed companies, the Department of Agriculture, State Experiment Stations and other agencies be enlisted in developing sources of seed for the native drought resistant grasses which we have heretofore been unable to utilize.

3. That where seed of native grasses is unavailable, field experiments be conducted in cutting these grasses at seasons when seed crops are ripening. Mulching with cured hay cuttings of native grasses containing viable seed may, we believe, accomplish the double objective of a mulching and a seeding operation.

4. That Soils Engineers and Landscape Engineers cooperate[1] in field investigations designed to analyze and improve soil texture on shoulder and gutter areas of new highways. By improving soil texture we believe that a major factor limiting installations of an all weather grass covered shoulder can be eliminated.

It should be emphasized that as a rule in both highway and airfield construction adequate site and soil analysis followed by soil amendment and soil tillage are the keys to rapid and permanent grass turf establishment.

1. See Figure 7 and Tables 6 and 7.

FIGURE 7

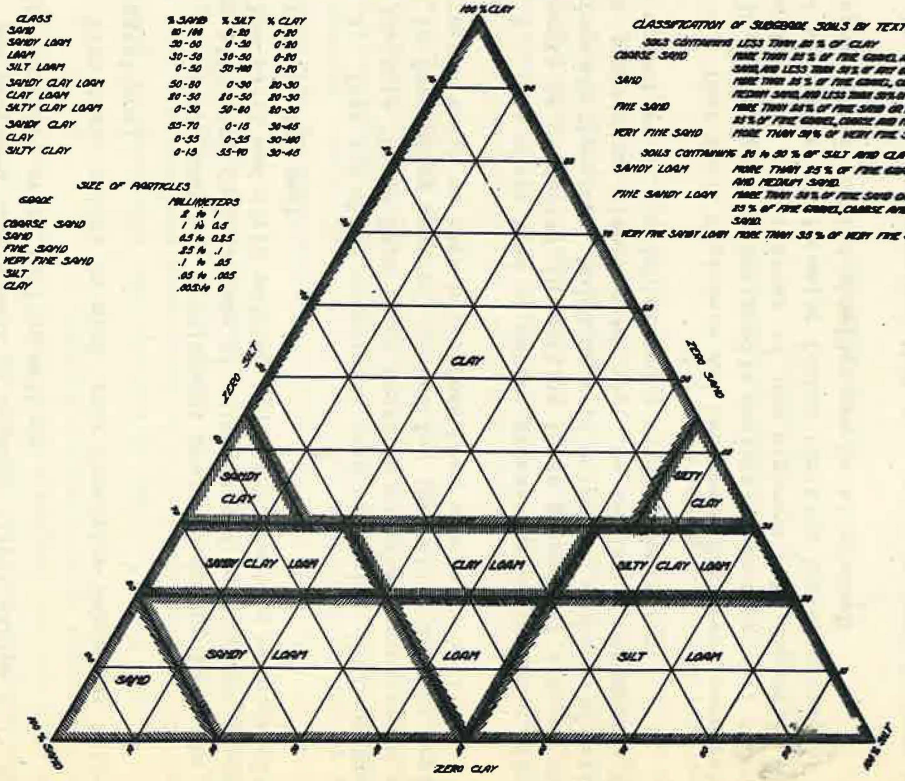
CLASSIFICATION CHART FOR SUBGRADE SOILS

U.S. BUREAU OF PUBLIC ROADS

CLASS	% SAND	% SILT	% CLAY
SAND	80-100	0-20	0-20
SANDY LOAM	50-80	0-50	0-20
LOAM	30-50	30-50	0-20
SILT LOAM	0-50	50-100	0-20
SANDY CLAY LOAM	50-80	0-30	20-30
CLAY LOAM	20-50	20-50	20-30
SILTY CLAY LOAM	0-30	50-80	20-30
SANDY CLAY	55-70	0-15	30-45
CLAY	0-55	0-55	30-100
SILTY CLAY	0-15	55-70	30-45

SIZE OF PARTICLES

GRADE	MILLIMETERS
	2 to 1
COARSE SAND	1 to 0.5
SAND	0.5 to 0.25
FINE SAND	.25 to .1
VERY FINE SAND	.1 to .05
SILT	.05 to .005
CLAY	.005 to 0



CLASSIFICATION OF SUBGRADE SOILS BY TEXTURE

SOILS CONTAINING LESS THAN 20 % OF CLAY

COARSE SAND — MORE THAN 25 % OF FINE GRAVEL AND COARSE SAND, AND LESS THAN 25 % OF ANY OTHER GRADE. MORE THAN 25 % OF FINE GRAVEL, COARSE AND MEDIUM SAND, AND LESS THAN 50 % OF FINE SAND.

SAND — MORE THAN 50 % OF FINE GRAVEL, COARSE AND MEDIUM SAND, AND LESS THAN 50 % OF FINE SAND.

FINE SAND — MORE THAN 50 % OF FINE SAND OR LESS THAN 25 % OF FINE GRAVEL, COARSE AND MEDIUM SAND.

VERY FINE SAND — MORE THAN 50 % OF VERY FINE SAND.

SOILS CONTAINING 20 to 30 % OF SILT AND CLAY

SANDY LOAM — MORE THAN 25 % OF FINE GRAVEL, COARSE AND MEDIUM SAND.

FINE SANDY LOAM — MORE THAN 50 % OF FINE SAND OR LESS THAN 25 % OF FINE GRAVEL, COARSE AND MEDIUM SAND.

VERY FINE SANDY LOAM — MORE THAN 35 % OF VERY FINE SAND.

TABLE 6

CLASSIFICATION OF SOILS*

Division of Tests
Public Roads Administration

Group	Character	Properties	Gradation (percent)	Plastic index	Shrinkage limit
A-1	Well graded. Excellent binder. Stable under all moisture conditions. High load bearing.	High Cohesion. Internal friction. Little expansion. Shrinkage. Capillarity or elasticity	Clay 5 to 10 Silt 10 to 20 Sand 70 to 85 Coarse sand) 45 to 60	4 - 9	14 to 20
	(Excellent base or surface material)				
A-2	Not well graded Inferior binder or both. Stable when dry but dusty. Soft when wet.	Good cohesion. Internal friction when moist. Some shrinkage. Capillarity. Elasticity. Two types (friable) (plastic)	More than 55% sand	15 or less	Very little 15 to 25
	(If plastic limit does not exceed 6 is excellent subbase)				
A-3	Coarse gravels -- sands. No binder. Stable when wet. Loose when dry.	No cohesion. High internal friction. Other qualities negative	More than 70% sand and gravel	None	None
	(Good subgrade materials in moist locations)				
A-4	Mainly silt without coarse particles. No sticky clay. Absorb water. Subject to frost heave.	Low bearing when wet Cohesion poor. Variable friction. Capillarity and shrinkage. No elasticity.	Less than 55% sand	0 to 15	20 to 30
	(Cover with granular soil for subgrade purposes)				
A-5	Similar to A-4 but poorly graded and contains mica, diatoms, etc.	Low stability. High elasticity.	Less than 55% sand as rule	0 to 60	30 to 120
	(Subject to frost heave - cover with granular mat in subgrade)				
A-6	Clay with few coarse particles Absorbs water, bad shrinkage	Low friction. Cohesion slight when moist. High when dry. Extreme expansion. No elasticity	More than 30% clay	18 or less	6 to 14
	(Cover in subgrade with mat of A-1 or A-2 soil. Compact when in moist condition)				
A-7	Like A-6 but deforms under load. May contain mica, organic matter. Variable grain shapes.	Troublesome elasticity	Sand less than 55%	Greater than 12	10 to 30
	(Cover with subgrade blanket of porous A-1 to A-3 soil)				
A-8	Soft peat or muck. No bearing strength.	Excessive organic matter. No cohesion on friction when wet.	Not significant	0 to 60	30 to 120
	(Remove in subbase - replace with better soil - not suitable as base or surface)				

Maximum dry weight lowest for A-8, highest for A-1, A-2 and A-3 soils.

* See Public Roads (Vol. 22, No. 12) February 1942, p. 273 - Table 2. Summary of soil characteristics and classification.

TABLE 7

Soil Classes Based on Texture

From *"Soils and Soil Management"* by A. F. Gustafson
McGraw-Hill Book Co. - 1941

Gravel)	**Coarse Textured Soils**
Gravelly loam)	
Sandy gravelly loam)	Dry, early, pervious
Sand)	Called 'light' because tillage
Loamy sand)	involves a minimum of power
Sandy loam)	**Medium Textured Soils**
Loam)	
Silt loam)	Intermediate
	Best general group for agriculture
Clayey silt loam)	**Fine Textured Soils**
Silty clay loam)	
Clay loam)	Called 'heavy' because tillage
Clay)	requires maximum of power
	These soils moisture retentive,
	impervious, cold, and late

Note: A comparison of this table with Table 6 shows that the coarse and sandy loam medium textured soils would roughly correspond with groups A-1, A-2 and A-3. Groups A-4, A-5 and A-6 are fine textured, undesirable subbase soils.

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Bulletin No. 409 - University of Arkansas - Establishment of Bermuda Grass from Seed in Nurseries by E. L. Nielsen.

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Silty clay loam)	
Clay loam)	Called 'heavy' because tillage
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	These soils moisture retentive,
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