grades the wave is low and the water flows smoothly into the inlet As the grade is increased, the height of the wave also increases and eventually the water actually leaves the gutter and forms an arc When the height of the wave is great enough to cause it to fall upon the top of the curb, the usefulness of this device is reduced This condition existed for all grades over 4 per cent with deflecting vanes above the gutter bottom.

One of the side inlets with grate gave the best over-all performance The inlet was 2 ft. long and had a 24 in x 24 in. grate. The bars of the grate were set at 45 deg with the curb and also inclined at 45 deg. This inlet, when used on an 8 per cent grade, discharged 290 per cent more water than did the same size inlet with conventional bars. The discharge was 0 462 cu. ft. per sec

Since the purpose of the investigation was to secure information on the capacity of several types of side inlets when used on various grades, no attempt was made to test a large number of inlets merely for quantitative results. The scope of the investigation was purposely limited. All of the tests were run on a 3-in. depression. The length of the inlets was limited by the quantity of water available.

It is planned to continue work on inlets Several possible lines of attack suggest themselves For one thing, other ways of causing water to flow into side inlets should be studied. This might be done by controlling the water as it approached the inlet by the shape of the gutter. Also there are many good inlet designs whose capacities are not known It would probably be worthwhile to conduct tests on some of these

In conclusion, the writer feels that so far the results obtained may be termed only a beginning. There is much to be learned about inlet design Suggestions as to further investigation will be welcomed.

REPORT OF COMMITTEE ON ROADSIDE DEVELOPMENT

THE DESIGN OF STABILIZED EARTH SHOULDERS FOR TURF COVER

H. J. Neale, *Chairman*

SYNOPSIS

A road shoulder is an essential part of the traveled way. No primary road is safe unless an adequate shoulder is provided where vehicles can stop in an emergency out of the way of moving traffic. A good shoulder provides free cross drainage of surface water from the pavement to the gutter and ready passage of subsurface water from beneath the subgrade Such a shoulder supports the edge of the surfaced traffic lanes and should be designed, stabilized and surfaced with as much care as the traffic lanes themselves

Many types of shoulder surfaces have been evolved and each has a place in the development of a highway system. All types to be satisfactory must be designed with proper pitch, with adequate subdrainage and with a mixture of soils selected for whatever surface treatment is to be given the finished shoulder.

Because untreated or unpaved earth shoulders in humid regions are sooner or later covered by growing grass or weeds, the Committee on Roadside Development, during 1945, made a study of all available information relating to the design and development of earth shoulders with turf surfaces This report analyses some of the main points of what has been learned and what still remains to be found out on this subject. It is hoped to bring to the attention of highway engineers the need for systematic field research, and recording of field experience relating to the design of better road shoulders constructed of selected stabilized soils and protected in humid regions by a cover of turf grasses

The cross section of a typical modern highway may be said to consist of five interrelated parts, the traffic lanes, the shoulder, a gutter or drainage area, the cut and fill slopes, and a strip of land bordering the right-of-way lines. Of these parts the shoulder has too often been a sort of "no man's land" constructed of whatever soil was left over after grading of the subgrade, and covered with a growth of weeds or whatever local grasses managed to establish themselves on hard packed and almost sterile soil. Such earth shoulders have usually been soft in wet weather, and unsatisfactory from standpoints of traffic use, traffic safety and maintenance.

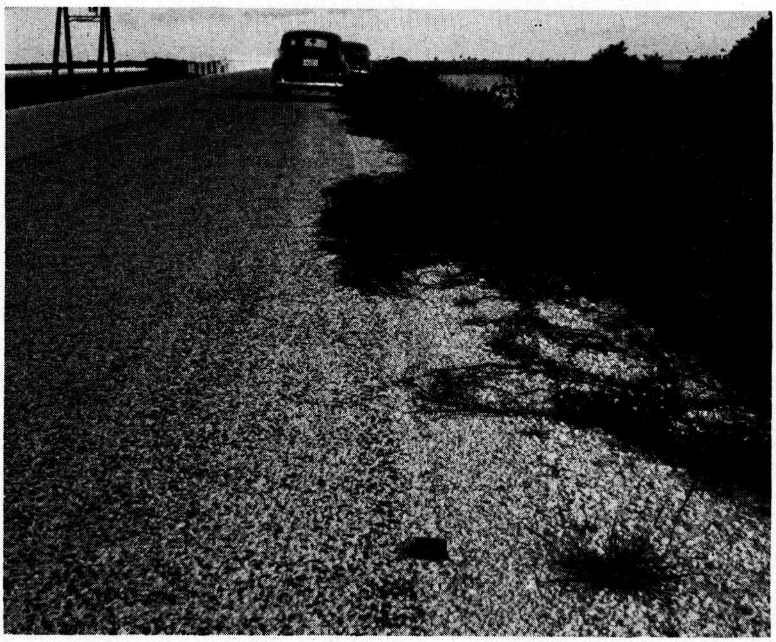

Figure 1. Limerock Shoulder on Florida Overseas Highway Showing Natural Tendency of Grass to Take Over Bare Shoulders in Favorable Climatic Regions.

As an answer to this problem highway engineers have evolved a number of types of road shoulders ranging from untreated gravel, shale or chert, to various aggregates and soil mixtures with and without bituminous and other binder materials. The stabilized earth shoulder with a turf cover of selected grasses is perhaps the latest in the series.

The Committee on Roadside Development has confined its investigations during 1945 to a study of turfs and shoulders. The report which follows will attempt in a brief way to: (1) analyze the high points of what is known regarding earth shoulders with turf surfaces, and determine the main factors in earth shoulder design, construction and maintenance of which more must be learned, (2) list certain basic principles and factors which should be considered in future design of highway shoulders constructed of stabilized soils with a cover of turf, (3) describe possible types of field research which may be carried out to determine essential facts as a basis for the design and construction of stabilized earth shoulders on which turf may be readily established and maintained.

WHAT WE KNOW ABOUT EARTH ROAD SHOULDERS—THE QUESTIONNAIRE

During the summer of 1945 the Committee circulated a questionnaire as a preliminary to discussion of the earth shoulder design problem at the annual meeting at Oklahoma City. It will be understood that expressions of opinion from members of 20 highway organizations answering the questionaire and discussing the questions at the annual meeting, are not considered conclusive evidence for or against any type of shoulder design. The analysis of the questionnaire which follows does, however, bring out some interesting facts. All answers were based on new highway location with traffic surfaces 22 ft. or more wide.

Purpose of a Road Shoulder

The first question asked was, "What is the purpose of shoulder design on primary highways in open country?" With very few exceptions the answers were that a shoulder must be designed for safe stopping of vehicles in an emergency. Shoulders are not expected to carry moving traffic as an extension of the pavement. The shoulder must contrast in color and texture with adjacent traffic lanes so that as far as possible shoulders will be reserved for standing vehicles. Parking for extended periods of time should not be on the shoulder, but on surfaced safety or scenic turn-out areas outside the shoulder.

Proper Width of Shoulders

It was generally agreed that width of shoulders should be increased in proportion to increases in traffic density; that topography is a main factor in shoulder width; and that the outer 10 ft. of wide median strips in divided highways should be kept free of posts, planted trees or other obstructions. The outer edges of median strips should not be developed as shoulders. All emergency stopping of vehicles should as far as possible be on the right hand side of traffic lanes in the direction of traffic movement.

Types of Earth Road Shoulders

All agreed that character and volume of traffic, climate, and prevailing types of soil largely determine the type of earth shoulder surface which should be established. Under certain favorable conditions turf can be established on granular soils without addition of loam.

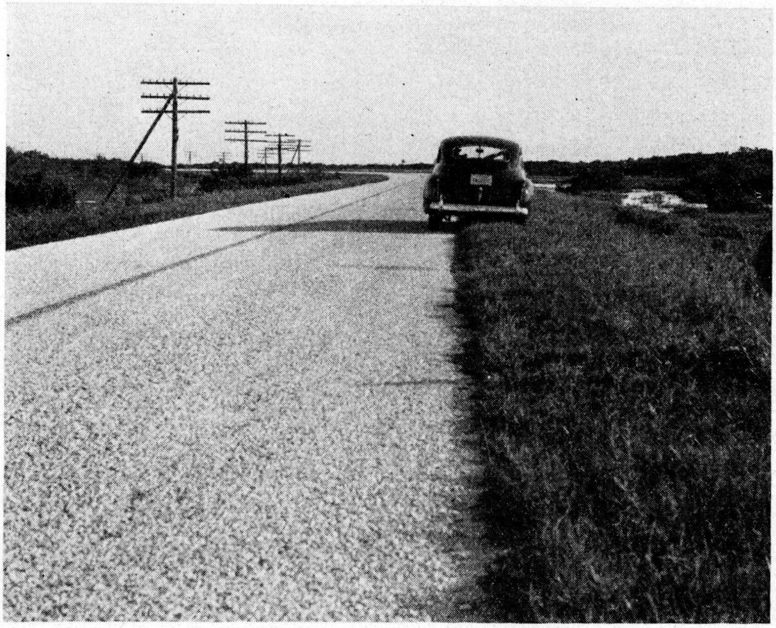

Figure 2. Same Limerock Shoulder on Adjacent Section of Highway Shown in Figure 1 after Grass Planting as an Item in the Construction Contract. An increase in pitch to 1-in. per foot would have been desirable with finished grade of shoulder slightly below edge of pavement to provide free cross drainage of surface water.

Lip Curb

The use of lip curb was questioned by a majority of participants in the discussion and in answers to the questionnaire. Particularly where heavy rainfall and snow and ice occur, lip curb was considered a hindrance to road drainage and was not favored.

"Build-up" and Pitch of Turf Shoulders

Objectionable building up of turf covered earth shoulders above traffic lane surfaces was largely due, it was said, to such factors as lack of free run-off of surface water across the shoulder, swelling of fine textured types of soils, and accumulation of dust or dirt on pavements. Use of sand, cinders and like materials on icy roads was reported to be a major factor in this problem. Such "build-up" was agreed to be greatest on flat profile grades and at the bottoms of steep grades. It was generally agreed that a pitch of 1 in. or more per foot of shoulder width would tend to reduce "build-up" on earth shoulders, particularly those with turf cover. It was also suggested that shoulders be graded to a point about 1 in. below the edge of pavement to allow for growth of sod.

A number of State highway engineers favored paved or oiled earth shoulders in deep cuts on roads carrying heavy commercial traffic and on important primary highways where climatic conditions are not favorable to establishment and maintenance of turf surfaces.

Where Turf Shoulders Cannot Be Maintained

It was agreed by those answering the questions that turf cannot usually be maintained:

at mail box turn-outs, milk-collecting stations, etc.,
along pavements narrower than 22 ft.,
on shoulders used by horse-drawn vehicles or cattle,
on shoulders used as foot walks,
on shoulders along business area frontage.

The consensus was that turf cover could, under favorable conditions, be maintained on shoulders fronting on residence property.

General Method of Establishing Turf on Shoulders

In answer to the question "how best may turf be established on earth shoulders?" it was agreed that under usual conditions in humid localities turf establishment should be based upon mulching combined with seeding. Seeding or sprigging without mulch, or solid sodding were not favored by a majority "vote." A factor in these answers is the point that only three or four States in the southeast and south, where sprigging without mulch is the prevailing method of turf establishment, answered the questionnaire.

Figure 3. A Federal-Aid Highway Constructed about 1924. Note lack of shoulder pitch and clogged drainage ditch resulting in saturated subgrade under both pavement and shoulder. Shoulders partly weed covered, soft and unsafe in spring when frost is leaving ground.

Maintenance of Turf Shoulders

The majority of answers to the question of how turf shoulders may best be maintained were that:

turf on shoulders should be mowed to a height of 2 to 3 in. or more;

all heavy grass cuttings should be removed from turf shoulders;

light rollers should be used in rolling clay shoulders.

It is implied that heavy rolling would not damage turf on sandy or gravelly soils, whereas heavy rollers on clay soils may compact the soil to the degree where grasses cannot grow. Some States favored periodic or seasonal rolling as a means of preventing "build-up" of turf shoulders

Shoulders should not be regularly mowed at fixed time intervals but only when grasses have reached a height of growth which makes mowing desirable.

Figure 4. Narrow Shoulder Covered with Johnson Grass. Here is a serious traffic hazard. This grass hides a deep V ditch from four to six feet deep.

Majority opinion among highway engineers answering the questionnaire or taking part in the discussion was that earth shoulders, regardless of type of surface protection, could not be expected to give satisfactory service:

(1) where the subgrade of the shoulder is a soil having low bearing power when saturated with moisture,

(2) when gutters are blocked or drainage is otherwise interfered with;

(3) where moving traffic uses the shoulder as an extension of the pavement.

It was agreed that the bearing strength of a well drained turf shoulder will depend mainly on the existing type of subgrade and surface soils on which turf is grown just as the bearing strength of a bituminous or other paved shoulder is mainly determined by underlying soil.

REVIEW OF OTHER DATA ON TURF SHOULDERS

Turf Shoulder Research

A paper describing turf shoulder research entitled "Construction of Stabilized Shoulders which will Support Vegetation" was prepared and forwarded to the Committee by Mr. Harry H. Iurka, Landscape Architect in the New York Division of Highways at Babylon, Long Island. This paper was circulated in abstract form in the "Clearing House Letter" by Mr Frank H. Brant in December 1945.

High points of this excellent account of a research project, were as follows;

Through the cooperation of Mr. J. J. Darcy, District Engineer, New York Department of Public Works, and representatives of the Soils Conservation Service and Cornell University, a series of test plots were set up on the shoulders of a State highway on Long Island in April 1945, to determine possibilities of establishing turf on stabilized soil shoulders.

On shoulders 12 ft wide with a pitch of 1 in. per foot and a natural sandy loam soil of the

Sassafras group a series of shoulder plots were laid out on a section of highway 3,000 ft long.

These test plots were harrowed to a 6-in depth. Fertilizer, lime, and various inorganic salts were added in varying mixtures and mulches were worked into the surface of certain shoulder plots. All plots were seeded with the same seed mixture except for the check plots left unseeded. Various mulches were applied over selected shoulder plots. Mr Iurka reports the following partial findings for the first season. Several seasons of observations

4. Moisture is another critical factor of growth under the conditions described. There must be enough fines in the material of the shoulder to hold moisture through dry periods. Any other treatment affecting the moisture factor favorably is desirable.

5 More informaton is needed about the varieties of turf grasses best suited to the conditions described Smooth Brome was the only permanent grass which gave good results Further study will probably indicate others of value

Figure 5. Excellent Turf on a Shoulder on a Federal-Aid Highway in the Piedmont Region. Clogged drainage resulting from erosion on steep bare cut slopes will probably render this shoulder soft and unsafe for vehicles leaving the pavement in an emergency in early spring. Soil is a red clay with low bearing strength when wet. See Figure 12 showing a method of solving this shoulder drainage problem on a stream lined cross section.

will be necessary before conclusive results of tests can be made available.

1. Vegetation can be grown on shoulders built of soil similar to that reported (Sassafras sandy loam) at densities as great as 135 lb. per cu. ft

2. Maximum density may not be desirable for vegetated stabilized shoulders. Increased quality of the vegetative cover may be of greater value to stability than increase of density of soil beyond a critical point

3. The importance of the accepted fundamentals in establishing turf is accentuated by adverse conditions of growth on shoulder areas. No factors are more important than seeding in the best season and mowing as required by growth of the grass.

6 A fast germinating nurse grass which will not compete too strongly with the permanent grass should be a part of the vegetation.

7. The soil grain size accumulation curves used by soil engineers should be considered for use in the field of agronomy They would be a valuable tool if correlated by observation and experience with conditions of plant growth and would afford a more rational specification of soil for many other purposes than stabilizing.

Mr Iurka also made these comments· The "C" horizon soils throughout Long Island, except for a few such as the Haven series along the north shore, require the addition of fines (clay soil materials) to provide a material satisfactory for shoulders. A and B horizon soils generally contain enough fines to serve as an amendment—to the C. A and B horizon soils (of the Sassafras series) will generally be satisfactory shoulder materials without amendment. In either case the "fines" (soils of A and B horizons) must be saved during grading operations or brought in from outside sources.

A program of cooperative research work has been developed by Purdue University and the Indiana State Highway Commission. Field tests for growing grasses on earth road shoulders were included in this program as described by Dr. G. O. Mott at the Ohio State University Fifth Annual Short Course on Roadside Development. Various methods of stabilizing turf shoulders with a minimum of topsoil are presented in the full text of Dr. Mott's report in the session papers published by Ohio State University.

Turf Shoulders in Ohio

Mr. Dallas D. Dupre, Landscape Architect of the Ohio Department of Highways, and a member of the Committee, wrote in *Contractors and Engineers Monthly* for January 1944 an article entitled, "Shoulder Build-up Checked in Ohio" which is of interest here. After many years of experience in installing and maintaining turf shoulders in Ohio Mr. Dupre brought out these points:

It is desirable to have turf cover to edge of surface traffic way.

Shoulder "build-up" has been caused by winter frost heaving and by dust, dirt and ice control on pavement.

The usual shoulder has not had enough slope (pitch) to clean itself by run-off of surface water.

A pitch of 1 in. per foot of shoulder width is now standard practice in Ohio. "Build-up" is controlled by sweeping off shoulder with a rotary broom or using a box drag in the spring to clean off sand or cinders used in ice control. The shoulders are then rolled with a 1,000-lb. roller.

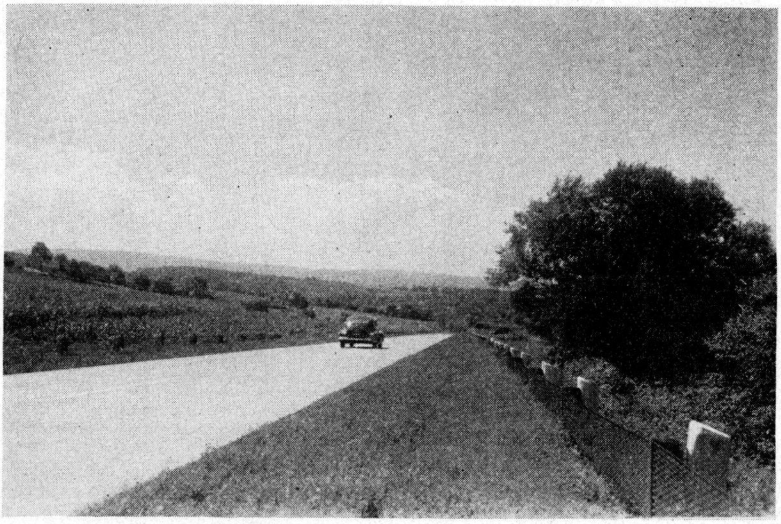

Figure 6. Good Turf on a Shoulder of Clay Soil into which about 2 in. of Cinders were Harrowed. This shoulder lacks adequate pitch away from the pavement and is already building up to the point where cross drainage is interfered with.

STATE HIGHWAY PLANS, SPECIFICATIONS AND FIELD REPORTS

Examination of plans, specifications and field reports in connection with current highway projects in a large number of States in the various regions brings out other interesting facts regarding turf covered earth shoulders.

Plans

In accordance with the recommendations of the A.A.S.H.O. for the design of interstate highways, most plans for current State highway construction on primary, as well as interstate systems now provide for shoulders of

8-ft. or greater width excepting in mountainous topography. Local soil materials without selection or stabilization are used on most shoulder surfaces shown on plans. A number of States carry selected granular subgrade materials under the shoulder as well as under proposed pavements when required by existing subbase soils. Some States still place the pavement in a "trench section" which with shoulders of impervious soils seldom provides adequate shoulder and subgrade cross drainage even when bleeder drains are provided. In the southeastern States where sprigging results in rapid turf establishment shoulders are designed with turf cover in mind. In dry regions, gravel or oiled shoulders are provided for and turf cover is not considered feasible.

There is a definite trend toward an earth shoulder pitch of $\frac{3}{4}$- or 1-in. per foot although some States continue to use the same $\frac{1}{2}$-in. pitch on turf shoulders as on bituminous oiled or paved shoulders.

Specifications

A few State specifications include items for mechanically stabilized earth shoulders. In one or two cases these items provide for establishment of turf cover by eliminating compaction of the 3-in. to 4-in. surface layer of shoulder soils until after turf has become established.

Most specification items dealing with shoulder construction are only concerned with shaping and finishing of shoulder surfaces and compaction of such shoulders, and say nothing of turf or other shoulder surfacing.

Field Records and Comments by State Highway Department Engineers

A number of field inspection reports and articles regarding shoulder conditions and shoulder maintenance have been examined by the Committee during 1945. Comments on shoulder problem made at various engineering meetings and recorded in their Proceedings also furnish information regarding earth shoulder conditions in various regions. Information from these sources may be briefly summarized as follows:

(1) Improvement in general shoulder design is considered vital if new highways in open country are to be safe, convenient, satisfactory in appearance, well drained, and free from high annual maintenance cost.

(2) In regions of adequate rainfall turf shoulders can be established at lower costs

Figure 7. A strip of plant mixed bituminous pavement with coarse aggregate serves as a transition between the turf shoulder and the concrete. Motorists are warned that they are leaving the pavement by the sound of tires on this "black top." Note clean edge of healthy turf and lack of the rut commonly found along traffic lanes less than 11 ft wide.

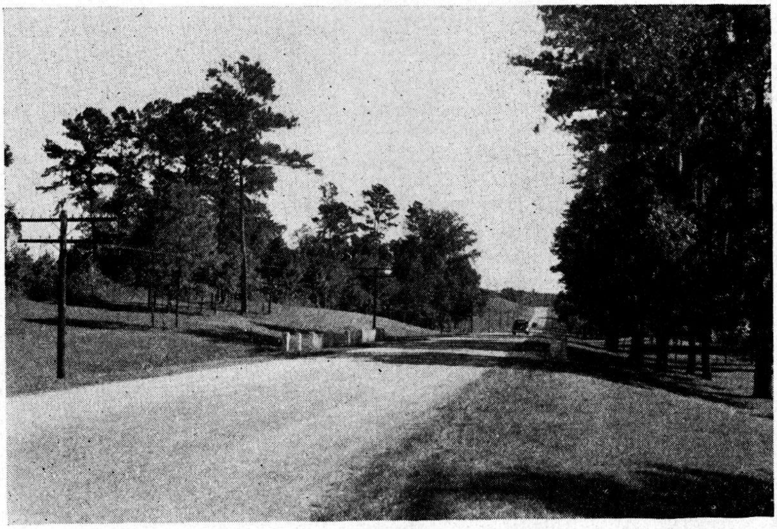

Figure 8. Shoulders should not be reduced to inadequate width at culverts and similar structures. This is otherwise an ideal Bermuda grass covered shoulder developed on pervious sandy soil and provided with a fine parabolic cross section. A car can leave the pavement on this Florida highway safely in an emergency.

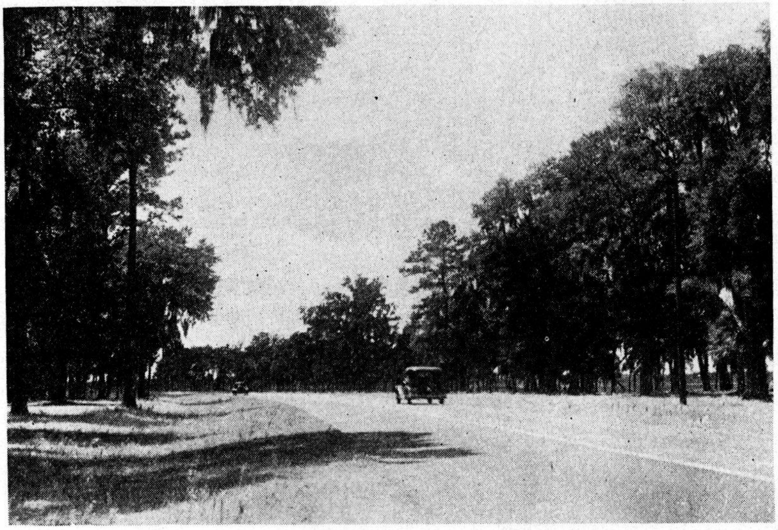

Figure 9. The Coast Highway, Glynn County, Georgia. Note parabolic cross section permitting free run-off, and excellent turf. A broad rounded gutter section and selective thinning of growth bordering the road complete a safe and beautiful highway.

than any other shoulder type, from both construction and maintenance standpoints.

(3) However, turf is said to be a cause for water getting under traffic surfaces.

(4) Turf shoulders are said to be too often soft in wet weather and subject to rutting and swelling.

(5) Typical photographs of existing turf shoulders shown in engineering reports and current magazine articles show that:

most turf shoulders on existing highways lack adequate pitch to get surface water off the traffic lanes;

most existing "turf" shoulders have a

cover of weeds and "bunch" rather than "turf" grasses, often resulting from volunteer seeding from adjacent fields;

many "turf covered" earth shoulders are bordered by steep cut slopes, and clogged ditches which result in such earth shoulders being saturated with water during wet weather.

EXPERIENCE OF THE U. S. ENGINEER CORPS IN ESTABLISHING TURF ON AIRFIELDS

During past years the U. S. Corps of Engineers has constructed a large number of airfields in the southeastern States on which turf cover has been successfully established on stabilized earth surfaces without the use of loamy topsoil. Space does not permit detailed description of the type of soil stabilization and the sprigging operations carried out on this series of airfields which are mainly in the Jacksonville, Florida, district.[1] It may be of interest, however, to note that prevailing shoulder soils were sandy and that runway shoulders were graded to a pitch of about 1 per cent. Both limerock and clay were used successfully as soil binder materials and soils were fertilized with a rather heavy application of 10:6:4 or equivalent high nitrogen content fertilizers. Sprigged Bermuda grass was planted as a ground cover and the soils before sprigging were compacted to maximum density. The resulting growth of grass as in the case of sandy stabilized road shoulders previously mentioned on Long Island was very satisfactory.

Figure 10. In dry climatic regions oiled shoulder surfaces like this may be desirable because good turf is all but impossible to grow. The same granular shoulder subbase provided here may also be essential on turf shoulders in humid regions.

SUMMARY—WHAT WE KNOW ABOUT TURF SHOULDERS

Study of the turf shoulder problem to date tends to bring out the following conclusions:

Shoulders covered with turf are not considered practicable or are not usually satisfactory:

1. In arid regions where conditions do not favor rapid growth of grass.

2. In humid regions where the pavement is narrow and moving traffic uses the shoulder as a traffic lane.

3. Where the shoulder has insufficient pitch or slope for adequate drainage.

4. Where the earth shoulder is badly drained because of clogged gutters or impervious soil materials under the shoulder.

5. Where the soil under the turf does not include a high percentage of particles of a granular type or for other reasons lacks adequate bearing power to carry reasonable traffic loads in all weather.

[1] See August 1944 Report "Stabilized Soil and Turfing," U. S. Engineer Office, Jacksonville, Florida.

6. Where coarse bunchy grasses or other grasses and weeds occur which do not form a smooth, durable turf. These may have been seeded or may have come in naturally on earth shoulders. Removing this growth by blading makes the shoulder still less stable, begins a cycle of more weed growth, and opens the shoulder to surface erosion.

Shoulders covered with turf may provide satisfactory traffic service for the occasional parking required on a shoulder in humid regions and certain drier localities with about 15 in. or more of annual rainfall where:

1. The shoulder cross section has been properly designed for turf, with adequate pitch, subdrainage and gutter drainage.

2. The soil under the turf is of a granular equivalent to: (a) sandy or sandy gravelly loam, (b) cinders or other fine aggregate worked into loam or clay soils, or (c) sandy or loose gravelly soils amended by addition of clay loam or other soil "fines" as required by mechanical soil analysis.

3. Adequate plant nutrients are present in shoulder soils or are added in the form of fertilizers with high nitrogen content.

4 Local rainfall conditions encourage rapid growth of desirable grasses.

5. Proper grass mixtures are seeded or the best types of grasses available in each locality are sprigged or sodded at a favorable season.

6. The turf after establishment is properly mown to a height of 2 to 3 in. and the shoulders are rolled in the spring after frost emerges or after periods of excessive rainfall.

7. Periodic top dressing with high nitrogen content fertilizers is practiced during the months when the grasses established on shoulders are making active growth. Such top dressing appears to be even more vital in regions of high summer temperatures than in cooler northern regions.

8. Where blading and other maintenance practices harmful to turf are replaced by beneficial practices of rolling and dragging which check "build-up" without damaging turf.

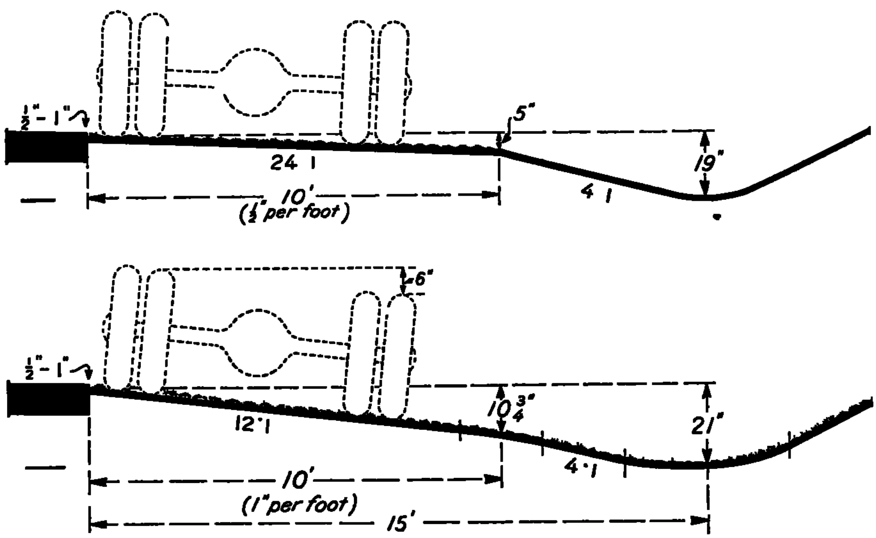

Figure 11. Typical Shoulder Cross Sections for Modern Highways. Top—Section lacks adequate pitch for turf surfaces. Bottom—Modified section with pitch increased to obtain free run-off of surface water over a turf surface.

WHAT WE NEED TO FIND OUT ABOUT TURF SHOULDERS

Under favorable conditions such as those cited in Long Island and Florida and where good technical supervision is provided, there may be no particular difficulty in establishing and maintaining a good turf shoulder on stabilized soil mixtures which remain firm in all weather. However, such favorable soil and growing conditions are found only in certain regions. Even under these favorable conditions we still have many things to learn regarding both establishment and maintenance of turf shoulders. For example we must find out:

1. How to mix and stabilize soils which vary from loose sand to clays and silts and loams, possibily containing peat and muck materials which have little load bearing strength when wet.

2. How to establish and maintain turf on unfavorable clay and silty soils by mixing them with granular materials (such as cinders, gravel, stone or slag) and fertilizers to attain the necessary permeability and fertility necessary for adequate drainage and a quickly established turf cover.

3. How to establish and maintain good permanent turf in less humid mid-western areas and in southern regions such as the belt of land which includes parts of Maryland and Virginia, where soils are impervious, extreme summer heat and sunbaked soils are usual, and the best of either northern or southern turf grasses sometimes fail to become established quickly or to maintain themselves when established.

We must determine costs of obtaining granular and permeable types of soils; costs of mixing and stabilizing various soil combinations; and costs of establishing and maintaining turf under varying local soil and climatic conditions.

We do not as yet know how to develop good turf cover on poor soils where stabilization and compaction of clays and silts would result in a dense impervious shoulder. Under such conditions necessary air and moisture cannot reach the roots of turf grasses.

Present indications are that fine cinders, coarse sand, rock dust or slag mixed in proper proportion with "tight" impervious soils enriched by heavy application of nitrogenous fertilizers may be among the answers. But what are the correct proportions of the various types of soil particles and granular materials? How far can we go in building up load bearing capacity by adding "fines" to granular soil materials, and by compaction, without adversely affecting turf establishment? Will turf survive hot summer weather on such stabilized soils in all regions?

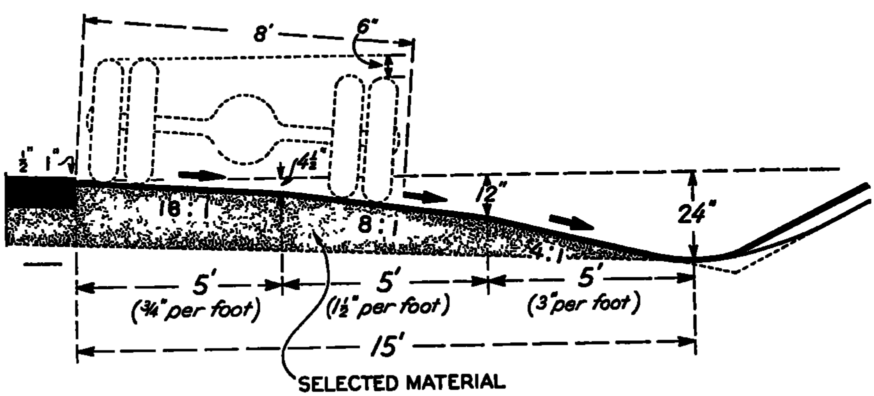

Figure 12. A Suggested Shoulder Section for Turf Shoulders. Note selected granular soil subgrade carried to the gutter edge and adjustment in gutter slope to fit variable cut slope ratios. If shoulder build-up occurs on this section by reason of cinders or other materials used in ice control, only the 5-ft. section of shoulder nearest the pavement edge will require blading to restore cross drainage of surface water. Three or four ft. units, if desired, may be used in place of the 5-ft. units shown.

These and many other similar questions remain to be solved. Their solution will, it is believed, come as a result of field research, experimentation, and experience by the State highway departments.

PROPOSED FIELD RESEARCH

We have, it is believed, an excellent field "laboratory" in the case of the new highways now proposed in the various States A series of field research projects might well be set up on the shoulders of these new roads to determine, for example:

1. How soils of various textural classification and sand, silt, clay proportions may be mixed with granular materials (cinders, gravel, etc) to produce an earth shoulder which will support traffic in all weather.

2. What the relationships are between plastic index and other soil test reactions, and the ability of a shoulder soil to support good turf.

3. How far may soils of various granular and clay, silt, and loam components be compacted toward maximum density without unduly prohibiting turf growth.

4 What grasses form the best turf cover particularly in those areas which represent transitions between typical cool, humid, western dry, and southern warm humid regional conditions

5. What the relationships are between various soil and climatic conditions, topography, and slope and gutter cross sections, and the design of shoulders as to surface pitch, surface soil, subgrade soil, width, type of best protective surface cover, etc.

The American public and highway engineers are alike disturbed by the increase in serious traffic accidents daily recorded by the press and radio. The Committee on Roadside Development suggests that nothing may do more to make our highways safer, more convenient and more beautiful than improvement in design of highway cross sections. The traffic lanes, the shoulder, the drainage area, the slopes and the strip of land bordering the highway must be considered as of equal importance in improving highway design.

We have learned to construct excellent pavements. Is it not high time that we resolved to design shoulders, and other portions of the highway cross section to equally high engineering standards?

DEPARTMENT OF MATERIALS AND CONSTRUCTION

C. H. Scholer, *Chairman*

IDENTIFICATION OF GRANULAR DEPOSITS BY AERIAL PHOTOGRAPHY

By Robert E. Frost, *Research Engineer*

Joint Highway Research Project, Purdue University

SYNOPSIS

This paper discusses the techniques used to interpret granular materials from aerial photographs This method of granular surveying is of great importance to highway and airport engineering because good sand and gravel are always at a premium whether it be as a source of borrow for subgrade improvement, base courses, for concrete aggregrate, or for location purposes Often it is not possible to locate highways or airports on ideal natural granular situations such as terraces or outwash plains because other influencing factors outweigh that of soils The importance of granular material to successful construction and performance makes it necessary to survey the area in great detail for available materials

In making a field reconnaissance, one is often handicapped by the inability to trace the areal extent of a deposit because of such factors as inaccessibility to the land because of lack of roads, dense vegetation or lack of co-operation on the part of the owner Such is not the case when studying a large area with the aid of aerial photographs The observer is able to view large areas from above and when a stereoscope is used the relief of an area can be studied Since the average pattern produced by granular materials is one of the easiest to identify, it is possible to make an airphoto survey of an exceedingly large area in a very short time