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FACTORS INVOLVED IN THE USE OF HERBACEOUS PLANTS FOR EROSION CONTROL ON ROADWAYS

Roadway construction annually reshapes thousands of acres of land in the United States. High rates of soil loss and resulting sediment yields from construction sites have caused a serious erosion problem. Although an excellent job is being done to stabilize and beautify Interstate and primary highways, secondary roads remain a problem. Numerous soil materials are being exposed that commonly have physical and chemical properties unfavorable to plant growth, thereby making roadway stabilization difficult. The basic principles for establishing vegetation are presented along with a recommendation that, where feasible, slopes steeper than 3:1 be flattened. Various planting methods and requirements for selecting plant species are discussed, emphasizing the necessity for mulching and maintaining established vegetation.

Soil management, soil and water conservation, landscape engineering, and plant ecology are all essential for controlling erosion and sediment on road construction sites. Thousands of acres of land in the United States are being reshaped annually by roadway construction. High rates of soil losses and subsequent sediment yields from these construction sites often cause serious problems. There is a high risk of runoff and erosion associated with major land modification, and, even when road builders are concerned, they may not be aware of the magnitude of soil losses. On highway cuts, annual losses of up to several hundred cubic yards per exposed acre were measured by Diseker and Richardson (1). Barnett, Diseker, and Richardson (2) measured 62 percent runoff and soil losses of almost 85 cu yd/acre from a single storm of 2.7 in. of intensive rainfall on a bare 2.5:1 highway cut.

An excellent job is being done in stabilizing and beautifying Interstate and primary highways, but much remains to be done on secondary roads. In one state there are 12,000 miles of secondary roads that need erosion control work. In another state there are 9,000 miles that need treatment. The need to stabilize secondary roads is urgent. Perhaps state highway departments and other agencies with a common interest should concentrate on this problem.

The Soil Conservation Service (SCS) can help solve these problems. It provides technical assistance in soil, water, and plant conservation through conservation districts (CDs), which are legal subdivisions of state governments. Boards of supervisors or directors of CDs are elected and are responsible for leading and coordinating the use and management of land, water, and plant resources within the district boundaries. These districts may be called soil conservation districts, soil and water conservation districts, or natural resources districts.

SCS technical assistance is available to any unit of government or group undertaking roadside stabilization projects. SCS specialists assist with detailed

erosion control plans based on scientific research and field experience. Alternative treatments are often suggested in the development of such plans. These technical assistance procedures are sometimes supplemented with more detailed agreements between interested groups. Examples of such agreements follow:

1. Memorandums of understanding between SCS and state highway departments—Such agreements are currently in effect between SCS and state highway departments in Oklahoma, Kansas, Montana, and many other states. The objective of these agreements is to have SCS furnish technical assistance in developing erosion control and pollution abatement plans on designated sections of federal-aid primary and secondary highway projects.
2. Project measure work plan agreements such as that between the Washington County soil and water conservation district in Ohio, the Washington County Commissioners, and the SCS—This plan covers roadbank seeding in the Buckeye Hills Resource Conservation and Development Project.
3. Cooperative technical agreements between SCS, CDs, and state highway departments—Agreements of this kind exist in New Mexico.

There are numerous examples where CDs, SCS, and highway departments are working together to stabilize and beautify highway corridors.

SOIL FEATURES AFFECTING ROADWAY STABILIZATION

Numerous kinds of soil materials are exposed during highway and road construction. They are formed from many different materials including glacial deposits, alluvial deposits, limestone, granite, gneiss, shale, sandstone, loess, and so on. These soil materials commonly have unfavorable physical and chemical properties and features such as steep slopes, south and west exposures, shallowness to rocks, high acidity or alkalinity, infertile subsoils, poor soil structure, high bulk density, slow aeration and permeability, shrink-swell potential, high clay or sand content, instability, low organic matter, and erosion susceptibility. The variations in parent materials and soil properties often adversely affect plant growth, making roadway stabilization difficult. These and other interacting soil features operate simultaneously to ensure the success or failure of establishing vegetation on roadside cuts and fills.

Soil surveys furnish much information on the extent of these interacting features. Such surveys have been made and published by USDA for more than 70 years. SCS has the federal leadership for making soil surveys, which include soil mapping, and has published them for about 2,000 counties and areas. Soil surveys and mapping are being prepared or updated in more than 3,000 soil conservation districts in the 50 states, Puerto Rico, and the Virgin Islands. Detailed soil surveys and maps are not yet available for all counties but less detailed soil surveys and maps are available and can be helpful in making soil interpretations of a general nature. SCS, working with the more than 3,000 soil conservation districts, usually has some kind of soils information available.

PREDICTING SOIL LOSSES

In the 19th century, the noted British scientist, Lord Kelvin, made the statement (3): "If you can measure that of which you speak, and can express it by number, you know something of your subject; but if you cannot..., your knowledge is meager and unsatisfactory." This axiom can be applied to soil losses on roadway construction sites. Such losses can be predicted by using the empirical universal soil loss equation or, as it is often called, the rainfall erosion equation. This formula was developed by the Agricultural Research Service and many state experiment stations in cooperation with the SCS. SCS has been using this formula in 37 states east of the Rocky Mountains for over 15 years to estimate soil losses on farmland. It provides the basic data for scientific farm planning for soil and water conservation, showing those factors that cause loss of soil by water and those that help to reduce such losses.

Estimated soil losses on construction sites can also be made by using the universal soil loss equation. The main advantage in its use on construction sites is to make a reasonable estimate of soil losses at a given location prior to actual construction. Such predictions may influence the degree of planning and treatment required for proper control of erosion. Soil losses on a construction site may be predicted for a whole or part of a year, or they may be predicted on the basis of "probability" storms and magnitudes of single storms.

The universal soil loss equation takes into account rainfall intensities (maximum 30-min intensity storm x kinetic energy of the storm), erodibility of soil, length and steepness of slope, supporting conservation practices, and vegetative ground cover (4).

Another equation has been developed to predict soil losses by wind erosion. This equation considers susceptibility of a given soil to movement by wind, soil surface roughness, climate (wind velocities, temperature, and soil moisture), maximum unsheltered distance along prevailing wind erosion direction, and the kind, quantity, and orientation of vegetative cover (5). Again, a predicted soil loss by wind can influence the degree of planning and treatment required for control of erosion.

HERBACEOUS PLANT ESTABLISHMENT

Principles and Criteria for Establishing Vegetation

We have already mentioned that highway construction may expose many soil properties and features unfavorable to plant growth such as subsoil and substrata materials that are infertile, steep, weakly structured, droughty, poorly aerated, and low in organic matter. Such conditions, if possible, need to be corrected.

Plant species that will suit climate, site conditions, and purpose of plantings must be used. It is also necessary to adhere to other general principles such as preparing a stable seedbed so seed and seedlings can remain in place long enough to grow; applying needed fertilizer, lime, or other soil amendments; using proper planting techniques; and covering the surface with mulch. Other considerations are to grade down to flatter and shorter slopes, if possible, and to spread topsoil when economically and technically feasible. Always avoid leaving land bare longer than absolutely necessary. Until permanent seedings can be made, seed fast-growing, temporary vegetative cover with or without a mulch or use mulch only. Mulching material may be vegetative or synthetic. Practice selective clearing by sections. Control water with interceptor ditches, grassed waterways, drop inlets, and the like.

Slope Stabilization for Establishing Plants

Cuts and fills are inevitable accompaniments of highway construction. These slopes present many erosion hazards and soil stabilization problems. Unless the surface is protected with vegetation or some form of mulch, considerable soil loss occurs from rainfall, flowing runoff water, or wind. Steep slopes make the establishment of vegetation difficult. Best slopes for seeding herbaceous plants and legumes, with tractor-drawn equipment are 3:1 or flatter. Slopes that are steeper than 3:1 may require hydroseeders, mechanical mulchers, or hand labor.

Vegetated slopes often need help from structural or mechanical practices, which may include retaining walls, protected outlets for water, diversions, berms, terraces, downspouts, ditch lining, furrows, and internal drainage facilities. Unstable soils will cause a vegetated slope to slip.

Topsoiling for Plant Establishment

Topsoiling is an expensive practice that should be used only when topsoil is readily available or stockpiled for respreading at the appropriate time. Topsoiling is usually required when soil material exposed for seeding is of extremely poor quality.

A study of soil profile characteristics should be made to determine the need for saving existing topsoil or bringing it in from an outside source. Many subsoils have desirable physical properties although they may be low in fertility. Satis-

factory stands of vegetation are usually obtained on such subsoils by applying sufficient amounts of fertilizer, soil amendments, and mulch. Critical soil areas, however, may need special care and management to maintain satisfactory plant cover.

The use of topsoil may be justified if the soil is extremely permeable, very fine textured, poorly aggregated, highly acid or alkaline, or very shallow and underlain with impervious layers. Care must be exercised in the latter case inasmuch as topsoil, when saturated, will slide. When topsoil is used, it should be friable and loamy in character. It should be capable of producing good stands of grasses, legumes, or other kinds of vegetation. A pH range of 5.0 to 7.5 is most desirable, and soluble salts should not exceed 500 ppm. A soil survey, incidentally, will often rate soils for topsoiling qualities.

Selection of Plant Species

The ability of a plant to grow in a given environment is mostly dependent on its inherent characteristics and its growing needs. There are numerous requirements that need to be considered in selecting species for highway stabilization. These include the plant's capabilities to fulfill the purpose of the planting; geographical, soil, and climatic adaptations; growth habits and longevity; ability to spread; pH, altitude, and winter-killing potentials; cool- or warm-season growing characteristics; susceptibility to drought or wetness; tolerance to inundation, shade, and traffic; seed dormancy properties; ability to grow on steep slopes; rate of growth; need to use hulled or scarified seed; hard seed content; inoculation requirements; needed level of maintenance; and aesthetic qualities.

Herbaceous plants that should not be overlooked for roadside stabilization are the native grasses. SCS plant materials centers and cooperating state experiment stations have developed improved strains of these grasses, and seed for most of these strains is available.

Two advantages of using native species are lower maintenance requirements and costs. These kinds of grasses need little or no fertilizer. They are competitive with weeds and are long-lived plants.

Techniques in Establishing Plants

Herbaceous plants are established from seed, planting stock, sprigs, or sod. Seeding is much less expensive than other planting methods. Commonly used methods of seeding highway construction sites are grass/grain drills; cultipackers or corrugated rollers with grass seeding attachments; hand-operated cyclone seeders; truck-mounted broadcast seeders; and hydroseeders.

The use of plant crowns, clones, or plugs for plant propagation is usually expensive because of higher costs of plant materials and increased labor required for planting. These methods are seldom used but may be feasible on hard-to-get-to sites.

Sprigging is used to propagate stolon herbaceous plants. Sod of stolon grasses is lifted, chopped, or shredded to provide sprigs 6 to 8 in. long. These are set promptly in well-prepared, moist seedbeds. Caution must be used to prevent drying or heating between lifting and planting.

Sodding is done in three possible ways: spot, strip, or solid. Spot sodding is planting small pieces of sod at more or less regular intervals; plants will grow and fill in blank spaces. This method is practiced with plant species that spread rapidly. Strip sodding, which is often done on slopes, is the laying of parallel strips at prescribed intervals. Spaces between strips may be seeded or sprigged to hasten complete ground cover. Solid sodding is complete coverage of an area. This method is used when immediate surface protection is required on critical areas such as drop inlets, grassed waterways, and steep slopes.

Soil acidity, salinity, and low fertility levels are common limiting factors in establishing plant cover on highway construction sites. Soil tests can identify these conditions, and corrective amounts of lime, soil amendments, and fertilizer can be applied. In the absence of soil tests, general recommendations used in the local area may suffice for applying these ingredients to the soil.

Mulching

Mulching is necessary in establishing plants on construction sites. Mulch protects soil, seed, and fertilizer from erosion by wind and water and markedly affects the microclimate and moisture relations in the soil by reducing extremes in moisture supplies and temperatures. Conditions under mulch are more uniform and favor germination and more rapid establishment of seedings. Mulch is essential if a proper seedbed cannot be prepared, if seeding is made outside commonly accepted seasons, if soil is highly erodible, or if slopes are steep.

Mulch should be applied uniformly and held in place by proper anchoring. Anchoring should be done simultaneously with the application of the mulch, or immediately after mulch is spread. Anchoring methods vary and include the use of tractor-drawn implements such as disk types of machines, cultipackers, sheepsfoot rollers, or pick chains; hydromulcher combined with asphalt emulsions; pegs, staples, or twine; and punching or slitting mulch with a square-edged spade. Common types of mulch materials are hay, small grain straw, wood chips or wood-based mulches, jute matting, cotton and paper netting, fiberglass netting, plastics, rubber compounds, polymers, and asphalt products.

Much research has shown that vegetative mulches such as straw or hay are very effective in reducing erosion and runoff on steeply sloping soils. The results of one study of a plot of Fox loam on an unplowed, 15 percent slope 10.7 m long are given in Table 1 (6). (The mulch rate and soil loss rate are given in metric-tons per hectare.)

Grassed Waterways or Outlets

Vegetation-lined waterways are used on construction sites to carry runoff water safely to a disposal point. The vegetation serves a dual purpose: It keeps down the speed of flowing water, and it provides a liner to protect the waterway from eroding.

In selection of grasses for a waterway lining, those that germinate quickly and grow rapidly are desirable. Early establishment of a complete grass cover is important. The most critical period for a waterway is during grass establishment. Rains may cause rilling of waterway bed and wash out seeds and seedlings. Sod grasses are preferred to bunchgrasses for waterway linings because the dense and uniform sod reduces turbulence of the water. Grass in a waterway should withstand bending and beating by flowing water without breaking. The grass plant should recover its normal growing position after the flow or it may rot in the waterway bed. The grass should also withstand some sedimentation. Under some conditions, soil is deposited in the channel, so established grass should be able to grow up through a layer of sediment that is not excessively thick. Grasses in a waterway may be established by sprigging or sodding. These are more expensive methods of lining a waterway, but the control is expedited.

If a new waterway is to be constructed and soil material left after construction is not suited for planting, topsoil should be stockpiled and replaced uniformly over the surface when the channel is completed. Mulch or netting over a heavy seeding will help protect the newly graded waterway from splash erosion and excessive runoff. Solid sodding down the center of a new waterway may retard cutting of the waterway bed during the grass establishment period.

Table 1. Effect of straw mulch rate on erosion rate and runoff velocity.

Mulch Rate (MT/ha)	Soil Loss (MT/ha)	Runoff Velocity (cm/sec)
0	62.3	13.9
0.56	20.1	7.1
1.12	19.4	6.9
2.24	11.5	5.6
4.48	2.5	–
8.96	1.5	–

Irrigation for Plant Survival

Water is essential to plant growth. In some regions, such as humid areas, plants will grow satisfactorily without irrigation because necessary soil moisture is supplied by rainfall. In other regions, during some years the rains may supply water needed by plants, but during other years this source is not

adequate. Where low rainfall is common, it may be necessary to apply irrigation water to ensure plant growth and vigor.

Maintenance of Plants

Establishing herbaceous plants on highway construction sites is only the beginning of the stabilizing process. The growth must be vigorous, dense, and visually pleasing for many years after construction is concluded. It is usually less costly to carry on a maintenance program than it is to make repairs after an extended period of neglect.

Maintenance should be consistent with favorable plant growth, kind of soil, and climatic conditions. This involves regular seasonal mowing, fertilizing, liming, watering, fire control, weed and pest control, reseeding, and timely repairs. It also requires prompt removal of debris, protection of vegetation from unintended uses or traffic, and special attention to critical areas. Well-maintained plants provide a comfortable margin of reserve that will carry through emergencies. A preventive maintenance program anticipates requirements and allows the accomplishment of work when it can be done with least effort and expense.

Mowing may be necessary once or twice a year to prevent erosion, eliminate fire hazards, and promote safety. The use of growth regulators is becoming more and more publicized. Some of the advantages attributed to this practice are reducing the frequency of mowing, cutting down on volume of clippings, reducing labor requirements, lessening fire hazards, and reducing potential for vehicle accidents.

A major input to proper maintenance is periodic fertilization for improving vegetative cover quality and function. Field observations indicate that a rate similar to that used for the establishment of vegetation can be applied once every 2 or 3 years. There is also evidence to indicate that a slow-release source of nitrogen fertilizer is more advantageous than rapid and highly soluble sources.

The importance of establishing and maintaining high-quality vegetation is reflected in vigorous plants, continuous development of extensive root systems, sustained functional qualities, and an overall gain in aesthetic properties.

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