"ROAD CUT SLOPE DESIGN FOR UTILITY AND BEAUTY"

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At the time of our entrance into the war, good highway appearance was a factor of growing importance in design and construction. It had become increasingly apparent that the road itself occupies a conspicuous part of the landscape as the foreground of the shifting scene viewed by the motorist. Better highway appearance is a resultant of improved highway design. The rounded cut slope cross-section here described for use in post-war highway construction combines good appearance and traffic safety with easier maintenance.

As constructed in ordinary practice in medium to heavy topography, the face of earth cut slopes may be likened in appearance to a series of planes set on end, each tipped to an angle determined by the height and degree of slope. In the better examples of this construction the slope of the planes has been flattened somewhat, as compared with earlier construction, with a resultant gain in stability. Some rounding of the top of cut slope has been accomplished, but in most cases this has been inadequate to give a pleasing transition between the cut slope and the natural ground slope. The curve between the two slopes has been too sharp or abrupt. At this junction of the constructed and natural ground slopes much improvement can be accomplished with relatively small increase in the excavation of the cross-section, by increasing the amount of rounding.

Landscape architectural design of road slopes has always considered the two complementary requirements of utility and good appearance. In practice, the grading design is accomplished with a detailed contour study of cuts and fills in conjunction with the cross-section, road profile and alignment. Where this ultimate type of design is not followed, and in order to obtain as good design for road slopes as possible under what may be called a mass production basis following standard engineering practice, we have prepared a series of cross-sections for various height of cuts that will in considerable degree produce in construction, the effect that can only be fully obtained with detailed contour grading study. The Perspective Sketch Figure 1 illustrates this type of design prepared by landscape architects of the National Park Service, and applied by the Public Roads Administration in the design and construction of several recent major road projects in the western national parks. This is further explained by the cross-section sheet described later. Although the perspective sketch indicates the flattening of low fill slopes, the description herein is confined to cut slopes in particularly critical topography.

Consideration was first given to obtaining stability in earth cut slopes by flattening them to an extent reasonable in proportion to the height of cut,

TRANSITION SLOPE IMPROVES APPEARANCE.
STABILIZING LOWER PART OF SLOPE ENABLES ESTABLISHMENT OF VEGETATIVE COVER.
TREE GROWTH BREAKS VIEW OF BARE CUT SLOPES.

Fig. 1

PERSPECTIVE SKETCH
PARKROAD ROUNDED SECTION

DRIVERS' VIEW OF FLAT FILL SLOPE ELIMINATES MENTAL HAZARD AND REDUCES NEED FOR GUARD RAILS

NATIONAL PARK SERVICE
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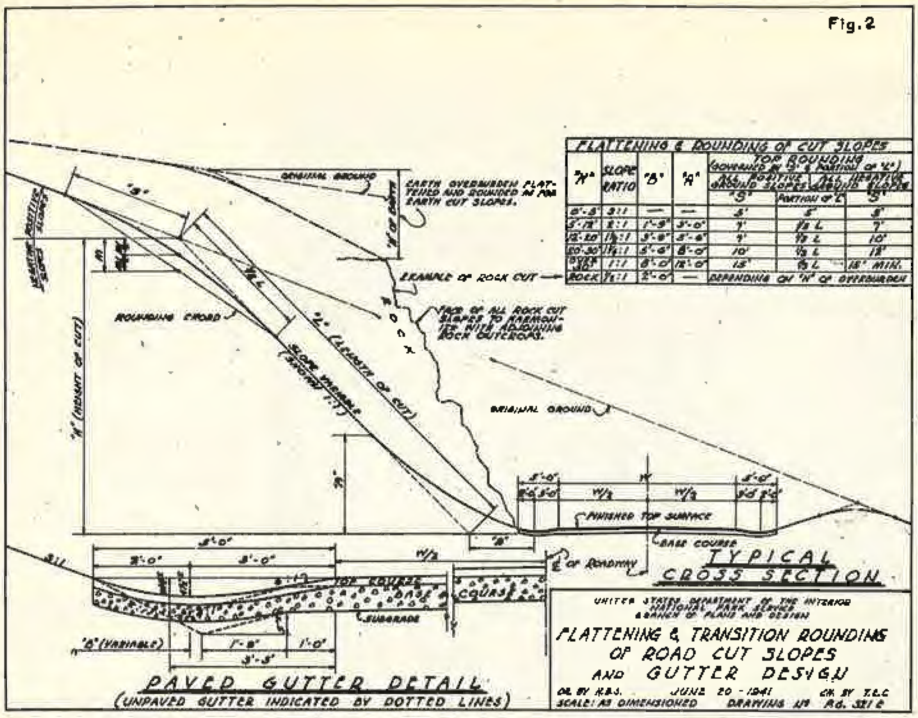
FLATTENING & ROUNDING OF CUT SLOPES
ORIGINAL GROUND
EARTH OVERBURDEN FLATTENED AND ROUNDED AS FOR EARTH CUT SLOPES.
EXAMPLE OF ROCK CUT
ROCK
FACE OF ALL ROCK CUT SLOPES TO HARMONIZE WITH ADJOINING ROCK OUTCROPS.
ROUNDING CHORD
"L" (LENGTH OF CUT)
SLOPE VARIABLE (SHOWN 1:1)
"H" (HEIGHT OF CUT)
ORIGINAL GROUND
FINISHED TOP SURFACE
BASE COURSE
SUBGRADE
PAVED GUTTER DETAIL
(UNPAVED GUTTER INDICATED BY DOTTED LINES)
TYPICAL CROSS SECTION
UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
BRANCH OF PLANS AND DESIGN
FLATTENING & TRANSITION ROUNDING OF ROAD CUT SLOPES AND GUTTER DESIGN
JUNE 20 - 1941
SCALE: AS DIMENSIONED

Fig. 2

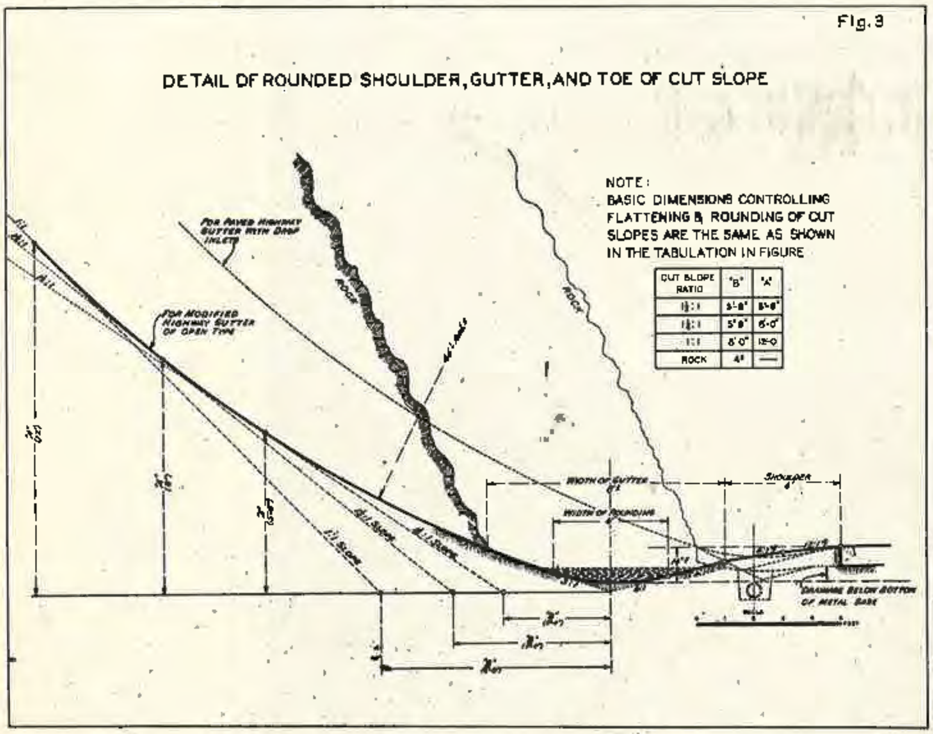
DETAIL OF ROUNDED SHOULDER, GUTTER, AND TOE OF CUT SLOPE
NOTE:
BASIC DIMENSIONS CONTROLLING FLATTENING & ROUNDING OF CUT SLOPES ARE THE SAME AS SHOWN IN THE TABULATION IN FIGURE
CUT SLOPE RATIO | "B" | "A"
ROCK | 4' | —
FOR PAVED HIGHWAY GUTTER WITH DROP INLETS
FOR MODIFIED HIGHWAY GUTTER OF OPEN TYPE
ROCK
WIDTH OF GUTTER
WIDTH OF ROUNDING
SHOULDER
DRAINAGE BELOW BOTTOM OF METAL BASE

Fig. 3

estimating a 1½:1 slope as the average maximum for stability. In medium to heavy topography much of the road construction involves high cuts, and slopes are designed steeper than 1½:1 in order to avoid excessive excavation and cost of construction, especially in fitting the road into natural ground slopes that in themselves approach maximum steepness for stability. There are of course conditions where retaining walls are needed against the cut slope, including those used to hold loose material such as scaled slides.

In this improved design, as compared with typical highway slope sections, the face of the cut slope is set back from the position it would occupy under ordinary design practice in its relation to the ditch and centerline of the road. This is done primarily in order to flatten and thereby stabilize the lower part of slopes steeper than 1½:1. The curve of this lower part of slope permits a better transition into the roadbed and thereby eliminates the sharp angle ordinarily formed by the cut slope and the ditch slope from the road shoulder. The amount of relatively flat curvature introduced for stability, in the lower part of the slope, is in proportion to the ratio or steepness of the slope. Likewise the upper part of the slope is rounded for transition an amount in proportion to the height (therefore length) of the proposed slope.

With this form, the perspective view of the whole slope is improved in appearance. There is a feeling of stability expressed as well as actual stability gained as a result of the transitions at the upper and lower parts of the slope. For cuts up to 30 ft. or 40 ft. in height the side-hill planes of older type design are resolved into form, simulating to a degree that which nature makes in ground slopes through erosion in reaching an angle of repose. In cuts above this height the proportionate amount of the lower part of slope transition is less, and could only be increased by additional set back of the slope, which operation would involve excessive excavation cost considering limitations of the present day. The cross-section is much improved, however, by additional top rounding in the highest cuts. Additional stabilization is gained with liberal rounding and there is less apparent height in the cut as seen from the road.

Figure 2 shows the type of flattening and rounding of cut slopes, and gutter design, constructed on some of the latest national park road grading projects. As indicated in the section and tables, dimensions A and B are based on various slope ratios with B horizontal on subgrade. In the bottom rounding the slopes of various degree enter the back of the ditch or gutter on a 3:1.

The design is adaptable to stage construction of grading and surfacing and to variations of base and top course surfacing design as indicated in the gutter detail. Slight modifications should be made where drainage conditions require. For example, the use of intercepting cut-off drains may be needed under the gutter where seepage layers occur in stratified soils, or a wider and deeper gutter section may be necessary in seepage areas and in tight or impervious types of poorly drained base soils. The paved gutter detail in Figure 2 illustrates the use of bituminous paved gutters with drain inlets in lieu of existing or typical deep ditches. The paved gutter placed adjacent to the pavement may serve as a shoulder. In Figure 3, showing detail of rounded

shoulder, gutter, and toe of cut slope, this is compared with the open type of highway gutter and shoulder of modified width. An 8-ft. or greater width of shoulder is preferred where feasible.

The "top rounding" dimensions of 1/3 L and S increase with the increase in height H, as indicated in the tabulation in figure 2. S is less with positive ground slopes and greater with negative ground slopes. Adherence to the rounding chord and $\frac{M}{2}$ is most important for obtaining good transition between cut slope and ground slope. The full curve should be used. To simplify staking it has been found desirable to resolve 1/3L into a fixed average dimension for each slope ratio.

With design on this basis, maintenance cost is decreased through the stabilization which considerably reduces the erosion of material into the gutter. The hand removal of such material from gutters is of high unit cost and steep slopes within certain limitations of height may eventually exceed the cost of flatter slope design, with initial construction on lower unit cost, that would avoid much erosion and reduce accumulative cost.

The set back of slopes provides additional horizontal sight distance, especially needed in curving alignment in heavy topography.

It should be obvious that with this design, the road alignment and gradient are adjusted to fit the set back slopes in the cross-section in order to balance cut and fill. In this way the increase in excavation over the ordinary design without set back slopes is relatively small. Of course, if line and grade were set on the basis of the ordinary position of cut slopes and then set back slopes were introduced in the cross-section, the increase in excavation would be large in proportion.

On reconstruction and betterment of road projects constructed under older standards, cut slopes have been stabilized and there has been opportunity to construct transition rounding in the lower part of these slopes. This has been done particularly in connection with surfacing projects providing for bituminous paved gutters with drain inlets in lieu of existing ditches. Generally the paved gutter occupies less width than the deeper ditch. The additional width gained at the back of the gutter enables stabilization of the lower part of the cut slope.

Throughout the greater part of the national park and forest roads of the west, nature is relied upon to revegetate the slopes with trees and shrubs. Stabilization of the soil on slopes through improved cross-section grading and drainage is essential for the estabilishment of this natural growth. The perspective sketch illustrates that natural vegetation may become established on the stabilized portions of steep cut slopes, governed by the existing ecological conditions. Trees and shrubs growing on the stabilized lower part of steep slopes will serve to screen relatively bare unstable sections of the slope above. Much of the cost of planting and maintenance of vegetation on steep slopes can be avoided through improved slope section design, as controlled by topographic and soil conditions.

While much advance has been made in the landscape design of roads, more is needed to further the appearance of the road fitting into the natural terrain and to preserve and restore the natural character of each roadside. Further progress can be made through study of typical cross sections for construction in light, moderate, and heavy or rough topography. Elements in design contributing good appearance to a road project, likewise add qualities of efficiency and safety.

SLOPE PROTECTION WITH RELATION TO SLOPE DESIGN

(Synopsis of Remarks during discussion of this subject)

The highway engineer can build a more stable earthwork cross-section through the correct application of basic principles of rounding of the tops and bottoms of slopes in combination with the warping and flattening of the ends of cut and fill sections. This is outlined in the previous paper on road cut slope design.

As soon as this streamlined earth grading is accomplished, however, the exposed soil surface is immediately subjected to weathering. Therefore, the engineer's first step after inspection and acceptance of the cross-section work is to provide positive and permanent slope protection suitable to the particular soil section and other local conditions. In general, vegetative methods of soil protection have proven to be most effective and economical for this purpose, and should be carried out as the immediate "follow-up" to slope grading operations. Slope protection from the agronomist's point of view is here briefly presented with relation to slope design.

An interesting highlight of the meeting was the special selection of colored slides used by Dr. Fred V. Grau to illustrate the various means by which the engineer may help nature along in the slope protection process. The relative steepness and height and the particular character of slopes found on the Pennsylvania Turnpike were presented as representative difficulties in the problem of slope protection. The compelling circumstances which had to be faced in the Turnpike construction gave rise to the use of mechanical methods of slope protection with apparently good results, as viewed one year after application of the specially developed treatment.*

The experience gained in the problem of selecting the right seed and method to fit site conditions on the Turnpike proved how fundamentally important it is that the engineer initially select the right slope ratio and provide natural surface roughness over the graded slope to fit plant growth requirements.

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* For detailed reports covering the experimental methods used on the Pennsylvania Turnpike, see Appendix III, p. 89.

Flattening of slopes and rounding of tops and toes of slopes to promote plant growth reduce erosion and the difficulties of establishment and subsequent maintenance. The "sandpapering" of slopes is detrimental and unnecessary. A natural "roughness" of earth slopes is desirable because a "scuffed-up" surface attracts moisture and favors air circulation in the soil. Too much emphasis cannot be made on this one point of economy that may be obtained by not "finishing" (sandpapering) slopes, but leaving them with a certain degree of "roughness" that is most favorable to plant growth.

The engineer may do much to make the facilities of transportation naturally attractive and economical to maintain. Basic slope design to effect a maximum emphasis on immediate slope protection will reduce the need for so-called "landscaping" (planting) to a minimum.

A brief report of the mechanical features of the work is included in the report of Division II covering construction and maintenance. (Page 23).

In Appendix III will be found a comprehensive ecological survey of the Pennsylvania Turnpike, with recommendations made by Dr. Fred V. Grau as consulting agronomist to the Pennsylvania Turnpike Commission. This report should be useful as a guide in the technical analysis of this phase of the highway design problem and as a basis for further research.

"Off-the-highway" facilities

The Project Committee on Waysides reports the need for suitably located and planned off-the-highway parking facilities on important motor routes. Roadside facilities for comfort and convenience of travelling public should be a definitely designed part of the highway system, and as far as possible these areas should be provided and developed during the preparation of regular construction programs, especially for post-war work.

In recognition of the fact that safety turnout sites need to be carefully selected, and require some care and upkeep in proportion to their use, certain proven policies are recommended for administrative application by highway officials. These project recommendations for the design and upkeep of waysides are enumerated in the annual report of Chairman Neale on page 3.

The Committee points out that these principles are equally basic to any roadside service development like gas stations, restaurants, and similar service facilities where off-the-highway parking of vehicles is necessary to traffic safety.

In this connection, the Committee feels that pertinent quotations from the 1942 Report of the Scott Committee on Land Utilization in Rural Areas (of Great Britain) will show the similarity in pressing problems of post-war reconstruction and development in the two countries.

The report advocates bold planning for highways but points out that roads may do considerable harm in country areas, both to agriculture through

the break-up of farm units and to the beauty of the countryside through inappropriate siting and construction.

The report refers particularly to the dislocation caused by taking agricultural land for constructional development, such as, for instance, the driving of a main road through an agricultural holding which forces machinery and stock to cross the road in order to go from one part of the farm to another and so cause loss of time and efficiency, apart from danger to stock and to traffic. A new road does often necessitate the regrouping of holdings which is cited as another example of the intimate interrelation of different forms of development. The report finds that in the past too much emphasis has been laid on the engineering aspect, and not enough attention paid to land use, social, and other considerations involved. Roads form an integral part of town and country planning and cannot be divorced from it. The report recommends close technical collaboration from the start of any new scheme, whether for town planning or for the construction of new roads. It is in this connection that we urge more care, thought and boldness in planning.

It is of interest to note also that the Scott report calls attention to "petrol stations" and "wayside cafes and restaurants," and their frequently unsightly effect on the complete highway. It is fortunate that planning authorities are emphasizing this subject as a general part of rural development.

On important routes, the needs of traffic safety may well be served through adequate provision of "off-the-highway" parking. "Roadside facilities for the comfort and convenience of the traveling public" is a legal aid definition used in Michigan to emphasize the utilitarian features in the 150 wayside areas in the State where "safety turnouts" properly located and designed are proving their wartime value. In Connecticut, another busy State where war workers in factories need outdoor recreation to bolster morale, wayside areas close to war centers have added value under wartime conditions. Truck safety, especially on convoy routes, is aided where safety turnouts are carefully located and distributed along important trunk lines used by war traffic. A minimum of maintenance for bivouac needs should be kept in mind in the development of facilities of convenience of utilities on convoy routes.

The development of turnout points to meet traffic service requirements should be considered in direct relationship to the land-use development adjacent to the highway. Each problem is local to itself. In rural sections, roadside facilities for public comfort and convenience may be simply "safety turnouts" or casual picnic spots. In more intensively developed suburban areas, their development may assume the characteristics and uses of city parks. Under these conditions, such areas may popularly be called "roadside parks."

We urge, therefore, that public officials and highway engineers review this question as a part of post-war construction policy and now consider plans for the orderly selection and development, through normal highway channels, of "off-the-highway" parking facilities.

GENERAL SUMMARY:

In a brief review of research progress in design, right-of-way and border control, it would seem that we have come a long way in our thinking and concern about what happens beyond the edges of the pavement. We still have a long way to go before the ideas and principles set forth in these reports are so generally understood and accepted as to make their effect apparent throughout the country as a whole.

An essential question in building a modern highway system for the streamlined motor vehicle is the design of proper land width (right-of-way and property easements) for adequate highway cross-section development. Progress by State and local highway authorities in securing satisfactory land widths and limited access controls for post-war construction programs is dependent on bringing up-to-date the land acquisition laws of the horse and buggy days of our grandfathers now in existence. This is the crux of the right-of-way problem and current attention must be concentrated on this pivotal point in highway development if essential land widths are to be provided in post-war projects.

The "ogee" or rounded "S" form of slope grading with broad, rounded gutter affords overall savings in construction through:

1. Better stability of slope
2. Easier establishment of planting or other protection
3. Reduced maintenance, through elimination of the troublesome V-ditch
4. More natural appearance, with improved efficiency and safety

"Off-the-highway" parking provisions are essential for both rural and urban traffic safety. The principles of development to be applied to such areas are similar whether the improvement is made on public right-of-way or on private property.

CONCLUSION

Roadside design, when properly handled, is an integral part of highway development. We must prepare now for orderly post-war improvement in highway construction programs so that plans for complete highway development may be ready for use immediately upon cessation of hostilities. As pointed out at the annual meeting by Mr. Thomas H. MacDonald, Commissioner of Public Roads Administration, "The purely functional and economic phases of roadside treatment have proven that it is cheaper to have roadside treatment than it is to go without it".