THE ROADSIDE IN HIGHWAY DESIGN

A brief analysis of progress in highway design
as it has affected roadside development
during the past 15 years

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SYNOPSIS

During the fifteen years since the setting up of the Joint Committee on Roadside Development, State highway departments in all regions of the country have carried out roadside development work on highways of the Federal-aid system. Most successful roadside work has been integrated with highway right-of-way acquisition, location, design, construction and maintenance. It is, therefore, believed by the author that for a full understanding of progress made in roadside development, it will be helpful to note the high points of change and advance made in the design of highways as a whole.

Improved highway location and design are necessary prerequisites for improvement in conservation of roadside features, improvement in shoulders, gutters, and drainage areas, better slope protection, safer and more convenient border development and better design and development of wayside areas and safety turnouts. Complete highway design considers all these roadside development objectives, and is based on good highway department staff organization. The landscape engineer is only one of a number of highway engineer specialists who are directly interested in, and responsible for, better roadsides. Success in highway landscape development requires teamwork within the highway department as well as public cooperation and support outside it.

It is believed that by making full use of the lessons of experience we shall be able not only to improve roadsides but also to improve the whole highway from standpoints of safety, convenience, and appearance and, at the same time, decrease some of the unit costs of construction and annual highway maintenance.

Dr. L. I. Hewes in his book on AMERICAN HIGHWAY PRACTICE speaks of the ideal highway location which "would provide, at a minimum cost to the public permanently optimum operating conditions for a gradually developing stream of composite traffic."

The more we study our American highways the more we realize that this quality called permanence is the one most needed. Many of our main highways have already been relocated two or three times, and some of them must again be relocated if they are to meet modern traffic safety and service requirements. History and experience alike tell us that pavements wear out, and must in time be replaced, or repaired; and that bridges become obsolete and must be rebuilt. But the roadside portion of the highway, and the adjacent land, with its hills and valleys and running streams, and its growing trees, can become permanent fixtures growing better with age. When we speak then of the "permanent way" or the "ideal highway" we mean a permanent location or a permanent strip of land. On this strip pavements and structures can be repaired, widened or replaced as the need arises while natural features such as streams and trees are allotted the permanent open space they require.

During the 15 years since the first Joint Committee on Roadside Development was set up in 1932 the writer has had occasion to look over plans for some thousands of primary highway projects, and to ride and walk over some thousands of miles of highways in various stages of completion in various regions. Current engineering literature relating to highway design and roadside development has been studied. It is proposed here to analyze briefly the high points of progress in highway design with particular regard to those design features, which provide the foundation for, or are a part of, what has been called roadside development.

What are these vital phases of highway development with which the landscape engineer is most concerned? For present purposes they may be classified under these headings:

1. Highway right-of-way acquisition
2. Highway alignment and profile design
3. Highway cross-section design
4. Conservation of existing features of the route
5. Highway drainage design
6. Highway slope protection
7. Highway border control and border protection

<u>Right-of-Way</u> - Adequate right-of-way must always be the essential factor in complete highway design. Roadside development naturally suffers more than other phases of highway development when right-of-way is inadequate, because it has too often been considered as a "stepchild" -- the last of the phases of highway development to be considered in design and construction. Observation of some of our best primary highways including both parkways and freeways brings out points like this:

1. The best highways have been designed to meet foreseeable future land use and traffic conditions. Their design has been based upon very careful study of existing topography by means of aerial surveys or equivalent ground surveys and contour mapping. Right-of-way has been acquired <u>after</u> all decisions regarding location and design have been made and the road line is laid down on a base map showing contours, land use, and other essential information. Well-rounded and warped slopes and drainageways and almost complete absence of erosion are characteristics of this type of highway.

2. Some of the worst of our newer highways have been designed to fit a strip of right-of-way land, selected before design was completed. Steep slopes

Figure 1. A Highway Right-of-Way More Than a Century Old, With Its Fine Old Trees. This highway is a permanent feature of a New England town. Adequate right-of-way is the first essential for complete and permanent highways.

without adequate rounding, narrow angular ditches, inadequate shoulders and more or less continuous erosion over the years following construction, are indications of this type of right-of-way and design relationship. Since there is no adequate space for it on these too narrow highways, roadside development tends naturally to be inadequate.

FITTING THE HIGHWAY TO TOPOGRAPHY

The phrase fitting the highway "to the lay of the land" or "to existing topography" will be found in engineering literature and in some of the earliest reports of the Committee on Roadside Development. The idea has been accepted in principle by most highway design engineers. Its application in practice is something else again. This fitting process includes a number of parts or phases all related to each other.

Alignment and Profile - In highway location outside built-up areas existing topography tends to control both alignment and profile. As all highway designers are aware, long sight distance and easy grades and curvature are essential requirements in designing primary highways for modern traffic speeds. The rougher and more broken the topography of the route the more difficult the problem of obtaining alignment and profile with these desirable qualities. The best possible line over a selected route might, therefore, be described as a successful compromise between (1) the tendency of broken topography to force abrupt changes in direction and (2) the traffic safety requirements of long sight distance and easy curves and grades.

Many highways following along the contour of rough topography have too many sharp curves to permit safe driving at modern traffic speeds. A road with long tangents following the same general route in rough topography will require extensive cuts and fills with large volumes of excavation and proportionally high costs of essential erosion control. A road with the long easy curves of a well-located curvilinear type of alignment over the same route will permit the best of possible compromises between the "contour" location and the long tangent type of alignment. Long tangents with few curves of any kind may in certain cases, however, appear to be the answer to the highway location problem in flat topography.

In practice we find two general types of alignment on primary highways, parkways and freeways in hill topography.

1. An alignment characterized by long tangents and relatively short arcs of circular curves. In recent years these curves (in open country) have a tendency to increase in length with transitions at points of curvature and tangency.

2. A type of alignment featuring very long easy transition curves connected by short tangents a station or two in length. This curvilinear alignment is usually laid down on contour map sheets with a spline, an instrument which tends to prevent abrupt curvature and resulting reduction of sight distance. For example, examination of a typical 20-mile section of an eastern parkway with spline alignment shows only one "sharp" curve of 6 degrees or about 950-ft. radius. Profiles consist of very long easy grades with the longest sight distance on vertical curves possible under existing topographic conditions.

From the standpoint of roadside development the curvilinear type of alignment has these advantages among others:

1. Because this type of alignment fits the road to topography with the least possible cut and fill, considering assumed design speeds, the cost of erosion control per mile is kept to the lowest possible figure.

2. The curvilinear type of alignment avoids many of the deep through cuts typical of long tangent alignment in hill country. Erosion control in drainage channels and ditches is more difficult and more costly in through cuts because of concentration of surface water in such cuts sometimes over long distances.

3. It is economically practicable to flatten and round low cuts and fills more liberally than higher slopes. This more liberal flattening and rounding makes for lower erosion control costs per unit of slope area, for better erosion control work, and for lower annual maintenance costs on the highway as a whole.

We recently drove over some fifty miles of parkway in an eastern State with the flowing spline alignment and rounded and warped cross section typical of such highways. Nearly perfect drainage was evident following the heavy rain the day

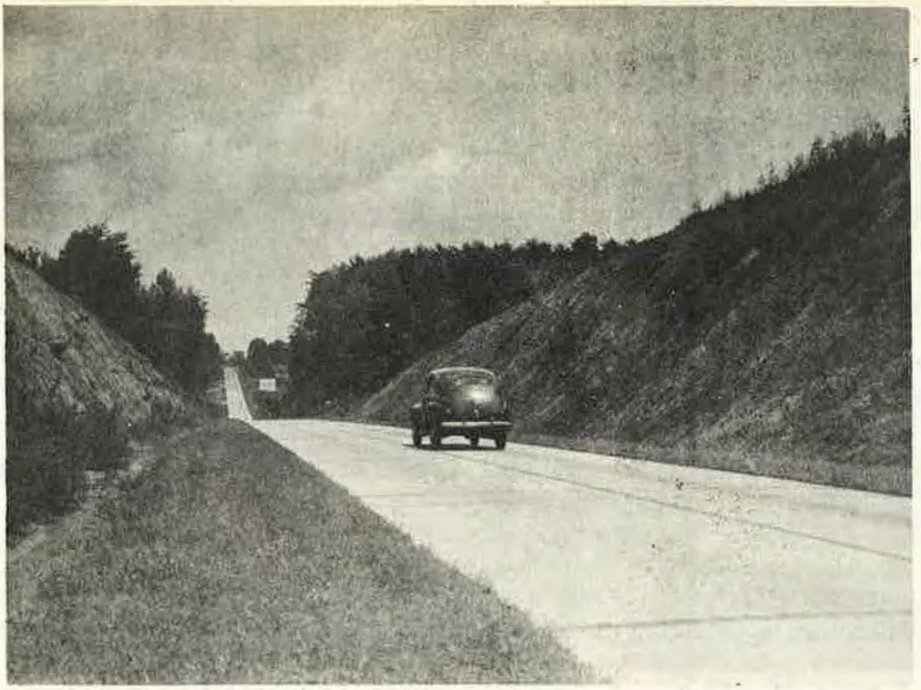


Figure 2. Long Tangent Alignment in Hill Topography Results in Heavy Through Cuts and High Fills. Original costs of excavation, and costs of essential erosion control tend to be higher than need be under such conditions. The curvilinear type of alignment (see Figure 30) results in a safer and more beautiful highway at lower cost because it fits the lay of the land better.

Figure 3. A Highway in Hill Topography With Long Easy Curves Designed to Fit the Lay of the Land. Flowing alignment results in reduced cut and fill and corresponding reduction in roadside development and maintenance costs.

before. Erosion on this highway had long ceased to be a problem. On an adjacent State highway constructed with long tangent alignment and steep cut slopes in equivalent topography, maintenance crews were very busy cleaning catch basins and repairing drainage channels and shoulders. Facts like these speak for themselves.

Highway Cross Section Design - Marked progress has been made in many States in recent years toward improving cross section design. Secondary roads are now being provided, in some States, with rounded slopes and gutters far superior to those of the most important primary highways fifteen years ago.. Trends in cross section progress may be perhaps too briefly described as follows:

In hilly and mountainous regions several interesting types of cross section design may be observed. A few States still construct both primary and secondary highways with typical cross sections calling for 1:1 and 1½:1 cuts and fills regardless of topography. These slopes must be rounded by use of hand tools and are therefore usually provided with a slight beveling of slope crests rather than true rounding. In these States earth slides are frequently reported and erosion damage is usually accepted as a natural result of heavy rainstorms. Costs of the various erosion control items in these States are higher than in those States where cross section design with easy slopes permits use of modern motor operated grading, seeding and tillage equipment.

In many States in hill country 2:1 or flatter cut slopes are now the rule and low fills up to about 6 to 8 ft. are flattened to ratios of 4:1 or better to eliminate need for guard rail. Guard rails should be eliminated wherever possible because they tend in themselves to be hazards to traffic and are, as every maintenance engineer knows, a hindrance to machine power mowing and snow removal.

Certain southern States with hill topography and very erodible soils may be said to have attained a leading place in fine rounding and flattening of slopes and drainageways. In an emergency a vehicle can leave these roads at normal speeds and stop along gutter or slope areas without serious damage. The same vehicle forced off the shoulder of a road with steep fill slopes and V type ditches is often completely wrecked. The erosion control problem appears to be definitely solved on these southern highways.

Two contrasting, variant types of cross section designs have been observed, one in a western prairie State and another on a freeway not far from Washington, D. C. The first of these examples illustrates the advantages of extremely flat slopes under certain conditions of easy topography. The second shows the disadvantages of slope flattening not closely related to and controlled by existing topography.

On the first of these, in flat topography, all cuts and fills were warped and flattened with blade excavation equipment until both "fore and back slopes" had literally disappeared. Excavation for fills was obtained by shallow grading beginning at points 75 ft. on each side of the center line. No snow plowing is said to be necessary on these roads in spite of usual heavy winter snowfall. Snowfall is usually accompanied by high winds in this western region. Wind tends to remove snow almost as soon as it falls upon the traveled way because there are no angles nor sharp depressions in the cross section to cause snowdrift formation.

Figure 4. Topographic Map of a Section of Northeastern Hill Country Showing Highways With Both Spline and Long Tangent Alignment Intersecting at Grade Separation Lower Left Centre.

Figure 5. One of the Earliest Federal-aid Highways Constructed in the 1920 Decade. Note steep side slopes and heavy erosion resulting in blocked drainage. Erosion can hardly be controlled since vegetation cannot be established or maintained on such a cross section.

Figure 6. Angular Ditch Cross Section on a Western Highway Constructed In the 1930 Decade. An excellent "man trap"; impossible to protect against erosion.

Figure 7. An Improved Modern Rounded Gutter Section, Safe and Easy to Protect Against Erosion.

Figure 8. An Old Model State Highway With Clogged Drainageways Resulting from Erosion of Steep Angular Slopes. Before reconstruction.

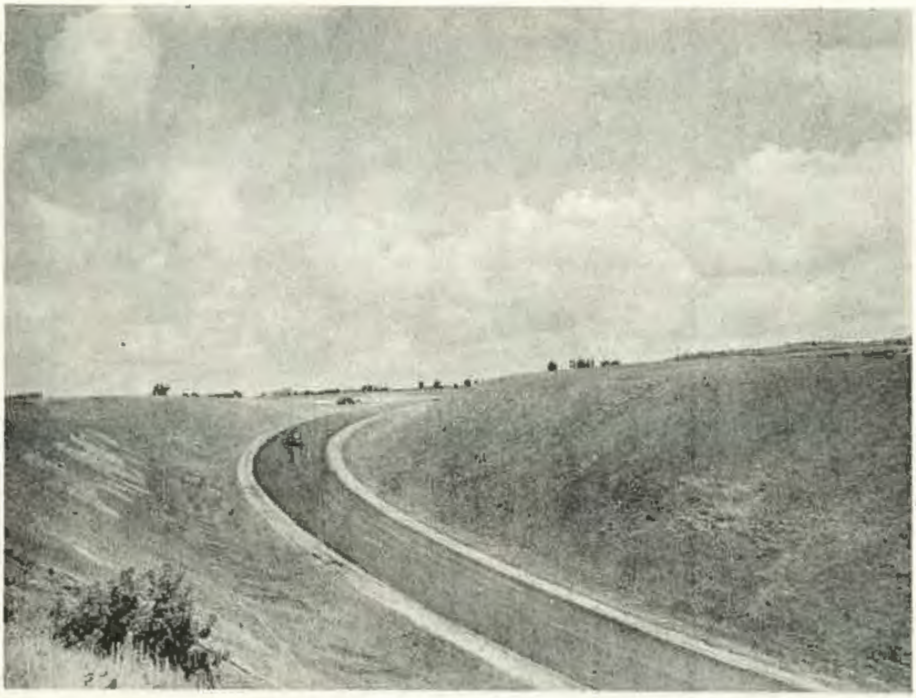


Figure 9. The Same Highway After Reconstruction. Note warped and rounded slopes and clean drainageways. Excellent appearance of this "new" highway is a product not of roadside improvement alone, but mainly of improved cross section design.

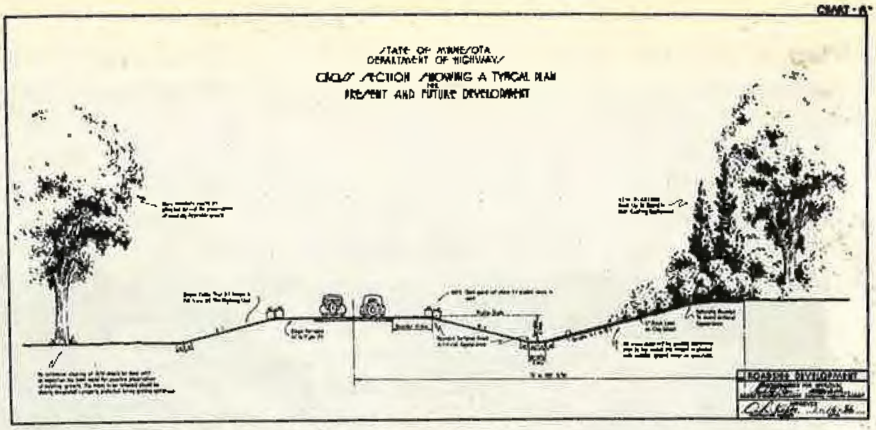


Figure 10. Ideal Cross Section Designed by a Consultant Landscape Architect. This typical cross section is now in use in many States with easy topography of the lake States region.

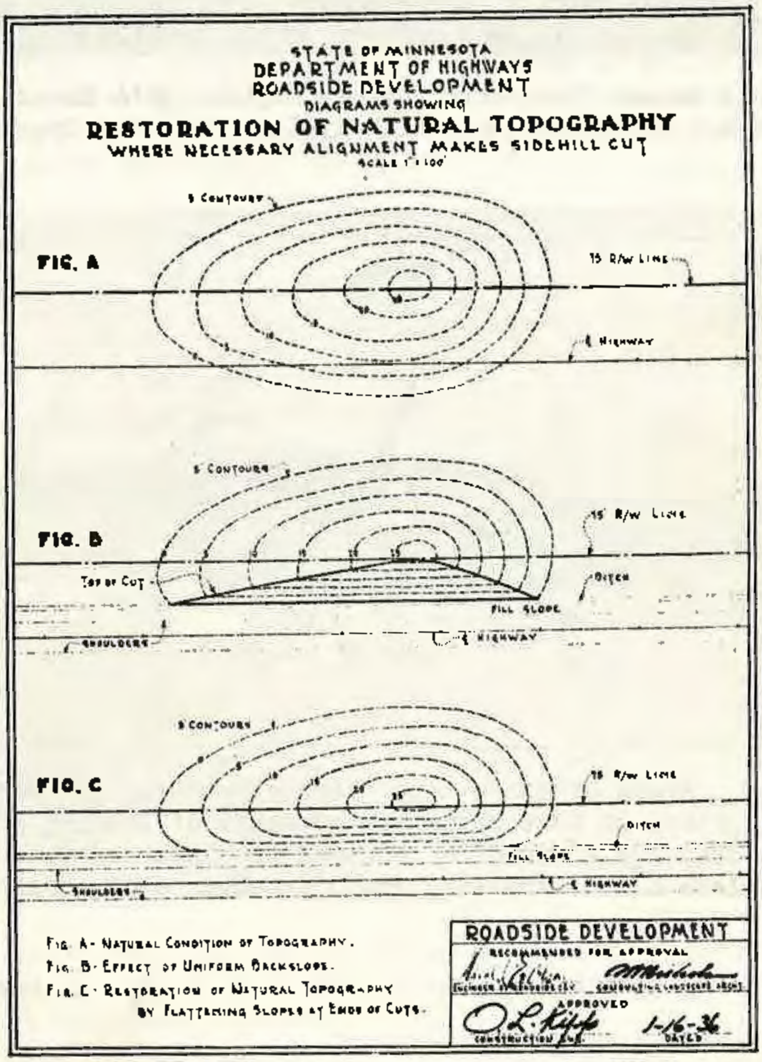


Figure 11. Basic Principles of Proper Rounded and Warped Slope Grading are Illustrated Here.

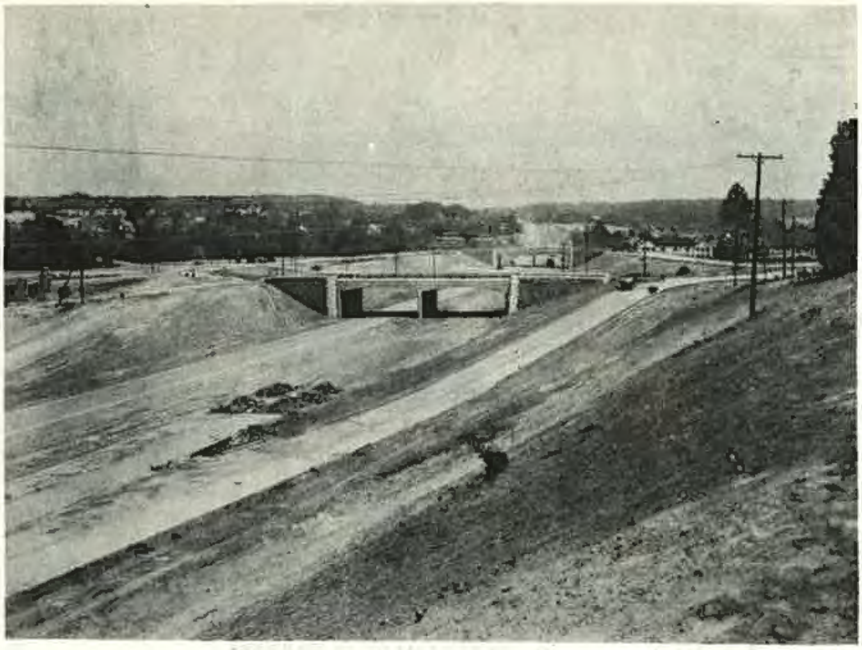


Figure 12. A Modern Controlled Access Highway With Rounded and Warped Slope Grading Which Fits the Highway Into Existing Ground Surfaces.

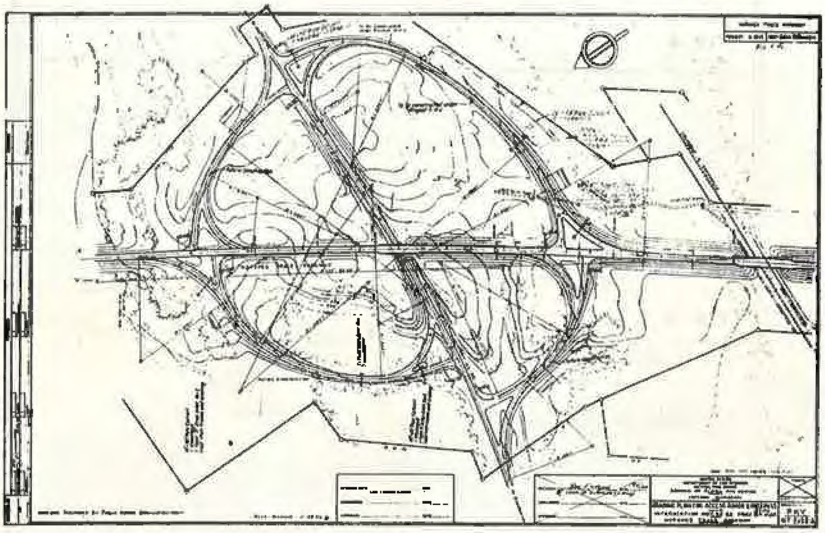


Figure 13. Areas of grade separation structures and major bridges can be graded to best advantage by means of grading plans. Difficult drainage and erosion control problems can be solved on these plans in the drafting room, in advance of construction.

The second interesting cross section is on a parkway passing through low hills with natural slopes of about an average 2:1 ratio. Here cuts sometimes 15 to 20 ft. high were flattened to 4:1, or even 5:1 exposing what appeared to be an unnecessarily large area of bare soil which was later seeded and mulched. Well-rounded and warped 2:1 to 3:1 slopes would have "looked better" here, and fitted the lay of the land better, at lower cost for erosion control as well as for excavation. This is not to argue against flat slopes, but to emphasize the point that existing natural slopes near the road should largely control cut and fill slope ratios.

Conservation and Highway Design - Engineers during recent years have been at great pains to protect and conserve two general types of landscape features more than all others during highway location and construction. Man-made structures have a readily calculated value and are always treated with respect by the highway locator. The sentimental as well as money value of fine trees may be great and is also usually considered by highway designers. Other features have not been so fortunate in this respect because their money value is difficult to compute though it may far exceed the value of all other features combined.

More forms of recreation are dependent upon clean waters than any other natural resource. Recent travel over the southern New York parkways where all streams and shore lines are carefully preserved, leads me to believe that conservation of springs, streams and shore line areas should receive greater emphasis in future highway design. The recreation business is a main source of livelihood of the people in many areas of a number of States.

Figure 14. Water resources can be conserved during highway location and construction. Here is a lake covering unsightly mud flats. Note low dam in bridge culvert.

Figure 15. Before Selective Cutting. Existing landscape features can be emphasized during construction by a little judicious selective cutting.

Figure 16. Same View From a Highway After Selective Cutting.

Water resources can be readily conserved in the location of the road by keeping embankments at a reasonable distance from shore lines. Changes in stream channels should always be carefully considered particularly in hill topography. Such changes have frequently resulted in flood damage to highway structures and embankments, and to private property downstream especially when they were not preceded by careful study of stream watershed areas.

Water and other landscape features should be conserved during highway construction. It will be to the advantage of highway departments and public alike to protect shore line areas against blasting or construction equipment operation. It is also possible to use riprap and willow planting for future protection of shore lines and road embankments against stream erosion. Such work will prevent siltation and pollution of water.

Roadside Drainage in Highway Design - One of the most important elements in highway design is satisfactory drainage. To design for best drainage is to fit the alignment and profile and cross section to the lay of the land. Also watershed areas above the highway must be studied with the idea of finding out not only how much water will drain to the highway now, but how much will be draining five or ten years from now.

Figure 17. Aerial Photograph of a Grade Separation on a New Controlled Access Highway. A city is growing up in this area which before highway construction was covered by woodland. Increased surface run-off resulting from change in land use has resulted in heavy erosion damage to stream channels and highway gutters.

We have learned by experience that run-off reaching highway drainage structures is likely to increase in volume as woodland is cleared above the highway or plow land is replaced by pavements. Every time a major highway is constructed near a city these changes are fairly certain to occur. This means liberal design of channels, culverts and other highway drainage structures. It also means care in sodding, riprapping and paving of channels on our new "freeways."

The highway departments have made much progress in the design of drainage structures and well-rounded drainage channels. Have they made equal progress in locating highways, and designing profiles and cross sections so that natural drainage works for rather than against the engineer? The author's observation on a number of new highways would indicate the answer to be a definite no.

Figure 18. A Bridge Shown at Left in Figure 17. Note heavy erosion resulting from increased run-off on paved city streets draining into the stream watershed. Riprap, combined with willow bank protection will now be necessary to protect bridge embankments and keep the channel open. Such erosion control work can be done most economically when it is part of the original highway design and construction.

Figure 19. Another Stream Channel Paralleling the Same Highway. Stream banks as well as the stream bed will require protection against increasing volumes of surface water resulting in changes of land use on adjoining watershed lands.

Highway Slopes and Highway Design - The relation between road center line location which fits the lay of the land, good warped and rounded slope grading, and slope erosion control have already been mentioned. Types of erosion control needed vary with varying soils and climates. Costs of erosion control vary also with the skills of highway locators and with those of the landscape engineers who must take over the work when grading has been completed. Successful slope protection work in all regions has been observed however to be subject to certain general principles. Assuming a location which fits the lay of the land and a liberally flattened and rounded cross section, control of erosion will mainly require:

1. A slightly roughened slope surface which holds mulch and seed in place until seeds germinate. Hand raking or "sand papering" of earth slopes should no longer be permitted.

2. A cover of loose hay, straw, cut brush, leaf litter or other locally available crop waste material. Mulches have been placed, covered with an inch or so of whatever soil is available, and slopes and drainage channels then seeded. Or slopes have been seeded with one or two inches of mulch placed over the seed. The important thing to remember is that mulches should be applied at once following finished grading.

3. Seeding with grass, legume, grain, or other crop seeds of types which will germinate within the shortest possible time under existing seasonal conditions.

4. Addition to the slope surface of a sufficient amount of commercial fertilizer, high in nitrogen content, to quickly establish dense grass, legume, vine growth. Fertilizers are usually best when disced into the seedbed. On steep slopes they have been applied in water solution with spray equipment. Or fertilizers can be applied as a top dressing after seeded plants emerge.

5. Proper mowing or other weed control measures may also be essential after a ground cover has been established.

Highway Borders and Traffic Safety - The problems of highway border development appear to be almost unsolved as yet on some of our finest highways. The principle of "Control of Access" has been applied on certain parkways and freeways. But many highways to be constructed in the years ahead will have to be constructed and operated without benefit of the controlled access principle.

The history of some of our best divided highways has been recounted in engineering literature. At first as the repeated pattern runs, these highways carry large traffic volumes and are as safe apparently as the designer could make them. Then gas stations, billboards, private driveways, and other types of border development appear. Finally these highways lose much of their traffic capacity and become both excessively dangerous and inconvenient, as well as unsightly. So-called roadside development on narrow right-of-way without border control is thus disclosed to be "a losing game." This is the story told on hundreds of miles of fine highways since 1932.

There appear to be two approaches to the problem of protecting the roadside borders and the safety and convenience of the traveled way.

Figure 20. An Easy Well-rounded Slope Being Mulched Immediately Following Construction of a New Highway. A light covering with soil over the mulch will be followed by seeding.

Figure 21. Results of Good Rounded Slope Grading and Mulching and Seeding Immediately Following Construction. Within one year this highway has been completely protected against erosion.

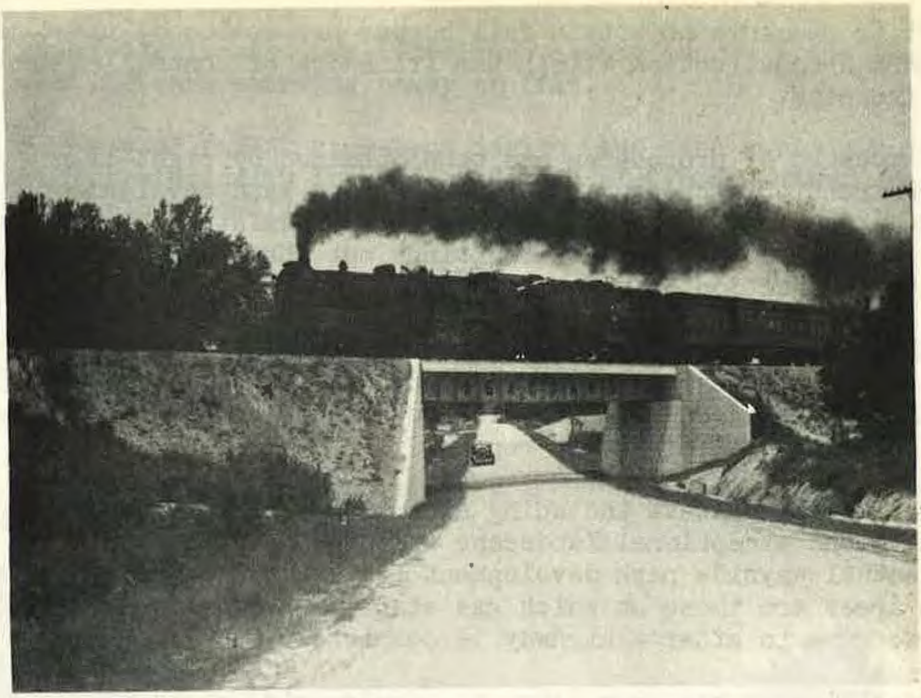


Figure 22. Highway bridges and grade separations can be designed with embankments that fit into "the lay of existing land surfaces." This early highway structure ignored such considerations and cannot therefore be readily protected against erosion damage.

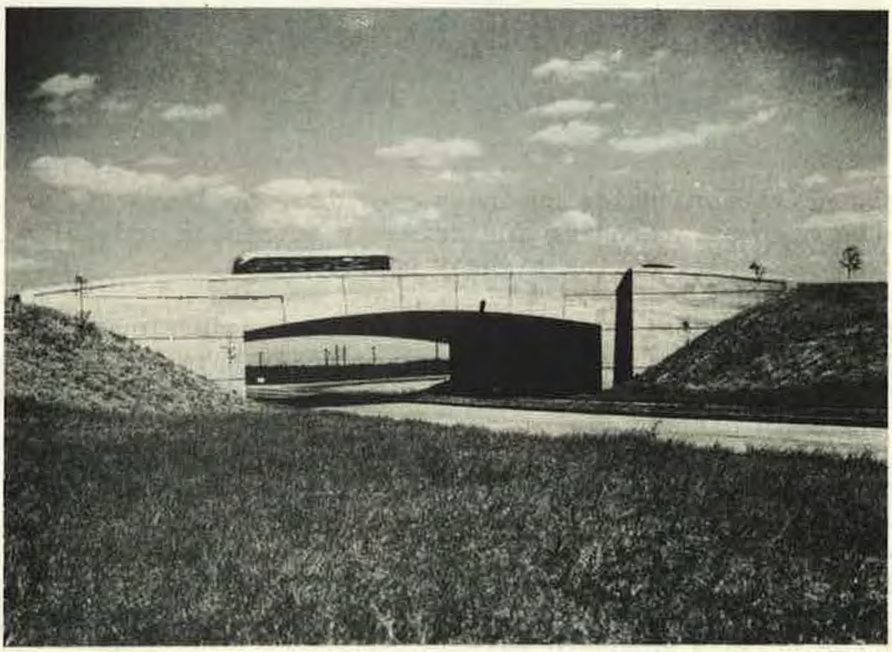


Figure 23. Adequate embankment protection begins with the design of structures like this. Fine appearance is mainly a product of good basic design rather than of the incidental "roadside improvement" which followed construction.

1. It is possible to obtain full border protection by right-of-way taking, highway design and construction within the framework of controlled access as on our parkways and freeways.

2. A measure of protection has been obtained by right-of-way acquisition, design and construction with probable future border land development in mind on highways without controlled access. Observation of existing highways carrying heavy traffic without controlled access brings out these examples of methods of providing border protection on major highways.

a. Right-of-way acquired has on some highways included "a strip of land of sufficient width to prevent erection of any private structure--within a distance of not less than one hundred feet from the outer edge of the road surface." (See page 154 of "Interregional Highways" report.)

b. Well-drained areas including exceptional shore lines, fine groves of trees and equivalent exceptional landscape features have been selected and acquired for eventual wayside park development for use by the traveling public. Many of these areas are those on which gas stations, roadside dance halls and whatnot tend to come in after a highway is completed.

c. Special care has been taken to acquire wide right-of-way at intersections to keep private development "back from the road" so that sight distances will not be interfered with even though gas station or equivalent business development should follow highway construction.

d. In the design of some new highways care has been taken to:

Provide well-designed driveway entrances to existing and proposed private land developments at points where such entrances will not introduce traffic hazards;

Leave a screen of growing trees or shrubs on a liberal width of right-of-way on the outside of curves or provide groups of planted trees to guide traffic around curves;

Encourage private roadside business operators to leave "islands" between structures and the highway. Grading for driveway entrances and islands should be done, as far as possible, during highway construction.

Where a connected series of business or housing development is contemplated by private operators, frontage or service roads have been provided off, but parallel to the highway, with entrance to and exit from such developments at safe points on the main highway.

e. Border control has proved effective and is sometimes preferable to marginal land acquisition alone. It consists of making appropriate legal arrangement for restricting or controlling the use of border lands. The legal arrangement may include zoning, acquisition or special easements, agreements with adjacent property owners, etc., all designed to preserve a maximum of private rights and utilization for private economic gain.

Safety Turn-out and Wayside Areas - A word at this point may be said regarding the need for carefully located, well-designed safety turn-out and roadside parking space on primary highways carrying heavy traffic.

Certain highways of recent high-type design have been seriously affected in operation by lack of strategically located surfaced safety turn-outs. These are observed to be particularly needed at:

1. Points where bus stops are required.

2. Points where mail, milk and other supplies are regularly loaded or unloaded.

Figure 24. The parkways of the 1925-35 decade considered the need for rest areas at scenic points during highway design and right-of-way acquisition.

Wayside parking space for numbers of vehicles are necessary on major highways as observations will readily demonstrate:

1. At scenic points, or near recreational facilities such as streams or lakes, athletic fields and the like where the public tends to stop whether such surfaced parking space is provided or not.

2. At points just outside intensively built up urban areas where heavy trucks and trailers carrying food supplies and other materials tend to stop during early morning hours before proceeding to ware-houses, docks or railroad sidings within the city.

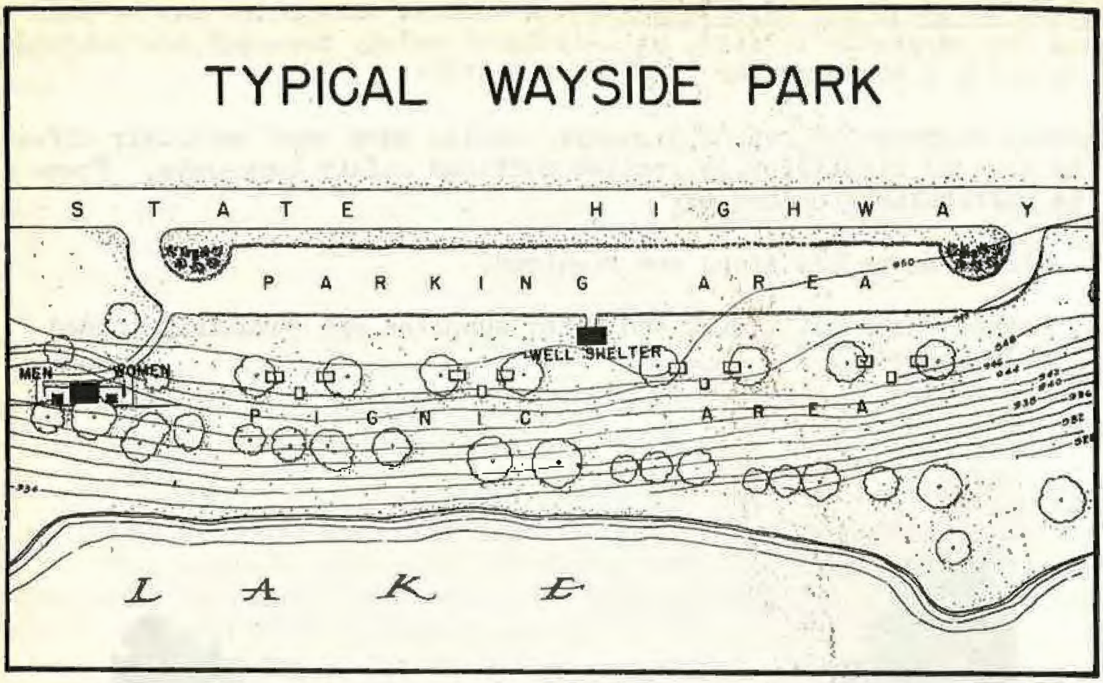


Figure 25. A number of State highway departments now provide rest areas at appropriate intervals on most heavily traveled primary roads.

Figure 26. Plan of a Typical Wayside at a Well Selected Area.

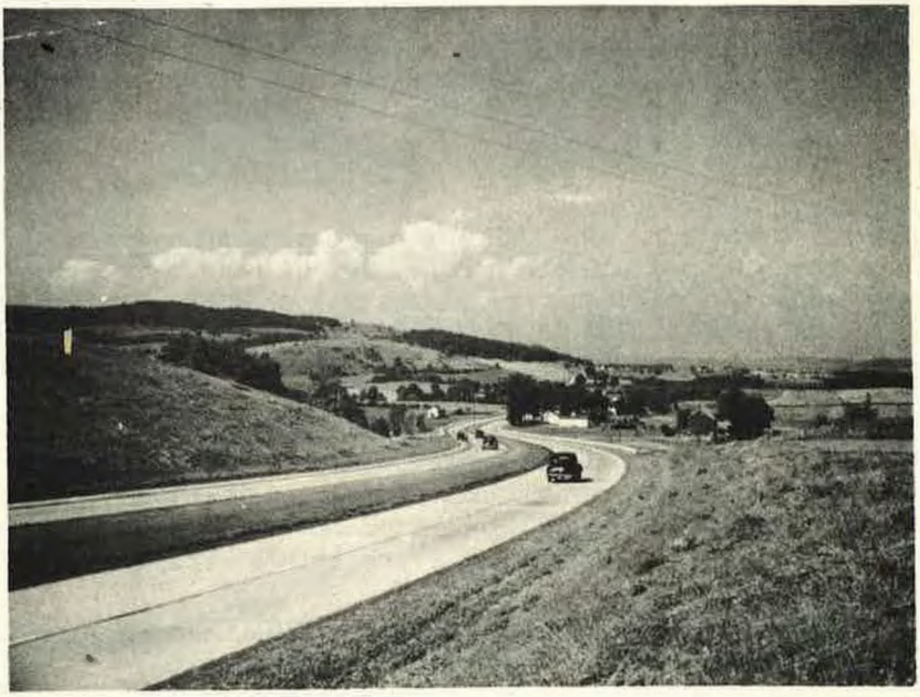
Looking Ahead - The problem of designing what we call a modern highway is probably less than half a century old.

During this time a number of new professions concerned with the design of structures and of land areas "for human use and enjoyment" have been growing up together. Today we find our great universities training men in the closely related fields of civil engineering architecture and landscape architecture. Where trained and experienced men of the three professions have worked together in highway design, construction and maintenance, the results speak for themselves.

This, then, is the lesson written into highway pavements, drainageways, slopes and highway borders down through the years. The way to complete highway development lies in friendly cooperation between highway officials and the public, and between specialists in the several professional fields involved in highway design, construction, maintenance, and traffic operation.

Figure 27. A Section of Controlled Access Highway Where the Essential Requirements of Erosion Control and Tree Planting Were Not Considered in Highway Location, Cross Section Design and Right-of-Way Acquisition Stages. Average costs of erosion control on less than 200 feet of right-of-way were very high per mile of highway on these steep slopes.

Figure 28. A Section of Controlled Access Highway Where the Essential Requirements of Erosion Control and Tree Planting Were Carefully Considered in Design and Location Stages. Cost of initial roadside development here on an average 300 feet or more of right-of-way about one-third cost of equivalent erosion control work in preceding photograph, per mile of highway.



Figures 29 & 30. These are Complete Highways, Safe and Convenient. Beautiful and low in annual maintenance cost because landscape architect and engineer worked together in design, location, construction and maintenance.