HIGHWAY RESEARCH BOARD
DIVISION OF ENGINEERING AND INDUSTRIAL RESEARCH
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Wartime Road Problems

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No. 2

DESIGN OF HIGHWAY GUARDS

HIGHWAY RESEARCH BOARD
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HIGHWAY RESEARCH BOARD

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Wartime Road Problems

There are two major wartime road responsibilities; to keep the traffic essential to the war effort moving, and to carry the existing roads through the war period in as good condition as possible. Discharge of these responsibilities entails consideration of many new factors in view of the limitations on time, money, labor, equipment and use of critical materials imposed by the exigencies of the national situation. Obviously, changing emphasis from devising better and more economical methods to a program, within the wartime limitations, of wartime traffic movement and conservation of the existing roads confronts highway engineers with many new problems and new aspects of old problems.

The Highway Research Board believes that it can be helpful by aiding in disseminating in usable form the best available information on those phases of highway technology in which common practice has not become established or in which practice must be modified during the war. To this end a series of bulletins on WARTIME ROAD PROBLEMS will be prepared by qualified committees and published by the Highway Research Board. Recommendations in this series of bulletins are based upon wartime restrictions and needs and are only intended for use as guides during the periods in which these conditions prevail.

This program has been endorsed by the Executive Committee of the American Association of State Highway Officials.

Suggestions for suitable subjects will be welcomed.

DESIGN OF HIGHWAY GUARDS

Under Wartime Limitations on Critical Materials

With a view to the conservation of critical materials, at the same time realizing the necessity for the preservation of highway safety, the Committee on Highway Guard of the Highway Research Board offers suggestions on the use of non-critical materials in highway guard construction. It is hoped that they will aid in bridging the gap, in this important phase of highway safety, during the war period. Recommendations are made for practice only during the prevalence of wartime restrictions.

In this report the Oregon, earth mound, boulder, masonry, and timber guards and a combination timber and boulder guard are described.

With speed reduction to 40 mi. per hr. the problem principally resolves itself into the protection of the motorist during the winter months when snow and ice conditions exist, and provision of day and night warning of dangerous conditions.

The principal question is: May highway guard be omitted? In other words, can we widen the shoulders and flatten the slopes in a manner that will make the erection of highway guard unnecessary. This problem is discussed in the section on Highway Guard of "A Policy of Highway Types (Geometric)" by the Special Committee on Administrative Design Policies of the American Association of State Highway Officials as follows:

"The use of guardrail (highway guard) is advised at points of extreme danger. Generally such points are considered to be fills over 6 ft. in height at locations where topographic or other conditions, such as sharp change in alinement, force a material reduction in speed. It may be omitted where it is practicable to provide slopes of 1 on 4 or flatter because a driver forced onto such a slope has a chance of regaining control of the vehicle. It often may be economically advisable to flatten embankment slopes to 1 on 4 instead of constructng guardrail (highway guard), provided right-of-way is available. If the cost of guardrail (highway guard) per linear foot is three times the cost of excavation per cubic yard, flattening slopes of 1 on 1½ to 1 on 4 is more economical than guardrail (highway guard) where the depth of fill is 8 ft. or less. Saving in maintenance cost increases the depth at which it is economic to flatten slopes rather than use guardrail (highway guard).

"Locations frequently are encountered where many drivers are confused regarding the direction of the road, particularly at night. Guide posts generally are used at such places. Where driving off the road is not highly hazardous guide posts may be light so that little damage will be done if they are struck. At the more hazardous locations guide posts should be heavy to resist impact and act in the nature of a barrier, or a guardrail (highway guard) should be constructed. In general, horizontal curves are outlined sufficiently by guide posts on the outside of curve only. They should be continued for some distance on the tangents at the ends of the curve Guide posts should be set near the shoulder line and should be made as visible as possible. The addition of reflector buttons may be desirable for better night visibility. Sometimes it is difficult to determine from the plans where guide posts are required. It may be more economical and satisfactory in some cases to defer the installation of guide posts until the road is completed and in operation."

If it is impossible in this emergency to design the road along these lines or to use the 2-, 3- and 4-cable, steel plate, woven wire mesh, steel beam, wood beam guards etc., the solution may be to place wood posts of the type normally used in these structures in the exact location where a structure

of this type would normally be placed, the posts to be centered in such a manner that they would be ready to take the type of guard normally used by the organization when the several types of guard again become available (Figure 1). In more hazardous locations it might be desirable to augment these post installations by placing additional posts in the line. In other words, if the posts are normally set on 16 ft. centers it might be desirable to set an additional post midway between or on 8 ft. centers. With this type of protection it would be advisable to place caution signs at intervals or use restricted speed zoning.

FIGURE 1.—Posts as warning—can later take the type desired

RECOMMENDED DESIGNS

OREGON TYPE, SPRING-STEEL BRACKET TIMBER GUARD[1]

If it is possible to obtain a nominal quantity of critical material, the Oregon design, with which Oregon has had very good success may fit into the picture.

This design utilizes 10 by 10-in. posts and a double-ply 6 by 10-in. horizontal timber rail. A metal bracket is interposed between the posts and the rail in order to give resiliency. The details are shown in Figure 2. The bracket is spring steel 5 in. wide and $\frac{7}{16}$ in. thick. It has a die-formed bend of such shape that the outer face is $5\frac{1}{2}$ in. from the face of the post.

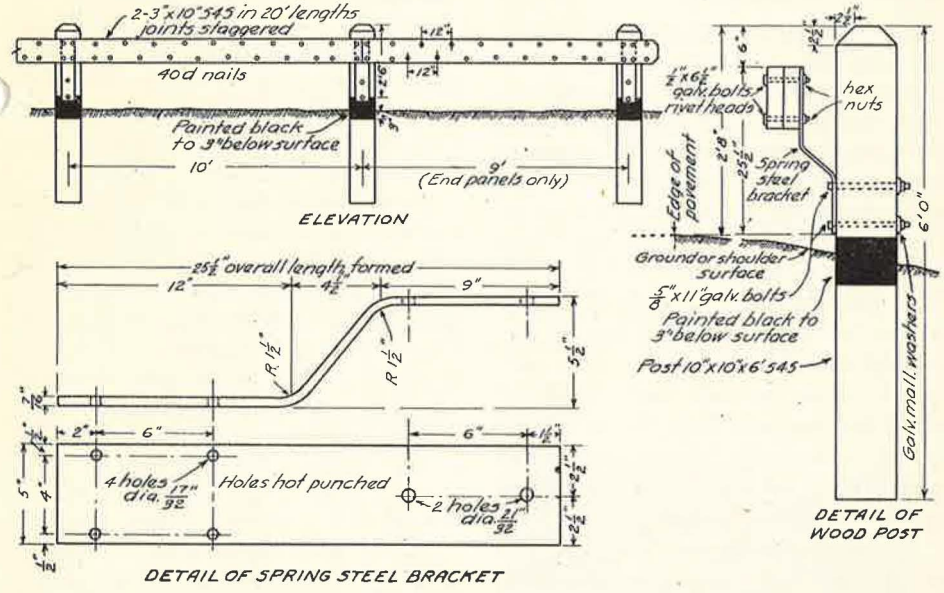

FIGURE 2.—Oregon Spring Steel Bracket Guard

[1] For a description of tests made on this guard see "Spring-Steel Brackets for Timber Guardrail" by J. N. Bishop and I. A. DeFrance, *Engineering News-Record*, April 24, 1941.

The specifications for the springs are as follows:

"They shall be heated in a gas-fired, automatic, temperature-controlled furnace equipped with automatic proportioning inspirators and tunnel-type burners. After carefully heating at 1,475 deg. F. to 1,500 deg. F., they shall be quenched in circulating, tempering oil of 100 viscosity at 100 deg. F. with cooling devices whereby the temperature of the oil remains constantly at 95 deg. F. to 105 deg. F. After the quench, they shall be drawn two hours in a gas-fired, convection-type, heated-conveyor, draw-furnace equipped with automatic temperature controls at 900 deg. F. or until a Brinell hardness of 341 to 388 is obtained. The brackets after the draw shall have a tensile strength of 160,000 lb. minimum. The brackets shall be die-formed and holes punched hot."

HIGHWAY GUARDS WITHOUT STEEL[2]

Earth Mound Guards

Barriers made of continuous mounds of earth have been used as highway guards with some success notably in West Virginia. They are constructed by dumping earth along the shoulder of the road and permitting it to take a natural slope of 1 on $1\frac{1}{2}$ or steeper. The height cannot be much more than 2 ft. unless the shoulders are widened. Visibility may be enhanced by spraying or brushing the road side of the mound with white stripes. This cannot be done on soft earth; however shale or other relatively hard material is best adapted for mound guards and paint stripes of a sort may be applied to this kind of material.

Earth mound guards cost about 5 to 10 cents per linear foot depending upon the availability of the material. They form effective barriers in that a vehicle is slowed up as soon as the outer wheels attempt to climb the guard and contact the soft earth. The vehicle is tilted toward the roadway at the same time. If a vehicle attempts to climb the guard at an angle it is suddenly tilted as if on a very steep grade giving the operator an opportunity to reduce the speed of the vehicle and get it under control. A vehicle which succeeds in climbing the guard is likely to straddle the top of the barrier and be held by it.

Earth mounds generally take the place of the shoulders and thus narrow the visible traveled way. While the mound itself may encourage a sense of safety the lack of a shoulder will cause most drivers to edge over towards the center of the road and thus increase the danger of collisions. To widen the fills to accommodate the earth mounds outside the limits of the shoulders would, in most cases, increase the cost beyond reasonable limits. Earth mound guards outside the shoulder limits, however, would fit some locations where fills are not deep and it is desirable to construct an inexpensive guard.

Earth mound guards do not present a pleasing appearance, do not fit in with the landscape and obstruct the view. They are likely to induce snowdrifts and to hinder removal of snow. The maintenance required to keep the slopes neat may be reduced or eliminated by covering the mounds with topsoil and growing some kind of ground cover. This would also add to the ability of the mounds to stop a vehicle but it would do away with the visibility of the earthy material against a foliage background and prevent the painting of stripes. The slopes may also be surfaced with a thin inexpensive road surfacing. It would reduce maintenance, facilitate the painting of stripes, and result in a neater appearance, but costs would be greater.

[2] Based on "A Preliminary Analysis and Discussion of Highway Guard Rails"—Division of Design—Bureau of Public Roads—1936.

In this type of guard weep holes or scuppers must be provided at periodic intervals, special attention being given to low points in grade. This type of protection is illustrated in Figure 3.

FIGURE 3.—Earth Mound Guard

Boulder Guard

Guards made of boulders are usually used along roads in mountainous country, especially where heavy rock cutting makes a supply of large stones available.

This guard is not resilient and any vehicle hitting the boulders at appreciable speed will probably be wrecked and the occupants injured. The angularity of stone blasted from the excavation and used for this purpose adds to the likelihood of injury; but this may be alleviated somewhat by hammer dressing the sharper corners and angles. These guards, however, are usually placed where a car leaving the roadway is likely to be wrecked and the occupants seriously injured anyway and where the prevention of any vehicle leaving the roadway is of prime importance.

Boulder guards have the advantages of fitting in with the topography, imparting a sense of safety, and costing little where the boulders are handy. Boulders should be heavy enough to form an effective barrier for all vehicles using the highway. Their size need not be restricted to the weight which can be lifted by two or three men since the use of tractor cranes on this type of construction is almost nationwide. The height above ground should be about 18 in. For pleasing proportions the width should be not less than the height and the length should be about two times the height. The spaces between boulders may be made about half the lengths of the adjoining stones. These dimensions are subject to considerable variation depending upon the available supply. The boulders should be placed on firm ground and the depth of burial should depend on the weights of the individual boulders. Large boulders need not be buried more than 3 or 4 in., whereas small boulders should be buried 1 to 2 ft. Some semblance of uniformity should be attained. Where the irregularities of a boulder result in a top slope the boulder should be set with the top sloping down away from the road. Soil pockets between boulders and planting of vines would improve the natural appearance of the guard.

Light boulders on end or on edge, even when deeply buried, do not make effective barriers. They are little better than isolated posts which upon heavy impact are bent over or knocked out of the ground permitting the vehicle to leave the roadway.

FIGURE 4.—Boulder Guard

A boulder guard of pleasing proportions is pictured in Figure 4. Details are given on Figure 5.

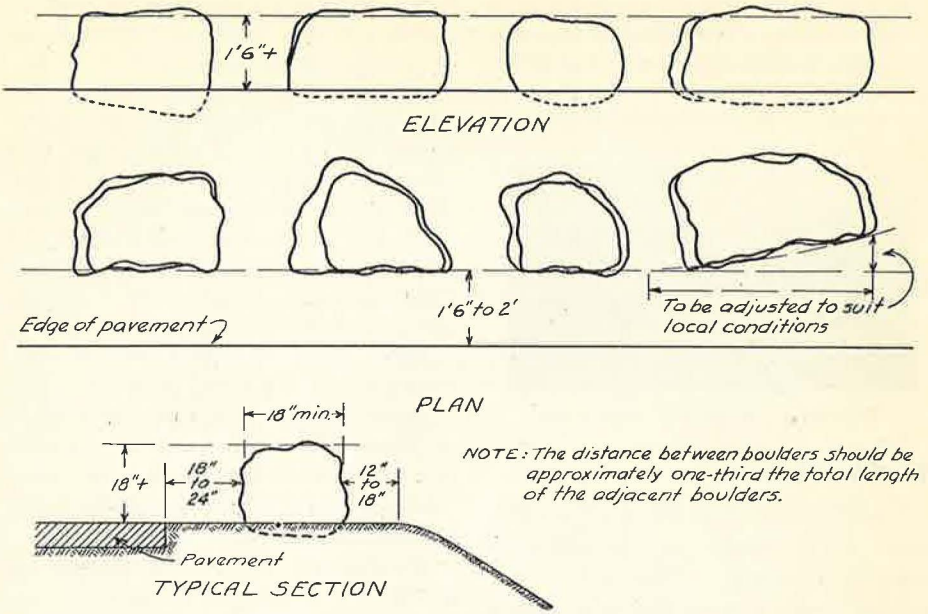

FIGURE 5.—Details of Boulder Guard

Stone Masonry Guards

Stone masonry guards are usually built where rock excavation makes a good supply of stone available. Like boulder guards they are not resilient and when hit at high speed will cause considerable damage to a vehicle and possible injury to its occupants. They are expensive even where the stone is at hand as the labor required to hammer dress and lay the stones usually costs more than the total of many other types of guards. Stone masonry guards, when properly constructed, however, present a pleasing appearance and usually fit in with almost any type of topography, particularly wooded and hilly country. They form effective barriers, and give a feeling of safety.

Stone masonry guards should be not less than 18 in. and generally not more than 24 in. high and about 18 in. wide. For higher guards the width may be decreased a little. Figures 6 and 7 show details of guards of this type. A rail of any one of the dimensions shown, properly bonded and resting on a reasonably good foundation should stop nearly all vehicles from leaving the roadway unless hit at high speed at nearly right angles.

Dry stone masonry walls should rest on compacted earth not less than 6 in. below the ground. Cement mortar stone masonry should rest on a simple concrete foundation of a width dependent upon the bearing power of the soil. Dry stone masonry in addition to saving the cost of a concrete foundation may be subjected to a slight settlement without serious injury whereas settlement under cement mortar stone masonry generally results in unsightly cracks. Dry stone masonry requires a little more care in the selection, hammer dressing, and placing of stones. If the available stone will not bond readily or cannot be fitted to approximately horizontal

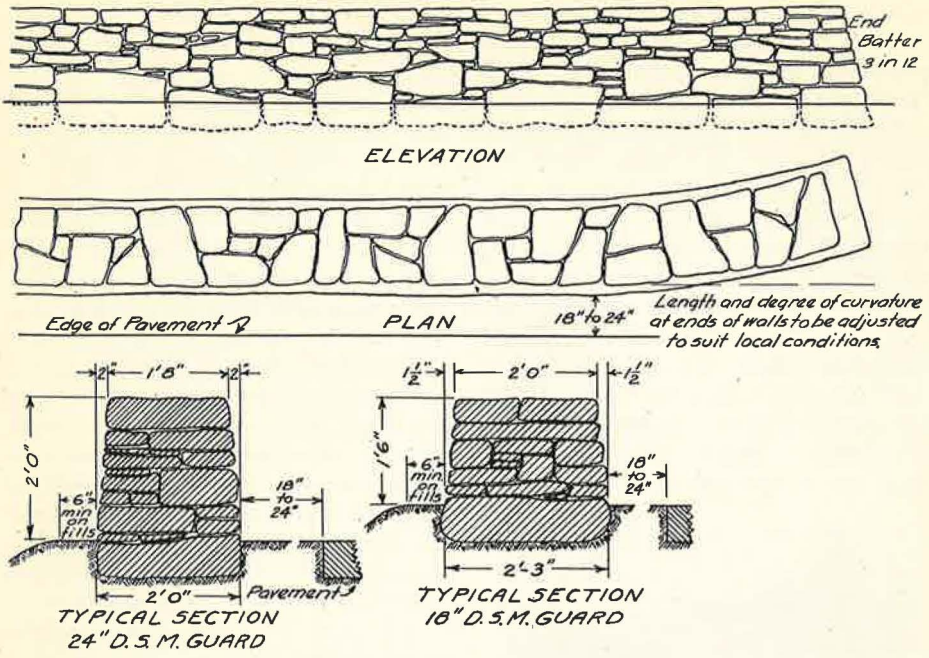

FIGURE 6.—Details of Dry Stone Masonry Guards

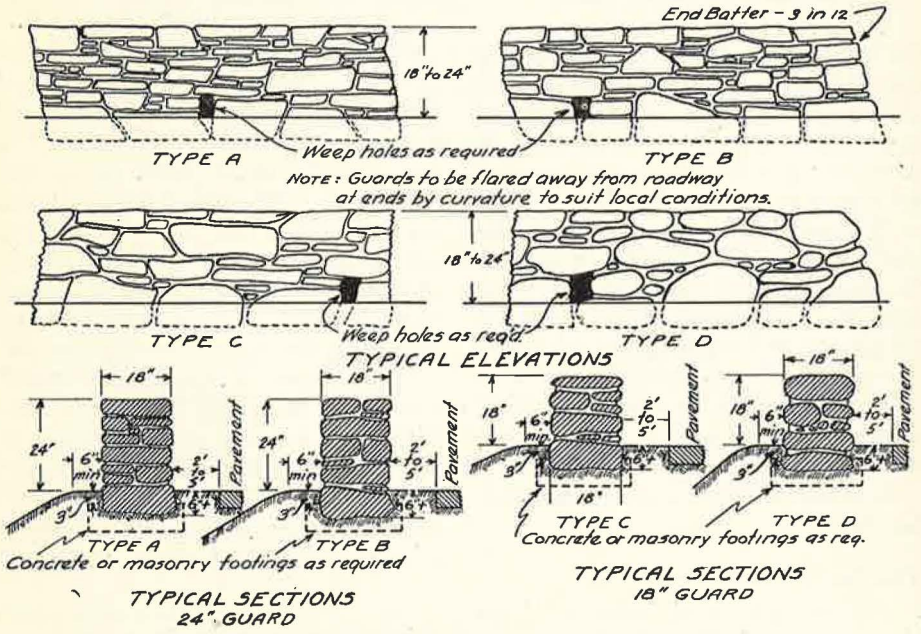

FIGURE 7.—Details of Cement Mortar Stone Masonry Guards

beds without considerable dressing, as in rounded boulder type stones, it is preferable to use cement mortar rather than dry stone masonry.

Stones should be of durable quality which will not deteriorate upon exposure. They should vary in size but for economy should not be heavier than 2 or 3 man stones unless lifting equipment is readily available. The larger stones should be placed at the bottom and the exposed faces should have the larger dimension level.

Small stones and spalls should be evenly distributed throughout the wall. The stones should be well bonded with an occasional header running

FIGURE 8.—Masonry Guard

through the wall. All horizontal joints should be level and all joints should be broken. Continuity of joints in any direction should be avoided. For cement mortar masonry all stones should be laid in full beds of 1:2 portland cement mortar and the vertical joints flushed with mortar. No dressing other than hammer dressing of sharp irregularities and no raking out and repointing of joints are necessary unless a more formal type of wall is desired. Coping stones are unnecessary except for special walls of a formal type.

A masonry guard wall is illustrated by Figure 8.

Timber Guards

Timber was used effectively for highway guards in the days when road speeds were low. At higher speeds they must be made very heavy to withstand the impacts of vehicles. Both tests and accident records indicate that timber guard rails subjected to heavy impact are very likely to split, permitting a vehicle either to leave the roadway or bump the posts resulting in damage to the vehicle and possible injury to the occupants. Splintered rails have caused considerable damage and injury by piercing or penetrating vehicles. Timber guards are relatively inexpensive where local materials are available, are easily erected and repaired, are highly visible when painted, fit in with almost all kinds of topography, serve to outline the course of the road, and, except for painting, require little maintenance unless broken by vehicle contacts.

The rails of a low height timber guard should be about 4 by 12 in. of a non-brittle species of wood of suitable structural grade.[3] The bottom of the rail should be placed 12 or 13 in. above the ground. Rails may be attached to the posts with 3 or 4 spikes 8 in. long by drilling $\frac{1}{4}$-in. holes through the rails. They may also be attached by two $\frac{5}{8}$-in. bolts, in which case the bolts either should be countersunk or have shallow round heads as on carriage bolts. The face of the rail should be as far from the inside face of the post as possible. No dapping of rectangular posts is necessary but round posts may be dapped about an inch to form a bearing surface for the rail.

Other types of low timber guards than that described have been used with some success. In Georgia 4 by 10 in. pine timbers faced with steel plates $9\frac{1}{2}$ in. wide by 16 gauge have been used with timber posts 10 ft. on centers. The steel plate presents a

[3] The plank and joist class of structural grades is recommended by the National Lumber Manufacturers Association.

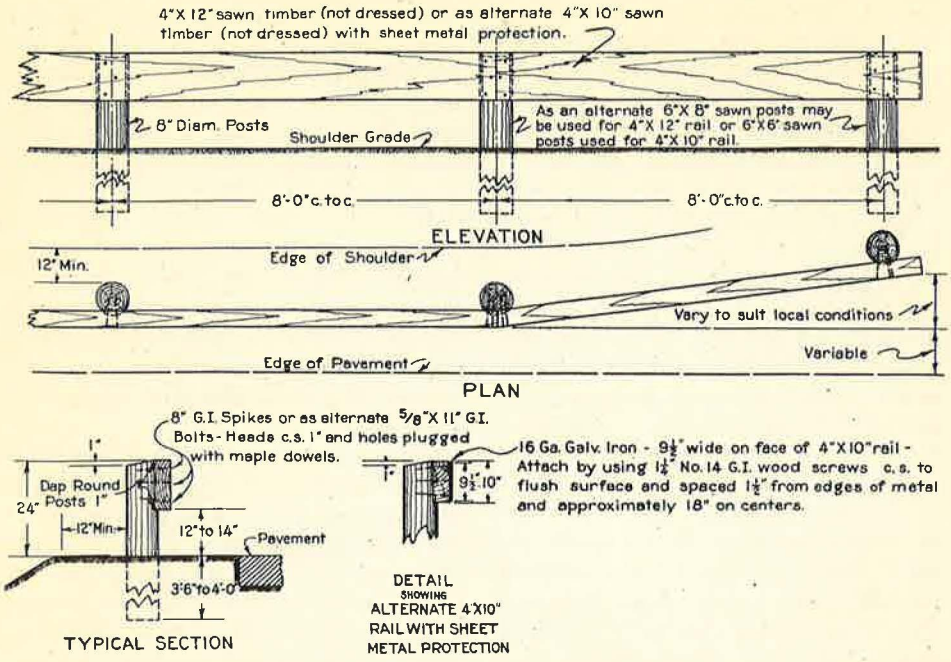

FIGURE 9.—Details of Low Type Single Rail Timber Guard

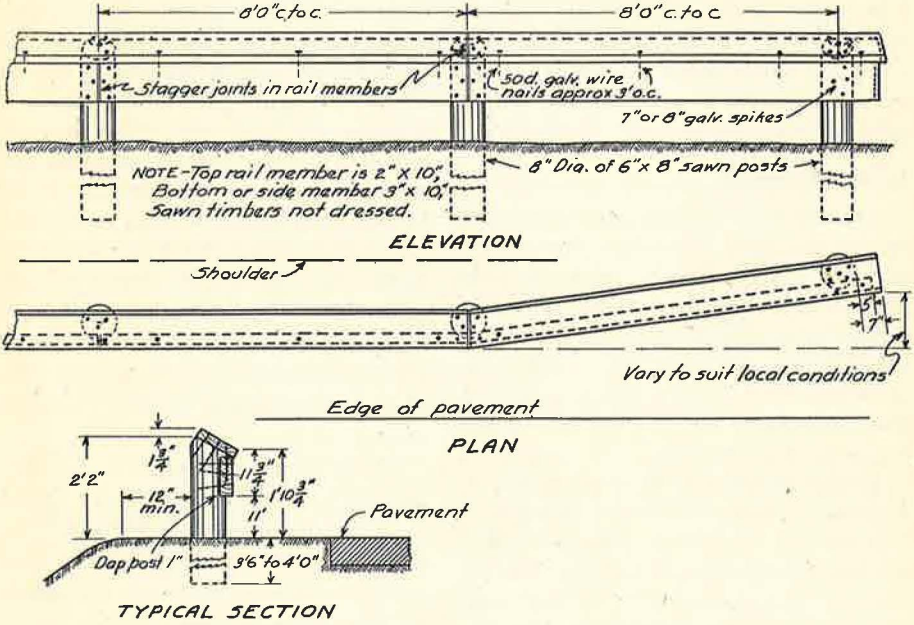

FIGURE 10.—Details of Low Type Double Rail Timber Guard

smooth face along which the vehicle may slide and, being attached with bolts closely spaced, acts to hold the timbers together if broken by contact. In South Carolina a standard design for a hub high guard consists of 6 by 6-in. posts on 8 ft. centers with a side rail 3-in. by 10-in. and a top inclined rail 2 by 10-in. spiked to the posts and to the side rail. This rail is highly visible and presents a rather pleasing appearance. The two rails acting more or less together result in much greater strength than a single rail containing the same volume of timber. All three types are shown in Figures 9 and 10.

The rails of timber guards are not so subject to decay as the posts and they must be painted to increase visibility, so treating them with preservatives is not advisable. The posts, unless they are all heartwood of a durable species, however should be treated with preservatives from a point 8 in. above the ground to the bottom of the post. Where pedestrians are likely to touch them the posts should be treated with a preservative which permits painting.

Rustic Guards

Logs as material for fences and rails have been used from the time of the earliest roads. Rustic guards look more natural and generally fit the adjoining countryside better than any other type. This is particularly true of wooded areas and has resulted in their extensive use in park and parkway construction.

Rustic guards of the type shown in Figure 11 make effective barriers if constructed of heavy logs but they are not effective in deflecting vehicles without damaging the vehicle and causing possible injury to the occupants. When the log rails are set so that they project toward the pavement a vehicle may glide along the rail without striking the posts. Painting rustic guards with white or aluminum paint would ruin their natural appearance so they are generally stained in some rustic color usually a reddish brown. This results in a guard of very low visibility especially at night when high visibility is essential. Due to the great amount of labor required to trim the logs, remove the bark, fabricate, and erect the rail, they are costly even when standing timber of proper size and species is available.

Since rustic guard rails are generally chosen because of their pleasing appearance all other factors have to be subordinated to this end. For no other guard is it as important to design to fit the scale of the landscape. Posts and top rails of 8-in. diameter look very substantial in rolling country but in mountainous country with vistas of many miles a rail of this type would look puny. Here logs of greater cross section resulting in a higher rail are necessary. Different types of rustic guards are shown in Figures 11 and 12. The low rail would give a sense of security only where the fills are comparatively low, say up to 6 ft. The high rail may be made as heavy looking as local conditions and available material make advisable. The designer should be given considerable leeway in proportioning the guard to the average scale of the country-side for any particular section of highway.

Black locust and eastern red cedar are very durable and require nothing more than a peeling of the inner bark and staining with one of the many weather resisting stains on the market to give long service. Other species will not withstand decay so well but a very durable guard may be con-

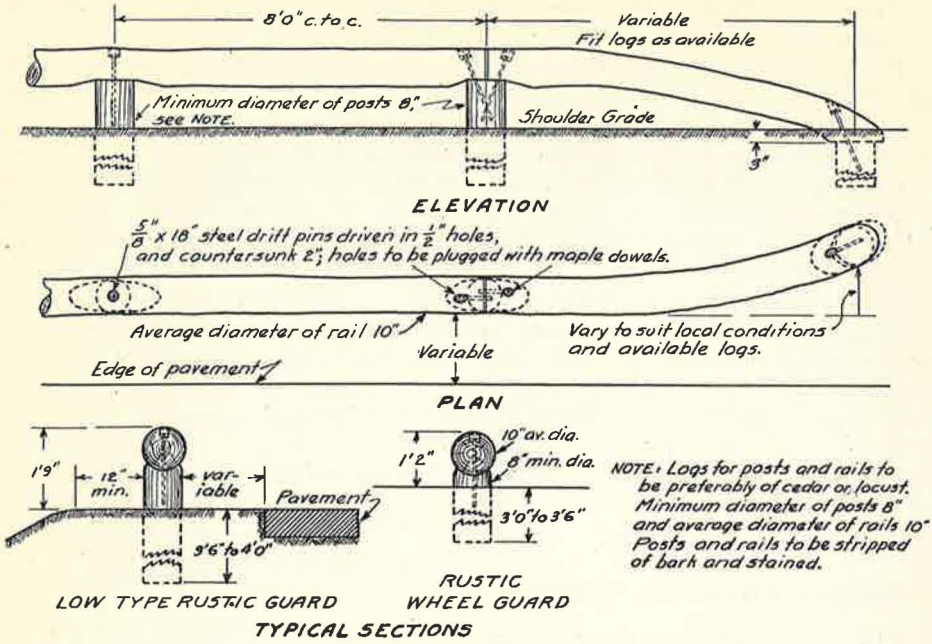

FIGURE 11.—Details of Low Type Rustic Guard and Rustic Wheel Guard

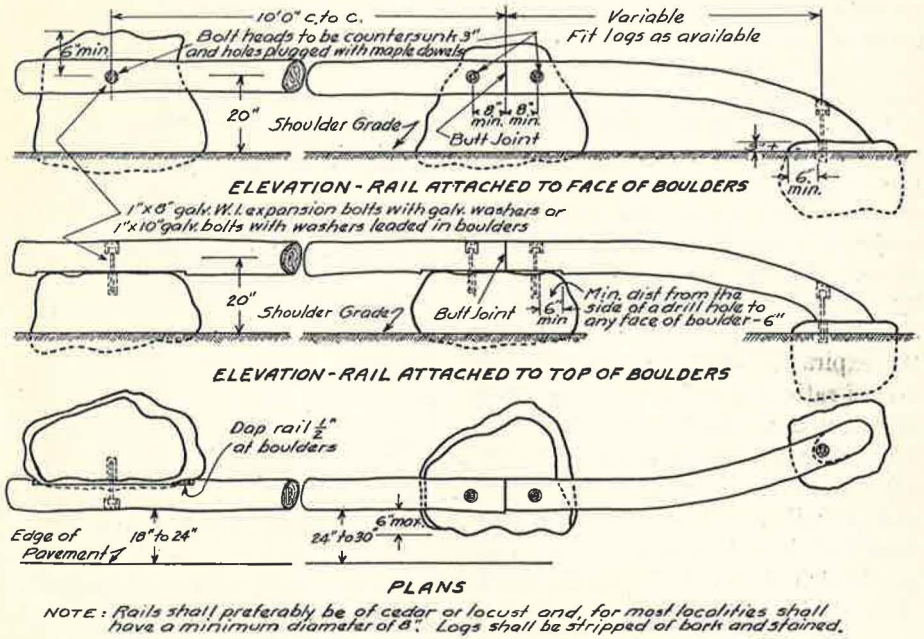

FIGURE 12.—Details of Boulder Supported Rustic Guards

structed by treating the posts with a preservative.[4]

In some locations where large stones are available from the excavation a combination guard made of logs and boulder supports as shown in Figure 12 makes a very pleasing rustic guard. The recommended design is the one where the rail is supported in front of the boulders.

Rustic guards more than any other type may be varied in appearance to fit a particular location and the ideas of the individual designer. Only a few typical designs are shown in Figures 11 and 12. When approaching urban areas, for instance, guards of a more formal type than those shown may be appropriate.

RESTRICTIONS ON TIMBER

The War Production Board under General Limitation Order No. L-121, recently froze for a period of 60 days (later extended through Aug. 27, 1942), all sales and deliveries by large producers of soft wood "construction" lumber, except to the Army, Navy and Maritime Commission. Pursuant to Order L-121 General Authorization PD-423 permits producers to deliver construction lumber required for completion of certain classes of road and street projects which have been certified as essential to the national defense by the Army, Navy or War Production Board. It is expected that after the expiration date a permanent system of rationing will be put into effect to direct most lumber into war uses. The present understanding is to the effect that the order does not include any sawmill which produced less than 5000 feet, board measure, per average day of eight hours of continuous operation, during the 90 days preceding the effective date (May 13, 1942) of the order.

This will limit the source of supply to the smaller producers and to standing timber. The small producers may not be able to supply the heavier sections in which case attention is called to the possibility of using laminated timber in a manner similar to the rail fabrication of the Oregon design. Standing timber, where available after trimming of the outer and inner bark can be used for posts, while logs obtained in this manner can be used to form the log rail similar to the rustic design. Order No. L-121 does not restrict the use of hardwoods.

DURABILITY OF TIMBER

As a guide in the selection of timber Table 1 will prove helpful.

TABLE 1

Life Expectancy of Posts

From Wood Handbook, Forest Products Laboratory, U. S. Department of Agriculture.

Type Wood	Life—Years	
	Untreated	Treated
Northern White Cedar with thin sapwood	12–15	20
Western Red Cedar with thin sapwood	12–15	20
Port Orford Cedar with thin sapwood	12–15	20
Redwood with thin sapwood	12–15	20
Cypress with thin sapwood	12–15	20
Chestnut with thin sapwood	12–15	20
Southern White Cedar	7.5	—
Douglas Fir	8	25
Tamarack	8	—
Southern Pine	1–2	25
Black Locust	20	*
Eastern Red Cedar	20	*
Lodgepole Pine	—	20

* Unnecessary.

The data in Table 1 are a rough estimate obtained from the source noted and apply to round posts which contain both sapwood and heartwood. As sapwood takes treatment better than heartwood no restriction on sapwood is needed on treated posts.

[4] For further detail see Table 1 or "Wood Handbook," Forest Products Laboratory, U. S. Department of Agriculture.

WARTIME ROAD PROBLEMS

No. 1. Curing Concrete Pavements Under Wartime Restrictions on Critical Materials.
No. 2. Design of Highway Guards.
No. 3. Design of Concrete Pavements Requiring a Minimum of Steel.

IN PREPARATION

Road Stabilization.

Compaction of Soil.

Maintenance Methods for Preventing and Correcting the Pumping Action of Concrete Pavement Slabs.