REPORT OF PROJECT COMMITTEE
ON
HIGHWAY TYPES AND ROADSIDE AREAS

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DESIGN OF LAND WIDTHS TO FIT MODEL HIGHWAY SECTIONS*

Introduction. - The nation is at war, and the easy going days of peace —— with unlimited tires and gasoline, and motor vehicle tax receipts —— are gone for the duration. Reduction in revenues due to rationing of tires and gasoline is resulting in a severe paring of highway budgets. In searching for ways and means to make the highway dollar go farther under these changed conditions, the highway engineer is now forced more than ever to adjust center line location and cross-section design to changes in topography for more effective use of both construction and maintenance funds, and to take full advantage of the close relation between improved cross-section design and lower maintenance costs. Engineering skill and technique in fitting roads to topography is therefore needed both in the weighing of future maintenance costs during initial design and construction, and in maintaining highways on a constantly shrinking budget.

The Maintenance Factor in Cross-Section Design. - Records of past years show that from 25 to 40 percent of State highway department

* The term "land widths" is here used in a broader sense than the commonly accepted meaning of the designation "right of way". The latter term refers generally to the width of land made available by fee-simple ownership or by land-easement for actual construction requirements. The broad term, "land widths", includes not only right of way but also additional widths reserved by grading easements, by roadside regulations, or by state and county legislation covering billboard regulations, building set-back lines, and highway zoning or control.

funds have been required for maintenance purposes.[1] These large percentages are partly due to steep slopes, narrow shoulders, and deep ditches, which lead to erosion and never-ending maintenance, as shown in Figure 1-A. Figure 1-B is a pictorial illustration of the same highway, with improved cross-section. Maintenance costs will be reduced to the extent that better roadside conditions are "built-in" during highway construction. With a well-flattened and rounded cross-section, machine methods will be more effectively used. Costly hand methods for mowing, snow removal, and cleaning of drainage systems will be either reduced or eliminated. By protecting the soil surfaces of slopes, gutters, and shoulders with vegetation, always costly and often impossible on steep slopes and in narrow deep ditches, the amount of work required by hand and machine will also be reduced.

As far as feasible the initial construction of highways should favor the growth of vegetation, prevent the accumulation of snow, provide the maximum degree of safety to high speed traffic, permit the dispersal of traffic in the event of aerial attack, and allow traffic to leave the highway in case of emergency. These better roadside conditions are the product of adequate cross-section design. The foundation for such design is right-of-way wide enough to meet the requirements of topography, soil, and traffic. (See Figure 2.) A deficiency in land width leading to defects in cross-section design may result in lack of protection of bare soil and of the highway investment. This deficiency can only result in decreased safety and operating efficiency, and in increased maintenance costs. Therefore, it is necessary that land widths be sufficient to provide for a well flattened and rounded cross-section.

For cross-section design to be adequate for these purposes, past reports of this committee have shown the need for variation in land widths to fit varying highway conditions.[2]

1. See page 13 of the 1940 Annual Report, issued May 1941, by the Committee on Roadside Development, Highway Research Board, summarizing data from annual reports of AASHO showing 41 percent of State highway budgets used for annual maintenance of systems.

2. Cf. - 1937 PROCEEDINGS, Highway Research Board, Vol. 17, p. 255 - The Design of the Highway Cross-Section.
1938 PROCEEDINGS, Highway Research Board, Vol. 18, p. 190 - Sectional Layout of Multiple Lane Highways.
1939 PROCEEDINGS, Highway Research Board, Vol. 19, p. 237 - Report of Subcommittee on Highway Types and Roadside Areas, outlining the influence of climatic and topographic factors on the design of highway sections.
1940 Report of Committee on Roadside Development at 20th Annual Meeting of Highway Research Board, issued May 1941, p. 6 — Design for Highway Right-of-way.

Classification of Highway Types. - This report groups rural types of highways into 8 classes of sections according to traffic density and the number of lanes required. Traffic, topography, soils, drainage, and adjacent land-use are the controlling considerations in fitting highways into the surroundings. It is hoped that the general classification of rural highway types shown in Table 1 may be an aid in simplifying and furthering the use of flexible sectional patterns in highway construction.

Highway Types. - Table 1 is a tabulation to show desirable land widths for each class of section according to traffic and topography. For convenience of reference, the vertical columns are numbered horizontally across the top of the tabulation.

Column 1. - The number of lanes depends upon the traffic density. Shoulders and other features of design are influenced greatly by the volume of traffic. (See AASHO - A Policy on Highway Types, p. 1, and conclusions, pp. 65-69.)

Column 2. - The daily number of vehicles is grouped in a series of traffic increments in geometric progression. The figures in circles at the left of column 1 indicate the number of times the average traffic density in each succeeding type is increased over the initial 300 traffic density group shown at the top of the tabulation. Note that each type is roughly double the preceding type. For example, the 2- or 3-lane highway type averaging 2400 vehicles is for convenience roughly considered as double the 2-lane highway type with an average of 1200 (600 to 1800) daily traffic density. Assuming a traffic volume of 4800 (3000 to 5000), or double the 2400 (1800 to 3000) average density, a 4-lane divided highway would be indicated.

Column 3. - The classes of sections are each subdivided into three types of topography: smooth, moderate, and rough, -- according to relative heights of average cuts and fills, and average volumes of earth excavation per mile of highway, as compared below:

Type of Topography (3 Classes)	Height of Slopes (Range in Feet)	Excavation per Mile (Average in Cu. Yds.)
1. Smooth	- 0 to 10	- 25,000 to 50,000
2. Moderate	- 10 to 30	- 50,000 to 100,000
3. Rough	- 30 to 60 (or over)	- 100,000 to 200,000

Figure 1-A. - THE OLD FIXED WIDTH OF STANDARD CROSS-SECTION WITH NARROW SHOULDERS, ROUGH, WEED-INFESTED DITCHES, AND STEEP, ANGULAR SLOPES, REQUIRING THE CONTINUAL CLEARING OF CLOGGED DRAINAGE BY HAND LABOR METHODS MAKES MAINTENANCE NOT ONLY COSTLY BUT DIFFICULT.

Figure 1-B. - THE SAME HIGHWAY WITH CROSS-SECTION IMPROVED TO PROVIDE WIDE SHOULDERS, BROAD SMOOTH GUTTER DRAINAGE, AND WELL-FLATTENED AND ROUNDED SLOPES. FLATTENING OF CUT SLOPES ON THE INSIDE OF CURVES IS AN EFFECTIVE MEANS OF INCREASING SIGHT-DISTANCE. THE HAZARD OF THE STEEP SLOPE AT THE LEFT IN FIG. 1-A HAS BEEN AUTOMATICALLY ELIMINATED IN THE NORMAL PROCESS OF IMPROVING THE CROSS-SECTION. THE LINE OF CRITICAL MAINTENANCE IS IN THE BOTTOM OF DRAINAGE CHANNELS, ESPECIALLY THOSE OF THE V-TYPE AND THOSE HAVING UNPROTECTED SOIL SURFACES. WASTEFUL WASHING OF THE NEWLY-GRADED GUTTER SECTIONS SHOWS THE NEED FOR PROTECTIVE GROUND COVER TO COMPLETE THE JOB OF IMPROVEMENT.

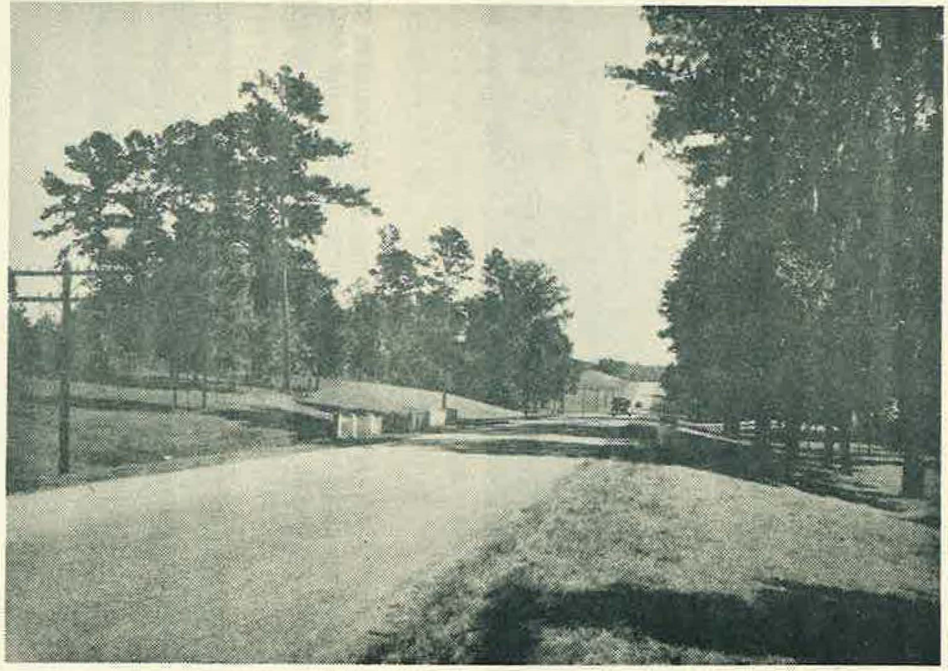

Figure 2.- A FINISHED ROAD SECTION WITH ROUNDED AND WARPED SLOPES AND GUTTERS PROTECTED BY GRASS. INCREASED TRAFFIC SAFETY, SIMPLIFIED MACHINE MAINTENANCE, AND A MOLDED HIGHWAY APPEARANCE ALL JUSTIFY THE ADOPTION AND MORE GENERAL USE OF THE FLEXIBLE DESIGN OF CROSS-SECTIONS VARIED TO FIT DIFFERENT TRAFFIC REQUIREMENTS AND CHANGES IN TOPOGRAPHY.

Table I

HIGHWAY TYPES

GENERAL CLASSIFICATION OF RURAL TYPES ACCORDING TO TRAFFIC AND TOPOGRAPHY INCLUDING "FLEXIBLE SECTIONAL" PATTERNS" FOR DESIGN OF LAND WIDTHS DESIRABLE

① CLASSES OF SECTIONS (See notes 1/ and 2/ below)	② DAILY TRAFFIC DENSITY (Mixed Traffic Except on Park Roads) (See note 2/ below)	③ TYPES OF TOPOGRAPHY (See note 3/ below)	④ COST PER MILE (Pre-War Cost) (See note 4/ below) Dollars	⑤ 7.5% FOR R.O.W. (Per Mile) (See note 5/ below) Dollars	⑥ ACRES PER MILE (See note 6/ below) Number	⑦ AVERAGE COST PER ACRE Dollars	⑧ LAND WIDTH (See note 6/ below) Min.–Desirable Feet	⑨ WIDTH OF 2 TRAFFIC LANES Desirable Feet	⑨ Min. Feet	⑩ SHOULDER WIDTHS In Cuts Min. Feet	⑪ SHOULDER WIDTHS On Fills (No Guard Rail) Desirable Flat Slopes Feet	⑪ On Fills (With Guard Rail) Steep Slopes Feet	⑫ GRADED ROADBED WIDTHS (See note 8/ below) Desirable Feet	⑫ Min. Feet	⑬ EARTH SLOPES (Cut or Fill) (See note 9/ below) Slope Ratio	⑬ Depth Feet	⑭ GUTTER SLOPE (Flatter Where Possible) (See note 10/ below) Slope Ratio	⑭ Width Feet	⑮ ROUNDED EARTH AND GUTTER SLOPES TOTAL WIDTH (Columns 13 + 14 + 5' to 10' Rounding) Flat — 4:1 Slopes – No Rounding; Moderate 2:1 Slopes – 5' Beyond Slope Stake; Steep 1½:1 Slopes 10' Beyond Slope Stake	⑯ REQUIRED SECTIONAL GRADED WIDTH BETWEEN SLOPE STAKES & ROUNDING LIMITS Feet	⑰ DESIRABLE TOTAL LAND WIDTH COLUMN 16 + BORDER SET-BACK & CONTROL STRIPS (See note 11/ below) Feet
① 2-LANE HIGHWAYS	0 TO 300	SMOOTH	20,000	1,500	(8-10)	150.	75-80	20	20	3-8	3-8	8	36	28	3:1	0-5	3:1	6	3:1 x 5' = 15+6'+0' = 21' x 2 = (42')	68-78	80+(2x35) = 150
		MODERATE	30,000	2,250	(12-15)	150.	100-120	20	18	2-8	2-8	8	36	24	2:1	5-10/15	3:1	5	2:1 x 15' = 30+5+5' = 40' x 2 = (80')	104-116	120+(2x40) = 200
		ROUGH	40,000	3,000	(15-18)	166.67	120-150	20	18	0-8	0-8	8	36	20	1½:1	15-30	3:1	4	1½:1 x 30' = 45+4+5' = 54' x 2 = (108')	128-144	150+(2x50) = 250
② 2-LANE HIGHWAYS	300 TO 600	SMOOTH	30,000	2,250	(12-15)	150	100-130	22	20	8	8	10	40	36	4:1	0-5/10	4:1	10	3:1 x 10' = 30+10+0' = 40' x 2 = (80')	116-120	130+(2x35) = 200
		MODERATE	40,000	3,000	(15-18)	166.67	130-150	22	20	8	8	10	40	36	2:1	10-20/30	4:1	8	2:1 x 20' = 40+8+5' = 53' x 2 = (106')	142-146	150+(2x50) = 250
		ROUGH	60,000	4,500	(18-24)	187.50	150-200	22	20	4-8	4-8	6-10	40	28	1½:1	30-60/75	4:1	6	1½:1 x 40' = 60+6+10' = 76' x 2 = (152')	180-192	200+(2x50) = 300
③ 2-LANE HIGHWAYS	600 TO 1800	SMOOTH	40,000	3,000	(15-18)	166.67	130-150	24	22	10	10-12		48	44	4:1	0-5/10	4:1	10	4:1 x 10' = 40+10+0' = 50' x 2 = (100')	144-148	150+(2x50) = 250
		MODERATE	60,000	4,500	(18-24)	187.50	150-200	24	22	10	10	12	48	44	2:1	10-20/30	4:1	8	2:1 x 30' = 60+8+5' = 73' x 2 = (146')	190-194	200+(2x50) = 300
		ROUGH	80,000	6,000	(24-36)	166.67	200-300	24	22	8	8	10	44	40	1½:1	30-60/75	4:1	6	1½:1 x 60' = 90+6+10' = 106' x 2 = (212')	252-256	300+(2x50) = 400
④ 2 OR 3 LANE* HIGHWAYS	1800 TO 3000	SMOOTH	40,000	3,000	(18)	166.67	150-180	24	22	12	12		48	46	4:1	0-5/10	4:1	10	4:1 x 10' = 40'+10+0' = 50' x 2 = (100')	148-146	150+(2x50) = 250
		MODERATE	60,000	4,500	(18-24)	187.50	180-250	24	22	10	10	12	48	44	2:1	10-20/30	4:1	8	2:1 x 30' = 60+8+5' = 73' x 2 = (146')	190-194	200+(2x50) = 300
		ROUGH	80,000	6,000	(24-48)	125.	200-400	24	22	8	8	10	44	40	1½:1	30-60/75	4:1	6	1½:1 x 60' = 90+6+10' = 106' x 2 = (212')	252-256	300+(2x50) = 400
										INCREASED FOR 3-LANES											
⑤ 4-LANE DIVIDED HIGHWAYS	3000 TO 5000	SMOOTH	100,000	7,500	(24-30)	250.	200-240	2-24	MEDIAN (43)	12	12		115*		4:1	0-5/10	4:1	10	4:1 x 10' = 40'+10+0' = 50' x 2 = (100')	215 ±	240+(2x30) = 300
		MODERATE	150,000	11,250	(30-36)	315.	240-300	2-24	(32)	10	10	12	104	100	2:1	10-20/30	4:1	8	2:1 x 30' = 60+8+5' = 73' x 2 = (146')	250 ±	300+(2x50) = 400
		ROUGH	200,000	15,000	(36-60)	250.	300-500	2-24	(25)	8	8	10	93	89	1½:1	30-60/75	4:1	6	1½:1 x 60' = 90+6+10' = 106' x 2 = (212')	305 ±	400+(2x50) = 500
⑥ 4-LANE DIVIDED HIGHWAYS	5000 TO 10000	SMOOTH	225,000	16,875	(24-30)	562.50	200-240	2-24	• (43)	12	12		115*		4:1	0-5/10	4:1	10	4:1 x 10' = 40'+10+0' = 50' x 2 = (100')	215 ±	240+(2x50) = 300
		MODERATE	250,000	18,750	(30-36)	520.	240-300	2-24	(32)	10	10	12	100*		2:1	10-20/30	4:1	8	2:1 x 30' = 60+8+5' = 73' x 2 = (146')	250 ±	300+(2x50) = 400
		ROUGH	300,000	22,500	(36-60)	375.	300-500	2-24	(25)	8-10	8	10-12	90*		1½:1	30-60/75	4:1	6	1½:1 x 60' = 90+6+10' = 106' x 2 = (212')	305 ±	400+(2x50) = 500
⑦ 4-LANE DIVIDED • HIGHWAYS	10,000 OR MORE	SMOOTH	300,000	22,500	(24-30)	750.	200-240	2-24	• (43)	12	12		115*		4:1	0-5/10	4:1	10	4:1 x 10' = 40'+10+0' = 50' x 2 = (100')	215 ±	240+(2x30) = 300
		MODERATE	400,000	30,000	(30-36)	833.33	240-300	2-24	(32)	10	10	12	100*		2:1	10-20/30	4:1	8	2:1 x 30' = 60+8+5' = 73' x 2 = (146')	250 ±	300+(2x50) = 400
		ROUGH	500,000	37,500	(36-60)	625.	300-500	2-24	(25)	8-10	8-10	12	90*		1½:1	30-60/75	4:1	6	1½:1 x 60' = 90+6+10' = 106' x 2 = (212')	305 ±	400+(2x50) = 500
			COST PER MILE MAY BE HIGHER FOR SPECIAL DESIGNS												(3:1	0-5/6	4:1				
															2:1	5-12					
2-LANE PARKWAYS	NO TRUCK TRAFFIC ON PARK ROADS	SMOOTH	35,000	R.O.W. IN PARK AREAS NOT A PROBLEM			200-400	22	20	2-3	3-5	5	32	26	1½:1	12-20	AND	3-5			AVERAGES 100 ACRES PER MILE = 500
		MODERATE	50,000				400-500	22	20	2-3	3-5	5	30	24	1½:1	20-30	6:1	3-5			750
		ROUGH	75,000				500-1000	22	20	2-3	3-5	5	28	24	1:1)	OVER 30		35			1000

1/ cf.-AASHO-A POLICY ON HIGHWAY CLASSIFICATION
"Three types of services are approved for the classification of highways: (See p.1)."

2/ (a) Traffic Density. (For definition. See AASHO-Policy on Highway Classn, p.6)
(b) Character of Traffic ◆
(c) Assumed Design Speed (For definition See AASHO on Highway classification(p.8); also in Types(p.6)
"Adequate design leads to the construction of a highway on which the traffic may move comfortably at reasonable speed without appreciable delay (p.3)."

◆ Highways used by passenger vehicles only and on which trucks or other commercial vehicles are prohibited and highways on which the character and percentage of trucks likely to use the highway will have little effect on the movement of passenger vehicles and on the essential details of design are designated by the letter "P". Highways used by all types of traffic - by the letter "M" denoting mixed traffic. (15% trucks assumed in mixed traffic in this tabulation. Most highways are in the "M" class.) Highways on which the percentage of traffic is abnormally high - by the letter "T" (p.7)."

3/ For explanation of three types of topography - See Summary on p.247 PROCEEDINGS 19th Annual Meeting Highway Research Board, December 1939. Also see POLICY ON HIGHWAY CLASSIFICATN.
"A principal (highway type) factor affecting the choice of a design speed is the character of the terrain (p.8)," and compare AASHO - POLICY ON SIGHT DISTANCE FOR HIGHWAYS, pp 6, 7, and 26, Topographic Conditions.

4/ PUBLIC ROADS JOURNAL - June 1941. (Vol. 22, No. 4) - p.82.
"Table-3 Interregional Highway Standards."

5/ PUBLIC ROADS JOURNAL - June 1941 (Vol. 22, No. 4 - p.85).
"R.O.W. costs for rural sections are estimated to be 7.5 percent of the construction costs"... also 1940

6/ Report of Committee on Roadside Development, Highway Research Board issued May 4, 1941, pp 6-17. Refer also to same 1940 Report - Charts on pp. 15, 16, and 17.

7/ AASHO - A Policy on Highway Types - Table on p.15 "Suggested Minimum widths of Surfacing for 2-Lane Highways," for various types, densities and speeds of traffic.

8/ See same AASHO reference, A Policy on Highway Types, (pp. 4, 5, 6, and 68) Graded Roadbed widths = traffic lanes + shoulders, as-
20' + 3' + 3' = 26'
20' + 8' + 8' = 36'

9/ PROCEEDINGS of the 17th Annual Meeting of Highway Research Board December, 1937, pp. 265-268, also - PROCEEDINGS of the 19th Annual Meeting of the Highway Research Board December, 1939, pp. 245-247.

10/ See PROCEEDINGS 17th Annual Meeting of Highway Research Board Dec. 1937, pp 261-265.

11/ See Fig. p.10 USDA Misc. Pubn. No.191 for Building Set-backs and Border Control.
Total - one-half section (cut or fill) each side of ℄ as $\frac{150}{2}$ = 75 or $\frac{200}{2}$ = 100

Columns 4, 5, 6 and 7. - Based on pre-war costs per mile, and assuming 7.5 percent of the estimated construction cost as a reasonable expenditure for right-of-way, an average comparative cost per acre is indicated in terms of a required number of acres of land per mile.

Column 8. - The minimum and desirable land widths listed in this column represent the approximate widths needed to equal the area of land expressed in acres per mile in column 6.

Column 9. - An increase in traffic density indicates more frequent passing of vehicles and the desirability for wider lanes. Note that 12-foot lanes are desirable for mixed traffic exceeding 600 vehicles per day.

The width of traffic lane should be greater for higher design speeds due to the greater hazards of driving and the necessity for more space in the traveled way. This also is true for the width of shoulder. The extra cost of wider lanes is offset to some extent by a reduction in cost of shoulder maintenance and a reduction in surface maintenance due to lessened wheel concentrations at the edges of pavements.

The figures inserted in parentheses in the box under the heading "MEDIAN" opposite the 4-lane divided highway classes of sections are minimum widths in feet at crossings in the separating strip when left turning movements are to be provided for.[5] Note that the width of separation at crossings may have to be decreased as the roughness in topography increases. Also, that greater widths than the indicated minimums are desirable. The median strip need not be of constant width and the two pavements need not be at the same level. Between crossings, the median strips should be as wide as possible; a minimum of 10 to 12 feet is recommended since plant growth is difficult to maintain on narrow strips. Paved strips encourage encroachment. It is desirable, therefore, to limit the width of paved median strips to about 6 feet if a 10 to 12-foot planted width cannot be provided.

5. Adapted from Figure 10 on p. 31 of AASHO - A Policy on Highway Types, showing median strip designs for left turns, assuming:
minimum design widths for truck type traffic - for smooth topography,
minimum design widths for mixed type traffic - for moderate topography,
minimum design widths for passenger type traffic - for rough topography.

Columns 10 and 11. - Shoulder widths increase with traffic density. On steep fills shoulders are two feet wider to provide space for necessary guard-rail construction. Shoulders should be of sufficient width to accommodate standing vehicles without obstruction or hindrance to moving traffic. On roads carrying a present average daily traffic of more than 1800 vehicles and on less heavily traveled roads wherever feasible, it is desirable that shoulders be continuous on both sides of the pavement and of sufficient width to permit parking. For this purpose a minimum width of 8 feet is essential. Such provision is desirable for the accommodation of normal civil traffic; it is necessary on roads that are likely to be used with some frequency by military convoy movements, to prevent excessive interference with moving traffic by halted convoys unable to clear the traffic lanes. Exception should be considered only in mountainous locations involving the heaviest grading. At no point should shoulders be less than 4 feet wide.

Column 12. - The roadbed represents the total width of surfacing and shoulders. Note that the differences in desirable and minimum roadbed widths for each type of topography are due mainly to the variation in widths of shoulders. Traffic surface width varies slightly as required by the safe design speed and density of traffic. The widths specified are substantially adequate for all normal civil traffic, including the usual percentages of wide and heavy vehicles, with range of speed from 15 to 70 miles per hour. They are completely adequate for all anticipated military usage.

New 3- and 4-lane pavements should be at least 11 feet wide, and where speeds of 60 or 70 miles per hour are expected or there is much heavy traffic at speeds of over 50 miles per hour, the total traveled way should provide a width of 12 feet per lane. Pavements so constructed will be adequate for all civil and military traffic.

Column 13. - The slope ratio for grading of earthwork is variable with the height of cut or fill. In general, 4:1 slopes are indicated to 5-foot and preferably to 10-foot heights; 2:1 from 10 feet to 20 feet or 30 feet; and 1½:1 for slopes over 30 feet high.

Column 14. - The gutter slope, sometimes referred to as the "foreslope", should be 4:1 or flatter where possible. The width or length of the slope section measured from the outer edge of shoulder to the drainage line or bottom of gutter is variable according to topography and depth of drainage section required. Reduction in velocity in flat topography requires an increase in width for equivalent drainage capacity; therefore, widths are indicated as 10 feet, 8 feet, and 6 feet respectively for smooth, moderate, and rough topography.

The drainage section should be designed with 4:1 or flatter slopes beyond the shoulder edge so that a vehicle forced off the roadbed can run down into the channel without danger of overturning. A natural machine rounding of the bottom of gutter is desirable as suggested in the detail grass-type-gutter in Figure 4. In moderate or rough mountainous country, practical considerations of first cost in cross-section development tend to reduce the 10-foot width indicated for smooth topography.

Column 15. - The width needed for rounded earth slope and gutter design in cut sections is the slope ratio times the height of slope as listed in column 13, plus the width of gutter slope suggested under column 14, plus length of rounding beyond the slope. In through cuts, this total would be doubled as indicated by the figures in parentheses on the right side of the column.

Column 16. - The graded roadbed widths listed in column 12, plus the slope grading widths tabulated in column 15, show the widths needed for earthwork grading. The range in total width indicated by the pairs of figures in column 16 is dependent upon whether a desirable or minimum graded width of roadbed is selected for two-lane highways.

Column 17. - By adding to the previous column (16) a reasonable width of 35, 40, or 50 feet as indicated in parentheses for set-back of buildings and for border-control on both sides of the highway section, the desirable total land width is obtained. The extra widths indicated in column 17 need not be acquired as right-of-way by fee-simple ownership or by land-easement, but may be reserved by grading easements, by roadside regulations, or by state and county legislation covering building set-back lines, billboard regulations, and highway zoning for border control. A comparison of columns 16 and 17 with column 6 showing the number of acres per mile, and with column 8 listing land widths for construction requirements, should be helpful in the analysis of minimum and desirable land widths for highway sections.

As a check example, let us assume it is desired to construct a 2- or 3-lane highway with 2400 traffic capacity through moderate topography. In column 6, for moderate topography, from 18 to 24 acres per mile are indicated. From column 8, a minimum land width of 150 feet is shown but a desirable land width of 200 feet would be needed to average the 24 acres per mile shown in column 6. Under column 16, a cross-section width of 190 to 194 feet, or approximately 200 feet, would be required in moderate topography. Using the round figure of 200 feet in column 17, and allowing 50 feet on each side as a border-strip, a total land width of 300 feet is found to be desirable for an adequately protected cross-section for the common type of highway with customary land access along its frontage. For the limited access highway or "freeway" type of construction, however, the 200-ft. width in column 8 is adequate. Thus, where traffic operations are protected by limited access highway legislation, the widths of land reserved along the borders of the highway construction are substantially reduced and the problem of regulating and controlling highway borders greatly simplified.

Similar comparisons with the land widths listed in column 8 will show the possible savings in widths of land when construction requirements of this protected highway character do not need to be supplemented by border-control and setback limits as shown in column 17. The differences in land widths indicated in columns 8 and 17 demonstrate the practical advantage of limited access highway design in reducing land widths as noted in column 16.

Land Widths for Divided Highways. - For divided highway types, the indicated widths for 2-lane highways should be increased to provide the added sectional space required for the extra traffic lanes and the median separation.[3] The design of median strips is governed by the following considerations: (1) dimensions and turning circles of vehicles; (2) crossings (left-turns and U-turns); (3) topography; (4) available right-of-way; and (5) construction and maintenance costs.

The indicated rural type highway patterns are in part applicable to urban highways where shoulders are replaced or supplemented

3. For detailed discussion of median strips in general, the widths of which are governed by topography, available right-of-way, cost of construction, and cost of maintenance, see p. 54 of AASHO - 1940 - Policy on Highway Types. A Summary of approved conclusions will be found on pp. 65-68.

by sidewalks and curb-gutter construction. Urban cross-section design is based on the lower speed requirements of city traffic and should be determined only after consideration of conditions peculiar to each location.

In urban and suburban construction, the suggested minimum widths of right-of-way may tend to be used because of high land costs, but lower land values in the open country should normally favor the adoption of the more desirable widths indicated in column 8 of Figure 3 for each class of highway section.

Figures 3, 4 and 5 suggest a relative method of determining various land widths required in the molding of cross-sections to fit changes in topography. The series of model sections show that land width requirements increase in direct proportion to roughness in topography. The classification of a highway as to type of topography as well as to traffic density, character, and speed is an aid in visualizing the entire width of cross-section improvement.

Topography, Traffic Density, and Speed Relations in Cross-Section Design. - In designing a road for maximum safety the speed of traffic must be considered. This factor is primarily influenced by the character of the terrain. For comparative design purposes, speed classifications of "under 50", "60", and "over 70" miles per hour are selected in the series of topographic-traffic-patterns used in this report. These cross-section patterns are prepared on a flexible basis with tolerances above and below the normal to fit variations in traffic use and in topographic conditions.

Each of the three types of topography (smooth, moderate, and rough, as shown in Figures 3, 4 and 5) is subdivided into three representative sections according to traffic density (600, 1200, and 2400 per day) and traffic speed (50, 60, or 70 miles per hour).[4]

4. From p. 8 - AASHO - 1940 - A Policy on Highway Classification:
"A principal factor affecting the choice of a design speed is the character of the terrain. In general, rolling terrain will justify a higher design speed than mountainous country since the cost of constructing almost every highway detail will be less. An important highway carrying a large volume of traffic will justify a higher design speed than a less important highway in similar topography due to the fact that the increased expenditure for right of way and construction will be offset by the savings in vehicle operation, highway maintenance, and other operating costs. A low design speed should not be assumed for a secondary road, however, if the topography is such that vehicle operators probably will travel at high speeds on the completed highway. Drivers do not adjust their speed to the importance of the road but to the physical limitations of curvature, grade,
(continued on p. 17)

The Normal pattern, indicated in the middle section of each figure, is based on a two-lane highway type with an assumed mixed traffic density of about 1200 motor vehicles per day at a speed of 60 miles per hour. This is assumed as the "norm" or basis for increase or decrease in width as may be necessary or desired to fit the controlling conditions. The normal width may be reduced to a "minimum" width as shown at the top of each figure when traffic density and speed are 600 or less per day and under 50 miles per hour respectively. When the traffic density is more than 1800 per day and when the design speed is over 70 miles per hour for mixed passenger and truck traffic, the indicated normal width for land design should be increased automatically to the desirable or "preferred" width as shown in the pattern at the bottom of each figure for the respective type of topography.

Smooth or Flat Topography. - Figure 3 suggests a 130-ft. normal width of land for two-lane highways constructed in relatively level to gently rolling terrain. Where the density of traffic is less than 600 per day and a design speed of under 50 miles per hour is satisfactory, a minimum width of 100 feet may be considered. A preferred width of 150 feet is desirable, however, on the more important highways with a traffic density of more than 1800 per day and for a design speed of over 70 miles per hour. It is desirable for purposes of safety that traffic lanes and shoulders be 12 feet wide for traffic of high-speed character.

Adequate width of stable shoulders has been found to be of major importance in motorized military operations. Colonel John W. Wheeler, Commanding Officer of the 113th Engineers at Camp Shelby, Mississippi, in discussing the lessons of Army Maneuvers in Louisiana and Texas at the Annual Meeting of the American Roadbuilders Association, stated that, for highways: "A Major need is shoulders 12 feet wide. Regardless of pavement width, all highways should have 12-foot shoulders wherever topography will permit. Military convoys cannot be moved satisfactorily without wide shoulders which

4. (concluded from p. 16)
sight distance, smoothness of pavement, etc...." (as determined by topographic conditions and controls.)
"The assumed design speed should indicate the speed at which traffic may travel under fair conditions with a reasonable margin of safety."

From p. 2 - AASHO - 1940 - A Policy on Highway Types:
"The assumed design speed selected for a highway is determined by consideration of the area traversed, economic justification based on traffic volume, cost of the right of way and other factors, traffic characteristics, and other pertinent factors such as esthetic considerations."

SMOOTH OR FLAT TOPOGRAPHY

RELATIVELY LEVEL TO GENTLY ROLLING

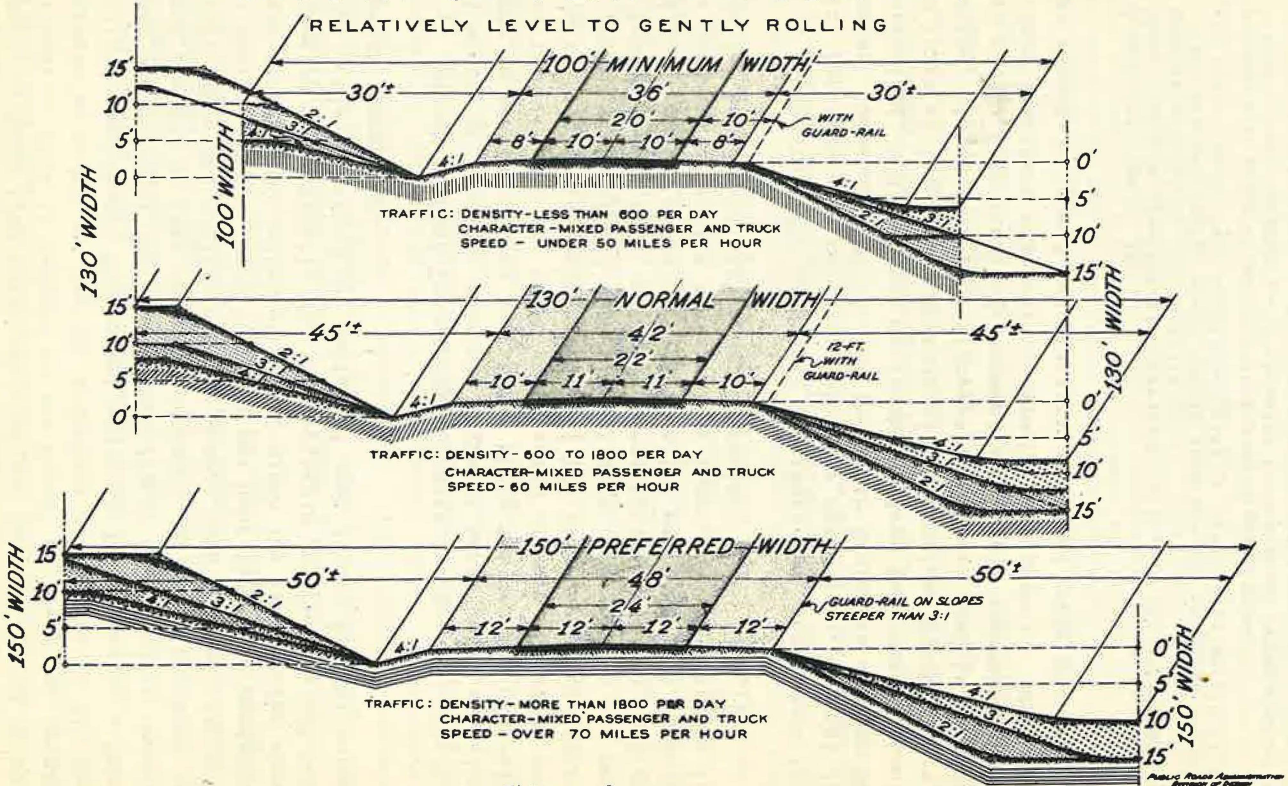

Figure 3

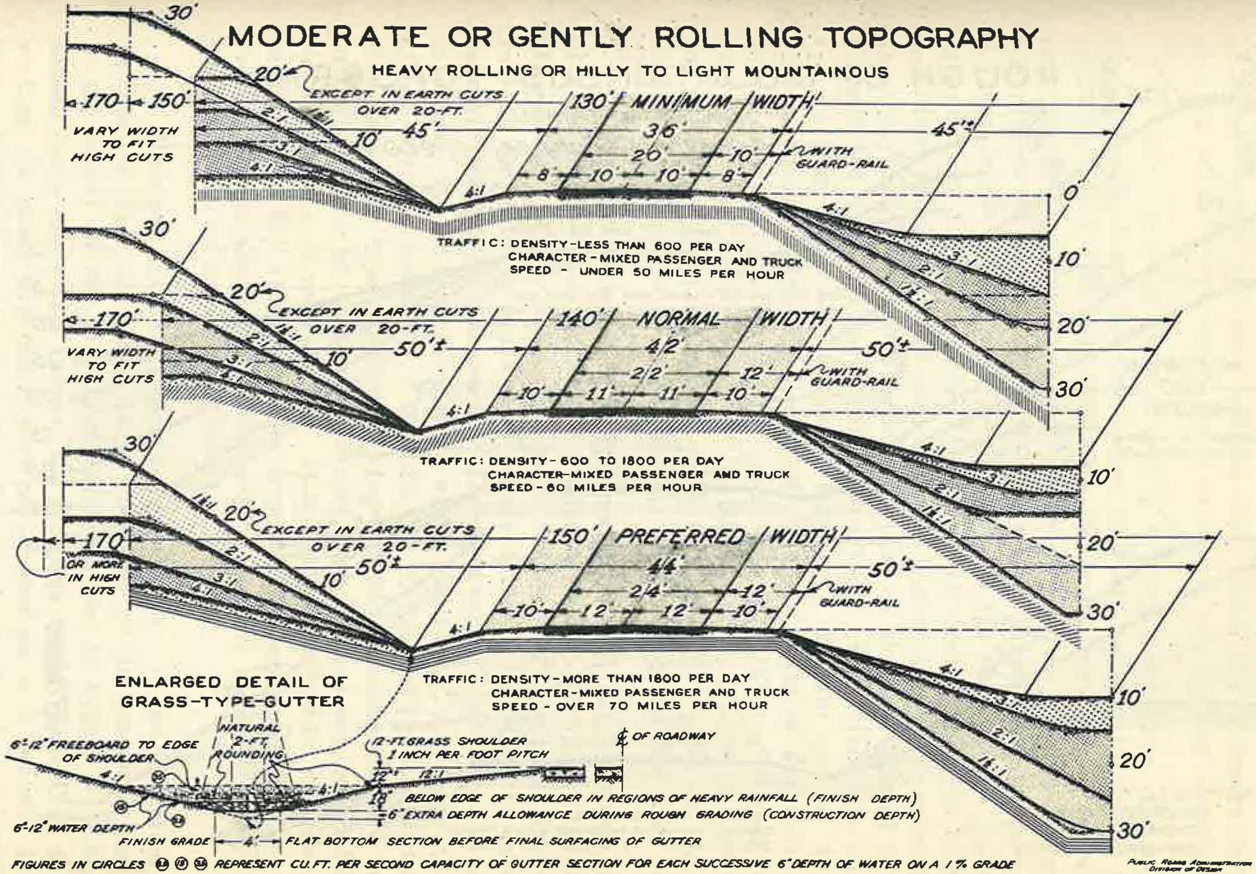
MODERATE OR GENTLY ROLLING TOPOGRAPHY
HEAVY ROLLING OR HILLY TO LIGHT MOUNTAINOUS
EXCEPT IN EARTH CUTS OVER 20-FT.
VARY WIDTH TO FIT HIGH CUTS
130' MINIMUM WIDTH
36'
20'
WITH GUARD-RAIL
TRAFFIC: DENSITY-LESS THAN 600 PER DAY
CHARACTER-MIXED PASSENGER AND TRUCK
SPEED - UNDER 50 MILES PER HOUR
140' NORMAL WIDTH
42'
22'
TRAFFIC: DENSITY-600 TO 1800 PER DAY
CHARACTER-MIXED PASSENGER AND TRUCK
SPEED-60 MILES PER HOUR
150' PREFERRED WIDTH
44'
24'
OR MORE IN HIGH CUTS
TRAFFIC: DENSITY-MORE THAN 1800 PER DAY
CHARACTER-MIXED PASSENGER AND TRUCK
SPEED-OVER 70 MILES PER HOUR
ENLARGED DETAIL OF GRASS-TYPE-GUTTER
NATURAL 2-FT. ROUNDING
6"-12" FREEBOARD TO EDGE OF SHOULDER
12-FT. GRASS SHOULDER 1 INCH PER FOOT PITCH
℄ OF ROADWAY
BELOW EDGE OF SHOULDER IN REGIONS OF HEAVY RAINFALL (FINISH DEPTH)
6" EXTRA DEPTH ALLOWANCE DURING ROUGH GRADING (CONSTRUCTION DEPTH)
6"-12" WATER DEPTH
FINISH GRADE
FLAT BOTTOM SECTION BEFORE FINAL SURFACING OF GUTTER
FIGURES IN CIRCLES REPRESENT CU. FT. PER SECOND CAPACITY OF GUTTER SECTION FOR EACH SUCCESSIVE 6" DEPTH OF WATER ON A 1% GRADE
PUBLIC ROADS ADMINISTRATION DIVISION OF DESIGN

Figure 4

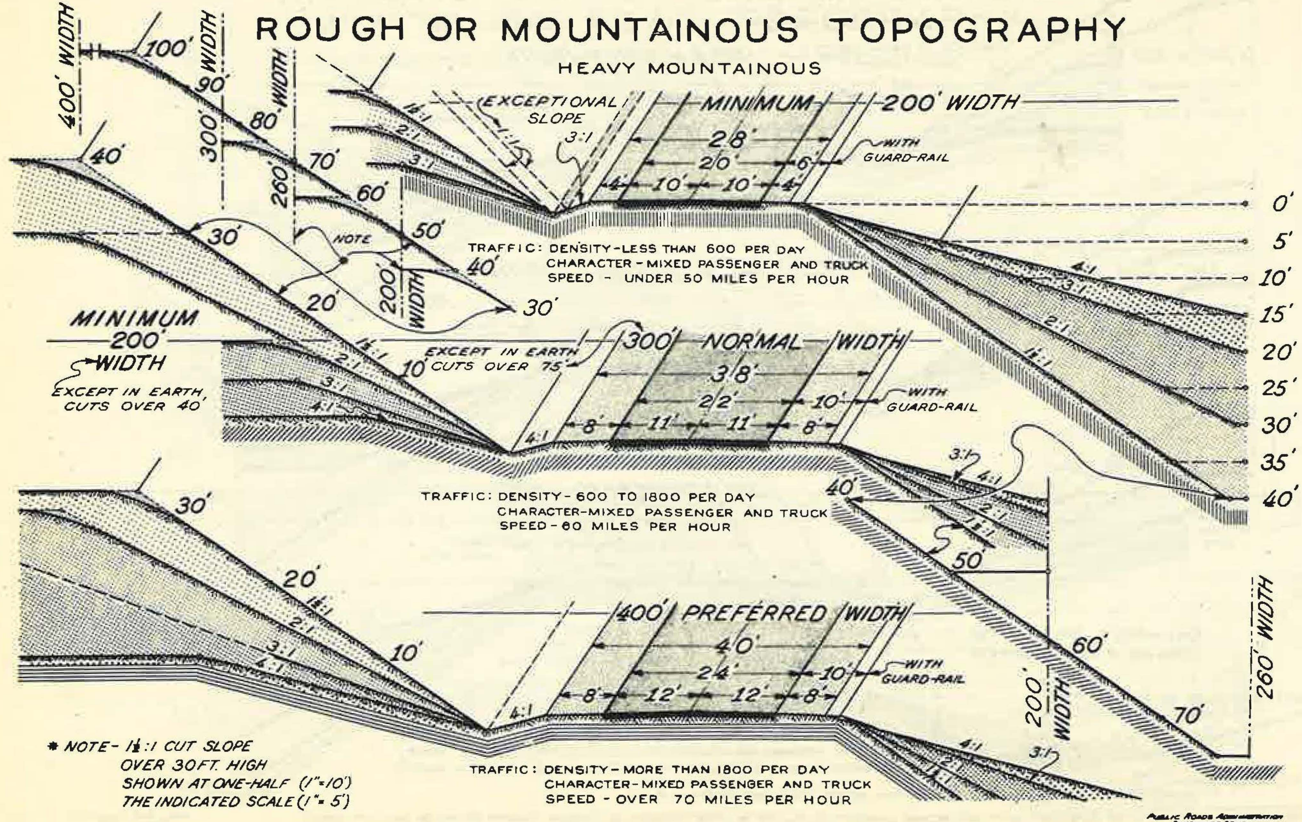
ROUGH OR MOUNTAINOUS TOPOGRAPHY
HEAVY MOUNTAINOUS
400' WIDTH
300' WIDTH
260' WIDTH
200' WIDTH
MINIMUM 200' WIDTH
EXCEPT IN EARTH, CUTS OVER 40'
EXCEPTIONAL SLOPE
MINIMUM
200' WIDTH
WITH GUARD-RAIL
NOTE
TRAFFIC: DENSITY-LESS THAN 600 PER DAY
CHARACTER-MIXED PASSENGER AND TRUCK
SPEED - UNDER 50 MILES PER HOUR
EXCEPT IN EARTH CUTS OVER 75'
300' NORMAL WIDTH
WITH GUARD-RAIL
TRAFFIC: DENSITY-600 TO 1800 PER DAY
CHARACTER-MIXED PASSENGER AND TRUCK
SPEED-60 MILES PER HOUR
400' PREFERRED WIDTH
WITH GUARD-RAIL
200' WIDTH
260' WIDTH
TRAFFIC: DENSITY-MORE THAN 1800 PER DAY
CHARACTER-MIXED PASSENGER AND TRUCK
SPEED - OVER 70 MILES PER HOUR
* NOTE- 1½:1 CUT SLOPE
OVER 30 FT. HIGH
SHOWN AT ONE-HALF (1"=10')
THE INDICATED SCALE (1"=5')
PUBLIC ROADS ADMINISTRATION
DIVISION OF DESIGN

Figure 5

permit one unit to stop clear of the roadway without blocking the movement of other units or essential civil traffic. --- Provision of points where military convoys can leave the highways to seek shelter among trees would be a valuable aid during maneuvers."

In relatively level to gently rolling topography, the majority of earth slopes are low (under 10 feet) and may be graded sufficiently flat (4:1 or 3:1) for the economical use of motorized construction equipment and of improved machine maintenance after completion. It is desirable that flat slope grading be used to the fullest extent possible to avoid the need for guard-rail. A transition zone for cuts and fills from 10 feet to 15 feet high is indicated between smooth and moderate topography. On embankment sections with 2:1 slope ratios, the width of shoulder should be increased two feet and guard rail installed. War priorities on materials for guardrail, however, suggest a greater use of 4:1 or flatter slopes in the design of earth fills would be desirable. It should be noted that the 50-ft. roadside portion of the highway section indicated either side of the 48-ft. graded roadbed width in the preferred 150-ft. pattern shown in Figure 3 will permit the use of 4:1 slopes up to 10 feet and a 3:1 slope ratio to about 15 feet.

Moderate or Gently Rolling Topography. - Figure 4 shows bands of slope ratios from 4:1 to 1½:1 suggested for use in the majority of cuts and fills ranging from 10 feet to 30 feet high in heavy rolling or hilly to light mountainous terrain. The 140-ft. assumed "normal" width will accommodate slopes of this range except in earth cuts over 20 feet. The normal width should be increased to fit higher cuts as indicated. The 150-ft. "preferred" width is desirable so as to keep grading of slopes from exceeding the 2:1 ratio in the majority of sections. Slopes over 20 feet may be graded at the 1½:1 ratio if necessary. It would be preferable, however, to maintain the 2:1 slope wherever possible through increase in land width. Establishing protective vegetation on slopes steeper than the 2:1 ratio is usually difficult.

Enlarged Detail of Grass-Type-Gutter. - The practical advantage of flat cut slope (4:1) sections is indicated in the enlarged detail of the grass-type-gutter shown in Figure 4. At the normal water depth of 6 inches, the drainage capacity of this gutter section is about 3.5 cubic feet per second on a 1 percent grade. With a 6-inch increase in depth of water, or a total running depth of 12 inches, the drainage capacity of the gutter would be 15 cubic feet per second, or 4 times the 6-inch water depth. Even if the

6-inch "freeboard" clearance in depth below the edge of shoulder should be filled to the edge of shoulder during an unusual storm, the water would still be 12 inches below the edge of surfacing. In such an extreme case, the capacity of the gutter would be increased to 35 cubic feet per second, or about 10 times the normal water flow at 6-inch depth.

The enlarged detail also shows that an extra 6 inches in depth should be allowed for during the rough grading operation before rounding and grassing takes place. Unless this is done, the latter operation is likely to decrease the finish depth and thus reduce the capacity of the gutter section.

Rough or Mountainous Topography. - Figure 5 shows that in rough or mountainous country, shoulder widths may be narrower and slopes may necessarily be steeper. The increased heights and ratios of slopes, averaging from 30 feet up to 60 or 75 feet in rough terrain, make slope sectioning a more dominant factor in the determination of the various land widths requisite for the roadway construction. The 300-ft. normal width is indicated except in earth cuts over 75 feet. A minimum width of 200 feet may be used except in earth cuts over 40 feet high. The 100-ft. range above and below the 300-ft. normal width for this type of topography illustrates the wide variation in widths to be expected in rough country.

SUMMARY

These patterns enable one to see at a glance the influence of topography on the design of highway sections. In the normal process of locating and designing a two-lane rural highway, we start with the center-line alignment and grade, and work outward from this center-line control, according to the type of cross-section that best fits each particular requirement and condition. The three interrelated factors of plan alignment, profile grade, and cross-section pattern are weighed and balanced by preliminary adjustment, one against the other, until the most satisfactory combination of all three is found.

In this report, the entire width of highway development is pictured as a unit. All the parts of the cross-section are looked at as an interrelated pattern of design in which the roadside widths required by drainageways, cut and fill slopes, etc., are added to the roadbed width to determine the total land width or right-of-way necessary for the satisfactory construction of each highway section. On this step by step basis, variation in right-of-way boundaries and in land widths to meet changes in topography and in traffic requirements is logical. This procedure naturally suggests the use of flexible patterns in cross-section development so that all details of highway construction may be fitted into the surroundings.

Under emergency war conditions, the tendencies are necessarily toward standardization and simplification of construction. The arbitrary use of "fixed standards" of design, however, without reference to the particular conditions surrounding each project is not an intelligent approach to the solution of cross-section problems. In principle, then, there is needed a more elastic method representative of advanced highway thinking and simplified practice.

An adequate cross-section adapted to the topography, must be founded upon time-tested methods devised by highway designers to make traffic safe and efficient. A simplified classification of the various factors controlling the design of the highway cross-section is tabulated in Table 1 as the basis for the series of patterns in Figures 3, 4, and 5 for measuring the adequacy of highway sections. These topographic-traffic-patterns will aid the designer to be more alert in meeting the conditions imposed by nature rather than being guided and unduly influenced by so-called "standard" design.

Conclusion. - Highway engineers are at the present time seriously handicapped in both rural and suburban areas by lack of available land width for well-designed construction. This report has attempted to outline a "yardstick" for measurement of the correct widths of land to be obtained for future highway use.

The design of proper land width (right-of-way) for adequate highway cross-section must be based upon:

1. Use of the best engineering skill available in fitting roads to topography in original location;

2. Systematic classification of highway types and cross-section patterns as related to topography; and

3. A sound flexible policy which weighs such factors as traffic safety, topography, and soil, as each is related in design to present construction and future maintenance costs.

Flying over a new highway one is impressed by the fact that steep cuts and fills are very prominent as viewed from above. In these days of expected bomber attacks, it is evident that the appearance of the finished highway cross-section is not only important as viewed from the ground but from the air as well. More than ever, therefore, the principle is emphasized that land widths for modern highways must be adequate and varied to meet the cross-section requirements imposed by traffic, topography, soil, and prevailing use of adjacent lands.